Vol. XIX 72 Dicembre 1976

PARTE 1

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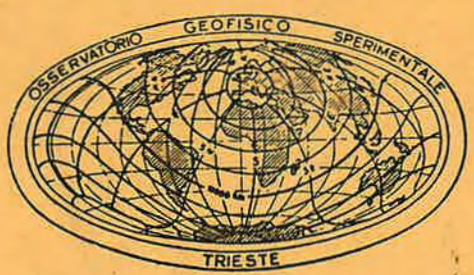

NUMERO SPECIALE:
ATTI DEL CONVEGNO INTERNAZIONALE
SUL TERREMOTO DEL FRIULI

Udine 4-5 Dicembre 1976

SEZIONE 1
SISMOLOGIA - GEOFISICA - GEOLOGIA

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INGEGNERIA SISMICA

SPECIAL ISSUE:
PROCEEDINGS OF THE INTERNATIONAL
MEETING ON THE FRIULI EARTHQUAKE

Udine, December 4-5, 1976

SECTION 1
SEISMOLOGY - GEOPHYSICS - GEOLOGY

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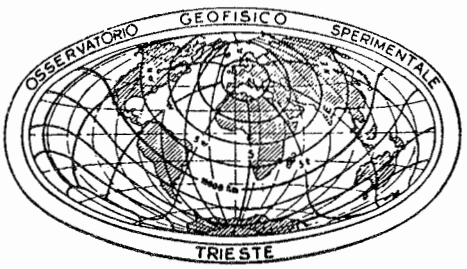

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Autorizzazione del Tribunale di Trieste, n. 242 del 17 settembre 1960

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In memory of the 1000 victimes of the 1976 Friuli Earthquake.

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PREFACE

Soon after the May 6, 1976 earthquake, many Italian and foreign scientists and seismic research groups organized study expeditions to Friuli. After the strong September aftershocks the interest in the seismicity of the Friuli region became even stronger. At present numerous different studies are still carried on, since the seismic phenomenon is not yet over.

Even if the results are obviously not definite, a vast quantity of observations have been collected. These observations will provide the basic material for further research- a valuable help for the future drawn from the painful experience of the past.

The publication of this information as articles scattered in the international scientific literature would however inevitably lead to dispersion and delay. It is for this reason that a number of Italian scientists decided to organize this Meeting. All those engaged in research in Friuli were invited to present the data they had collected, together with any further work that might have been completed so far. Thus, through the Proceedings of this Meeting, all those interested in seismic problems will have access to the most complete collection of information so far available on the 1976 Friuli earthquake.

The Meeting has been also organized for a second important reason: to give the scientists an opportunity to compare the collected data and discuss any conclusions that might have been reached. The Organizing Committee is aware of the fact that there may be overlapping and even contradictions in some of the information presented here. This is by no means strange, as it falls in the normal reserach dialectics.

The Proceedings, presented in Author's alphabetic order, are divided into the following two sections:

1. - SECTION 1: SEISMOLOGY, GEOPHYSICS AND GEOLOGY
2. - SECTION 2: SEISMIC ENGINEERING.

The Organizing Committee wishes to take this opportunity to thank all those who have supported this initiative, particularly CISM for its organizational help. A particular thank is due also to OGS (Osservatorio Geofisico Sperimentale) of Trieste for having dedicated the present issue of the Bollettino di Geofisica Teorica ed Applicata to the Proceedings and for the financial support granted. Our warmest thanks goes of course to all those scientists who have participated in this Meeting and who responded with such enthusiasm to the invitation to present their work united in this way.

Udine, December 5, 1976

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GEODYNAMIC OUTLINE AND SEISMICITY OF FRIULI VENETIA JULIA REGION

BY

A. AMATO* - P. F. BARNABA* - I. FINETTI** -
G. GROPPI* - B. MARTINIS*** - A. MUZZIN*

S U M M A R Y

Mostly based on a large amount of geological, seismic reflection and seismological data the regional geodynamic characters of the Friuli-Venetia Julia Region, the main active faults and the maximum expected earthquake intensity for a given return period of 1000 years are outlined. The seismicity map shows that Central Friuli area is one of the most active of the region with a maximum expected intensity of 10 (MCS scale) in the area of Gemona-Osoppo-Trasaghis-Venzone-Somplago, across the Tagliamento River. Around this maximum there is a large area having an high seismicity ($I_{o_{max}} = 9$). Other active areas

* AGIP - Attività Minerarie, Milan

** OGS - Osservatorio Geofisico Sperimentale, Trieste

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O.G.S. - Osservatorio Geofisico Sperimentale - Trieste - Contrib. n. 253.
Research carried out in the frame of CNR's Italian Geodynamics Proiect. Pubbl. n. 13.

are those of Cansiglio and Cividale. Outside,but close to the boundary of the region, two areas of very high seismic intensity are to mention: the area of Belluno ($I_{o_{max}}$=11) and Villach in Austria ($I_{o_{max}}$=11). The most important earthquake sources and generating fractures are also examined and identified. Using the hypocenter distribution of aftershocks of May and September 1976, projected on a N-S vertical plane, and considering the main regional fractures, the focal mechanisms of the two shocks having the greatest magnitude are proposed. The high magnitude aftershocks of september are attributed to a southward movement of a thrust-block towards the next southernmost one which produced the May 6 earthquake.

1.-INTRODUCTION

The 1976 earthquake of the Friuli area with its thousand victims is one of the most destructive shocks occurred in Europe during the last decades.The densely populated area of the epicentral region,the old hystorical stone houses,the soft alluvial and/or morenic surface layer,in several places with water level near the surface or outcropping,the several intense aftershocks, together with the tremendous main one of May 6, contributed to bring this calamity to a big dimension.

Soon after the main shocks several Italian, European, American and Japaneese earth's scientists (seismologists, geologist, seismic engineers) arrived in Friuli to visit or study the various scientific and social aspects related to this earthquake and to express their human solidarity.

The aftershocks activity is presently still persisting,

and therefore before to evaluate entirely the earthquake one has to wait the end of the shock sequence. Anyhow, a large amount of data has been already collected and a first study of the Friuli main earthquake of May 6, and of the strong aftershocks occurred in September 1976 is now possible.

The present paper intends to give a synthetic picture of some regional aspects of the Friuli-Venetia Jiulia Region which can contribute to understand the geodynamics and the seismicity of the investigated area.

All considerations presented here are the result of a study jointly conducted by AGIP, Attività Minerarie of Milan, OGS (Osservatorio Geofisico Sperimentale) of Trieste, and University of Milan that coordinated the CNR's geological surveys in Friuli. Soon after the destructive earthquakes of May 6, the CNR's Committee of the finalized program "Geodynamics" decided to support financially and to conduct several investigations with regard geology, geophysics and seismic engineering. AGIP, conducted a specific seismic reflection exploration on the area of Spilimbergo, S. Daniele, Maiano, Buia, Osoppo, Gemona and Trasaghis. Moreover, AGIP put at disposition a large amount of geophysical and geological data covering the entire Friuli Plain.

OGS contributed with all the seismological data existing at its Trieste Station, including a careful study of all the known earthquakes from Roman epoch up to 1976, and the complete epicenter distribution of 1976 earthquakes and aftershocks. The paper gives a geological outline of the Friuli-Venetia Julia Region based on surface geology for the mountainous area and on geophysical exploration for the plain.

Then the seismicity with focal mechanisms of the 1976 earthquakes, and the main regional geodynamic characters of the region are outlined.

2.- SOURCES OF DATA

The considerations and conclusions carried out in this paper are based on consultation of a large amount of various documents, mostly consisting of geological, geophysical, drilling and seismological data.

2.1.- Surface Geology Data

In addition to the official geological cartography, all the contributions published about the Region up to now have been considered for the purposes of preparing this report. The main sources prior to 1971 are cited in the work of one of the authors (Martinis, 1971) to which reference should be made for all further details. For the more recent sources, particular mention is made of Auboin et al. (1972), Cousin (1972), Amadesi & Leonarduzzi (1973), Bosellini (1973), Zanferrari (1973), Chorowicz (1975) and Gnaccolini & Martinis (1975). For the area nearer the Plain, consideration has been given to the results of the survey conducted by the CNR (National Research Council) Group which operates in Friuli within the sphere of the studies known as the "Geodynamics Project".

2.2.- Geophysical and Drilling Exploration Data

The geological characteristics of the Friuli Plain can

only be reconstructed from the interpretation of the gravimetric and seismic data and from the information furnished by the deep wells drilled for petroleum exploration, because the area investigated is completely covered by a thick layer of quaternary sediments.

The bulk of data used for the delineation of the tectonic set-up of the Friuli Plain has been furnished by AGIP - Attività Minerarie. SNIA VISCOSA also made available 117 km of seismic profiles recorded in the area during 1971.

AGIP contributed with the geological knowledge acquired during several years of exploration activities and with over 1000 km of multichannel digital seismic reflection profiles recorded in the Friuli-Venetia Julia Region during 1972, 1973 and 1974 (Fig. 1).

In addition to the seismic data, AGIP also made available the Bouguer Gravity Map (Fig. 2) resulting from nearly 6000 gravimetric Stations, and the drilling reports and electrical logs of the exploratory wells BUTTRIO 1 (1954), BERNADIA 1 (1959), CESAROLO 1 (1960), CAVANELLA 1 (1961), LAVARIANO 1 (1962) and TERENZANO 1 (1963).

All this information allows a reliable reconstruction of the subsurface conditions to a depth of about 5 km in the south and of 3 km in the north of the Plain.

After the May 6 earthquake, according to a request from CNR, AGIP recorded a seismic reflection programme of 64 km of multichannel digital seismic lines in the damaged area. This survey was carried out in July and August 1976, with the purpose of acquiring additional structural and tectonic information in the macroseismic area.

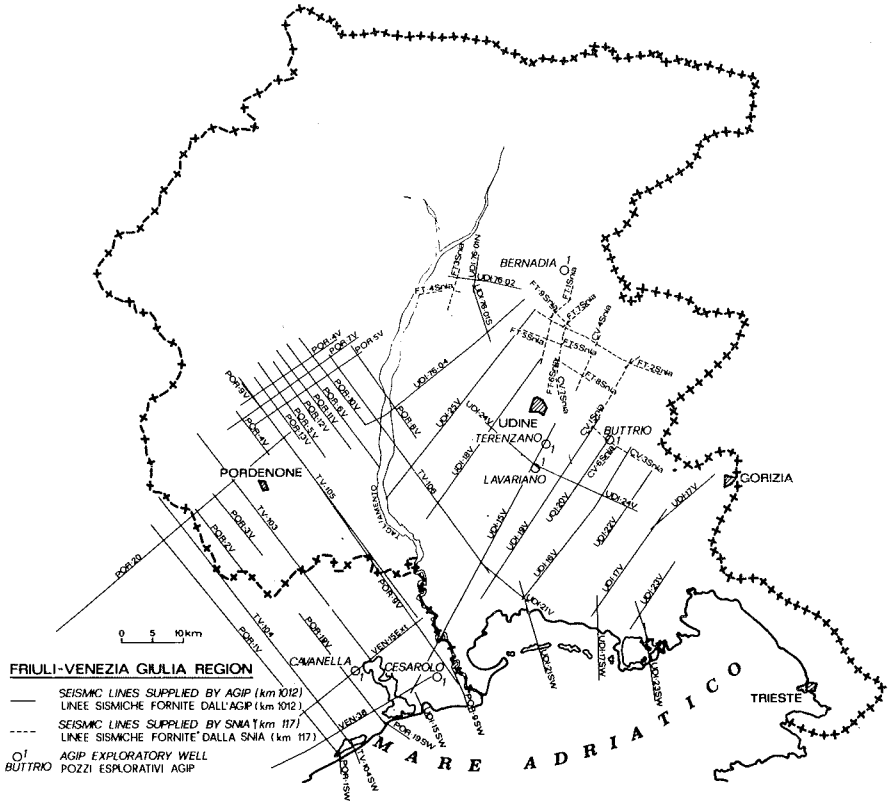

BERNADIA 1
UDINE
TERENZANO 1
BUTTRIO 1
LAVARIANO
PORDENONE
GORIZIA
CAVANELLA
CESAROLO 1
TRIESTE
M A R E A D R I A T I C O
0 5 10km
FRIULI-VENEZIA GIULIA REGION
SEISMIC LINES SUPPLIED BY AGIP (km 1012)
LINEE SISMICHE FORNITE DALL'AGIP (km 1012)
SEISMIC LINES SUPPLIED BY SNIA (km 117)
LINEE SISMICHE FORNITE DALLA SNIA (km 117)
AGIP EXPLORATORY WELL
POZZI ESPLORATIVI AGIP

Fig. 1

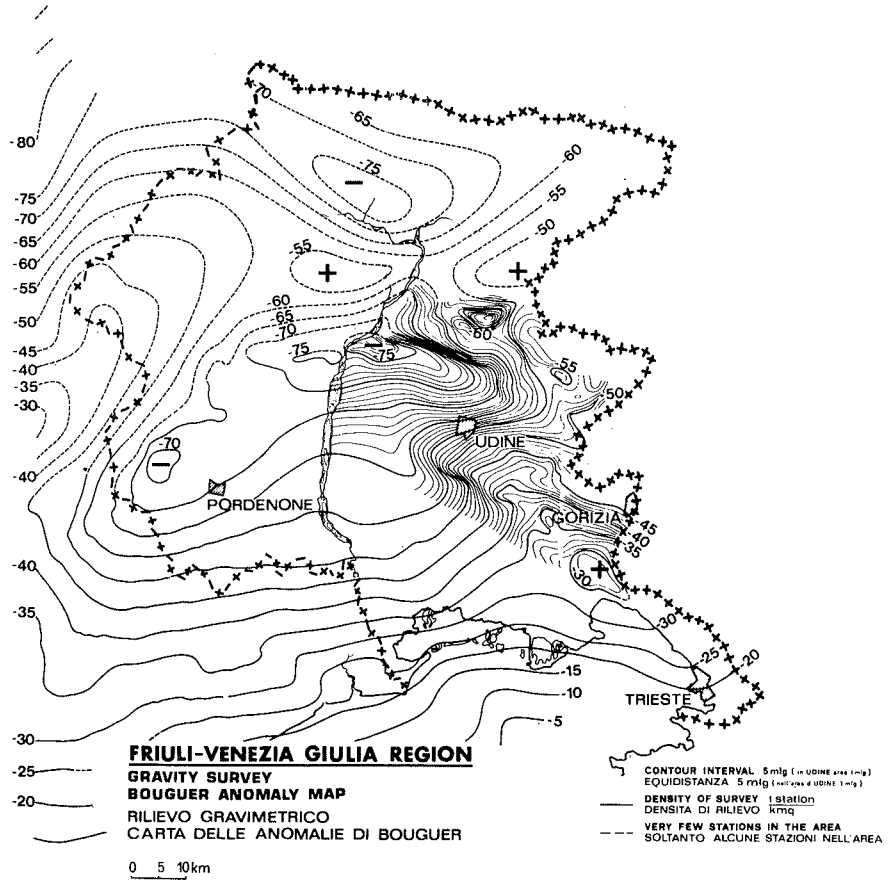

UDINE
PORDENONE
GORIZIA
TRIESTE
FRIULI-VENEZIA GIULIA REGION
GRAVITY SURVEY
BOUGUER ANOMALY MAP
RILIEVO GRAVIMETRICO
CARTA DELLE ANOMALIE DI BOUGUER
0 5 10km
CONTOUR INTERVAL 5 mlg
EQUIDISTANZA 5 mlg
DENSITY OF SURVEY 1 station / kmq
DENSITA DI RILIEVO
VERY FEW STATIONS IN THE AREA
SOLTANTO ALCUNE STAZIONI NELL'AREA

Fig. 2

The new obtained data permitted the tie up of the geological situation of the mountain outcrop area to that of the plain. The reflection profiles performed in the macroseismic area are very valuable in providing fundamental information on its seismotectonic aspects.

However, as expected due to high tectonization and structural complexity, the quality of the seismic sections deteriorates in the neighbourhood of the outcrops, where the reflections from the subsurface are fragmented.

2.3.- Seismological Data

The OGS seismological station of Trieste is active since 1890 and during all this long time recorded a great amount of seismic data with specific reference to the Friuli area. Before and after the 1976 earthquake a team of OGS's seismologists examined all the numerous available documents reporting shocks of the hystorical seismic activity of Friuli. Assembling the hystorical and the instrumental earthquake data these OGS seismologist compiled the complete earthquake catalogue of Friuli which is presented at the Udine meeting (Bartole et al., 1976). This catalogue constitute a basic document for the reconstruction of the seismo-tectonic map with the maximum expected intensity (Fig. 10).

Moreover the OGS's seismic station of Trieste, the nearest one to the Friuli area, made continuous recording with all its seismographs (Wood-Anderson, short and long period) gathering important information regarding the main shock and the numerous aftershocks of the May 6 earthquake.

In addition to this, other portable seismic stations were

installed on the damaged area to study the local seismicity.

In cooperation with the I.P.G. (Institut of Physique du Globe) of Strasbourg a teleseismic system of seven stations was also set up which resulted determinant for the understanding of the focal mechanisms.

Other portable seismic stations of CNR (Institu of Geophysics for Lithosphere of Milan) and of IVC (Institute of Vulcanology of University of Catania), coordinated with those of OGS, contributed to improve the seismic information.

3. GEOLOGICAL PICTURE

3.1.- Mountainous area (Alps, Pre-Alps and Dinarides) of Friuli-Venetia Julia

The Friuli-Venetia Julia region includes both the Calcareous Southern Alps and the Dinarides s.s.; the latter, however, rise only on the south-eastern border.Between these two large geological units there is a transitional zone with intermediate structural characteristics. To the North, the Southern Alps and the Dinarides are in contact with the Austrides through a large dislocation, known as the Pusteria line and Gail line, which marks the Alpine-Austroalpine boundary but which outcrops, however, in Austrian territory.

Sedimentary rocks of marine environment and transitional deposit are essentially present in the region, with a total thickness exceeding 15.000m. Eruptive rocks crop out only locally. The succession comprises formations which range from the Paleozoic to the Quaternary; a few formations which are

lacking in the vicinity of the high areas are reported to exist in the sub-surface of the Friuli Plain.

The paleozoic rocks primarily make up the Carnic Range and are represented by lithotypes of both calcareous and terrigenous nature which give to this range an irregular morphology. The first kind of lithotypes, for example, outcrops in particular to the West of Pontebba where the Devonian reefs, over 1000m thick, give rise to the highest point in Friuli-M. Coglians. Of the second kind of lithotypes, the argillitic-arenaceous rocks of the Hochwipfel Formation, deposited by turbidite currents during the Carboniferous, are particularly widespread. During this same interval of time, volcanic activity is shown to have taken place with sub-marine eruptions which give rise locally to massive spilites and to pillows, keratophyres and pyroclasts. Towards the East, a complex known as the "Pontebba Permo-Carboniferous" follows the Hochwipfel Formation and comprises the product of a single late-Hercynian sedimentary cycle characterized by widely differing lithotypes.

The mesozoic sediments make up the greater part of the heights to the South of the Carnic Range and take on a particular significance for the purposes of this study. During most of the Triassic, the sedimentation is very varied - with limestones, siltites, sandstones, marly limestones, etc. - which goes to prove firstly the presence of an epineritic environment, which had already established itself at the end of the Paleozoic, and secondly the existence of local emergences and accentuated sinking of the sea bed due to the mobility of the basin with a varying degree of subsidence. The si

tuation changes towards the end of the Upper Triassic (whose rocks are present above all in the Julian Alps and in the Pre-Alps) where the essentially carbonate sedimentation (Main Dolomite and Dachstein Limestone) is characteristic of an epicontinental shelf which extends beyond the Friuli region over all the Southern Alps.

With the beginning of the Jurassic, this carbonate platform splits up and zones of basin and ridge with different characteristics are formed. One of the latter zones is to be found in the center of the region: it is known as the Friuli Platform and is bounded to the West by the Bellunese trough and to the East by the Julian trough. The sedimentation, however, is not uniform here even though, during the entire Jurassic, limestones of a more or less cherty nature prevail. The outcropping lithotypes permit the identification, to the North of the Friuli Platform which extends to about the height of M. San Simeone, of a thick pelagic layer with condensed sedimentation.

At the end of the Cretaceous, the sediments of the typical pelagic Scaglia Formation are deposited; this continues during part of the Paleocene as well and delineates a wide basin extending from the Belluno region, across Friuli, to Yugoslavia. In the eastern sector, coarser terrigenous sediments are deposited by turbidite currents (Flysch) which become dominant with the arrival of the Eocene and which affect the greater part of the region. In the Plain, the platform conditions are maintained throughout the Jurassic and the entire Cretaceous; the sedimentation of the Flysch begins with the Tertiary.

The Oligocene in Friuli is characterized by isolated and restricted outcrops of lagoonal and estuarine environment; over the whole Friuli area, therefore, continental conditions were established, with sporadic and really limited marine invasions.

The Miocene is present only on the border of the Carnic Pre-Alps where a very thick terrigenous succession (about 2100m) crops out comprising all the interval ; it is closed by the pontic conglomerates which represent the last outcropping pre-quaternary formation.

The structural arrangement of the region is the result of two orogeneses - Hercynian and Alpine - which gave rise to elements whose complexity differs widely. For the sake of simplicity, it is useful to describe the fundamental elements which distinguish the following geographical units: Carnic Range, Tolmezzo and Julian Alps, Pre-Alps and the Gorizia-Trieste Karst.

a) The Carnic Range has a complex structure as it was involved in both the orogeneses; it is bounded to the North by the Gail line which has already been mentioned and to the South by the Degano Valley-Valcalda-Valcanale alignment. The structural elements are represented by intensively faulted and overthrusted wedges, elongated in an E-W and WNW-ESE direction. At the southern border of the range, where mesozoic sediments crop out, the tectonics are simpler with wide monoclines affected by faults.

b) The Tolmezzo Alps are characterized by monoclinal blocks lying in an E-W direction, with subordinate plicative phenomena and overthrusting towards the South. Of these, the

Sauris line - which crosses the whole sector - is particularly extensive and important. A system of sub-vertical faults, following the normal direction of the preceding ones, is to be found to the North of Tolmezzo (But-Chiarsò displacements). These have also given rise to horizontal movements with a southwards traverse of the rock-masses situated in the West.

c) In the Julian Alps, the structural elements are represented by extensive monoclinal blocks with immersion of the layers in a general SSW direction. Two important faults with a general approximate E-W direction border these Alps - to the North with the Fella-Sava line and to the South with the Resia Valley line.

d) The Pre-Alps, both Carnic and Julian, can be divided from the structural point of view into two sectors separated by the Periadriatic overthrust. This tectonic element, which concerns more than just the region in question, has an E-W direction from the eastern boundary of the region to Barcis, thence NE-SW. The sector to the North is characterized by the presence both of thrust-belts elongated in an E-W direction and overthrusted to the South, which mainly involve Main Dolomite, and of plicative phenomena involving more recent rocks. Between the Tagliamento River and Cavazzo Lake the tectonics become more complex and the E-W trend is cut by vertical faults in an approximate N-S direction.

To the South of the Periadriatic overthrust, we have the characteristic "ellipsoids zone" in which there are mesozoic anticline outcrops verging to the South and overthrusts, like those of the Ciaurlèc, the Arzino and the Bernadia. To the West of the Tagliamento, the structural trends firstly run in

an E-W direction and then, moving towards the West, change to NE-SW. To the East of the river, on the other hand, they take on almost immediately a dinaric direction, i.e. NW-SE. In the vicinity of the Tagliamento, the N-S faults, which have already been seen, continue and crop out up to the Colle di Susàns.

e) The Gorizia-Trieste Karst is a typical dinaric element. It is an asymmetrical cretaceous anticline with a NW-SE axis verging to the S W and bounded in the southernmore part of the region by the Trieste-Capodistria syncline in whose core the Flysch crops out extensively. A little to the North of the Karst, M. Medea rises in isolation; this is of modest height but is nonetheless of structural interest since it represents the culmination of a cretaceous anticline whose position in the general context is not yet clear.

3.2.- Plain Area

The outstanding structural elements of the Friuli Plain fit into the Dinaric trend in the northeastern and into the Alpine System in the N and NW.

The main regional tectonic characteristics resulting from the interpretation of the well data and of the seismic and gravity surveys are (Fig. 3):

a) A highly faulted area in the region encompassed by Gemona del Friuli in the North, and by Maiano and Tricesimo in the SW and SE respectively. This area coincides with the sector of the Plain which suffered the largest amount of destruction and damage, and corresponds to the convergence region of the Alpine and Dinaric trends (Fig. 7). In the North, the seismic section UDI 76-01 (Fig. 4) intersects the major

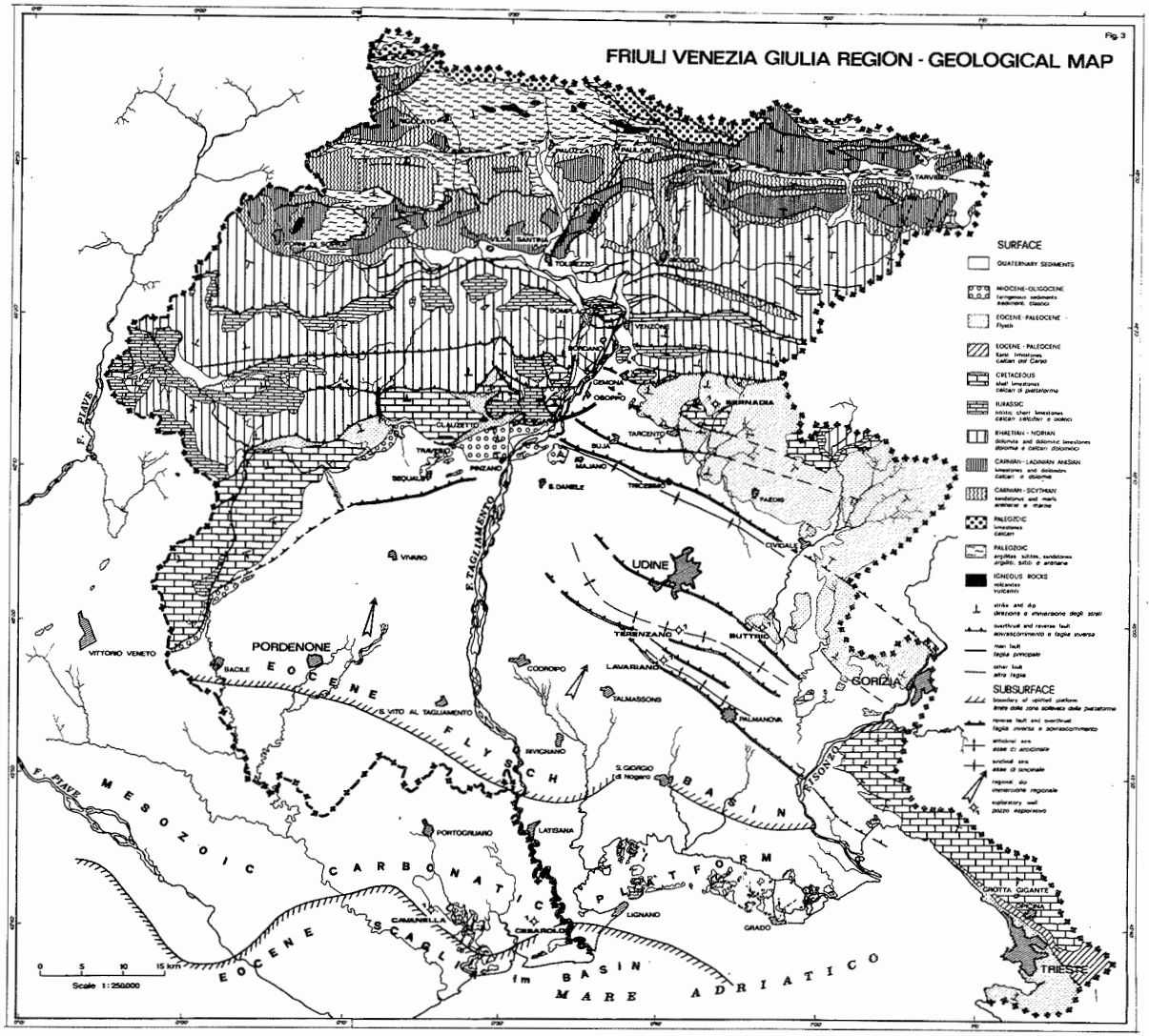

FRIULI VENEZIA GIULIA REGION - GEOLOGICAL MAP
Fig. 3
SURFACE
QUATERNARY SEDIMENTS
MIOCENE-OLIGOCENE
EOCENE - PALEOCENE
Flysch
EOCENE - PALEOCENE
Karst limestones
Calcari del Carso
CRETACEOUS
Shelf limestones
Calcari di piattaforma
JURASSIC
RHAETIAN - NORIAN
Dolomia and dolomitic limestones
CARNIAN - LADINIAN ANISIAN
CARNIAN - SCYTHIAN
PALEOZOIC
Limestones
PALEOZOIC
IGNEOUS ROCKS
SUBSURFACE
UDINE
PORDENONE
GORIZIA
TRIESTE
VITTORIO VENETO
SACILE
CODROIPO
LAVARIANO
PALMANOVA
TERENZANO
BUTTRIO
TARCENTO
SUBIDA
MAJANO
FAEDIS
CIVIDALE
S. DANIELE
VIVARO
PRATA
PINZANO
OSOPPO
GEMONA
TOLMEZZO
TARVISIO
S. VITO AL TAGLIAMENTO
RIVIGNANO
S. GIORGIO di Nogaro
LATISANA
PORTOGRUARO
CAMPOROSSO
CAORLE
LIGNANO
GRADO
MARANO
GRADISCA
CAORLE
F. PIAVE
F. TAGLIAMENTO
ISONZO
MESOZOIC CARBONATIC PLATFORM
EOCENE FLYSCH BASIN
EOCENE SCAGLIA BASIN
MARE ADRIATICO
Scale 1:250000

Fig. 3

overthrusts of the Periadriatic System in the area of Gemona and two large parallel overthrusts with Dinaric trend in the South: the first in the area of Buja, the second near Tricesimo. This southernmost overthrust, surrounded by some minor faults, extends NW across Maiano ending against the Carnic Prealps and SE towards Cividale and further (Sabotino overthrust) into Jugoslavia. South of Osoppo, the Buja overthrust meets another overthrust, trending SW-NE, evidenced by the seismic lines recorded in the area, and which may be considered the easterly extension of the overthrust found on the southern boundary of the mesozoic outcrops of Forgaria. The total vertical displacement caused by the Buja and Tricesimo overthrusts, which can be considered the north-western appendix of the Dinaric System, is nearly 2 km. The orogenetic process which formed these overthrusts probably started during the Oligocene-Miocene and has continued during the successive phases of the Alpine orogenesis.

b) A reverse fault in the area of Sequals. This fault with Alpine alignment represents the southern boundary of the outcropping folds of the Pinzano area and can be connected, to the West, with the Cansiglio overthrust (Fig. 4).

c) A deep trough, which developed in the area limited by the Tricesimo overthrust and by the Buttrio reverse fault. This trough is indicated by the negative gravity anomaly of the Bouguer map and it is confirmed by the seismic sections (Fig. 5). It is assumed that this trough was filled with sediments of Oligocene to Quaternary age.

d) A structural "High", limited by the Buttrio and by the Terenzano-Lavariano reverse fault system. This "High" also

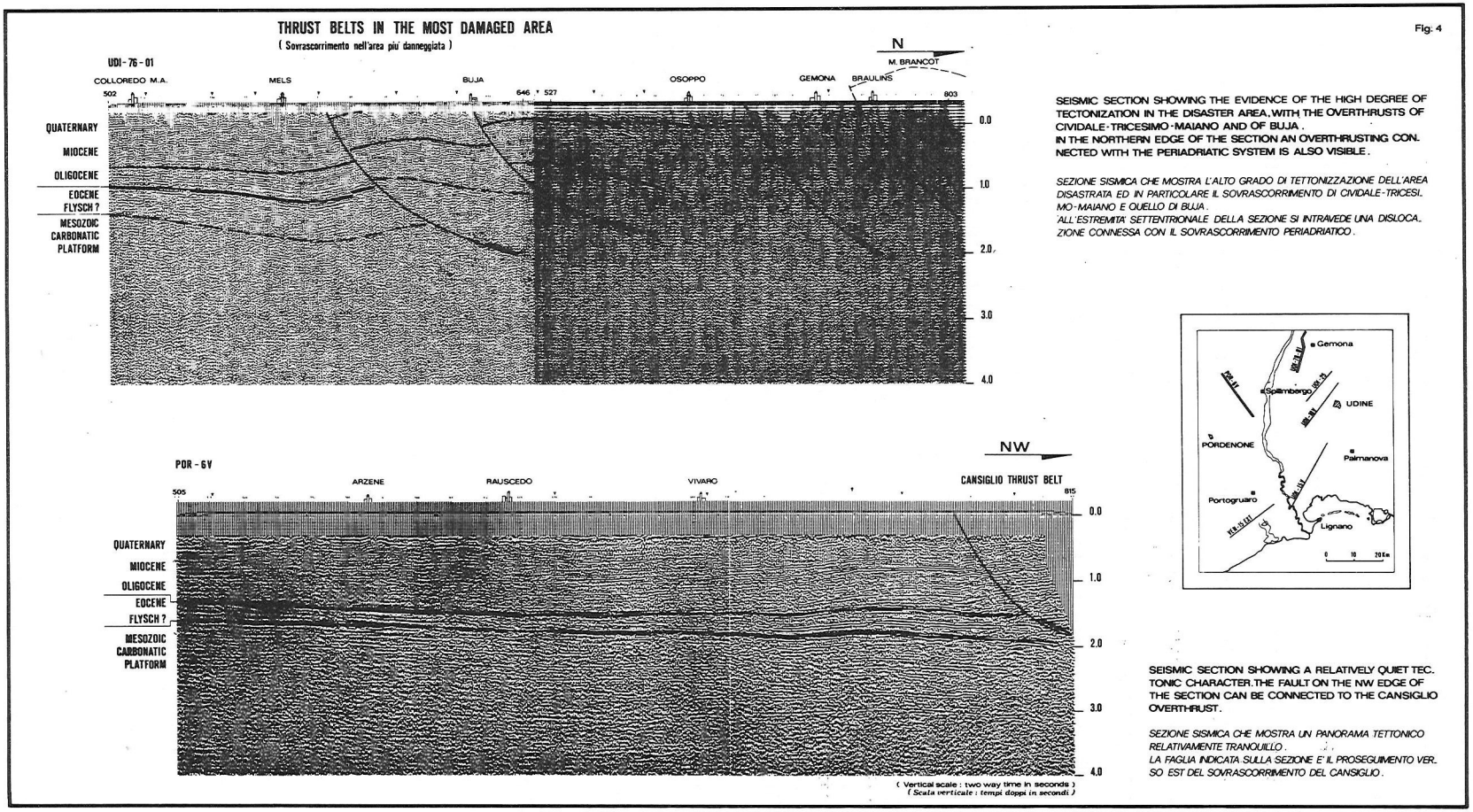

THRUST BELTS IN THE MOST DAMAGED AREA
(Sovrascorrimento nell'area piu' danneggiata)
Fig: 4
UDI - 76 - 01
N
M. BRANCOT
COLLOREDO M.A.
MELS
BUJA
OSOPPO
GEMONA
BRAULINS
502
646
527
803
QUATERNARY
MIOCENE
OLIGOCENE
EOCENE
FLYSCH ?
MESOZOIC
CARBONATIC
PLATFORM
0.0
1.0
2.0
3.0
4.0
NW
POR - 6V
ARZENE
RAUSCEDO
VIVARO
CANSIGLIO THRUST BELT
505
815
QUATERNARY
MIOCENE
OLIGOCENE
EOCENE
FLYSCH ?
MESOZOIC
CARBONATIC
PLATFORM
0.0
1.0
2.0
3.0
4.0
(Vertical scale : two way time in seconds)
(Scala verticale : tempi doppi in secondi)
SEISMIC SECTION SHOWING THE EVIDENCE OF THE HIGH DEGREE OF TECTONIZATION IN THE DISASTER AREA, WITH THE OVERTHRUSTS OF CIVIDALE-TRICESIMO-MAIANO AND OF BUJA.
IN THE NORTHERN EDGE OF THE SECTION AN OVERTHRUSTING CONNECTED WITH THE PERIADRIATIC SYSTEM IS ALSO VISIBLE.
SEZIONE SISMICA CHE MOSTRA L'ALTO GRADO DI TETTONIZZAZIONE DELL'AREA DISASTRATA ED IN PARTICOLARE IL SOVRASCORRIMENTO DI CIVIDALE-TRICESIMO-MAIANO E QUELLO DI BUJA.
ALL'ESTREMITA' SETTENTRIONALE DELLA SEZIONE SI INTRAVEDE UNA DISLOCAZIONE CONNESSA CON IL SOVRASCORRIMENTO PERIADRIATICO.
Gemona
Spilimbergo
UDINE
PORDENONE
Palmanova
Portogruaro
Lignano
0
10
20 Km
SEISMIC SECTION SHOWING A RELATIVELY QUIET TECTONIC CHARACTER. THE FAULT ON THE NW EDGE OF THE SECTION CAN BE CONNECTED TO THE CANSIGLIO OVERTHRUST.
SEZIONE SISMICA CHE MOSTRA UN PANORAMA TETTONICO RELATIVAMENTE TRANQUILLO.
LA FAGLIA INDICATA SULLA SEZIONE E' IL PROSEGUIMENTO VERSO EST DEL SOVRASCORRIMENTO DEL CANSIGLIO.

Fig. 4

has a pronounced Dinaric alignment (Fig. 5). As illustrated by the seismic sections in Fig. 5, the "High" culminates in the area of the Terenzano well. Between the Terenzano 1 and Lavariano 1 wells there is a reverse fault, with a throw of several hundred meters. Terenzano 1 reached, at the total depth of 702 m, the detritic limestone of Danian Age, while Lavariano 1, at the total depth of 1011m, reached the arenaceous limestones of the Middle Miocene. The "High" plunges from the Terenzano 1 area to the NW and finishes between Fagagna and S. Daniele; to the SE it is aligned with the Monte di Medea and the Gorizia-Trieste Karst.

e) An area of quieter tectonics, corresponding to a mesozoic carbonatic platform which crosses the lower Friuli Plain in an E-W direction and separates two different basins as illustrated in Fig. 6. The highest area of the platform is located in the neighbourhood of Latisana.

On the basis of the subsurface interpretation and taking into account the geological features of the region it is possible to outline the geological history of the Friuli Plain (Fig. 8). During the Cretaceous, the environmental conditions in the whole basin are of restricted shallow platform and a wide spread limestone shelf develops. At the beginning of Eocene, the basin is divided by an E-W uplifting of the carbonatic platform into two basins. The sediments in the northern basin are represented by flysch, whose deposition is related to an uplifting phase of the Alpine orogenesis. In the southern basin, extending in the Adriatic offshore and in the western Veneto Plain, farther from the source area, a deposition of marly limestone (Scaglia fm.) took place. The same

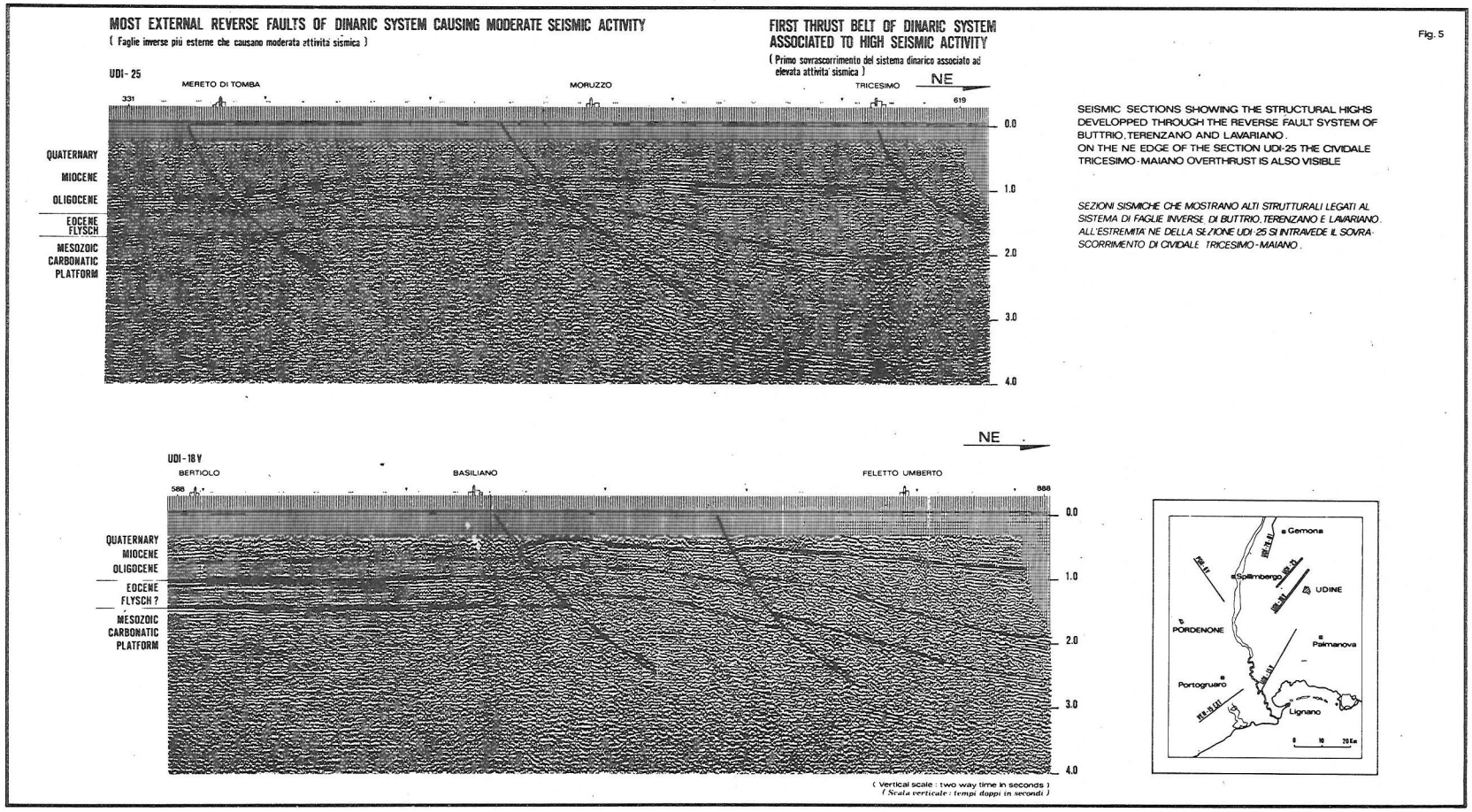

MOST EXTERNAL REVERSE FAULTS OF DINARIC SYSTEM CAUSING MODERATE SEISMIC ACTIVITY
(Faglie inverse più esterne che causano moderata attività sismica)
FIRST THRUST BELT OF DINARIC SYSTEM ASSOCIATED TO HIGH SEISMIC ACTIVITY
(Primo sovrascorrimento del sistema dinarico associato ad elevata attività sismica)
Fig. 5
UDI-25
MERETO DI TOMBA
MORUZZO
TRICESIMO
NE
331
619
QUATERNARY
MIOCENE
OLIGOCENE
EOCENE FLYSCH
MESOZOIC CARBONATIC PLATFORM
0.0
1.0
2.0
3.0
4.0
SEISMIC SECTIONS SHOWING THE STRUCTURAL HIGHS DEVELOPPED THROUGH THE REVERSE FAULT SYSTEM OF BUTTRIO, TERENZANO AND LAVARIANO.
ON THE NE EDGE OF THE SECTION UDI-25 THE CIVIDALE TRICESIMO-MAIANO OVERTHRUST IS ALSO VISIBLE
SEZIONI SISMICHE CHE MOSTRANO ALTI STRUTTURALI LEGATI AL SISTEMA DI FAGLIE INVERSE DI BUTTRIO, TERENZANO E LAVARIANO.
ALL'ESTREMITA' NE DELLA SEZIONE UDI-25 SI INTRAVEDE IL SOVRASCORRIMENTO DI CIVIDALE TRICESIMO-MAIANO.
NE
UDI-18 V
BERTIOLO
BASILIANO
FELETTO UMBERTO
588
888
QUATERNARY
MIOCENE
OLIGOCENE
EOCENE FLYSCH ?
MESOZOIC CARBONATIC PLATFORM
0.0
1.0
2.0
3.0
4.0
(Vertical scale : two way time in seconds)
(Scala verticale : tempi doppi in secondi)
Gemona
Spilimbergo
UDINE
PORDENONE
Palmanova
Portogruaro
Lignano
0 10 20 Km

Fig. 5

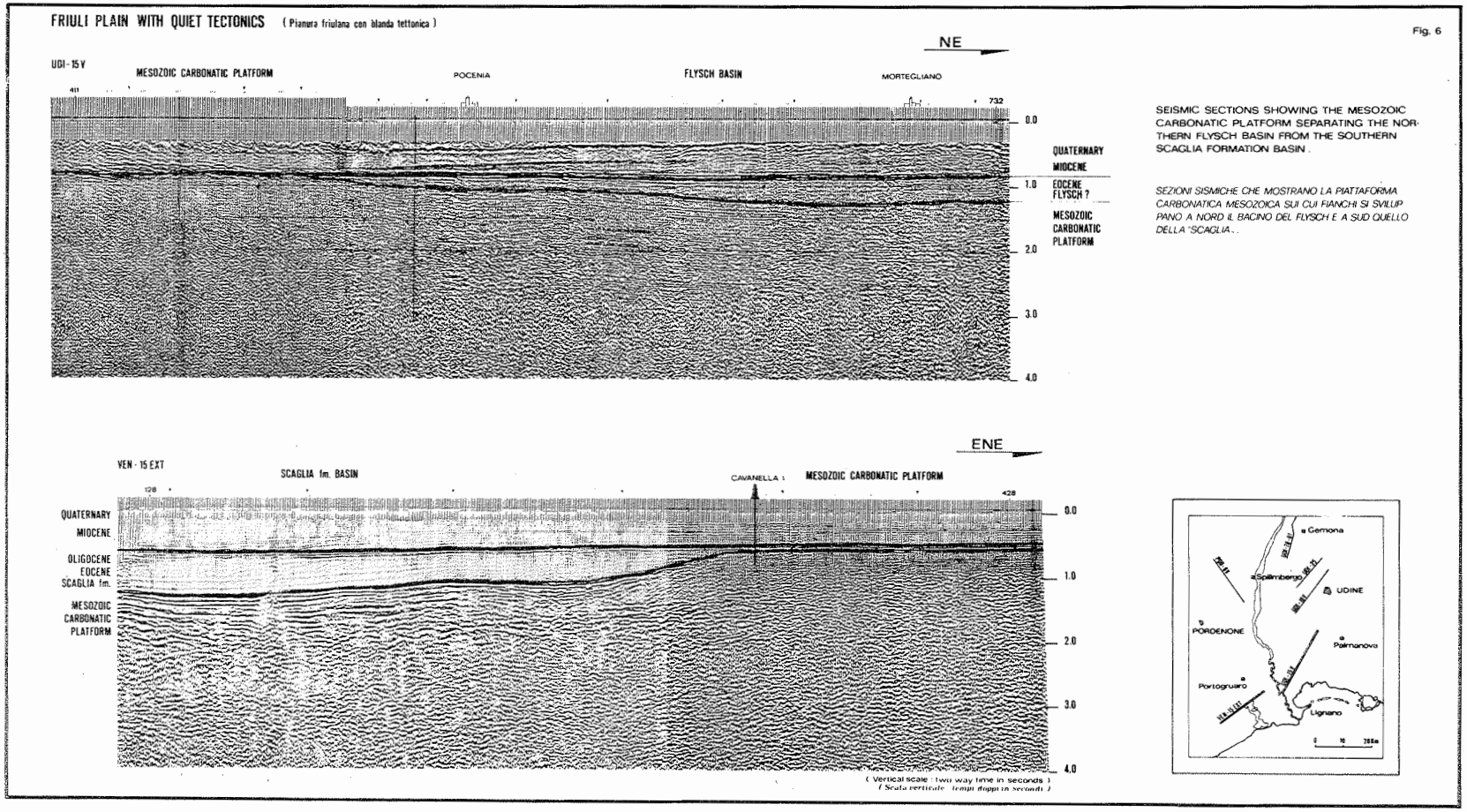

FRIULI PLAIN WITH QUIET TECTONICS (Pianura friulana con blanda tettonica)
Fig. 6
NE
UDI - 15 V
MESOZOIC CARBONATIC PLATFORM
POCENIA
FLYSCH BASIN
MORTEGLIANO
411
732
0.0
1.0
2.0
3.0
4.0
QUATERNARY
MIOCENE
EOCENE FLYSCH ?
MESOZOIC CARBONATIC PLATFORM
SEISMIC SECTIONS SHOWING THE MESOZOIC CARBONATIC PLATFORM SEPARATING THE NORTHERN FLYSCH BASIN FROM THE SOUTHERN SCAGLIA FORMATION BASIN .
SEZIONI SISMICHE CHE MOSTRANO LA PIATTAFORMA CARBONATICA MESOZOICA SUI CUI FIANCHI SI SVILUPPANO A NORD IL BACINO DEL FLYSCH E A SUD QUELLO DELLA "SCAGLIA" .
ENE
VEN - 15 EXT
SCAGLIA fm. BASIN
CAVANELLA
MESOZOIC CARBONATIC PLATFORM
128
428
QUATERNARY
MIOCENE
OLIGOCENE
EOCENE
SCAGLIA fm.
MESOZOIC CARBONATIC PLATFORM
0.0
1.0
2.0
3.0
4.0
(Vertical scale : two way time in seconds)
(Scala verticale : tempi doppi in secondi)
Gemona
Spilimbergo
UDINE
PORDENONE
Palmanova
Portogruaro
Lignano

Fig. 6

environmental conditions persist at least for the Lower Oligocene. At the end of Oligocene and at the beginning of Miocene a regressive cycle, ending with a total emergence, is being set up. Terrigenous sediments and sandy limestone of very shallow shelf are being deposited. In the northern basin in the Oligocene and Lower Miocene there is a hiatus due to a tectonic phase, developed through reverse faults and overthrusts, which cause a regional uplifting and a trough elongating in the E with Dinaric trend and in the W with Alpine trend. It is possible to assume the presence of oligocene and miocene sediments in this trough. During the Middle Miocene a subsidence occurs in the whole basin where sandy merls and marly limestone are being deposited. The Upper Miocene and Pliocene coincides over almost the whole area with a hiatus which probably marks the most intense tectonic phase of the Alpine orogenesis. The preexistent faults are reactivated, new ones are originated and the northern edge of the plain is affected by foldings. The pontic outcrops in the molassa facies evidence this strong tectonic phase. After this orogenic phase, during the Quaternary, setting and slow subsidence phenomena occur. Nevertheless, the thickness difference of Quaternary sediments in Lavariano 1 (580m) and in Terenzano 1 (216m) confirms a tectonic activity. This young tectonic activity within the Friuli Plain is also confirmed by the older Quaternary deposits, outcropping from recent alluvium, near the faults, which have been identified by seismic lines (Pozzuolo del Friuli, Orgnano, Variano, Udine etc.).

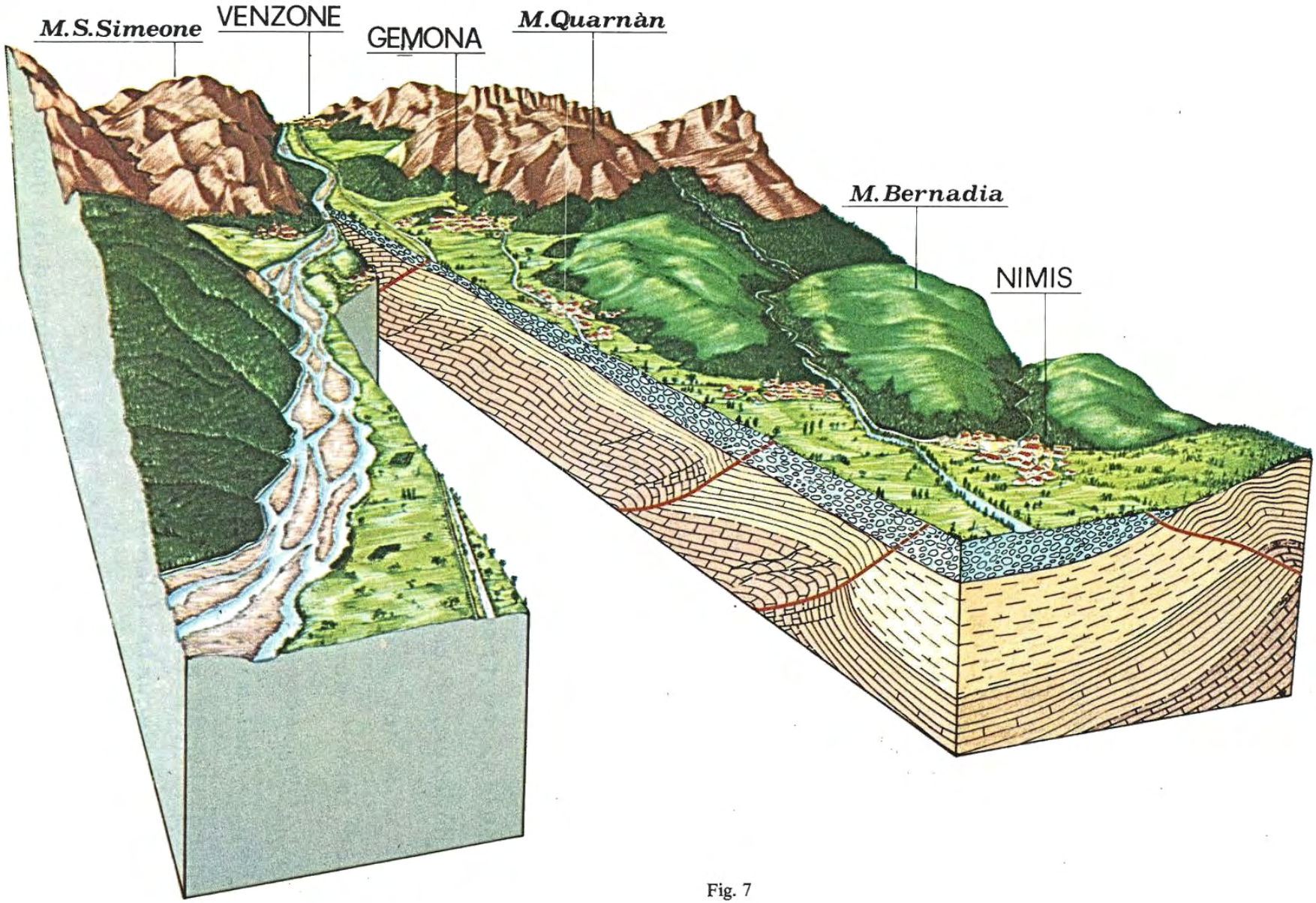


Fig. 7

4.- GEODYNAMIC OUTLINE

The area investigated can be divided, from N to S, according to its structural features, into four structural provinces (Fig. 10):

- The first, located N of the "Periadriatic Line"; is characterized by several large thrustbelts which gave rise to the Carnic and Julian Pre-Alps.

The prevailing tectonic trend is the Alpine, trending E-W, locally intersected by cross fractures.

The thrust planes at surface dip up to about 40°.

Within this structural province, in the past, several desctructive earthquakes occured in the area between the 1976 shocks and Tolmezzo.

All this earthquakes can be associated with the thrust belt of the "Periadriatic System".

In this province, furthermore, it is possible to identify some transverse fractures, which correspond, at least partially, to transcurrent faults.

However, from the seismogenetic point of wiev, these faults do not seem to constitute geodynamic elements of major importance.

- The second province, which corresponds to the damaged area, is delimited to the N by the "Periadriatic Line", and to the SW and to the SE respectively by the thrust faults of Sequals (Cansiglio) and of Tricesimo (Mt. Sabotino).

In this province, strongly deformed by geodynamic forces, which appear to be still active, the Tagliamento River marks the junction of the Alpine and Dinaric Systems.

As evidenced by the drilling and seismic data, the main structural elements are a succession of overthrusts, (Buja, Tricesimo) with southward polarity, gently dipping thrust planes, and large horizontal displacement, and some eradicated thrust blocks (Mt. Bernadia and Mt. Peroc).

The orogenic junction area of this part of Friuli, under the tectonic point of view, is one of the most complex of the entire region.

The degree of seismicity is intimately related to this complex tectonics situation, resulting from intense geodynamic activities.

- The third province, delimited to the N by the Sequals and Tricesimo lines and to the S by the Mesozoic carbonate platform, is less tectonized than the two just described.

In fact in this province, which is farther from the sources of the geodynamic stresses, there are only reverse faults (Buttrio, Terenzano-Lavariano).

The fourth and last province, coinciding whith the Mesozoic carbonate platform, occupies the Southern Friuli down to the coats.

This province does not have evidence of recent geodynamic activity.

Summarizing, with regard to the age of the orogenic movements which affected the area under study, the following considerations can be made based on surface and subsurface geological data.

The first movements of the Alpine orogeny are datable to the Paleocene-Eocene as is witnessed by the flysch deposits in the area, but it is chiefly after the Oligocene

that the most significant geodynamic phenomena occurred.

The particular sinorogenic features of the Pontico deposits, and the fact that these are directly involved in the main foldings of the region suggest that the most important orogenic phase occurred during the Upper Miocene and continued probably into part of the Pliocene.

The geodynamic movements connected with this orogenic phase led to the present morphologic configuration of the region.

More recent geodynamic movements affected the region even after the attenutaion of the main phase described above.

In fact there is evidence of Quaternary tectonics.

The amount of seismicity, which characterizes the central part of Friuli, indicates that geodynamic phenomena are still under way.

5.- FOCAL MECHANISM AND SEISMOGENETIC FAULT SYSTEM OF 1976 FRIULI EARTHQUAKES

The basic data for the examination and conclusion made on the focal mechanism of the 1976 Friuli earthquakes are the following:

a) Time and space epicenter distribution determined by

the OGS central seismic station of Trieste (TRI-WWSSS) of the main shocks and all related aftershocks.

b) Epicenter and hypocenter distribution of the aftershocks occured soon after the main shock of May 6 and September 11 and 15, determined by the IPG's (Institute de Physique du Globe, Strasbourg) teleseismic system, installed in the epicentral area.

c) Subsurface structural data carried out by a digital seismic reflection exploration conducted by AGIP.

d) Tectonic setting reconstructed by the recent CNR's geological investigations in the framework of the "Geodynamic Project".

The most important contribution to the understanding of the focal mechanisms is given by the IPG's teleseismic system. The first observation is that the epicenter location of the main shock and aftershocks of May are in the area of Peanis, Osoppo, Buia, Artegna, Gemona etc. (Fig. 10), while the shocks of September are concentrated on an area which is some 8 km North of the previous one.

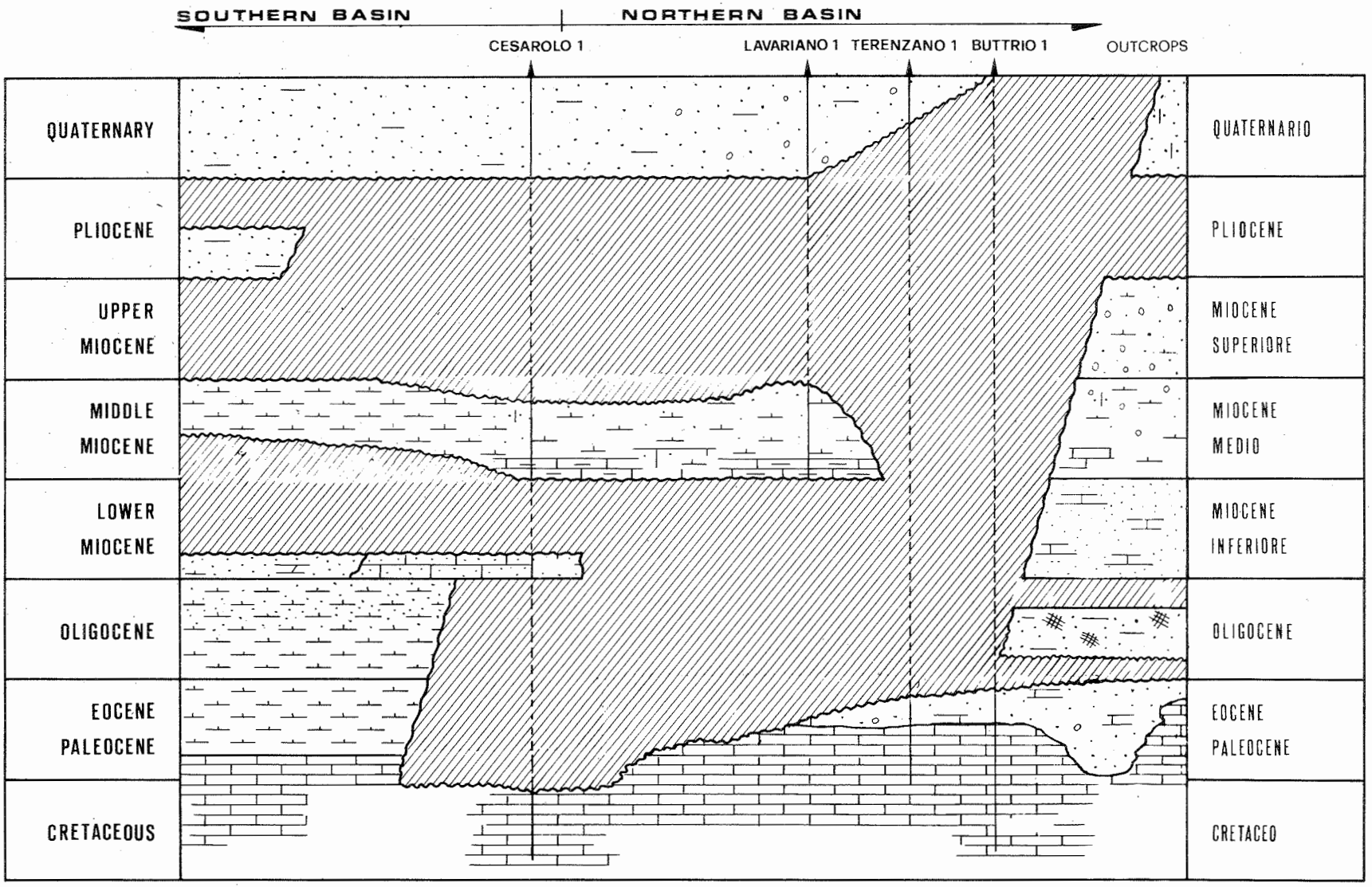
Tendency to a progressive northward migration of the epicenter even into a more scattered picture, is observable also on the general OGS's epicenter map (Colautti et al., 1976), determined by the Trieste station. Obviously this map cannot have the same position accuracy as the teleseismic system determination.

The earthquake of May 6 seems to be connected to the Dinaric thrust-fault system edging to the S along the Buia-Tricesimo line. If we consider a fault-plane slope of about 25° it is possible to correlate this plane with the hypocentral positions

CHRONOSTRATIGRAPHIC PICTURE

QUADRO CRONOSTRATIGRAFICO

Fig. 8



REIM Dis. n° 88 Generali

projected on a N-S plane (Fig. 9). The maximum energy concentration of the aftershocks lies at a depth of 2 to 8 km, with the highest density around 5 km.

Calculating the focal depth with the empirical procedure of Sponheuer (1960) based on the isoseismal map, one obtains roughly the same focal depth (Giorgetti, 1976) of 5 km, using an origin intensity I_o=10 and a calculated average attenuation coefficient α=0.0015.

Thus , all the considered data confirm that the destructive earthquake of May 6 had a very shallow focal depth.

The area of epicenters determined soon after the strong shocks of 11 and 15 September, as said above, has a position which is about 8 km N of that relative to the epicenters of May (Fig. 10). The hypocentral position is mostly concentrated around a depth of 5 to 7 km, but several aftershocks of the short period of teleseismic observation show a depth fitting a plane of about 40° of slope and extended downward to a depht of about 16-17 km. All this indicates that the strong shocks of September are connected to a fracture lying N of that of May and their focal depth is a little deeper. Such a position suggests the idea that these shocks are associated to the Periadriatic thrust-fault system.

The aftershocks of both May and September main shocks are distributed along ellipses elongated E-W and in accordance to the picture of the thrust-fault systems. This aspect seems to indicate that even if the effects of some transcurrent faults cannot be excluded at all, in any case this type of fault did not play an important role.

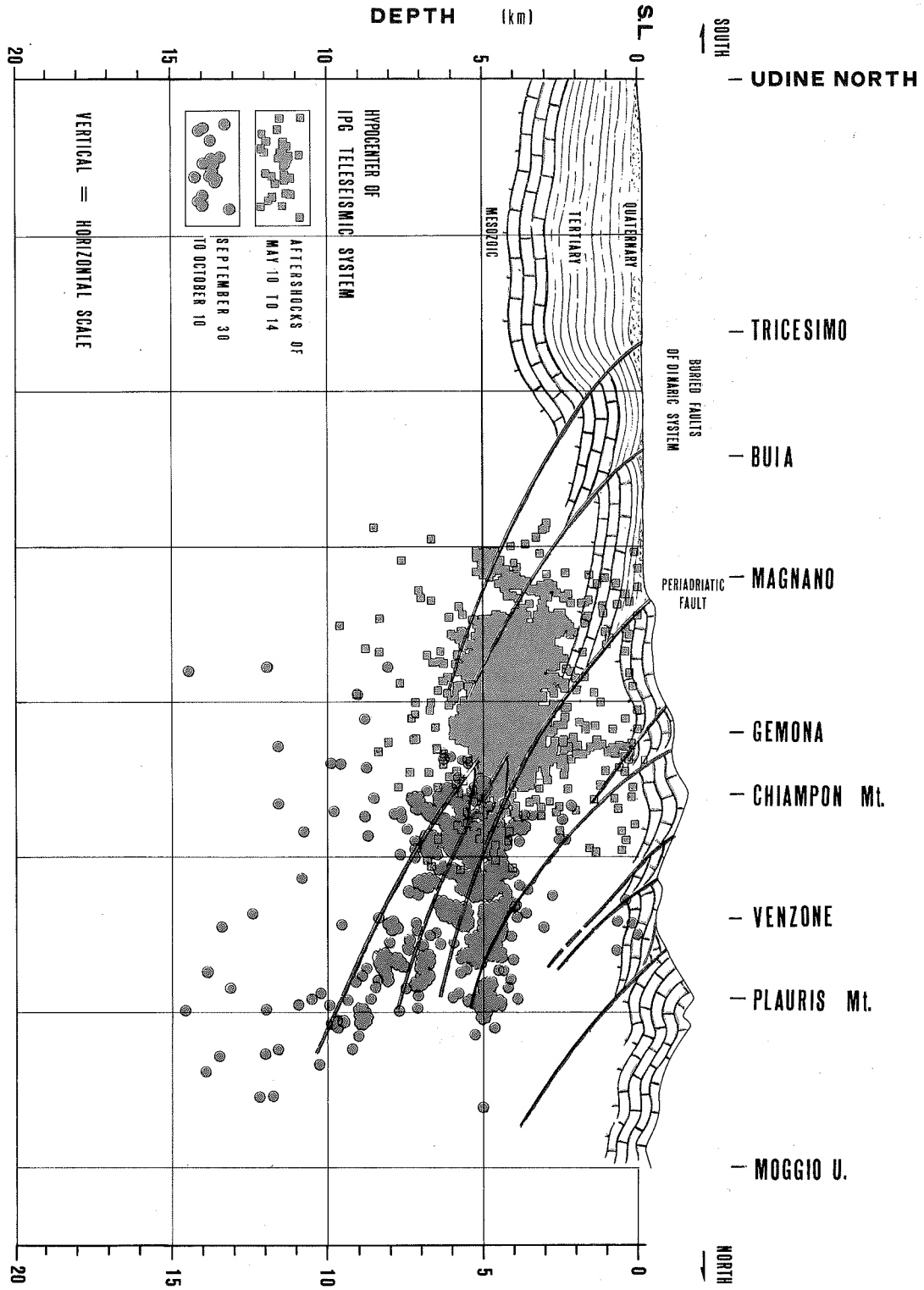

DEPTH (km)
S.L.
0
5
10
15
20
SOUTH
NORTH
UDINE NORTH
TRICESIMO
BUIA
MAGNANO
GEMONA
CHIAMPON Mt.
VENZONE
PLAURIS Mt.
MOGGIO U.
QUATERNARY
TERTIARY
MESOZOIC
BURIED FAULTS OF DINARIC SYSTEM
PERIADRIATIC FAULT
HYPOCENTER OF IPG TELESEISMIC SYSTEM
AFTERSHOCKS OF MAY 10 TO 14
SEPTEMBER 30 TO OCTOBER 10
VERTICAL = HORIZONTAL SCALE

Fig. 9

Tab. 1 - LIST OF 1976 HIGHER MAGNITUDE EARTHQUAKES (M > 5) OF FRIULI

N.	DATE (1976)	HOUR (GMT)	COORDINATES		MAGNITUDE
			LAT.	LONG.	
1	May, 6	20 00 08.6	46 16.7	13 06.1	6.4
2	May, 9	00 53 42.0	46 14.4	13 19.4	5.3
3	Sep.,11	16 31 08.2	46 18.6	13 10.9	5.1
4	Sep.,11	16 34 57.2	46 19.7	13 09.8	5.6
5	Sep.,15	03 15 17.0	46 18.6	13 10.9	5.8
6	Sep.,15	09 21 16.2	46 19.2	13 08.8	6.1

A probable explanation of the four big aftershocks having a magnitude higher than 5.0 (5.1, 5.6, 5.8, 6.1), which occured four months after the main May 6 shock (6.4), could be the following. The May 6 earthquake was accompanied by a southward displacement of the Dinaric blocks lying between the Gemona and Buia areas. This movement produced a decompression on the north side of the blocks. The decompression was compensated with a southward displacement of the Mt. Chiampon area thrust-blocks lying immediately to the north of the Gemona-Buia ones. The Mt. Chiampon area blocks overthrusted those on the Gemona-Buia area.

In order to obtain an indication regarding the values of the focal parameters characterizing the two main shocks of the Friuli 1976 earthquake, the direct observations furnished by the teleseismic network were utilized. Practical simplifications and arbitrary assumptions regarding the seismic moment

were also made, according to the Eaton et al. (1970) procedure applied to the Parkfield-Cholame seismic area (California).

The lenght of the activated fracture was estimated considering the epicenter areas determined with high accuracy by the teleseismic system. Dispersed events at the extremities were excluded. This precise information was also considered indicative in what regards the determination of focal depths.

The calculated displacements have to be taken only as a rough indication. They have been determined using the Wyss et Smith (1969) formula:

$$\bar{u} = \frac{M_o}{A_o \mu}$$

where:

$\bar{u}$ = average displacement of the entire slip surface

M_o = seismic moment

μ = rigidity of the faulted rocks

The seismic moment has been determined using the equation (Eaton et al., 1970), with a different constant:

$$M_o = 1.5\ M + 16.0$$

where M is the earthquake magnitude. The coefficient, the constant value and the μ value were arbitrarily selected from the magnitude-moment relationship for Parkfield-Cholame earthquakes obtained by Aki (1969) and by Wyss et Boune (1968). For the constant it was assumed an intermediate value of 16 with respect Aki (1969) and Eaton et al. (1970).

$$\mu = 3.0 \times 10^{11} \text{ dyne/cm}^2$$

The assumed area was taken to be 200 km^2 for the May 6 earthquake and 270 km^2 for the Sept. 15 one. The resulting parameter are those listed in Tab. 2.

6.- SEISMICITY

The purpose of this study is to construct a general map showing the maximum expected intensity for a given long return period and to establish the type and the position of the main seismic sources.

The following steps were made:

1) Compilation of isoseismal maps of individual earthquakes having intensity $I_o \geqslant 6$ (MCS scale) and epicenter location in the studied region for all the hystorical shocks sufficiently documented.

2) Isoseismal maps calculated from magnitudes values of instrumental shocks using the Karnik's empirical conversion for the Alps: $M = 0.53\ I_o + 0.95$ (Karnik, 1969).

3) Compilation of isoseismal maps of all available shocks with epicenter outside the Friuli-Venetia Julia Region, felt on the studied territory with intensity $I \geqslant 6$ (MCS scale).

4) Identification of the main active faults and evaluation of their order of importance as seismic sources. Correlation of the seismicity to the active faults.

An important contribution is given by the detailed study of the May 6 earthquake for which a large and reliable information is available (Giorgetti, 1976). For the understanding

Tab. 2 - INDICATIVE PARAMETERS OF THE TWO MAIN DESTRUCTIVE EARTHQUAKES OF FRIULI(1976)

SHOCK	GENERATING FRACTURE	MAGNITUDE (M)	LENGTH OF THE ACTIVATED FRACTURE (km)	FOCAL DEPTH OF THE ENERGIZING PLANE (km)			DISPLACEMENT (AVERAGE (cm)
				TOP	BOTTOM	MAXIMUM CONCENTRATION OF ENERGY	
MAY, 6 H 20 00' 08".6	THRUST-FAULTS OF BUIA-OSOPPO (DYNARIC SYSTEM) PRESSED BY THE PERIADRIATIC THRUST-FAULT SYSTEM	6.4	19	2	8	4	66.3
SEPT. 15 H 09 21' 16".2	PERIADRIATIC THRUST-FAULT SYSTEM AS REACTION TO THE DEPRESSION CREATED BY THE PREVIOUS SHOCKS.	6.1	22	3	12	5	17.4

of the main source type a clear information is furnished by the teleseismic data.

On the maps of Fig. 10 the resulting conclusions are plotted regarding the maximum expected intensity, calculated for a return period of 1000 years, based on a long hystorical observation time (386 to 1976).

As indicated by the map, central Friuli is the most important seismic zone of the studied area. Other areas of high seismicity are those of Cansiglio, Cividale, Belluno and Villach. The last two don't lie in the region Friuli Venetia Julia territory, but are very close to its borders.

The high seismicity of the Central Friuli and Cansiglio areas is related to the compressional geodynamics of the Periadriatic thrust-fault system and to its successive internal thrust belts.

The seismicity of the Cividale area is quite high but has a much larger return period than central Friuli. Its source is also constituted by the most external active thrust-faults of the Dinaric system.

The Belluno seismic area, with an observed earthquake of 10 degrees of intensity, is associated to more complex tectonic features. These are determined by the intersection of different fracture systems belonging to the Alpine range, which are predominantly overthrusting.

Near Tarvisio an active zone of high intensity is related to the Villach zone, whose seismicity is connected to the regionally important Fella-Sava and Gail line.

Other seismic areas of Friuli to the North of the May 6 epicentral area, are associated mostly to compressional tecto

nics of the Carnic, Tolmezzo and the Julian Alps, with over thrusts. Along the fracture line Tolmezzo-Paularo, a transcurrent fault system is probably also consistently active.

A seismically very important datum is the high Vp to Vs ratio which reaches a maximum value of about 1.94 in the area of central Friuli. Calculating this value for the seismic station of Trieste it results that from May to October the average Vp to Vs ratio went from 1.88 to 1.84.

The delimitation of this anomalous area and the possible evolution of the ratio against time is of great importance for the local seismic implications.

7.- CONCLUDING REMARKS

The large amount of data analyzed, the considerations made, and the interpretations given, suggest the following concluding remarks:

a) The area of Central Friuli, now disastered, presents a high seismicity with a relatived short earthquake return period. The expeted high intensity ($I_{o_{max}} = 9$) extends to a large part of the Friuli Region with other two main seismic sources in the areas of Cansiglio and Cividale.

b) The high seismicity of Friuli Region is connected with regional fault-systems in which the thrusting effects are largerly dominating with respeet to other fracture types like transcurrent faults.

c) The Friuli Plain area, south of Pordenone, Udine and Palmanova is constituted by a stable non-seismogenetic Mesozoic platform where the earthquakes coming from the seismic

areas of central and north Friuli arrive with a non dangerous intensity ($I_{max} \leqslant 7$).

d) The 1976 destructive earthquakes present the same type of focal mechanism (thrust-faulting) with very shallow focal depth, but different focal zones for May 6 and September shocks respectively. The first main shock (May 6) is associated with the Buia-Tricesimo thrust-fault system, and the September 11 and 15 strong shocks are connected with activity of the Periadriatic thrust-belt, North of the first source.

e) The Vp to Vs ratio gives for central Friuli a very high value of 1.94 which may be furtherly investigated and controlled in its possible evolution against time.

ACKNOWLEDGEMENTS

The Authors wish to thank AGIP Attività Minerarie for permission to publish the gravity and seismic exploration data presented here. Thanks are also due to SNIA VISCOSA for the seismic information furnished, to CNR for the support granted to the investigations conducted on the damaged area and in the whole Friuli. Particular gratitude is also expressed to all OGS's seismological staff for the enourmous amount of seismological data analyzed during the last months.

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BIBLIOGRAPHY

AUBOIN J. et al. (1972) - Essai sur la géologie des Dinarides Bull.Soc.Géol.France, 12(1970), 1060-1095 pp., 3 fig., Paris.

AKI K. (1969) - Analysis of the Seismic Coda of Local Earthquakes as Scattered Waves. J. Geophys.Res. 74, 615-631.

AMADESI E., LEONARDUZZI G. (1973) - Geologia del Gruppo di M. Festa (Friuli Udinese). Mem.Museo Trident.Sc.Nat., 19, 23 pp., 5 fig., Trento.

BARTOLE R., BERNARDIS G., GIORGETTI F., NIETO D., RUSSI M., (1976) - Earthquake Catalogue of Friuli-Venetia Julia Region (From Roman Epoch up to 1976). Proceedings of the Udine Meeting, 4-5 December 1976.

BOSELLINI A. (1973) - Modello geodinamico e paleotettonico delle Alpi Meridionali durante il Giurassico-Cretacico. Sue possibili applicazioni agli Appennini. Atti Conv. Moderne vedute sulla geologia dell'Appennino, Acc.Naz. Lincei, Quaderno 183, pp. 163-205, 17 fig., 2 tav.,Roma.

CHOROWICZ J. (1975) - Le devenir de la zone de Budna vers le Nord-Ouest de la Yougoslavie. Bull.Soc.Géol.France, 17, pp. 699-707, 5 fig., Paris.

COLAUTTI D., FINETTI I., NIETO D., PUPIS C., RUSSI M., SLEJKO D., SUHADOLC P. (1976) - Epicenter Distribution of Aftershocks of Friuli Earthquakes. Proceedings of the Udine Meeting, 4-5 December 1976.

COUSIN M. (1972) - Esquisse géologique des confins italo-yougoslaves: leur place dans les Dinarides et les Alpes méridionales. Bull.Soc.Géol.France, 12(1970), pp. 1034-1047, 3 fig., Paris.

EATON J.P., O'NEILL M.E., MURDOCK J.N. (1970) - Aftershocks of the 1966 Parkfield - Cholame, California Earthquake: A Detailed Study. Bull.Seism.Soc.An. 60, 1151-1197.

FINETTI I., GIORGETTI F., HAESSLER H., HOANG T.P., SLEJKO D., WITTLINGER G. (1976) - Time-space Epicenter and Hypocenter Distribution and Focal Mechanism of 1976 Friuli Earthquakes. Proceedings of Meeting on the Friuli Earthquake, Udine 4-5 December 1976.

GIORGETTI F. (1976) - Isoseismal Map of the May 6, 1976 Friuli Earthquake. Proceedings of Meeting on Friuli Earthquake, Udine 4-5 December 1976.

GNACCOLINI M., MARTINIS B. (1974) - Nuove ricerche sulle formazioni calcaree giurassico-cretaciche della regione compresa tra le valli del Natisone e del Piave. Mem. Riv.Ital.Paleont.Strat., 14, 48 fig., Milano

KARNIK V. (1969) - Seismicity of the European Area. Reidel Publishing Company, Dordrecht, Holland.

LUCCHETTI L. et al. (1968) - Geologia e ricerca petrolifera - Pianura Padano-Veneta. Enciclopedia del Petrolio e del Gas Naturale a cura dell'Ente Nazionale Idrocarburi.

MARTINIS B. (1971) - Geologia generale e Geomorfologia del Friuli-Venezia Giulia. In: Enciclopedia monografica del Friuli-Venezia Giulia, 1, pp. 85-172, 90 fig., Udine.

MARTINIS B. (1975) - The Friulian and Julian Alps and Pre-Alps. Structural Model of Italy. C.N.R., Quaderni de "La Ricerca Scient.", 90,pp. 17-49, 19 fig., Roma

SMITH S.W., WYSS M. (1968) - Displacement on the S. Andreas Fault Subsequent to the 1966 Parkfield Earthquake. Bull.

Seism.Soc.Am. 58, 1955-1973.

SPONHEUER W. (1960) - Metoden zur Herdtiefenbestimmung in der Makroseismik. Geoph. Akad.Verlag. Berlin C 88.

WYSS M., BRUNE J. (1968) - Seismic Momenti, Stress and Source Dimensions for Earthquakes in the California-Nevada Region. J. Geophys.Res. 73, 4681-4694.

ZANFERRARI A. (1973) - Osservazioni geologiche sui terreni attraversati dalla galleria dell'autostrada di Alemagna presso Vittorio Veneto. Significato dei dati in rapporto alla tettonica del margine meridionale del Cansiglio. Mem.Soc.Geol.Ital., 12, pp. 529-548, 11 fig., 1 tav., Roma.

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ENGINEERING SEISMOLOGY ASPECTS OF THE GEMONA-FRIULI EARTHQUAKE

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Introduction

The information on earthquakes which is available for Friuli is sufficient to establish the fact that the region is seismic. The analysis of this information is given in Reference (1)+.

Documentary information concerning the occurrence of earthquakes in Friuli and in adjacent regions for a period spanning at least 800 years contains a wealth of information, the study of which shows that so far there has been no serious attempt to review critically early

+ UNESCO Report

sources of information, and no attempt to disentangle the various accounts given for a particular event. For instance, the earthquake of the 25th January, 1348 has long held a place among the great earthquakes in Europe[++]. This it owes not only to the destruction of the town of Villach and of a good part of Friuli, Carnia and Carinthia, but also to the large area over which it was felt, about 1.8 million square kilometres (Figure 1.). But anyone reading the accounts of the Carinthian chroniclers will find that they always refer to this event as the "Villach Earthquake" which is described in great detail with accounts of the damage wrought to the town and to the villages in the Gail and Drau valleys, and of the major landslide at Dobratsch which was associated with the collapse of 1000 million cubic metres of slide material (Figure 2.). They say very little, however, of what happened in Friuli. On the other hand, in Italian accounts one finds very little detailed information about Carinthia and the isolated northern districts of Pontebba and Moggio, but more about the effects of the earthquake in Friuli and in Venice. The same is true of the earthquake of the 26th March, 1511 and of its destructive aftershock of 8th August which was felt within an area of 1.1 million square kilometres (Figure 3.).

[++] This earthquake is usually confused with the earthquake of 1356 which caused damage in Basel.

Reference (1) gives the results of an attempt to reconcile data from the available sources of information for the period 1116 to 1975. A special effort was made to assess the average radius of perceptibility (r_3) for each earthquake and the duration of aftershocks. In all, over 200 earthquakes were studied.

Examination of calculated epicentres for the period after 1910 shows serious deficiencies in the determination of hypocentral data. Early locations worked out by ISS are grossly erroneous in most cases, often "adopted" without calculation. An attempt was made, therefore, to relocate a number of earthquakes in Friuli. These efforts have proved unsuccessful on the whole; out of 26 events tested, 21 were rejected as inconsistent. For the smaller shocks errors in arrival times were found to be large. Thus, for the majority of the earthquakes in Friuli which are of relatively small magnitude, there is always a small number of stations that can supply onset times. These stations are nearby and require much greater corrections than distant stations. However, it was found possible to calculate surface-wave magnitudes (M_s) for almost all instrumental events, using amplitude-period readings. Body-wave magnitudes (m) were also calculated for the larger events.

For 20th century data the following relationship between M_s and radius of perceptibility was found:

$$M_s = 0.91(\pm 0.17) + 1.98(\pm 0.09)\log(r_3) \quad \ldots\ldots \quad (1)$$

This relationship was used to assign the order of magnitude (M) of pre-20th century events.

The cumulative magnitude-frequency relation for central Friuli (46° to 46.5°N and 12.5° to 13.5°E $\pm$ 1°) shows a significant departure from the linear form $\log(N_c) = a - b(M)$, where N_c is the average annual number of earthquakes of magnitude equal to, or greater than M. The best fit is given by:

$$\log(N_c) = -2.018 + 1.286(M_s) - 0.207(M_s^2) \quad \ldots\ldots \quad (2)$$

Earthquakes in central Friuli do fit a Gumbel type-1 distribution. It can be shown that the largest probable earthquake should not exceed a magnitude $M_s = 6.8$. An earthquake of magnitude greater than this has a very small probability of occurring. In one hundred years this probability will only be a few percent, while a much larger shock than the Gemona earthquake of 1976 is not really overdue since the 350-year earthquake of about magnitude 6.6 had an 80% chance of occurring and did occur in 1348. The chance that other earthquakes of similar magnitude could have escaped notice is very unlikely.

During the last seven centuries the seismicity of Friuli has been

discontinuous both in time and space. The region as a whole has shown short intervals of high seismicity separated by relatively long periods of quiescence of approximately 160 years. Seismicity is restricted along two well-defined conjugate zones (AB) and (BC) which in fact ran along the demarcation line between the pre-Alp massifs and the Tagliamento valley (Figure 4). It is of interest that short and long-term seismicity should be associated with a transverse system rather than with the well-established east-west trending thrusts. It may very well be that these two transverse zones correspond in their general trend to actual through-going basement dislocation zones associated with a northward thrust. The activity in these two zones is discontinuous in the sense that it alternates with time from one zone to the other. In the eastern zone (BC) activity persisted for almost four centuries before it passed onto the western zone (AB) which, in the meantime, was to all practical purposes totally quiescent. For the next two centuries the western zone (AB) remained fully active. By the turn of this century the pattern was once more reversed, the activity of the eastern zone culminating with the Gemona earthquake.

The Gemona-Friuli earthquake of 1976

What follows is a summary of the most interesting characteristics of the Gemona earthquake. A full description of the event is given in Reference (1).

The Gemona earthquake occurred at 9.00 pm. local time and had a magnitude of 6.5. It was preceded by a foreshock of magnitude 4.5. Another phenomenon which could have been premonitory was the reported appearance of a glow in the sky above the northern parts of the epicentral region which persisted for some time after the earthquake. There is also some unauthenticated evidence of changes in the magnetic flux in the region.

The main shock killed 965 and injured 2,286 people. The average rate of fatalities for the whole area is just under 1% of the affected population. All age groups except the infants and elderly suffered fatalities roughly proportional to their numbers. People in the former group either were more protected by the agile groups of adults who saved them or were not in the most vulnerable locations. In densely populated villages and historical town centres the more agile group of youths suffered more casualties in their attempts to seek refuge outdoors than the adults and elderly. People who ran into the wide streets of modern towns survived; many of those who escaped into

the narrow streets of old town centres were buried as the old houses collapsed, or were crushed under falling parapets and balconies.

The material damage caused by the earthquake is estimated at ₰ 2,800 million; damage to historical monuments and the loss in terms of art and architecture is inestimable.

So far there is no evidence that the earthquake was associated with surface faulting. Ground deformations originally suspected to be of tectonic origin proved on examination to be of secondary nature, associated with ground slumping and landsliding. Persistent patterns of ground fracturing found in a few places and caused by slumping do not align with any minor or major local fault.

The earthquake produced ground fracturing in the form of slumping and cracking on flat and sloping ground, as well as a few cases of local liquefaction. Landslides, rockfalls and debris-flows from steep slopes triggered by the earthquake and by its aftershocks as well as by heavy rains, caused heavy damage to property. Most of the rock faces and slopes that collapsed were already unstable.

More than three quarters of the houses in the region are very old. Their walls consist of coarse, short-bedded, badly-laid rubble masonry sometimes mixed with bricks, with great thickness of lime or clay mortar joints, concealed by plaster or rough cast. Floors and roofs are heavy,

resting on joists of timber. The use of tie-rods in masonry walls, laid at floor and roof level has saved many houses from collapse. New houses, mostly those built with some care after the earthquakes of 1928 and 1939, have brick walls and reinforced concrete columns with cast-in-situ slabs. These houses, as well as structures built more recently with few openings and light roofs, survived the shock with little damage. Both old and new houses which had recently been renovated suffered the most. A common cause of unintentional weakening is the installation of new electricity and water conduits in old houses, the re-location of bathrooms and of sewer and drainage pipes in old walls. Clearly, damage to only less than one quarter of the houses in the region could have been prevented had modern houses been built to resist earthquakes, the rest were built long before the advent of modern technology. Lack of ductility and eccentric stiffness in open ground floors were the main causes of damage to modern reinforced concrete houses and blocks of flats. Very few major buildings in the region had been designed to resist lateral forces; the region was not considered to be highly seismic.

Within the region of maximum damage intensities of shaking varied erratically from place to place and in only a few isolated points did they reach a maximum of about IX (MM). The maximum horizontal ground

accelerations deduced from displaced objects should have reached 75%g on hard ground with periods of 0.2 seconds and more generally 55%g with longer periods of 0.4 seconds. There is some evidence that ground motions underground were far less intense; delicately poised rock masses and thin stalactites and stalagmites in underground caves in the epicentral area showed absolutely no signs of disturbance. The only evidence of shaking was found in tensile cracks that developed in soft clay layers deposited in sloping depressions in the floor of the caves.

Conclusions

One of the first conclusions that can be drawn from the study of the Gemona earthquake is that this event could easily have been expected from what we know about the seismicity of Friuli. The field study of old and recent earthquakes is equally important, particularly in the investigation of local and regional tectonics. Historical research into early events, using first-hand information, is invaluable as it provides a link between present-day activity and inferred activity during the distant past, a unique tool for the assessment of seismic risk.

In assessing earthquake risk the revision of pre-1955 events is

absolutely essential. Such a revision should be based on a JED-type of method, applied to geographically limited areas, in which macroseismic data is used to reduce bias. When instrumental data is inadequate, priority should be given to the macroseismic study of the events. The unification of magnitudes using amplitude-period data and the re-calibration of old mechanical instruments is equally important.

Ground motions in the epicentral region were much higher than they are normally believed to be. However, damage was mainly due to the extremely poor condition of most of the houses, particularly in historical centres and mountain settlements. Damage was also augmented and the region affected increased by the intense and persistent aftershock activity. The study of historical earthquakes of Friuli shows that earthquakes of large magnitude are invariably associated with an abnormally long period of damaging aftershocks, an important consideration that must be taken into account in the design of structures against progressive damage.

References

(1) Ambraseys N. (1976) The Gemona di Friuli (Italy) earthquake of May 1976, UNESCO Rec. Mission Report, No. 273.182, pp.280, Paris.

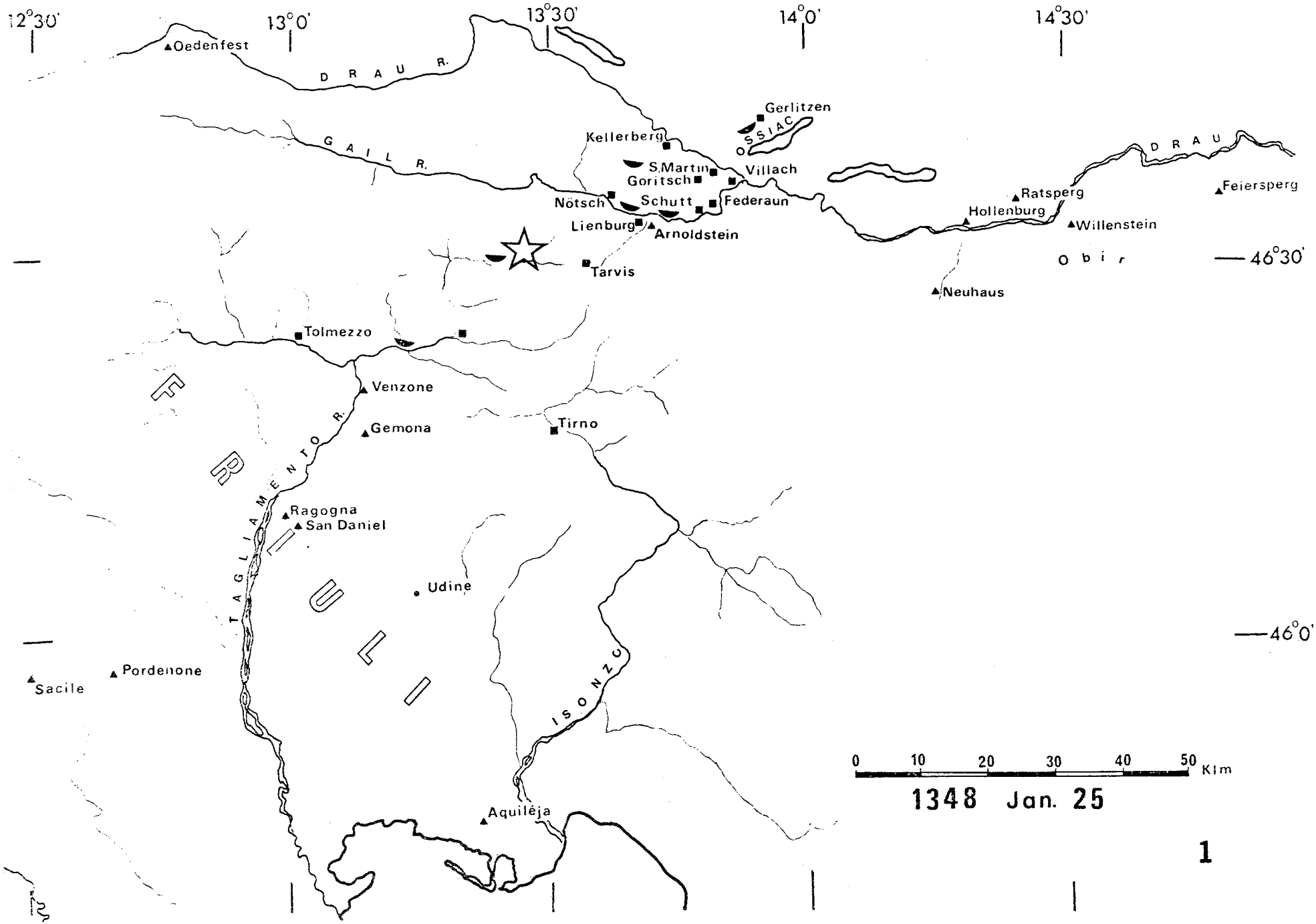
Figures

(1) Area affected by the earthquake of 25th January 1348.
Squares: destroyed sites; triangles: damaged sites; landslides.
Star: inferred location of epicentre.

(2) Landslide triggered by 1348 earthquake from Mount Dobratsch.

(3) Area affected by the earthquake of 26th March 1511.
Notation as in Figure 1; open symbols indicate sites that suffered some damage.

(4) Distribution of damaging earthquakes in Friuli for the period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Villach
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Federaun
Lienburg
Arnoldstein
Tarvis
Ratsperg
Hollenburg
Willenstein
Feiersperg
DRAU
Obir
46°30'
Neuhaus
Tolmezzo
Venzone
Gemona
Tirno
FRIULI
TAGLIAMENTO R.
Ragogna
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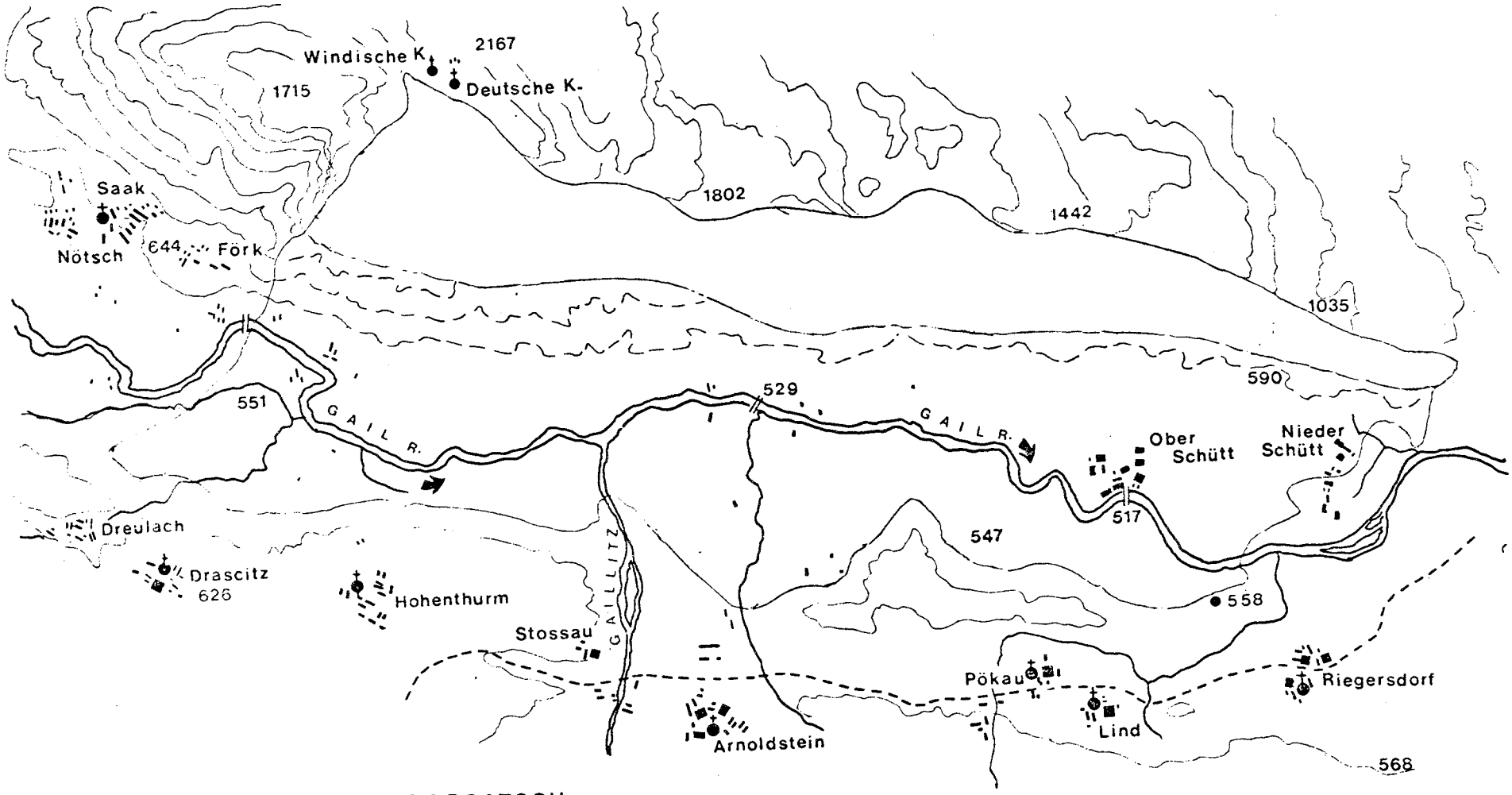
1



LANDSLIDE OF DOBRATSCH
25 JAN. 1348

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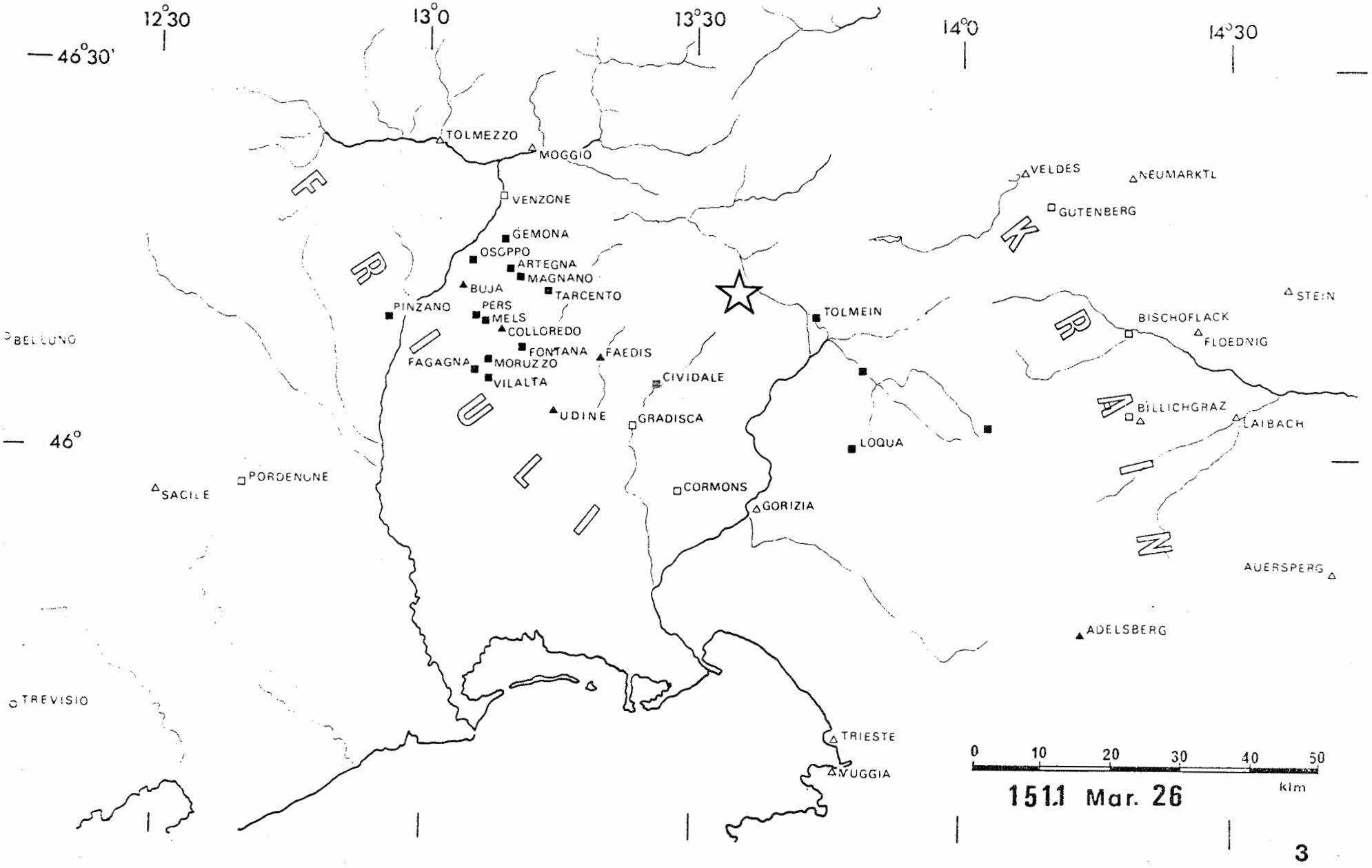
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TOLMEZZO
MOGGIO
VENZONE
GEMONA
OSOPPO
ARTEGNA
MAGNANO
BUJA
TARCENTO
PINZANO
PERS
MELS
COLLOREDO
FONTANA
FAEDIS
FAGAGNA
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VILALTA
CIVIDALE
UDINE
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GORIZIA
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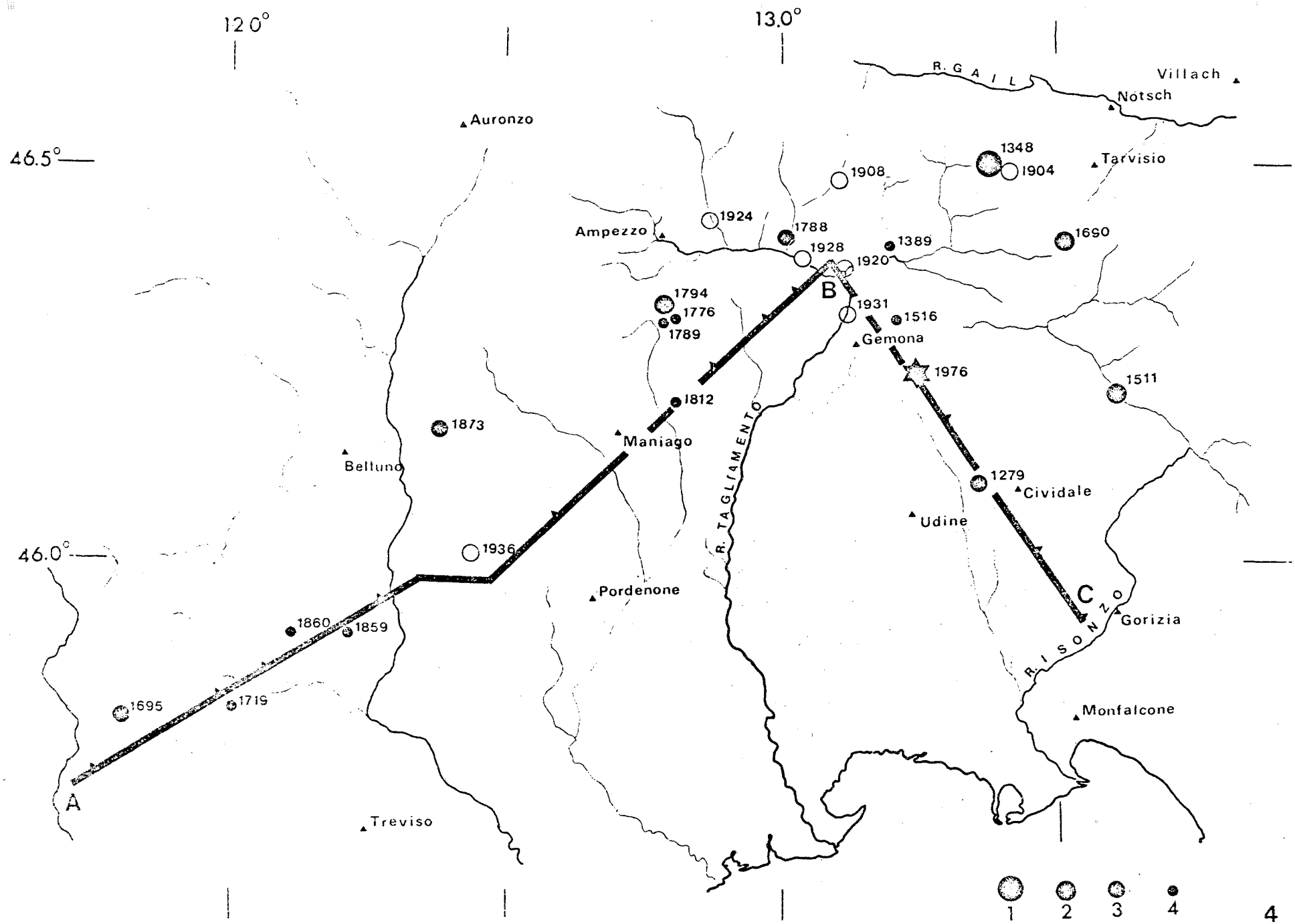
NEUMARKTL
GUTENBERG
STEIN
BISCHOFLACK
FLOEDNIG
BILLICHGRAZ
LAIBACH
AUERSPERG
ADELSBERG
BELLUNO
PORDENONE
SACILE
TREVISIO
TRIESTE
MUGGIA
FRIULI
KRAIN
0 10 20 30 40 50
km
151.1 Mar. 26
3


12.0°
13.0°
46.5°
46.0°
R. GAIL
Villach
Notsch
Auronzo
Tarvisio
1348
1904
1908
1924
Ampezzo
1788
1928
1389
1690
1920
1794
1776
1789
B
1931
1516
Gemona
1976
1511
1812
1873
Maniago
Belluno
R. TAGLIAMENTO
1279
Cividale
Udine
1936
Pordenone
C
Gorizia
R. ISONZO
1860
1859
1695
1719
Monfalcone
A
Treviso
1
2
3
4

1279 - 1976.

Black circles indicate macroseismic epicentres of events of magnitude 1: greater than 6.5; 2: between 6 and 6.5; between 5.5 and 6.0 and 4: between 5.0 and 5.5. White circles indicate location of major shocks after 1900.

Crustal Structure and Seismicity of Northern Italy

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The Friuli area is situated in a region where the Dinarides split off from the Eastern Alps. Besides, this region is not far from the eastern end of the Alps and the transition to the Carpathians and the Pannonian basin. Each of these tectonic units has its own typical crustal and upper mantle structure, and the structure at the joining point has to be seen within the pattern of the surrounding mountain system.

In the eastern part of the Southern Alps, this unit changes its tectonic behaviour. In respect to the Alps, it acts as hinterland, with regard to the Dinarides, it begins to behave as foreland.

From detailed seismic refraction investigations of crustal structure in young mountain systems in the Mediterranean area, it can be stated that, in general, a crustal cross-section, running from foreland to hinterland, shows a quite asymmetric pattern which is caused by the development of the orogene starting in the internal zones and running outwards to the foreland [GIESE and PAVLENKOVA 1976].

In most cases, when proceeding from the foreland to the central zone of the orogene, crustal thickness increases continuously, but between the internal zones and the hinterland, crustal thickness decreases abruptly within some few ten kilometers. The hinterland has, in general, a thin crust of about 20 - 30 km.

This paper shall draw the attention to such zones that show a distinct change in crustal thickness and give information where these zones are situated within the Alps, Carpathians, and Dinarides. Finally, a comparison between these zones and those of main seismic activity shall be attempted.

A strong change of crustal thickness can be associated with different geological structures. A vertical displacement of the crust/mantle boundary may form a simple flexure or, if the amplitude of displacement is large enough, a normal or thrust fault may develop. Furtheron, a flat overthrust may extend into a thrust sheet and a basement nappe. Finally, a basement nappe forms the transition to a "nappe" of crustal thickness. The great crustal thickness in the central zone of many young orogenes is mainly caused by a pile of basement- and crustal nappes which have been moved over more or less large horizontal distances.

In the Carpathians, the Dinarides, the Alps, and also in the Apennines, there are numerous seismic refraction profiles being evaluated by different authors under different aspects. Details of crustal structure may be controversial

but a change of crustal thickness by 50% or even 100% within some few ten kilometers in lateral direction is a feature that cannot be overlooked or wrongly interpreted.

Some seismic refraction profiles traverse the Carpathians [BERANEK et al. 1972]. In the Eastern as well as in the Western Carpathians, a distinct reduction in crustal thickness from 40 to 25 or even 20 km could be detected when passing the Klippenzone from the Inner to the Outer Carpathians. This abrupt change in crustal thickness is associated with a gravity gradient.

When moving south-westwards into the Alps, the strong gravity gradient zone separates the Graz basin from the Eastern Alps. The Alpine seismic longitudinal profile shows W of Graz a distinct increase of crustal thickness from 25 km to more than 40 km in the Central Alps [MILLER 1976].

Going southwards into the Dinarides, the zone of rapid change of crustal thickness is situated in front of the Vardar zone [BERANEK et al. 1972].

In conclusion, the Pannonian Basin including the Inner Carpathians, the most eastern parts of the Alps, and the inner zones of the Dinarides forms a crustal plate being 20 to 30 km thick which borders on young orogenic zones with a thickness of 40 - 50 km.

What does this special structure look like in the Alps?

Starting in the Western Alps, a W-E cross-section shows a quite asymmetric pattern [CHOUDHURY et al. 1971]. The rapid change of crustal structure and thickness occurs in front of the gravity high of Ivrea which must be regarded as the western borders of the Southern Alps and the Po-plain. Proceeding eastwards, the strong gravity gradient as well as the rapid change of crustal thickness follow the Insubric line up to the S-N running Judicarian line but do not follow it any further.

In the Eastern Alps, the negative Bouguer anomaly be-

comes very broad, and the strong gravity gradient diminishes. Thus the question arises whether there is still any remarkable and distinct change of crustal structure and thickness in the Eastern Alps.

The seismic profile available to study this question is the line Eschenlohe - Lago Lagorei [ANGENHEISTER et al. 1972] and Innsbruck - Colli Euganei [POLIZZI 1976, SCARASCIA and COLOMBI 1976]. A detailed reinterpretation of these two lines confirms the statement of previous interpretations that, when passing the Periadriatic line, no remarkable change of crustal thickness can be detected, but the former picture, showing a continuous reduction of thickness southwards, must be revised. The range of reduction of the thickness from 50 to 30 km is bound to occur between Bolzano and Trento, a distance of 40 to 50 km.

A new interpretation of the profile Eschenlohe-SE by MILLER at al. 1977 shows in principle the same result, reduction of crustal thickness about 15 km S of the Periadriatic line.

In conclusion, the zone of rapid or at least moderate change of crustal thickness passes the Friuli region and its eastern continuation must meet the zone bordering the western margin of the Pannonian basin.

Looking at a map of seismic zoning in Europe, e. g. KARNIK 1966, a clear correlation can be seen between seismic active zones and zones of abrupt change in crustal thickness in the northern part of the Eastern Carpathians, in the Western Carpathians, and in the Eastern Alps as well.

In the Western Alps, the line of main seismic activity coincides with the western side of the Ivrea gravity high. The situation is different along the Insubric line between Locarno and the Judicarian line. Here, no seismic activity has recently been recorded.

Going eastwards, a well-expressed coincidence between

seismic activity and discontinuous change of crustal thickness exists in the Southern Alps including the Fruili area.

In conclusion, it can be stated that there may exist a correlation between zones of moderate and strong seismic activity and zones of distinct change of crustal thickness.

In general, the hinterland behaves as a more or less rigid block showing a reduced seismic activity whereas in front of this block compression is still in action as evidenced by the higher seismic activity in this zone. Thus the high seismic activity in the NE corner of Italy must be seen within this special feature of crustal structure.

Finally, an additional remark shall refer to the seismic line along the Adriatic coast of the Dinarides and Hellenides. Here, seismic activity is to be found just near the foreland. A seismic refraction profile, however, passing the Peloponnesus, reveals a distinct jump in crustal thickness in the foreland near the coast [JACOBSHAGEN et al. 1976]. It is very probable that this crustal fault continues northwards up to the Dinarides. Whether the Friuli region is reached by this zone is unkmown up to the present due to the lack of corresponding data.

REFERENCES

BERÁNEK, B., J. WEISS, A. HRDLICKA, A. DUDEK, M. ZOUNKOVA, M. SUK, M.FEIFAR, H. MILITZER, H. KNOTHE, E. MITUSCH, K. POSGAY, J. UCHMAN, V.B. SOLLOGUB, A.V. CHEKUNOV, D. PROSEN, B. MILOVANOVIĆ, M. ROKSANDIĆ: The Results of the Measurements along the International Profiles, in: Geophysical Transactions - The Crustal Structure of Central and Southeastern Europe based on the Results of Explosion Seismology, 133 - 139, Budapest 1972

MILLER, H.: A Lithospheric Seismic Profile along the Axis of the Alps, 1975 - I: First Results, in: Pageoph, Vol. 114 (1976), Birkhäuser Verlag Basel 1976

ANGENHEISTER, G., H. BÖGEL, H. GEBRANDE, P. GIESE, P. SCHMIDT-THOME, W. ZEIL: Recent investigations and surficial and deeper crustal structure of the Eastern und Southern Alps, in: Geol. Rdsch. 61, 349 - 395, 1972

POLIZZI, D.: Tesi di laurea in scienze geologiche "Interpretazione di un profilo sismico crostale attraverso le Alpi Orientali (Vicenza-Innsbruck). Unpublished Report, Università degli Studi di Milano, Istituto di Geologia, 92 p., 1976

CHOUDHURY, M., P. GIESE, G. DE VISINTINI: Crustal structure of the Alps - some general features from explosion seismology. Boll. Geofis. teor. ed appl. 13, 211 - 240, 1971

SCARASCIA, S., B. COLOMBI: A deep seismic sounding in the Eastern Alps. Report at the 15th General Assembly of the E.S.C., Krakov, 1976

MILLER, H., H. GEBRANDE, E. SCHMEDES: Ein verbessertes Strukturmodell, abgeleitet aus refraktionsseismischen Daten unter Berücksichtigung des Alpen-Längsprofils. Journ. of Geophysics, in press 1977

KÁRNÍK, V.: Seismicity of the European Area /2. D. Reidel Publishing Company, Dordrecht-Holland 1971

JACOBSHAGEN, V., J. MAKRIS, D. RICHTER, G.H. BACHMANN, U. DOERT, P. GIESE & H. RISCH: Alpidischer Gebirgsbau und Krustenstruktur des Peloponnes, in Z.dt. geol. Ges.127, 337-363, 1976

Remarks about the structure of the earth's crust near the Friuli area

K. ARIC and R. GUTDEUTSCH*

The aftershock of 1976-10-13 2h 48 min has been chosen for a special investigation of the crustal structure and the focal coordinates.

The arrival times used for the determination of the focal time and coordinates have been taken from 7 teleseismic stations of the Institut de Physique du Globe, Straßbourg, which have been installed closeto the epicenter (H. HAESSLER and G. WITTLINGER, personal communication 1976). These stations are as follows: SUBBIT, FRATTINS, AVASINIS, OSPEDALETTC, CARNIA, BORDANO, BUIA, see fig. 1 and 2.

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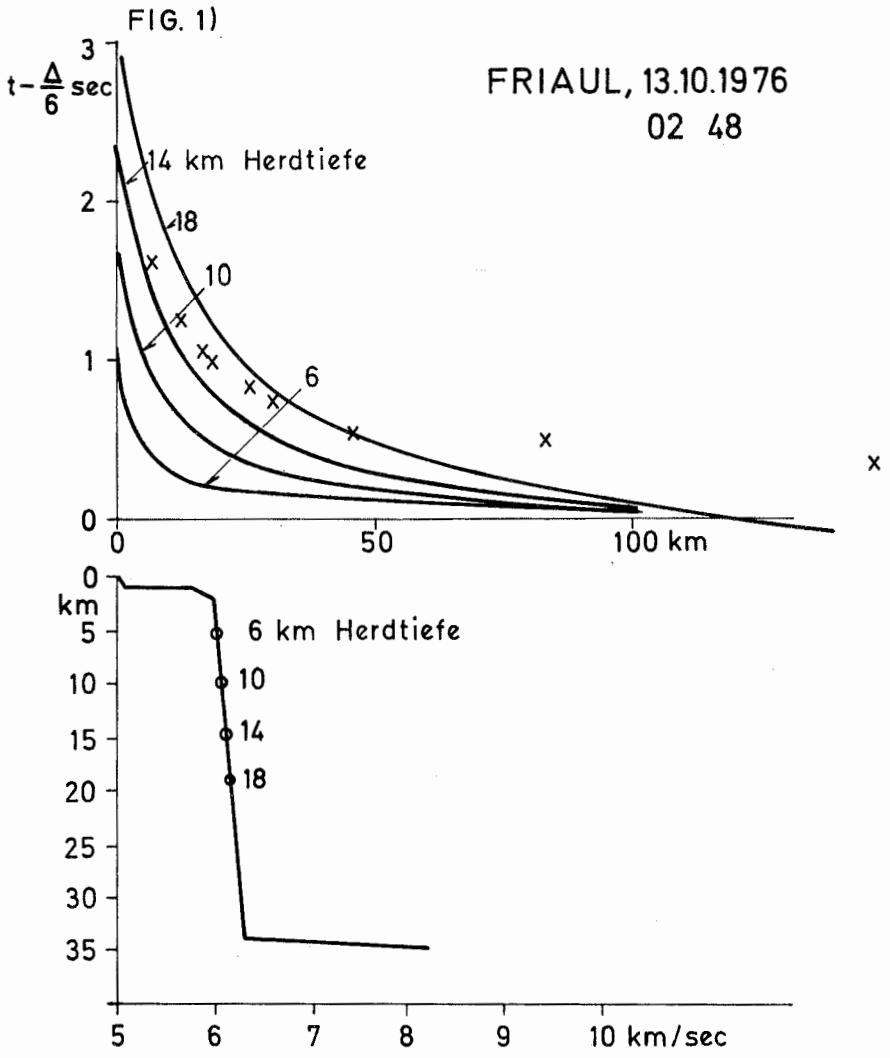
FIG. 1)
FRIAUL, 13.10.1976
02 48
t − Δ/6 sec
3
2
1
0
14 km Herdtiefe
18
10
6
0
50
100 km
km
0
5
10
15
20
25
30
35
6 km Herdtiefe
10
14
18
5
6
7
8
9
10 km/sec

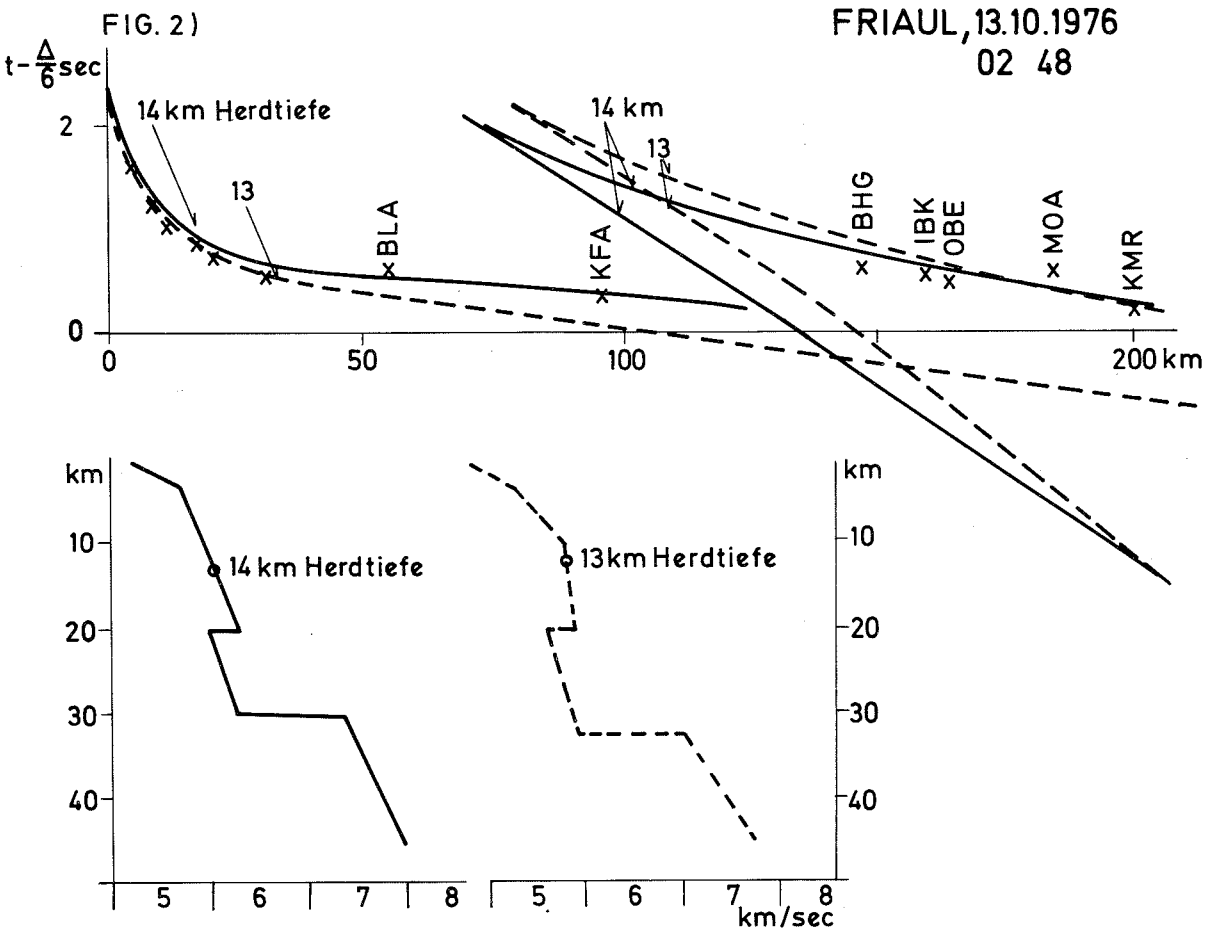
FIG. 2)
FRIAUL, 13.10.1976
02 48
t - Δ/6 sec
14 km Herdtiefe
13
14 km
13
BLA
KFA
BHG
IBK
OBE
MOA
KMR
0
50
100
200 km
km
14 km Herdtiefe
13 km Herdtiefe
10
20
30
40
5
6
7
8
km/sec

Preliminary computations have been performed in Straßbourg under the assumption of a simple model of the earth's upper crust:

velocity	depth
5 km/s	0 - 5 km
6 km/s	2 -18 km
6,2 km/s	>18 km

They yielded the following values:

epicentral coordinates: 13^{o} 04' 25" E, 46^{o} 23' 35" N

focal depth $h = 13$ km

focal time $t_o = 2h\ 48'\ 39{,}44"$

These informations have been used for a refined computation of the velocity distribution and the focal depth as well.

First arrival times have been taken from the following stations: Innsbruck, Bad Reichenhall, Obergurgel (Institut für angewandte Geophysik der Universität München) MOA, KMR, VKA (Zentralanstalt für Meteorologie und Geodynamik Wien) MZA, PIA, GHA, BLA, KFA, VKA (Lehrkanzel für Geophysik der Universität Wien) and further 30 stations in central Europe.

A simple two-layered model of the upper crust as can be seen in figure 1 was used for a first attempt. The experimental values in the figures are indicated with crosses. The approximation of the the theoretical travel times is quite well either at small or greater

distances but not in both cases simultaneously. This leads to the conclusion that a simple model of this kind cannot fit the data. We have tried to improve the approximation with different models published sofar but the results were not satisfactory. There are 2 exemptions:

Figure 2 represents two possible models valid for the area north of Friuli. Model A(drawn lines) fits all data up to distances of 85 km. Model B(dashed lines) fits only the data in the range of distances up to 35 km. Both models include only one velocity channel in the lower crust according to the results of the Alpine Explosion Seismology Group (1976). A striking feature is the delay of the observed traveltimes of KFA and BLA with respect to the theoretical curve. It cannot be interpreted as a result of a low velocity channel in the upper crust. We assume that lateral variations of the velocity have to be taken into account. The travel times of Innsbruck, Bad Reichenhall, Obergurgel and KMR show a considerable delay as well. It cannot be decided whether this range of distances belongs to another branch of the travel time curve or not. A thorough explanation of this phenomenon cannot be given now. But the fact that the respective stations are situated in the alpine area should be emphasized. At distances greater than 200 kmthe theoretical traveltime curve fits the data white well. It agrees also with the local p_n travel time curve valid for VKA.

It should be emphasized that only the first arrivals have been evaluated here as only these data are available sofar. The use of the original seismograms will give more important informations. At present one can only say that the average p-velocity in the crust is of the order of 6.0 km/s and that the final model of this area probably will not differ very much from the velocity distribution proposed here.

THE RELATION BETWEEN SEISMOLOGICAL AND NEOTECTONIC CHARACTERISTICS OF FRIULI AND NEIGHBOURING AREAS

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Abstract

Outstandingly contrasting vertical movements in Pliocene and the Quaternary in the district of Friuli (the sinking of the Venice depression to about 2500 m and rising of the Julian Alps to about 1500 - 2000 m) have resulted in the formation of a special morphostructural unit of II order within the existing structures of I order. A tendency to differentiated vertical movements has been preserved up to now. They take place along the numerous faults among which the most remarkable ones are the Idrija and the Branik faults. Both faults, besides others which run from south and southwest, converge towards the tectonic knot in the district of Gemona and Tolmezzo, where faults of various directions cross. Expanse and energetic features of seismic activity in this region are in good correlation with corresponding neotectonic movements. The amounts of accelerations recorded in September 1976 in Breginj (0,52 g), Kobarid (0,13 g) and Robič (0,11 g) were also conditioned by corresponding geological features.

Abstract

PREFACE

In connection with the Balkan Seismicity Research as an international project, a special attention was paid to seismotectonic researches. The results show that there is a good correlation between geological processes and seismological phenomena(1). Some of the results of the mentioned researches were used in this work together with the basic characteristics of neotectonic processes and seismological phenomena in Friuli and neighbouring areas, in order to explain the intensified seismic activity in 1976.

NEOTECTONIC

The muntain systems of the Julian Alps and the Karawanken are mostly built of Mesozoic carbonate rocks. Towarsd south they are drawn over limestone formations of the subalpine area and turn into the Venice depression. The depression was in the Pliocene and the Quaternary filled with terrigenours, clastic sandy layers. Whereas the Venice depression presented in those times a zone of intensive sinking (the Quaternary layers were as much as 1000m thick and together with the pliocene ones over 2500m), the Julian Alpes rose to more than 1500m. The tectonic movements, which resulted in formation of morphostructures of I order and the contemporary relief, had a particularly differentiated character, preserved up to now. As a result, separate units of II order within the existing structures of I order were formed. In the Alps were formed blocks which stretch towards east and west and are separated by longitudinal faults. The highest rises are in the northern parts of the Alps and in Yugoslavia in the mountain massive of the Triglav (more than 2000m), where even today the rising is 8 mm a year.

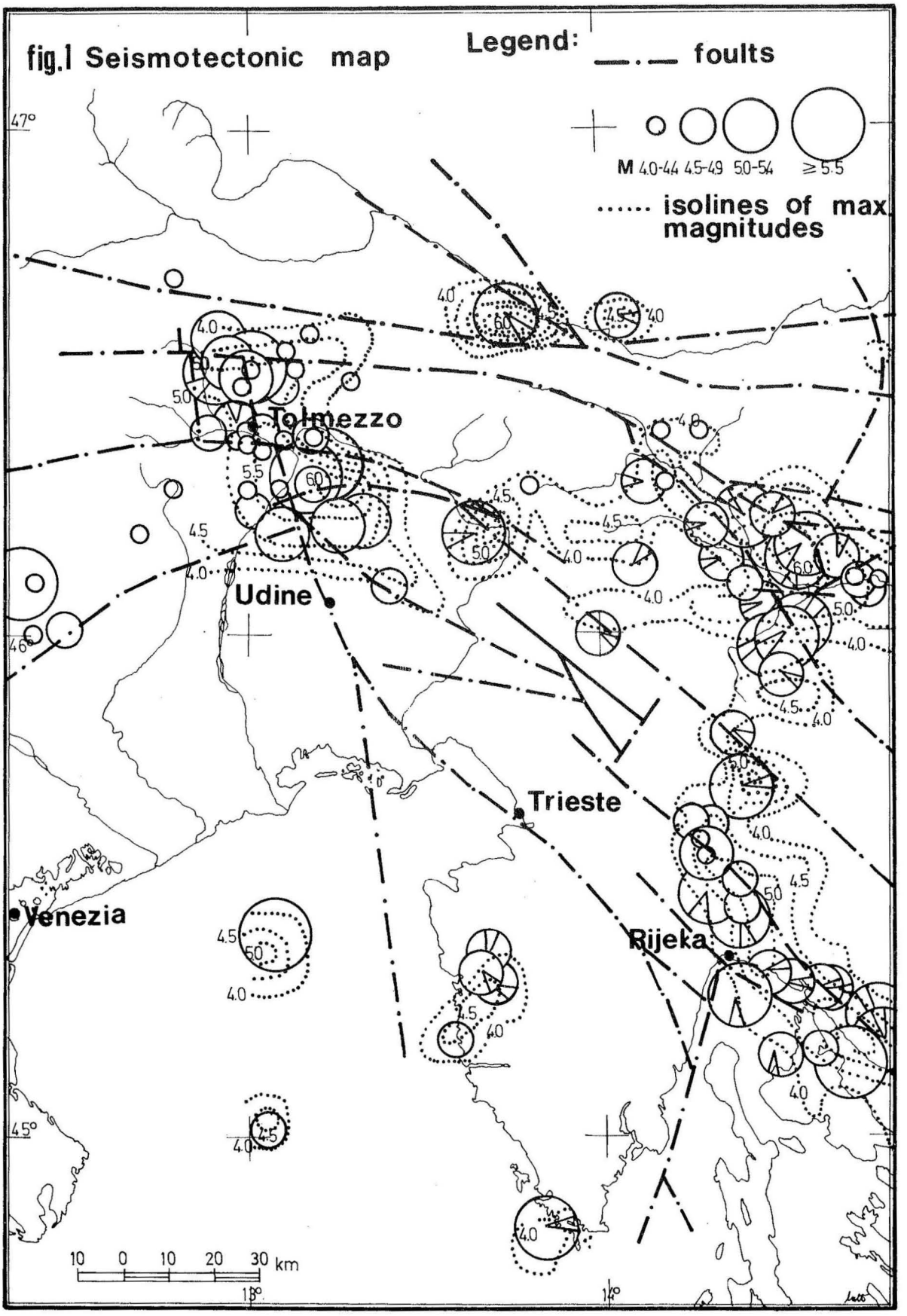


fig.1 Seismotectonic map
Legend:
foults
M 4.0-44 4.5-49 50-54 ≥5.5
..... isolines of max magnitudes
Tolmezzo
Udine
Trieste
Venezia
Rijeka
47°
46°
45°
13°
14°
10 0 10 20 30 km

On the southwest side the natural border of the block is the Idrija fault, about 150 km long within Yugoslavia. West from Tolmin this fault runs across the upper Soča valley, where it forks in two: the southern branch goes towards Gemona, the northern one near Tolmezzo, along the upper stream of the river Tagliamento. The Idrija fault presents in this region the most remarkable neotectonic dislocation, which divides two morphostructural blocks caught by different rise intensity. The southern wing blocks of this fault are raised to about 1000 - 1200 m, the northern ones to about 2000 m. Today the southern wing blocks rise at a rate of about 6 mm a year. Towards the Adriatic, Istria being morphologically included, the terrain gradually lowers and the rising speed becomes smaller, about 4 mm a year. The Branik fault stretches from Nova Gorica towards Rijeka and contrastingly reflects in the relief along the southern brim of Trnovski Gozd, whereas it disappears in the quaternary and contemporary deposits (fig. 1).

The upper stream of the Tagliamento is the district of great transformations as well as the inner depressions and tectonic knots where the faults of various stretching directions cross. The deepened river valley bed in its upper stream points at a relation between the valley and the fault zone. The valley sinks, the neighbouring terrains rise. In the tectonic knots like this one, conditions for maximum strain occur(2). The mentioned neotectonic features and contemporary tectonic movements, which are characterized by divided morphostructures of the Julian Alps and the Dinarides on one side, the Venice depression on the other, show that the tectonic processes intensively take place even today, and that we should there look for an explanation for intensified seismic in 1976.

SEISMICITY

Expanse and energy features of the northwest part of the Balkan peninsula and Friuli area seismic activity are represented by the lines of same maximum magnitudes and epicenters of stronger ($M \geq 4,0$) earthquakes. The lines of same maximum magnitudes constructed so that in each of the elementary fields, size of each being latitude 5', longitude 7,5', the maximum earthquake magnitude has been established and on the base of the fields of these values isolines for each 0,5 M have been drawn. All seismological data have been considered back from the year 361 up to now.

The relation established for the observed area as a unit has been used for the relation between magnitude M and maximum intensity I_o:

$$M = 0,55\ I_o + 1,03$$

Areas with increase amounts of maximum earthquake magnitudes ($M \geq 4,0$) form two distinguished zones of stronger seismic activity:

- one in the inland of northwest part of the Balkan peninsula and
- another along the Adriatic coast.

Zone of stronger seismic activity in the inland part of the Balkan peninsula is the touching point between the Panonian basin and the Medvednica - Kalnik range and goes from the Balaton lake over Nagykanizse in Hungary and partly over Bilogora, Kalnik, Medvednica, Pokuplje and Žumberačka gora in Croatia. It continues along the Sava valley in Slovenia to Ljubljana (along the border between the Dinarides and the Alps) and most probably further in the direction of Friuli at the bottom of the Alps.

Another zone of stronger seismic activity exists on the border between the Adriatic basin and the Dinarides. It can be followed along the whole Adriatic coast and further on from Rijeka over Klana and the Cerkniško jezero with one arm towards Ljubljana and another continuing the northwest direction toward Friuli at the bottom of the Alps.

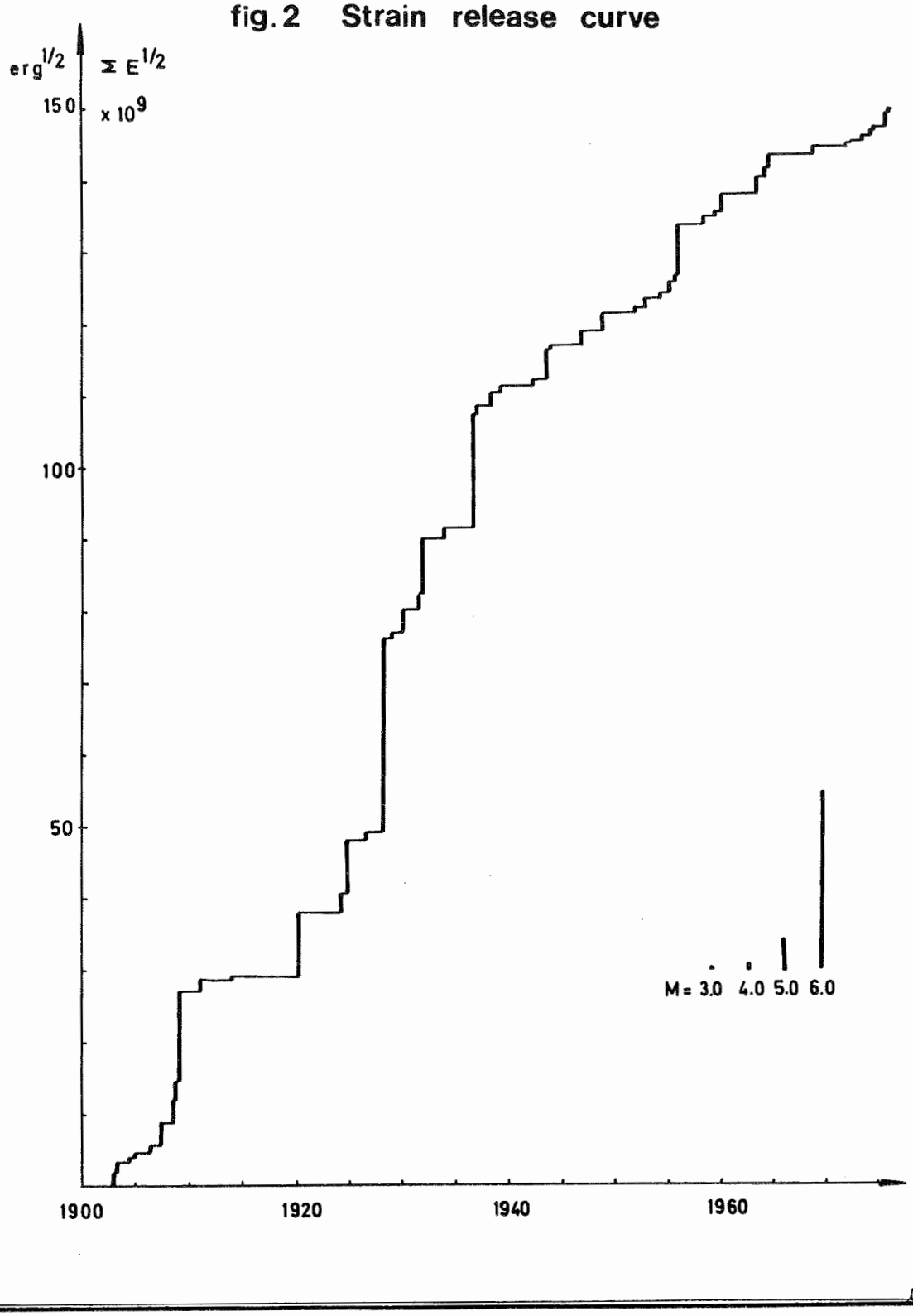
Both zones of stronger seismic activity converge towards Friuli where they cross. It is the same direction as that of stronger seismic activity which stretches along the Apennines peninsula on the border of the Alps and the Venice depression.

Thus is the Friuli region the crossing point of more zones of stronger seismic activity which explains the character and intensity of the earthquakes having happened in 1976 year.

Time characteristics of the observed region seismicity (12^{o} - 14^{o} E, 45^{o} - 47^{o} N) in the period 1900 - 1976 are shown by the strain release curve (fig. 2), which may be described as follows:

- in the period 1900 - 1909 the seismic activity is weaker. The strongest earthquake of the period was in 1908 with magnitude 4.8;
- the period 1909 - 1936 is characterised by an intensified seismic activity. There were 6 earthquakes with magnitudes higher than 5, the one in 1928 of magnitude 5.8 being the strongest earthquake of the period 1900 - 1976.
- the period between 1936 - 1976 has again a weaker seismic activity. The strongest earthquake of the period was in 1956 with magnitude 5.1.

fig. 2 Strain release curve



The comparison of the strain release curves in 1976 (fig. 3) with the previous period 1900 - 1976 shows that throughout only 9 months in 1976 more strain was released than in the past 76 years.

The energetic classification of earthquakes with their epicentres in Friuli was based on earthquake magnitudes in the Catalogue of Earthquakes in Europe and the Mediterranean (3), and for the great majority of earthquakes the magnitudes have been calculated according to the data of the Seismological Station Zagreb with equations (4,5)

$$M = \log A + 2{,}094 \log\Delta + 2{,}19$$

and

$$M = \log \left(\frac{A}{T}\right)_{max} + 1{,}462 \log\Delta + 2{,}798$$

In the period of intensified seismic activity in 1976 the strongest earthquake in the Friuli region occured, and according to the data of the Seismological Station in Zagreb, where the earthquake was fully registered by the horizontal seismograph Wiechert 80 kg, its magnitude was M = 6,3.
It should be noted that the level of the seismic activity in 1976 in Friuli is considerably higher than all known so far. A similar phenomena has been noted in the north-west part of the Balkan peninsula, in the Diljgora area in 1964, in Banja Luka in 1969 and the Promina mountain in 1970.

Isoseismals of the strongest earthquake from the series of Friuli earthquakes for the Yugoslavian region (fig. 4) have been made on the basis of macroseismic data obtained in two ways. For the north-west Slovenia along the Italian border the terrain observations data were used and the intensity was valued by the MSK scale. For other areas the data obtained in the usual way by postal questionaires about the earthquake were used to value the earthquake intensity by MCS scale.

The following conclusions about earthquake energy spreading may be derived from the Map of earthquake isoseismals for the given region. Earthquake energy spread most intensively in direction ESE, which is more remarkable with shorter epicentral distances. Such form and division of isoseismals

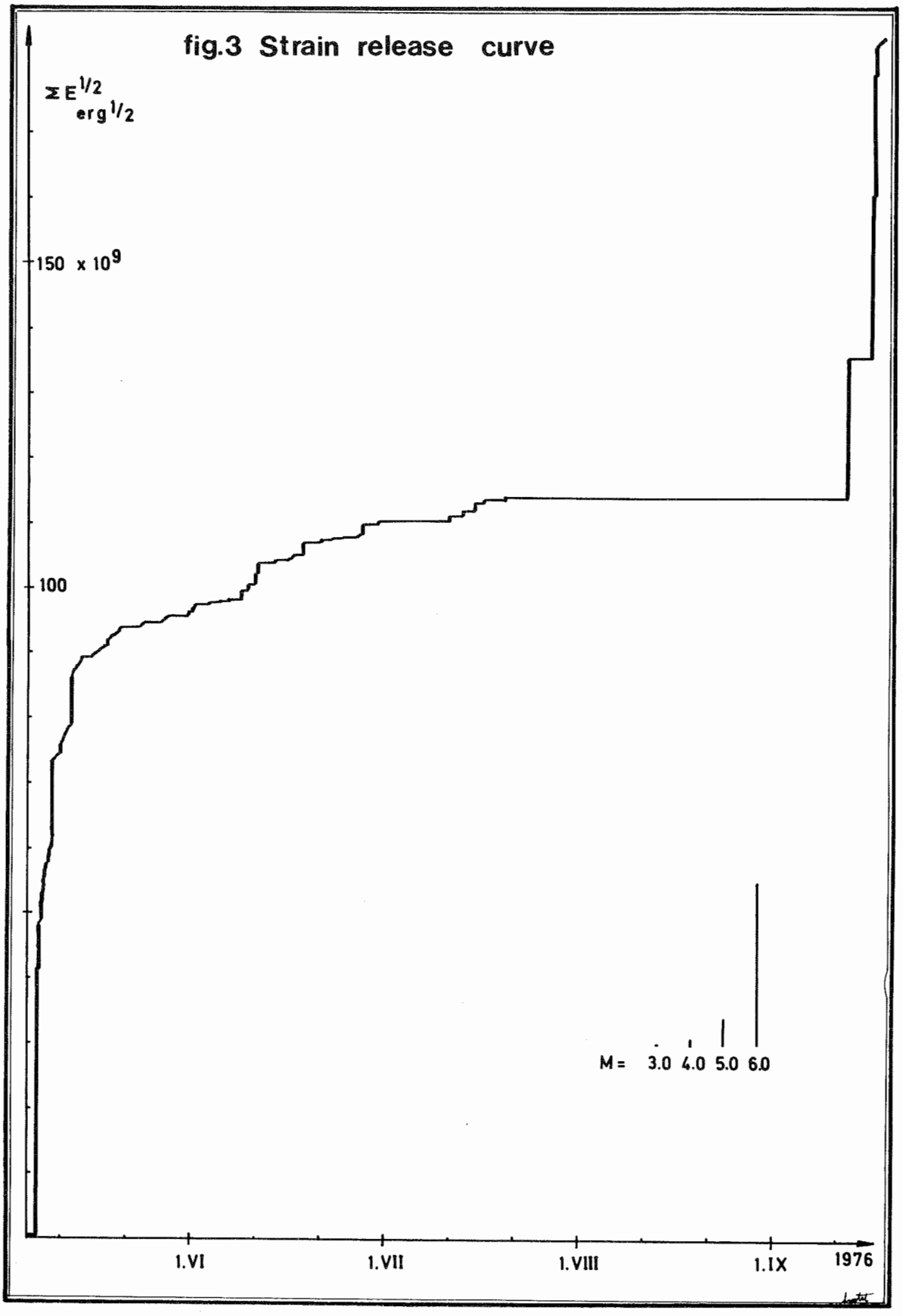


fig.3 Strain release curve
Σ E^1/2
erg^1/2
150 x 10^9
100
M = 3.0 4.0 5.0 6.0
1.VI
1.VII
1.VIII
1.IX
1976

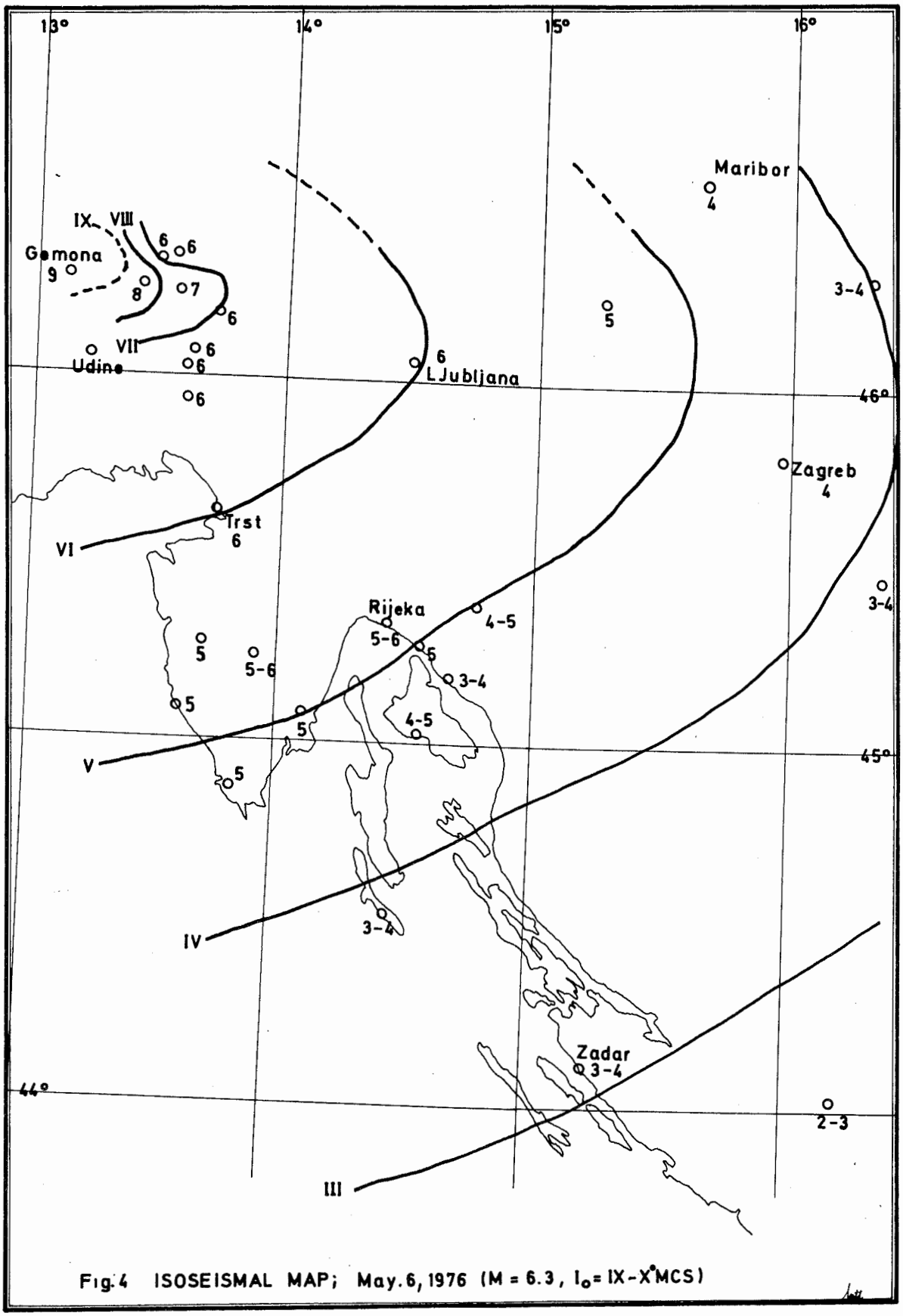


Fig. 4 ISOSEISMAL MAP; May. 6, 1976 (M = 6.3, I_o = IX-X°MCS)

are conditioned by blocks extending in direction E-W and their separation by longitudinal faults. The particular extension of the isoseismal VII respectively VIII degree in direction E has resulted from the Idrija fault.

R. Köresligethy's method (6) was used to define the absorption coefficient. The calculation was made for azimuths 100^{o} and 145^{o} with the following starting values: $M = 6,3$, $I_{o} = 9,5$. The obtained results point at the depth of the hypocentre of 6 - 9 km and the absorption coefficient of $\alpha_{100^{o}} = 0,002$, $\alpha_{145^{o}} = 0,005$ (7).

Immediately after the earthquake of May 6th 1976, three accelerographs were installed as a part of the Yugoslavian net for strong earthquakes. The instruments are located in Breginj, Kobarid and Robič, and together with the formerly installed accelerograph in Tolmin, present a small local net for registration of strong earthquakes in this region. The choice for location of these accelerographs was made according to the geotectonic characteristics of the region. The Robič accelerograph was installed on the monolith stone mass on the Triassic dolomites and limestone, which form one morphostructural unit - the block south from the Idrija fault. Other locations (Tolmin, Kobarid and Breginj) follow the zone of the Idrija fault, which predisposes the river Soča valley from Tolmin to the west. Along the valley there are moraine-glacial and fluvial-glacial layers represented by big oblong pebbles and coarse gravel, covered with a thin layer of clay. The infirmity of this fault and the geological composition of the base, which the accelerographs are installed on, were also confirmed by the registration of the earthquakes in question.

The comparison of earthquake registrations of September 15th 1976 at 03^{h}, 15', 22'' in Breginj, Kobarid and Robič (0,52 g, 0,126 g, and 0,105 g) provides a clear picture of the influence of geological factors on the acceleration amount. The influence of the fault zone of the Idrija dislocation and the fluvial-glacial composition of the base, on which the instruments are located in Breginj and Kobarid, have resulted in a considerably stronger acceleration when compared with the Robič instrument installed on monolith carbonate rocks and in other tectonic conditions within one single block.

Seismicity

SEISMOTECTONIC RELATIONS

The comparison of the geological processes with seismological phenomena in the Friuli region and neighbouring areas clearly proves the causality between them. It is particularly obvious in the space correlation of the zone of intensified seismic activity and the fault zones that divide greater basic structures - the Alps, the Dinarides and the Venice depression. However, earthquake epicentres do not continuingly follow the faults but accumulate in narrower locations that are regularly the crossing points of more faults of various stretching directions. Typical examples are Gemona and Tolmezzo in Friuli and Ljubljana in Slovenia.

Although there is not a sufficient number of quantitative data, a stronger intensity of the recent neotectonic movements obviously corresponds with a higher level of seismic activity. It should also be noted that the epicentral Friuli region was activated in the period of intensified seismic activity, which started in 1962 and has lasted until today, extending over the most part of the Balkan and the Apennines peninsulas. This proves the regional character of the recent neotectonic movements.

REFERENCES

1. UNDP/UNESCO Survey of the seismicity of the Balkan region, Proceedings of the seminar on the seismotectonic map of the Balkan region, UNESCO, Skopje, 1974.

2. Arsovski, M., General characteristics of neotectonic structure in SFR Yugoslavia, Proceedings of the seminar on the seismotectonic map of the Balkan region, UNESCO, Skopje, 1974, p. 179.

3. Karnik, V., Seismicity of the European area, Part 1, D.Reidel Pub.Comp., Dordrecht - Holland, 1969.

4. Skoko, D., Mikroseizmički podaci i učinci potresa, Geofizički institut Zagreb, 1967 (manuscript).

5. Cvijanović, D., Function $\sigma(\Delta)$ for earthquake magnitude for short distances according to the data of the seismological station Zagreb, 15th General Assembly E.S.C., Krakow, 1976. (in press).

6. Sponheuer,W., Methoden zur Herdtiefenbestimmung in der Makroseismik, Akad. - Verlag, Berlin, 1960.

7. Kuk, V., Pojačana seizmička aktivnost u području Furlanije u 1976.god., Geofizički zavod Zagreb, 1976. (manuscript).

EARTHQUAKE CATALOGUE OF FRIULI-VENEZIA GIULIA REGION
From roman epoch up to 1976

BY

R.BARTOLE, G.BERNARDIS, F.GIORGETTI,
D.NIETO, M.RUSSI - O.G.S. TRIESTE

S U M M A R Y

This catalogue contains data of more than thousand earthquakes felt in Friuli-Venezia Giulia region from Roman epoch up to 1976. All data (date, origin time, geographic coordinates, magnitude, maximum intensity, macroseismic reference and meizoseismal area)are collected and punched using one card for each earthquake.

O.G.S. - Osservatorio Geofisico Sperimentale - Trieste - Contrib. n. 254.
Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 14.

EARTHQUAKE CATALOGUE OF FRIULI-VENEZIA GIULIA REGION
From roman epoch up to 1976

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O.G.S. - TRIESTE

1. Introduction

This catalogue comes from the "General Catalogue of Italian Earthquakes" (M.T. Carrozzo, G. De Visintini, F. Giorgetti, E. Iaccarino) printed by Comitato Nazionale Energia Nucleare in 1973. This version has been revised and extended considering more data concerning the Friuli-Venezia Giulia region.

All the data are collected on punched cards and are available on request both on magnetic tape and on print outs.

One punched card is used for each earthquake, in order to reduce as much as possible the size of the catalogue.

The data referring to each earthquake are printed from the left in the following order:
date, origin time, coordinates, magnitude, maximum intensity, macroseismic radii, reference, meizoseismal area.

2. Explanatory notes

2.1 - Data is reported as year, month, day; months are written according to the following code:

JA = January	FE = February	MR = March
AP = April	MA = May	JU = June
JL = July	AU = August	SE = September
OC = October	NO = November	DE = December

The letter in col. C has the following meaning:

A : reported data are precise

B : reported data are approximate

C : reported data are very roughly known

E : possible beginning of a seismic period

G : possible end of a seismic period

H : shock belonging to a seismic period

2.2 - Origin time

Origin time is expressed in hours, minutes, seconds of Greenwich Time.

If hours and/or minutes and/or seconds are unknown the corresponding columns are left blank. If time is expressed in tenth of a minute, the figure of the minute is followed by a dot and by the actual figure of the 10th of a minute. If time is expressed in fourths of a hour (or of a minute), the two columns following the actual figures of the hour (or minute) are: 1st column: blank; 2nd column: letter according to the following code: A = 1/4; B = 1/2; C = 3/4; D = 0. For better explanation, let us consider the following example:

121530 = 12h 15m 30s

1215.5 = 12h 15.5m

1215B = 12h $15\frac{1}{2}$m

12A = 12 1/4h

12 = 12h

2.3 - Coordinates

The catalogue includes all known earthquakes felt in Friuli-Venezia Giulia. The coordinate range is: lat.: 45° to 47° Nord and long.: 12° to 14° East. Coordinates are usually expressed in degrees and minutes. If they are given in degree and tenths of a degree, the figure of the degree is followed by a dot and by the actual figure of the 10th of a degree. If coordinates are given to the fourth (or half) of a degree, the following notation is used:

1st column after the degree: blank;

2nd columns: letter according to the code: A=1/4; B=1/2; C=3/4; D=0.

If no sub-multiples of a degree are given, the two columns following the degree figure are left blank.

2.4 - Depth of focus

Depth of focus, reported in column H, is expressed in km.

The following symbols are used also:

A : very shallow focus ($h \leq 10$ km)

B : shallow focus ($h \leq 25$ km)

C : focus within the crust

X : focal depth unknown

2.5 - Magnitude

Whenever possible two magnitudes are given:

ML : magnitude of local shocks determined from surface waves

MM : magnitude for macroseismic data

Listed values are multiplied by 10; that is the two magnitude figures are not separated by the decimal point. Magnitude from macroseismic data has been determined in one of the following ways:

I : if the focal depth h (by microseismic or macroseismic data) is known, Karnik's (1968) formula was used:
$M = 0.51_o + \log h + 0.35$

II : if the focal depth is unknown, then karnik's (1968) formula was used: $M = 0.53\ I_o + 0.95$ (North Italy)

2.6 - Intensity and macroseismic radii

The first group of 5 figures E I gives the maximum intensity (4 figures) followed by a special symbol (5th figure). Intensity is expressed according with the M S K scale in 12 degrees. If the maximum intensity degree cannot be determined the first 4 figures of E I report:

FELT : felt without damages ($I_o < VI$)

DAMA : damages ($VI \leqslant I_o < VIII$)

DEST : destructions ($VIII \leqslant I_o$)

UNKN : unknown intensity

The reliability of the maximum intensity I_o is given by the 5th figure of the E I group according with the following code:

= : I_o is determined with good accuracy

/ : I_o is determined with poor accuracy.

The successive groups 1 to 6 give (in decreasing order) up to 6 isoseismal radii (preceeded by the corresponding inten

sity degree). The isoseismal radii are the radii of the circles of area equivalent to the isoseismal area. Radii are expressed in km from 000 to 999 km. For example, let us consider the cases:

6.5 135 = isoseismal corresponding to VI-VII degree = 135 km

2.7 - Meizoseismal area

In the column is reported the main town or the geographic locality ware the earthquake has been felt.

2.8 - References

The main reference is reported in the S D (source data) column.

The following symbols are used:

BA : Baratta M., 1901: I terremoti d'Italia; F.lli Bocca, Torino

BC : B.C.I.S., Bulletin Mensuel; Strasbourg

BM : Istituto Nazionale di Geofisica; Bollettino Sismico Definitivo, Roma

BS : R. Ufficio Centrale Meteor. e Geofisica; Notizie sui terremoti osservati in Italia; Roma

CI : R. Ufficio Centrale Meteor. e Geofisica, Bollettino sismico, 1917-1936; Roma

CA : Cavasino A., 1935: I terremoti d'Italia nel trentacinquennio 1899-1933; I.P.S., Roma

DP : De Panfilis M., 1959: Attività sismica in Italia (1953-1957); Ann. **Geofis.**,XVIII, 3

EN : Ente Nazionale Energia Elettrica, Bollettino sismico provvisorio limitato alle scosse locali; Friuli-Venezia

Giulia seismological stations

FM : Feliziani P., Marcelli L., 1965: Il terremoto di Tolmezzo del 16 aprile 1959; Ann. Geofis.,XVIII, 3

GC : Carrozzo M.T., De Visintini G., Giorgetti F., Iaccarino E., 1973: General catalogue of Italian earthquakes; C.N.E.N., RT/PROT (73/12)

KI : Karnik V., 1969: Seismicity of the European Area; Reidel, Dordrecht, Holland

OG : Osservatorio Geofisico Sperimentale, Trieste Seismological station

3. Acknowledgements

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R. BARTOLE - G. BERNARDIS - F. GIORGETTI - D. NIETO - M. RUSSI

EARTHQUAKES CATALOGUE OF FRIULI V.G. REGION

PROVISIONAL OCTOBER 1976

DATE Y	M	D	C	TIME	COORDINATES LA	N	LO	E	H	MAGNIT ML	MM	INTENSITY AND MACROSEISMIC RADII EI	I1	I2	I3	I4	I5	I6	MEIZOSEISMAL AREA	REFER SD
0365	JL	21	C		46		12		X		68	11.0/							BELLUNO	GC
0745			C		45	B	12	A	X		52	8.0/							CORTINA	GC
0778			B		45	C	12	A	X		52	8.0/							TREVISO	GC
0840			C		45	B	12	A	X			FELT/							VENEZIA	FM
0974			C		45	B	12	B	X			FELT/							TREVIGIANO	GC
1093	OC	03	C		45	B	12	A	X		52	8.0/							VENEZIA	BA
1106	MR		C		45	B	12	B	X		57	9.0/							TREVIGIANO	BA
1114	JA		C		46	A	12	A	X		52	8.0/							BELLUNO	FM
1123	DE	25	C		45	B	12	A	X		52	8.0/							VENEZIA	GC
1212			C		45	B	12	A	X		52	8.0/							**	GC
1233			B		45	B	12	A	X		57	9.0/							**	GC
1268	NO	03	C		45	C	12	A	X		52	8.0/							TREVISO	GC
1275	AP	24	C		45	B	12	B	X		41	6.0/							VENEZIA	FM
1278	AP	07	C						X		52	8.0/							FRIULI	GC
1279	AP	24	C	17	46	D	13	B	X		52	8.0/							CIVIDALE	BA
1279	AP	24	C	23	46	D	13	B	X		52	8.0/							**	GC
1282	JA	17	C		45	B	12	A	X		47	7.0/							VENEZIA	BA
1301	JU	11	F		46	A	13	D	X		47	7.0/							FRIULI	GC
1301	JU	11	H		46	A	13	D	X			FELT/							**	BA
1301	JU	12	G		46	A	13	D	X			FELT/							**	BC
1321			B		45	B	12	A	X		47	7.0/							VENEZIA	GC
1348	JA	25	F	1545	46	B	13	C	X		68	11.0/							VILLACCO	OG
1365	MR	04	B		45	B	12	D	X		47	7.0/							TREVISO	GC
1373	MR	01	F	09	45	B	12	A	X			FELT/							VENEZIA	BA
1373	MA	19	H		45	B	12	A	X			FELT/							**	BA
1373	JU	05	G		45	B	12	A	X			FELT/							**	BA
1389	AU	20	F	08	46	B	13	A	X		52	8.0/							MOGGIO UDINESE	GC
1401	JA	29	A	11	46	A	12	A	X			FELT/							BELLUNO	BA
1401	NO	20	A		46	A	12	A	X			FELT/							**	BA
1403	JA	12	A	06	46	A	12	A	X		47	7.0/							**	GC
1403	JA	29	A	2030	46	A	12	A	X		47	7.0/							**	BA
1403	SE	06	A		46	A	13	D	X		52	8.0/							FRIULI	BA
1404	FE	01	A		46	A	12	B	X		47	7.0/							BELLUNO	GC
1410	AU		A		45	B	12	A	X			DAMA/							VENEZIA	BA
1429			B		45	B	12	A	X		52	8.0/							**	GC
1451	FE	22	A	21	46	A	12	C	X		47	7.0/							SPILIMBERGO	GC
1455	FE	03	A	20					X		52	8.0/							**	GC
1457	DE		C		45	B	12	A	X		47	7.0/							VENEZIA	BA
1472	MA	14	F	20	46	B	13	A	X		36	5.0/							FRIULI	BA
1472	MA	14	G	20	46	B	13	A	X		47	7.0/							**	GC
1511	MR	26	F	1930	46	B	13	D	10		59	9.0=	9.0 004	8.0 021	7.0 064				CARNIA	GC
1511	MR	27	H		46	B	13	D	X			FELT/							**	BA
1511	MR	28	H	89	46	B	13	D	X			DAMA/							**	BA
1511	AP	01	H	19	46	B	13	D	X			FELT/							**	BA
1511	AP	01	H	23	46	B	13	D	X			FELT/							**	BA
1511	JU	24	H	2230	46	B	13	D	X			FELT/							**	BA
1511	JU	25	H	2230	46	B	13	D	X			FELT/							**	BA
1511	JU	26	H	21	46	B	13	D	X		52	8.0/							**	BA
1511	JU	27	H	02	46	B	13	D	X			FELT/							**	BA
1511	JU	27	H	03	46	B	13	D	X			FELT/							**	BA

DATE Y	M	D	C	TIME	COORDINATES LA	N	LO	E	H	MAGNIT ML	MM	INTENSITY AND MACROSEISMIC RADII EI I1 I2 I3 I4 I5 I6	MEIZOSEISMAL AREA	REFER SD
1511	AU	08	H		46	D	13	D	X		57	9.0/	CIVIDALE	GC
1511	AU	16	H		46	D	12	B	X			FELT/	SACILE	BA
1512	JA	25	H		45	B	12	A	X			FELT/	VENEZIA	BA
1512	FE	08	H		45	B	12	A	X			FELT/	**	BA
1512	FE	13	G		46	A	13	D	X			FELT/	UDINE	BA
1514	JA	01	F		46	A	13	D	X			FELT/	GEMONA	BA
1514	JA	15	H	01	46	A	13	D	X			FELT/	**	BA
1514	JA	30	H	21	46	A	13	D	X			FELT/	**	BA
1514	JU	17	H	06	46	A	13	D	X			FELT/	**	BA
1514	JL	04	H	18	46	A	13	D	X			FELT/	**	BA
1514	JL	07	H		46	A	13	D	X			FELT/	**	BA
1514	JL	12	H	21 B	46	A	13	D	X		47	7.0/	**	GC
1514	OC	01	H	01	46	A	13	D	X			FELT/	**	BA
1514	OC	01	G	03	46	A	13	D	X			FELT/	**	BA
1516	MR	02	A	10 D	46	A	13	D	X		36	5.0/	**	FM
1516	MR	09	A		45	B	12	A	X		41	6.0/	VENEZIA	BA
1516	DE	20	H	0530	46	A	13	D	X		41	6.0/	GEMONA	BA
1516	DE	20	G	06	46	A	13	D	X		31	4.0/	**	BA
1522	JL	06	F	24	45	B	12	A	X		41	6.0/	VENEZIA	GC
1522	JL	07	H	01	45	B	12	A	X		36	5.0/	**	BA
1522	JL	07	H	02	45	B	12	A	X	4	31	4.0/	**	BA
1522	JL	24	H	00	45	D	13	A	X		31	4.0/	UDINE	BA
1522	AU	01	G		46	D	13	A	X			FELT/	**	BA
1523	JU	07	A	17	46	D	13	A	X			FELT/	**	BA
1523	JU	20	B		45	B	12	A	X		44	6.5/	VENEZIA	BA
1529	AP	13	F	00	46	D	13	A	X		36	5.0/	UDINE	BA
1529	AP	14	H	03	46	D	13	A	X			FELT/	**	BA
1529	AP	15	H		46	D	13	A	X			FELT/	**	BA
1529	AP	16	G		46	D	13	A	X			FELT/	**	BA
1591	JL	12	A	11	46	D	13	A	X			FELT/	**	BA
1622	MA	06	A		45	B	12	A	X		41	6.0/	VENEZIA	FM
1690	DE	04	A	18 D	46	B	13	C	X		57	9.0/	VILLACO	GC
1690	DE	04	A	19 D	46	B	13	C	X			FELT/	**	BA
1695	FE	24	F	1830	45	C	12	A	X			FELT/	TREVISO	BA
1695	FE	24	H	21 D	45	C	12	A	X			FELT/	**	BA
1695	FE	24	H		45	C	12	A	X			DAMA/	**	BA
1695	FE	25	H	0530	45	C	12	A	X		57	9.0/	**	GC
1700	JL	28	F		46	B	13	D	X		52	8.0/	ENEMONZO	GC
1719	JA	07	A	20	46	D	13	D	X		41	6.0/	FRIULI	GC
1746	OC	08	F	10	46	D	13	D	X			FELT/	CIVIDALE	BA
1746	OC	08	H	16	46	D	13	D	X		47	7.0/	**	GC
1746	OC	08	H	23	46	D	13	D	X		52	8.0/	**	BA
1750	NO	28	F	19 D	46	D	12	C	X		41	6.0/	PORDENONE	FM
1750	NO	28	H	22 B	46	D	12	C	X			FELT/	**	BA
1750	DE	05	H	07 D	46	D	13	A	X		31	4.0/	UDINE	FM
1750	DE	17	H	04 D	46	D	12	C	X		33	4.5/	PORDENONE	FM
1750	DE	17	H	1130	46	D	12	C	X		41	6.0/	**	FM
1750	DE	18	H		46	D	12	C	X		31	4.0/	**	FM
1750	DE	18	G	14 D	46	D	12	C	X		25	3.0/	**	FM
1756	AP	13	H		45	C	12	A	X		47	7.0/	TREVISO	GC

DATE			TIME	COORDINATES				MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y	M	D C		LA N	LO E	H		ML	MM	EI	I1	I2	I3	I4	I5	I6	SD
1776	JL	09F		46 A	12 C	X				FELT/							TRAMONTI BA
1776	JL	10H	15	46 A	12 C	X			52	8.0/							** GC
1788	OC	20F	2130	46 B	13 D	X			57	9.0/							TOLMEZZO GC
1788	NO	01H	0715	46 B	13 D	X			36	5.0/							** FM
1788	NO	05G	0305	46 B	13 D	X			31	4.0/							** FM
1789	MR	16F	07 B	46 B	13 D	X				FELT/							SUTRIO BA
1789	MR	31H		46 A	12 C	X				FELT/							TRAMONTI BA
1789	AU	03H	09 B	46 A	12 C	X				FELT/							** BA
1789	AU	03H	20	46 A	12 C	X			41	6.0/							** GC
1789	AU	04G	15	46 A	12 C	X			47	7.0/							** GC
1790	JA	26B	0730	46 B	13 D	X			57	9.0/							SUTRIO GC
1790	JA	26B	1330	46 B	13 D	X			33	4.5/							** FM
1790	JL	16B	02 D	46 B	13 D	X			31	4.0/							** FM
1794	JU	06F	0015	46 A	12 C	X			57	9.0/							TRAMONTI GC
1794	JU	07B	0230	45 C	13 C	X			44	6.5/							TRIESTE GC
1794	JU	12H	05 D	46 A	12 C	X				FELT/							TRAMONTI BA
1794	JU	16H	03 D	46 A	12 C	X				FELT/							** BA
1794	JU	19H	10 B	46 A	12 C	X				FELT/							** BA
1794	JU	30H	0830	46 A	12 C	X			47	7.0/							** GC
1794	SE	01G		46 A	12 C	X			52	8.0/							** GC
1812	OC	24F	13 D	4610	1246	X				FELT/							MANIAGO BA
1812	OC	25H	07	4610	1246	X			55	8.5=	8.5 006	8.0 021	5.5 046				** GC
1812	OC	25H	09 D	4610	1246	X				FELT/							** BA
1812	OC	25H	12 D	4610	1246	X				FELT/							** BA
1839	OC	06F	0330	46 B	13 D	X			47	7.0/							ARTA GC
1841	OC	06F	03	46 B	13 D	X			41	6.0/							TOLMEZZO GC
1841	OC	07H		46 B	13 D	X				FELT/							** BA
1841	OC	08H		46 B	13 D	X				FELT/							** BA
1853	FE	19F	10	46 B	13 D	X			47	7.0/							AMARO GC
1853	FE	20H	17 D	46 B	13 D	X				FELT/							** BA
1853	FE	21H	19 A	46 B	13 D	X				FELT/							** BA
1853	FE	22H	15 A	46 B	13 D	X				FELT/							** BA
1853	FE	23H	1010	46 B	13 D	X				FELT/							** BA
1853	FE	24H	1012	46 B	13 D	X				FELT/							** BA
1853	FE	25H	2104	46 B	13 D	X				FELT/							** BA
1853	FE	26H	08 D	46 B	13 D	X				FELT/							** BA
1853	FE	26H	1811	46 B	13 D	X				FELT/							** BA
1853	FE	27H	1703	46 B	13 D	X				FELT/							** BA
1853	FE	28H	1003	46 B	13 D	X				FELT/							** BA
1853	MR	01H	1013	46 B	13 D	X				FELT/							** BA
1853	MR	02H	0015	46 B	13 D	X				FELT/							** BA
1853	MR	03H	1845	46 B	13 D	X				FELT/							** BA
1853	MR	04H	03 D	46 B	13 D	X				FELT/							** BA
1853	MR	04H	1416	46 B	13 D	X				FELT/							** BA
1853	MR	04H	2130	46 B	13 D	X				FELT/							** BA
1853	MR	10H	0403	46 B	13 D	X				FELT/							** BA
1853	MR	10H	2105	46 B	13 D	X				FELT/							** BA
1853	MR	12H	0915	46 B	13 D	X				FELT/							** BA
1853	MR	15H	1231	46 B	13 D	X				FELT/							** BA
1853	MR	16H	1304	46 B	13 D	X				FELT/							** BA

DATE Y	M D C	TIME	COORDINATES LA N	LO E	H	MAGNIT ML	MM	INTENSITY AND MACROSEISMIC RADII EI	I1	I2	I3	I4	I5	I6	MEIZOSEISMAL AREA	REFER SD
1853	MR16H	1915	46 B	13 D	X			FELT/							**	BA
1853	MR17H	1318	46 B	13 D	X			FELT/							**	BA
1853	MR17H	18 D	46 B	13 D	X			FELT/							**	BA
1853	MR17H	1917	46 B	13 D	X			FELT/							**	BA
1853	MR18H	1810	46 B	13 D	X			FELT/							**	BA
1853	MR19G	0411	46 B	13 D	X			FELT/							**	BA
1857	MR10A	03 D	45 C	12 D	X		39	5.5/							VALDOBBIADENE	FM
1859	JA20F	0755	4554	1212	X		44	6.5/							COLLALTO	BA
1859	JA28H		4554	1212	X			UNKN*							**	BA
1859	JA30H		4554	1212	X			UNKN*							**	BA
1859	FE01H	06 D	4554	1212	X			UNKN*							**	BA
1859	FE01H	1730	4554	1212	X			UNKN*							**	BA
1859	FE02H	03 D	4554	1212	X			UNKN*							**	BA
1859	FE02H	05 D	4554	1212	X			UNKN*							**	BA
1859	FE02H	06 D	4554	1212	X			UNKN*							**	BA
1859	FE08H	23	45 C	12 A	X		41	6.0/							**	BA
1859	FE19H	11	4554	1212	X			UNKN*							**	BA
1859	FE19H	19	4554	1212	X			UNKN*							**	BA
1859	FE20H		4554	1212	X			UNKN*							**	BA
1859	FE20H		4554	1212	X			UNKN*							**	BA
1859	AP08H	23	4554	1212	X			UNKN*							**	BA
1859	AP29H	01	4554	1212	X			UNKN*							**	BA
1859	MA20H	11	4554	1212	X			FELT/							**	BA
1859	MA20H	12	45.9	12.2	X			FELT/							**	BA
1859	MA31H	14 D	4554	1212	X			FELT/							**	BA
1860	JL19G	153740	46 D	12 D	X		41	6.0/							**	GC
1872	MA14F	1745	46 D	13 B	X		41	6.0/							CIVIDALE	GC
1872	MA14H	20 D	46 D	13 B	X		36	5.0/							**	BA
1872	MA15H		46 D	13 B	X		36	5.0/							**	BA
1872	JU11H	2245	46 D	13 B	X		36	5.0/							**	BA
1872	JU12G	23 D	46 D	13 B	X		36	5.0/							**	BA
1873	JU13B	01 D	46 B	13 A	X		36	5.0/							MOGGIO UDINESE	BA
1873	JU29F	0358	4608	1213	X		60	9.5=	9.5 003	9.0 008	8.0 023	7.0 044			BELLUNO	GC
1873	JL03H	0847	4611	1222	X		41	6.0/							**	BA
1873	JL11H	0143	4611	1222	X		47	7.0/							**	BA
1873	JL22H	1205	4611	1222	X		47	7.0/							**	BA
1873	JL05H		4611	1222	X		41	6.0/							**	BA
1873	JL27H	1210	4611	1222	X		47	7.0/							**	BA
1873	AU08H	0715	4611	1222	X		41	6.0/							**	BA
1873	AU21G	0905	4611	1222	X		47	7.0/							**	BA
1875	OC24A	22 D	46 D	12 A	X			FELT/							**	BA
1878	MR06A	091416	46 D	12 A	X		41	6.0/							**	GC
1879	JU15F	0957	46.4	13.0	X			FELT/							TOLMEZZO	BA
1879	JU21H	0915	46 A	13 A	X		28	3.5/							**	FM
1879	JU21H	1610	46 A	13 A	X		25	3.0/							**	BA
1879	JU22H	0415	46 A	13 A	X		47	7.0/							**	GC
1879	JU23G	0045	46 A	13 A	X		31	4.0/							**	BA
1887	AP14A	0110	45 C	12 D	X		52	8.0/							TREVISO	GC
1889	JU24F	0330	4625	1301	X		36	5.0/							TOLMEZZO	BA
1889	JU24H	0645	4625	1301	X		31	4.0/							**	BA

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1889 JU25H	0125	4625 1301	X	36	5.0/	**	BA
1889 JU27H		4625 1301	X	31	4.0/	**	BA
1889 JL06H	23 D	4625 1301	X	20	2.0/	**	BA
1889 AU21H	0115	4625 1301	X	36	5.0/	**	BA
1889 AU26H	0515	4625 1301	X	47	7.0= 7.0 002 6.0 006	**	GC
1889 SE05H		4625 1301	X	25	3.0/	**	FM
1889 SE13H		46.4 13.0	X	47	7.0/	**	MR
1889 OC12H	0347	4625 1301	X	36	5.0/	**	BA
1889 OC12H	0357	4625 1301	X	31	4.0/	**	FM
1889 OC13H		46.4 13.1	X	39	5.5/	**	FM
1889 OC13H	0625	4625 1301	X	33	4.5/	**	FM
1889 OC13H	1010	4625 1301	X	49	7.5= 7.5 003 6.0 008 5.0 013 4.0 023	**	GC
1889 OC14H		4625 1301	X	31	4.0/	**	BA
1889 OC15H		4625 1301	X		FELT/	**	BA
1889 OC16H	03 D	4625 1301	X		FELT/	**	BA
1889 NO03H	08 D	4625 1301	X		FELT/	**	BA
1889 NO03H	0845	4625 1301	X		FELT/	**	BA
1889 NO09H		4625 1301	X		FELT/	**	BA
1889 NO10H	18 D	4625 1301	X		FELT/	**	BA
1889 NO10G	21 D	4625 1301	X		FELT/	**	BA
1890 MR26A	2008	4616 1218	X	44	6.5= 6.0 007 5.0 040 4.0 068	LONGARONE	GC
1892 JU23H	2320	4616 1231	X	47	7.0= 7.0 003 6.0 011 5.0 030 4.0 044	CLAUT	GC
1893 OC27A	1631	46 A 12 A	X	41	6.0/	LONGARONE	GC
1895 FE27F	1538	4616 1231	X	41	6.0= 6.0 003 5.0 012 4.0 030 3.0 060	CLAUT	GC
1895 FE27H	2316	4616 1231	X	41	6.0/	**	GC
1895 MR03G	05 D	4616 1231	X	39	5.5/	**	FM
1895 AP14A	2217	4606 1430	16	59	8.5= 8.0 018 7.0 052 6.0 110 5.0 180 4.0 250 2.0 350	LUBIANA	GC
1895 MA25F	114250	45 D 12 D	X	41	6.0/	ROVIGO	GC
1895 MA25H	1145	45 D 12 D	X	25	3.0/	**	BA
1895 MA25H	20 D	45 D 12 D	X		FELT/	**	BA
1895 MA29H		45 D 12 D	X		FELT/	**	BA
1895 MA31G		45 D 12 D	X		FELT/	**	BA
1895 JU10F	014726	4558 1208	X	44	6.5= 6.5 002 5.0 024 4.0 065 3.0 115	FOLLINA	GC
1895 JU10H	015855	4558 1208	X		FELT/	**	BA
1895 JU10H	2124	4558 1208	X	31	4.0/	**	BA
1895 JU11H	00	4558 1208	X		FELT/	**	BA
1895 JU11G	0835	4558 1208	X		FELT/	**	BA
1896 DE01F	0225	46 B 13 A	X	41	6.0/	PONTEBBA	GC
1896 DE01H	0255	46 B 13 A	X		FELT/	**	BA
1896 DE01H	0230	46 B 13 A	X	31	4.0/	**	BA
1896 DE01G	0815	46 B 13 A	X		FELT/	**	BA
1897 JU11F	114052	4557 1207	X	44	6.5= 6.5 007 5.0 027 4.0 035	FOLLINA(TV)	GC
1897 JU11H	1303	4550 1204	X	36	5.0=	**	FM
1898 FE20F	0452	4605 1326	X		FELT/	CIVIDALE	BA
1898 FE20H	0452	4605 1326	X		FELT/	**	BA
1898 FE20H	0457	4605 1326	A	49	7.5= 7.5 001 6.0 017 5.5 018 5.0 029 4.0 049	**	GC
1898 AP12G	1915	4605 1326	X	41	6.0= 6.0 013 5.0 020 4.0 021	**	GC
1900 MR04F	17	4547 1202	X	44	6.5/	MONTEBELLUNA	BS
1900 MR05H	19	45.7 12.0	X	36	5.0/	**	BS
1904 MR10A	0415	46.5 13.8	X	41	6.0/	TARVISIO	GC

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1904	OC09A	0641	46.3	12.5	X		41	6.0/							CLAUT	GC
1906	JU03F	1940	46.4	13.0	X		41	6.0/							TOLMEZZO	CA
1906	JU03H	22	46.4	13.0	X			FELT/							**	CA
1906	JU04G	2130	46.4	13.0	X			FELT/							**	CA
1907	JL01F	21 B	46.4	13.0	X			FELT/							**	BS
1907	JL02H	0130	46.4	13.0	X			FELT/							**	BS
1907	JL02H	0145	46.4	13.0	X			FELT/							**	BS
1907	JL02G	0230	46.4	13.0	X		39	5.5/							**	BS
1908	JL10F	021335	4628	1312	C	48	52	8.0/	8.0 002	7.0 003	6.0 007	5.0 016			MOGGIO UDINESE	GC
1908	JL10H	064039	46.5	13.2	C	44	47	7.0/							**	GC
1908	JL31G	0733	46.5	13.2	C	41	41	6.0/							**	GC
1908	NO18A	032015	46.2	12.5	X		36	5.0/							BARCIS	BS
1909	JA13A	0045			25	56	48	6.0/							ADRIATICO	GC
1912	AU05A	1033	46.1	12.4	X		41	6.0/							CANSIGLIO	GC
1916	MR12F	09 C	46.3	12.4	X		28	3.5/							CLAUT	BS
1916	JU26H	18 C	46.3	12.4	X		28	3.5/							**	BS
1916	JL07G	08 C	46.3	12.4	X		28	3.5/							**	BS
1917	AU08A	0710	46.1	13.4	X		31	4.0/							CIVIDALE	CI
1918	FE19A	110305	46.5	13.0	X		44	6.5/							PALUZZA	KI
1919	JL05A	1215	46.0	12.3	X		25	3.0/							VITTORIO VENETO	CI
1920	MA05F	144155	4620	1308	A	54	47	7.0=	7.0 004	6.0 013	5.0 026	4.0 050			VENZONE	GC
1920	MA13H		4621	1306	X		41	6.0=							**	GC
1920	MA25H	1740	4621	1306	X		31	4.0=							**	CI
1920	MA25G	2110	4621	1306	X			FELT/							**	CI
1921	AU17A	0450	46.5	13.0	X		36	5.0/							PALUZZA	CI
1922	NO08A	102828	46.0	12.0	X		41	6.0/							BELLUNESE	KI
1923	MA08F	2015	46.4	12.9	X		28	3.5/							VILLA SANTINA	CI
1923	JL2HA	0455	46.4	12.9	X		31	4.0/							**	CI
1924	MA07H	04 B	46.4	12.9	X		33	4.5/							**	CI
1924	MA07H	1040	46.4	12.9	X		31	4.0/							**	CI
1924	MA12H	084555	46.4	13.0	C	47	41	6.0/							**	GC
1924	MA14H	1650	46.4	13.0	X		31	4.0/							**	CI
1924	MA17G	0536	46.4	13.0	X		31	4.0/							**	CI
1924	DE12F	032943	4628	1302	C	53	47	7.0=	7.0 010	6.0 021	5.0 045				CARNIA	GC
1924	DE12H	0335	46.5	13.0	X		25	3.0/							**	CI
1924	DE12H	0450	46.5	13.0	X		25	3.0/							**	GC
1924	DE12H	1045	46.5	13.0	X		25	3.0/							**	CI
1924	DE12G	1130	46.5	13.0	X		31	4.0/							**	CI
1925	JA20F	1708	46.1	12.2	X		36	5.0/							BELLUNO	CI
1925	FE03H	2330	46.1	12.2	X		25	3.0/							**	CI
1925	MR01H	2338	46.1	12.2	X		31	4.0/							**	CI
1925	MR01H	2342	46.1	12.2	X		20	2.0/							**	CI
1925	JL04G	1748	46.2	12.2	X		39	5.5/							**	CI
1927	DE22A	0157	45.8	12.0	X		25	3.0/							VALDOBBIADENE	CI
1928	MR26F	1441	46.4	13.0	C	54	41	6.0/							VERZEGNIS	GC
1928	MR26H	1444	46.4	13.0	X		23	2.5/							**	CI
1928	MR26H	1520	46.4	13.0	X		25	3.0/							**	CI
1928	MR27H	01 D	46.4	13.0	X		31	4.0/							**	CI
1928	MR27H	03 D	46.4	13.0	X		36	5.0/							**	CI
1928	MR27H	083228	4623	1302	C	58	57	9.0=	9.0 002	8.0 003	7.0 012	6.0 018	5.0 037		**	GC

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1928	MR28H	0110	46.4	13.0	X		31	4.0/							**	CI
1928	MR28H	02 D	46.4	13.0	X		36	5.0/							**	CI
1928	MR28H	1420	46.4	13.0	X		31	4.0/							**	CI
1928	MR29H	1452	46.4	13.0	C		41	6.0/							**	GC
1928	MR30H	0111	46.4	13.0	X		39	5.5/							**	CI
1928	MR30H	0940	46.4	13.0	X		31	4.0/							**	CI
1928	MR30H	1705	46.4	13.0	X		31	4.0/							**	CI
1928	MR31H	0430	46.4	13.0	X		31	4.0/							**	CI
1928	MR31H	0620	46.4	13.0	X		31	4.0/							**	CI
1928	MR31H	16 D	46.4	13.0	X		31	4.0/							**	CI
1928	AP01H	0030	46.4	13.0	X		36	5.0/							**	CI
1928	AP01H	08 D	46.4	13.0	X		31	4.0/							**	CI
1928	AP03H	0430	46.4	13.0	X		36	5.0/							**	CI
1928	AP04H	2050	46.4	13.0	X		31	4.0/							**	CI
1928	AP04H	2055	46.4	13.0	X		20	2.0/							**	CI
1928	AP04H	22 D	46.4	13.0	X		31	4.0/							**	CI
1928	AP05H	10 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP06H	0550	46.4	13.0	X		25	3.0/							**	CI
1928	AP06H	1345	46.4	13.0	X		31	4.0/							**	CI
1928	AP06H	1430	46.4	13.0	X		25	3.0/							**	CI
1928	AP06H	2255	46.4	13.0	X		36	5.0/							**	CI
1928	AP07H	02 D	46.4	13.0	X		31	4.0/							**	CI
1928	AP09H	1620	46.4	13.0	X		20	2.0/							**	CI
1928	AP10H	01 D	46.4	13.0	X		31	4.0/							**	CI
1928	AP10H	03 D	46.4	13.0	X		31	4.0/							**	CI
1928	AP10H	0730	46.4	13.0	X		20	2.0/							**	CI
1928	AP10H	2210	46.4	13.0	X		25	3.0/							**	CI
1928	AP11H	0622	46.4	13.0	X		20	2.0/							**	CI
1928	AP11H	1530	46.4	13.0	X		25	3.0/							**	CI
1928	AP11H	17 D	46.4	13.0	X		28	3.5/							**	CI
1928	AP11H	2050	46.4	13.0	X		25	3.0/							**	CI
1928	AP11H	2220	46.4	13.0	X		36	5.0/							**	CI
1928	AP12H	00 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP12H	0145	46.4	13.0	X		20	2.0/							**	CI
1928	AP12H	0550	46.4	13.0	X		20	2.0/							**	CI
1928	AP12H	2020	46.4	13.0	X		20	2.0/							**	CI
1928	AP12H	2040	46.4	13.0	X		20	2.0/							**	CI
1928	AP13H	00 D	46.4	13.0	X		25	3.0/							**	CI
1928	AP13H	02 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP13H	1840	46.4	13.0	X		36	5.0/							**	CI
1928	AP13H	2220	46.4	13.0	X		20	2.0/							**	CI
1928	AP14H	02 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP15H	10 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP15H	1240	46.4	13.0	X		25	3.0/							**	CI
1928	AP17H	1150	46.4	13.0	X		20	2.0/							**	CI
1928	AP17H	1230	46.4	13.0	X		25	3.0/							**	CI
1928	AP17H	2010	46.4	13.0	X		25	3.0/							**	CI
1928	AP18H	08 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP18H	0920	46.4	13.0	X		25	3.0/							**	CI
1928	AP18H	1125	46.4	13.0	X		36	5.0/							**	CI

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1928	AP18H	1130	46.4	13.0	X		20	2.0/							**	CI
1928	AP18H	17 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP18H	2005	46.4	13.5	X		31	4.0/							**	CI
1928	AP20H	1150	46.4	13.0	X		20	2.0/							**	CI
1928	AP22H	02 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP22H	16 D	46.4	13.0	X		25	3.0/							**	CI
1928	AP23H	00 D	46.4	13.0	X		25	3.0/							**	CI
1928	AP23H	0530	46.4	13.0	X		20	2.0/							**	CI
1928	AP23H	07 D	46.4	13.0	X		25	3.0/							**	CI
1928	AP23H	08 D	46.4	13.0	X		20	2.0/							**	CI
1928	AP24H	0550	46.4	13.0	X		20	2.0/							**	CI
1928	AP24H	1330	46.4	13.0	X		25	3.0/							**	CI
1928	AP25H	0040	46.4	13.0	X		20	2.0/							**	CI
1928	AP25H	0530	46.4	13.0	X		20	2.0/							**	CI
1928	AP25H	1530	46.4	13.0	X		20	2.0/							**	CI
1928	AP26H	0725	46.4	13.0	X		25	3.0/							**	CI
1928	AP27H	1030	46.4	13.0	X		20	2.0/							**	CI
1928	AP27H	2305	46.4	13.0	X		20	2.0/							**	CI
1928	AP28H	1330	46.4	13.0	X		25	3.0/							**	CI
1928	AP29H	0110	46.4	13.0	X		28	3.5/							**	CI
1928	AP29H	0115	46.4	13.0	X		20	2.0/							**	CI
1928	AP29H	0440	46.4	13.0	X		20	2.0/							**	CI
1928	AP29H	0855	46.4	13.0	X		25	3.0/							**	CI
1928	MA01H	0440	46.4	13.0	X		20	2.0/							**	CI
1928	MA01H	1030	46.4	13.0	X		20	2.0/							**	CI
1928	MA01H	21 D	46.4	13.0	X		20	2.0/							**	CI
1928	MA01H	23 D	46.4	13.0	X		20	2.0/							**	CI
1928	MA01H	2335	46.4	13.0	X		25	3.0/							**	CI
1928	MA02H	02 D	46.4	13.0	X		20	2.0/							**	CI
1928	MA02H	0430	46.4	13.0	X		20	2.0/							**	CI
1928	MA02H	06 D	46.4	13.0	X		20	2.0/							**	CI
1928	MA03H	02 D	46.4	13.0	X		25	3.0/							**	CI
1928	MA03H	0555	46.4	13.0	X		20	2.0/							**	CI
1928	MA05H	0520	46.4	13.0	X		25	3.0/							**	CI
1928	MA06H	02 D	46.4	13.0	X		31	4.0/							**	CI
1928	MA06H	0550	46.4	13.0	X		33	4.5/							**	CI
1928	MA07H	0105	46.4	13.0	X		20	2.0/							**	CI
1928	MA07H	0205	46.4	13.0	X		20	2.0/							**	CI
1928	MA07H	03 D	46.4	13.0	X		20	2.0/							**	CI
1928	MA09H	0840	46.4	13.0	X		25	3.0/							**	CI
1928	MA11H	02 D	46.4	13.0	X		25	3.0/							**	CI
1928	MA11H	1145	46.4	13.0	X		25	3.0/							**	CI
1928	MA11H	1155	46.4	13.0	X		17	1.5/							**	CI
1928	MA11H	1155	46.4	13.0	X		20	2.0/							**	CI
1928	MA11H	1545	46.4	13.0	X		25	3.0/							**	CI
1928	MA12H	01 D	46.4	13.0	X		28	3.5/							**	CI
1928	MA12H	1345	46.4	13.0	X		28	3.5/							**	CI
1928	MA12H	1350	46.4	13.0	X		20	2.0/							**	CI
1928	MA12H	1650	46.4	13.0	X		36	5.0/							**	CI
1928	MA12H	1653	46.4	13.0	X		25	3.0/							**	CI

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1928	MA13H	01 D	46.4	13.0	X		25	3.0/							**	CI
1928	MA13H	1455	46.4	13.0	X		25	3.0/							**	CI
1928	MA14H	1730	46.4	13.0	X		31	4.0/							**	CI
1928	MA15H	1403	46.4	13.0	X		36	5.0/							**	CI
1928	MA15H	1403	46.1	13.2	X		25	3.0/							**	CI
1928	MA15H	1408	46.4	13.0	X		25	3.0/							**	CI
1928	MA16H	2120	46.4	13.0	X		25	3.0/							**	CI
1928	MA17H	1725	46.4	13.0	X		31	4.0/							**	CI
1928	MA18H	0215	46.4	13.0	X		25	3.0/							**	CI
1928	MA19H	0633	46.4	13.0	X		31	4.0/							**	CI
1928	MA20H	1030	46.4	13.0	X		31	4.0/							**	CI
1928	MA21H	1020	46.4	13.0	X		25	3.0/							**	CI
1928	MA21H	2130	46.4	13.0	X		20	2.0/							**	CI
1928	MA22H	0155	46.4	13.0	X		31	4.0/							**	CI
1928	MA22H	04 D	46.4	13.0	X		20	2.0/							**	CI
1928	MA22H	2015	46.4	13.0	X		20	2.0/							**	CI
1928	MA25H	0705	46.4	13.0	X		25	3.0/							**	CI
1928	MA25H	2020	46.4	13.0	X		25	3.0/							**	CI
1928	MA27H	0415	46.4	13.0	X		31	4.0/							**	CI
1928	MA28H	0040	46.4	13.0	X		25	3.0/							**	CI
1928	MA28H	0130	46.4	13.0	X		20	2.0/							**	CI
1928	MA28H	2115	46.4	13.0	X		25	3.0/							**	CI
1928	MA29H	1655	46.4	13.0	X		28	3.5/							**	CI
1928	MA29H	1705	46.4	13.0	X		25	3.0/							**	CI
1928	MA30H	02 D	46.4	13.0	X		25	3.0/							**	CI
1928	MA31H	20 D	46.4	13.0	X		25	3.0/							**	CI
1928	JU02H	03 D	46.4	13.0	X		25	3.0/							**	CI
1928	JU05H	2155	46.4	13.0	X		25	3.0/							**	CI
1928	JU06H	0015	46.4	13.0	X		36	5.0/							**	CI
1928	JU09H	0910	46.4	13.0	X		31	4.0/							**	CI
1928	JU10H	0145	46.4	13.0	X		25	3.0/							**	CI
1928	JU14H	07 D	46.4	13.0	X		31	4.0/							**	CI
1928	JU17H	03 D	46.4	13.0	X		33	4.5/							**	CI
1928	JU20H	0530	46.4	13.0	X		25	3.0/							**	CI
1928	JU21H	15 D	46.4	13.0	X		25	3.0/							**	CI
1928	JU22H	09 D	46.4	13.0	X		25	3.0/							**	CI
1928	JU23H	0730	46.4	13.0	X		25	3.0/							**	CI
1928	JU23H	1040	46.4	13.0	X		36	5.0/							**	CI
1928	JU23H	1045	46.4	13.0	X		20	2.0/							**	CI
1928	JU26H	2326	46.4	13.0	X		39	5.5/							**	CI
1928	JU26H	2331	46.4	13.0	X		20	2.0/							**	CI
1928	JU26H	2350	46.4	13.0	X		25	3.0/							**	CI
1928	JU27H	17 D	46.4	13.0	X		25	3.0/							**	CI
1928	JU28H	2330	46.4	13.0	X		25	3.0/							**	CI
1928	JU29H	00 D	46.4	13.0	X		25	3.0/							**	CI
1928	JU29H	01 D	46.4	13.0	X		31	4.0/							**	CI
1928	JU29H	0110	46.4	13.0	X		20	2.0/							**	CI
1928	JU29H	0125	46.4	13.0	X		20	2.0/							**	CI
1928	JU29H	0140	46.4	13.0	X		20	2.0/							**	CI
1928	JU29H	02 D	46.4	13.0	X		20	2.0/							**	CI

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1928	JU30H	1110	46.4	13.0	X		36	5.0/							**	CI
1928	JL01H	0850	46.4	13.0	X		25	3.0/							**	CI
1928	JL02H	0550	46.4	13.0	X		25	3.0/							**	CI
1928	JL09H	0045	46.4	13.0	X		25	3.0/							**	CI
1928	JL09H	1110	46.4	13.0	X		25	3.0/							**	CI
1928	JL10H	18 D	46.4	13.0	X		31	4.0/							**	CI
1928	JL11H	1645	46.4	13.0	X		25	3.0/							**	CI
1928	JL12H	03 D	46.4	13.0	X		25	3.0/							**	CI
1928	JL12H	0350	46.4	13.0	X		28	3.5/							**	CI
1928	JL12H	2030	46.4	13.0	X		25	3.0/							**	CI
1928	JL13H	0915	46.4	13.0	X		25	3.0/							**	CI
1928	JL13H	1120	46.4	13.0	X		28	3.5/							**	CI
1928	JL17H	1045	46.4	13.0	X		25	3.0/							**	CI
1928	JL17H	11 D	46.4	13.0	X		25	3.0/							**	CI
1928	JL18H	21 D	46.4	13.0	X		28	3.5/							**	CI
1928	JL19H	22 D	46.4	13.0	X		25	3.0/							**	CI
1928	JL22H	2050	46.4	13.0	X		25	3.0/							**	CI
1928	JL24H	2040	46.4	13.0	X		28	3.5/							**	CI
1928	JL24H	2045	46.4	13.0	X		20	2.0/							**	CI
1928	JL25H	10 D	46.4	13.0	X		25	3.0/							**	CI
1928	JL25H	12 D	46.4	13.0	X		25	3.0/							**	CI
1928	JL25H	1315	46.4	13.0	X		25	3.0/							**	CI
1928	JL26H	0955	46.4	13.0	X		25	3.0/							**	CI
1928	AU02H	0714	46.4	13.0	X		20	2.0/							**	CI
1928	AU02H	0842	46.4	13.0	X		39	5.5/							**	CI
1928	AU02H	22 D	46.4	13.0	X		25	3.0/							**	CI
1928	AU03H	02 D	46.4	13.0	X		25	3.0/							**	CI
1928	AU06H	09 D	46.4	13.0	X		25	3.0/							**	CI
1928	AU10H	00 D	46.4	13.0	X		28	3.5/							**	CI
1928	AU17H	1644	46.4	13.0	X		31	4.0/							**	CI
1928	AU24H	21 D	46.4	13.0	X		31	4.0/							**	CI
1928	AU31H	22 D	46.4	13.0	X		31	4.0/							**	CI
1928	SE16H	0530	46.4	13.0	X		28	3.5/							**	CI
1928	SE22H	0930	46.4	13.0	X		28	3.5/							**	CI
1928	SE22H	1130	46.4	13.0	X		28	3.5/							**	CI
1928	SE25H	1655	46.4	13.0	X		23	2.5/							**	CI
1928	SE25H	20 D	46.4	13.0	X		20	2.0/							**	CI
1928	SE26H	08 D	46.4	13.0	X		20	2.0/							**	CI
1928	SE27H	0940	46.4	13.0	X		23	2.5/							**	CI
1928	SE28H	0151	46.4	13.0	X		31	4.0/							**	CI
1928	SE28H	0350	46.4	13.0	X		25	3.0/							**	CI
1928	SE28H	16 D	46.4	13.0	X		25	3.0/							**	CI
1928	OC02H	2340	46.4	13.0	X		20	2.0/							**	CI
1928	OC03H	0645	46.4	13.0	X		28	3.5/							**	CI
1928	OC06H	0240	46.4	13.0	X		23	2.5/							**	CI
1928	OC07H	1905	46.4	13.0	X		20	2.0/							**	CI
1928	OC09H	0955	46.4	13.0	X		20	2.0/							**	CI
1928	OC11H	0245	46.4	13.0	X		23	2.5/							**	CI
1928	OC15H	0320	46.4	13.0	X		23	2.5/							**	CI
1928	OC16H	14 D	46.4	13.0	X		23	2.5/							**	CI

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1928	OC19H	0240	46.4	13.0	X		20	2.0/							**	CI
1928	OC19H	0650	46.4	13.0	X		23	2.5/							**	CI
1928	OC20H	1115	46.4	13.0	X		23	2.5/							**	CI
1928	OC21H	0450	46.4	13.0	X		23	2.5/							**	CI
1928	OC22H	2120	46.4	13.0	X		23	2.5/							**	CI
1928	OC25H	0410	46.4	13.0	X		20	2.0/							**	CI
1928	OC25H	1810	46.4	13.0	X		23	2.5/							**	CI
1928	OC25H	23 D	46.4	13.0	X		20	2.0/							**	CI
1928	OC30H	1730	46.4	13.0	X		23	2.5/							**	CI
1928	NO08H	0140	46.4	13.0	X		28	3.5/							**	CI
1928	NO10H	08 D	46.4	13.0	X		20	2.0/							**	CI
1928	NO11H	0720	46.4	13.0	X		20	2.0/							**	CI
1928	NO11H	08 D	46.4	13.0	X		20	2.0/							**	CI
1928	NO13H	2150	46.4	13.0	X		25	3.0/							**	CI
1928	NO16H	031715	46.4	13.0	C	42	41	6.0/							**	GC
1928	NO16H	0323	46.4	13.0	X		23	2.5/							**	CI
1928	NO16H	0452	46.4	13.0	X		20	2.0/							**	CI
1928	NO16H	0935	46.4	13.0	X		20	2.0/							**	CI
1928	NO16H	1245	46.4	13.0	X		20	2.0/							**	CI
1928	NO17H	1530	46.4	13.0	X		20	2.0/							**	CI
1928	NO19H	18 D	46.4	13.0	X		20	2.0/							**	CI
1928	NO20H	1910	46.4	13.0	X		20	2.0/							**	CI
1928	NO21H	0120	46.4	13.0	X		20	2.0/							**	CI
1928	NO21H	0350	46.4	13.0	X		20	2.0/							**	CI
1928	NO29H	05 D	46.4	13.0	X		25	3.0/							**	CI
1928	NO29H	17 D	46.4	13.0	X		20	2.0/							**	CI
1928	NO29H	2015	46.4	13.0	X		20	2.0/							**	CI
1928	DE02H	1830	46.4	13.0	X		20	2.0/							**	CI
1928	DE03H	0230	46.4	13.0	X		20	2.0/							**	CI
1928	DE06H	1745	46.4	13.0	X		20	2.0/							**	CI
1928	DE07H	2120	46.4	13.0	X		20	2.0/							**	CI
1928	DE10H	2035	46.4	13.0	X		20	2.0/							**	CI
1928	DE11H	01 D	46.4	13.0	X		20	2.0/							**	CI
1928	DE15H	1630	46.4	13.0	X		20	2.0/							**	CI
1928	DE16H	1930	46.4	13.0	X		20	2.0/							**	CI
1928	DE17H	1315	46.4	13.0	X		23	2.5/							**	CI
1928	DE29H	0330	46.4	13.0	X		25	3.0/							**	CI
1928	DE30G	0415	46.4	13.0	X		20	2.0/							**	CI
1929	SE02A	0552	46.0	13.7	X		33	4.5/							GORIZIA	CI
1929	OC03A	1705	46.1	13.5	C		41	6.0/							CIVIDALE	GC
1929	DE06A	1621	46.4	13.0	X		31	4.0/							TOLMEZZO	CI
1929	DE25A	0538	46.1	12.9	X		36	5.0/							SPILIMBERGO	CI
1930	JA10A	2153	46.4	13.0	C	41	41	6.0/							CAVAZZO	GC
1930	FE25F	1324	46.0	13.7	X		25	3.0/							GORIZIA	CI
1930	FE25H	1336	46.0	13.7	X		36	5.0/							**	CI
1930	MA14F	000000	46.6	12.5	X		31	4.0/							AURONZO	CI
1930	MA14H	000119	46.6	12.5	C	47	41	6.0/							**	GC
1930	MA14G	0007	46.6	12.5	X		31	4.0/							**	CI
1930	NO03A	0400	45.7	13.4	X		31	4.0/							GRADO	CI
1930	NO10F	2150	46.3	12.5	X		31	4.0/							CLAUT	CI

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1930	NO22H	19 D	46.3	12.5	X		31	4.0/							**	CI
1930	NO24H	194313	46.3	12.5	X		31	4.0/							**	CI
1930	NO24H	2036	46.3	12.5	X		20	2.0/							**	CI
1930	NO24G	2105	46.3	12.5	X		20	2.0/							**	CI
1931	AP24F	0915	46.3	12.5	X		31	4.0/							**	CI
1931	AP24H	2210	46.3	12.5	X		31	4.0/							**	CI
1931	AP24G	2227	46.3	12.5	X		20	2.0/							**	CI
1931	OC05F	1133	46.3	12.5	X		31	4.0/							**	CI
1931	OC12G	1129	46.3	12.5	X		25	3.0/							CLAUT	CI
1931	OC23A	02 D	46.3	12.9	X		31	4.0/							PIELUNGO	CI
1931	NO20A	0830	46.5	12.4	X		28	3.5/							LOZZO CADORE	CI
1931	DE25A	114117	4617	1306	13		50	7.0=	7.0 006	6.0 017	5.0 025	4.0 057			TRASAGHIS	GC
1932	JA15A	2149	46.4	13.3	X		36	5.0/							RESIA	CI
1932	FE08A	2053	46.2	13.2	X		25	3.0/							TARCENTO	CI
1932	AU18A	1345	46.0	14.0	X		31	4.0/							IDRIA	CI
1932	SE20A	2330	46.3	12.5	X		25	3.0/							CLAUT	CI
1932	DE01A	12	46.3	12.5	X		25	3.0/							**	CI
1933	JL20A	1930	46.3	12.5	X		31	4.0/							**	CI
1933	AU23A	1645	46.3	12.5	X		31	4.0/							**	CI
1933	DE27A	044353	46.2	12.2	C	44	31	4.0/							BELLUNO	K1
1934	JA13A	0355	46.2	12.2	X		31	4.0/							**	CI
1934	FE24F	1330	46.2	12.8	X		20	2.0/							CAVAZZO NUOVO	CI
1934	FE27H	0127	46.2	12.8	X		25	3.0/							**	CI
1934	MR02H	0545	46.2	12.8	X		20	2.0/							**	CI
1934	MA04F	135610	46.4	12.9	C	43	41	6.0/							VILLA SANTINA	GC
1934	MA07H	0144	46.4	12.9	X		36	5.0/							**	CI
1934	JU08F	031709	46.3	12.5	20	45	47	6.0/							CLAUT	GC
1934	JU08H	0715	46.3	12.5	X		25	3.0/							**	CI
1934	JU12A	0250	46.1	12.9	X		25	3.0/							SPILIMBERGO	CI
1934	JU20A	0447	46.1	12.9	X		25	3.0/							**	CI
1934	JL14A	1457	46.3	12.5	X		31	4.0/							CLAUT	CI
1934	SE08A	180326	46.3	12.5	C	42	31	4.0/							**	K1
1934	OC04A	1918	46.3	12.5	X		31	4.0/							**	CI
1934	OC22A	1858	46.2	12.8	X		36	5.0/							CAVAZZO NUOVO	CI
1934	NO19A	06	46.2	12.5	X		25	3.0/							CLAUT	CI
1935	JA11F	0546	46.3	12.5	X		25	3.0/							**	CI
1935	JA11H	0601	46.3	12.5	X		31	4.0/							**	CI
1935	JA17G	0545	46.3	12.5	X		36	5.0/							**	CI
1935	MR31A	07 D	46.3	12.5	X		28	3.5/							**	CI
1935	JL31A	1119	46.4	12.9	X		25	3.0/							TOLMEZZO	CI
1935	DE29A	0504	46.0	13.8	X		25	3.0/							GORIZIA	CI
1936	JA24F	0325	46.2	13.2	X		36	5.0/							ARTEGNA	CI
1936	JA24G	0347	46.2	13.2	X		36	5.0/							**	CI
1936	JU07F	2115	46.3	12.5	X		25	3.0/							CLAUT	CI
1936	AU19A	0504	46.6	12.4	X		31	4.0/							AURONZO	CI
1936	OC17F	2330	45.9	12.8	X		25	3.0/							S.VITO AL TAGLIAM.	CI
1936	OC18H	031012	4604	1224	10	56	59	9.0=	9.0 008	8.0 016	7.0 030	6.0 049	5.0 130	4.0 180	CANSIGLIO	GC
1936	OC18H	0428	4600	1227	X		36	5.0/							**	CI
1936	OC18H	0725	4600	1227	X		41	6.0/							**	GC
1936	OC18H	214940	4600	1227	X	43	41	6.0/							**	GC

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1936	0C19H	070554	4600	1227	B	45	47	7.0=	7.0 006	6.0 010	5.0 016	4.0 042			**	GC
1936	0C19H	0944	4600	1227	X		31	4.0/							**	CI
1936	0C23H	0355	4603	1235	X		25	3.0/							AVIANO	CI
1936	0C23H	0657	4603	1235	X		28	3.5/							**	CI
1936	0C23H	1436	4603	1235	X		31	4.0/							**	CI
1936	N017H	1845	4632	1236	X		33	4.5/							AURONZO	CI
1936	N021H	0115	4600	1227	X		36	5.0/							CANSIGLIO	CI
1936	N021H	0129	4600	1227	X		31	4.0/							**	CI
1936	N021G	0206	4600	1227	X		31	4.0/							**	CI
1937	JA05H	205815	46.5	13.0	C	41	41	6.0/							PALUZZA	K1
1937	JA09H	191336	46.3	13.0	C	42		UNKN*							TRASAGHIS	K1
1938	JL07A	0748	46	13	X		36	5.0/							FRIULI	FM
1938	JL14H	195748	46.4	12.9	C	45	41	6.0/							VILLA SANTINA	GC
1939	FE11H	1116	46.1	13.1	10	47	47	6.5/							FAGAGNA	GC
1939	AP25H	182459	4620	1308	05	41	41	6.0=	6.0 006	5.0 010	4.0 014				VENZONE	GC
1939	JL02A	1551	46	13	X		31	4.0/							FRIULI	FM
1939	JL10H	162753	46.3	12.2	C	44	41	6.0/							BELLUNO	GI
1939	JL10A	1639	46	13	X		36	5.0/							FRIULI	FM
1942	JA27A	0145	46.3	12.5	X		28	3.5/							CLAUT	FM
1942	FE26A	22 D	46.2	12.5	X		36	5.0/							BARCIS	FM
1943	MR28A	0239	46.3	12.5	X		31	4.0/							CLAUT	FM
1943	MR28A	0259	46.3	12.5	X		25	3.0/							**	FM
1943	MR29A	0135	46.3	12.5	X		25	3.0/							**	FM
1943	MR30A	0430	46.3	12.5	X		31	4.0/							**	FM
1943	JU13A	052116	4625	1249	X		36	5.0/							AMPEZZO	FM
1946	AU23F	2030	46.1	12.4	X			FELT/							CANSIGLIO	OG
1946	OC23H	211745	46.1	12.4	X			FELT/							**	OG
1946	DE25A	072253	46.1	12.4	X		39	5.5/							**	OG
1947	MR12A	1330	46.6	13.5	X		25	3.0/							TARVISIO	OG
1947	AU23A	0550	46.4	13.0	X		31	4.0/							TOLMEZZO	FM
1947	AU23A	2400	46.2	12.8	X		31	4.0/							SEQUALS	FM
1948	MR10A	130816	45.9	12.3	X		31	4.0/							VITTORIO VENETO	OG
1948	JL28A	163900	46.2	14.5	X			FELT/							SLOVENIA	OG
1948	AU07A	2200	46.3	12.5	X		31	4.0/							CLAUT	FM
1948	OC05A	0130	46.3	12.5	X		33	4.5/							**	FM
1948	NO19A	110749	46.3	12.8	X		31	4.0/							TRAMONTI DI SOTTO	OG
1949	JA20A	044854	46.1	12.6	X		36	5.0/							**	FM
1949	FE03A	222917	46.1	13.0	X		36	5.0/							PALUZZA	FM
1949	FE03A	222920	46.5	13.1	C	47	47	7.0/							PAULARO	GC
1949	MR03A	120651	46.5	13.1	X			FELT/							**	OG
1949	MR08A	022208	46.5	12.5	X		28	3.5/							VIGO DI CADORE	OG
1949	MR13A	073222	46.5	12.5	X		28	3.5/							**	OG
1949	AU07A	1415	46.3	13.2	X		23	2.5/							VENZONE	OG
1949	NO02A	183408	46.4	13.0	X			UNKN*							TOLMEZZO	OG
1949	DE07A	024354	46.0	14.0	X		36	5.0/							IDRIA	OG
1950	JA13A	131234	46.4	12.4	X		36	5.0/							AURONZO	OG
1950	FE20A	015512	46.4	13.1	X		39	5.5/							PAULARO	OG
1950	MA05H	205345	46.5	13.0	X		36	5.0/							PALUZZA	OG
1951	FE20G	0155	46.4	13.0	X			FELT/							TOLMEZZO	OG
1951	JU10A	032851	46.2	12.5	X			FELT/							VALCELLINA	OG

DATE Y	M D C	TIME	COORDINATES LA N	LO E	H	MAGNIT ML	MM	INTENSITY AND MACROSEISMIC RADII EI	I1	I2	I3	I4	I5	I6	MEIZOSEISMAL AREA	REFER SD
1951	NO19A	191755	4627	1254	X		31	4.0/							TOLMEZZO	FM
1952	JA18F	013612	46.2	12.3	X		36	5.0/							BELLUNESE	OG
1952	JA18H	013613	4614	1242	X		33	4.5/							COL NUDO	FM
1952	AP20A	044246	46.4	13.0	15		36	4.0/							TOLMEZZO	FM
1953	JL25A	013450	46.5	13.1	X		36	5.0/							ARTA TERME	DP
1954	AP25H	221719	4625	1248	20	42	47	6.0=	6.0 004	5.0 026	4.0 036	3.0 049			RAVEO	GC
1954	MA16A	131350	46.4	13.0	X		31	4.0/							TOLMEZZO	FM
1954	OC11F	2348	46.3	13.1	X			FELT/							**	DP
1954	OC11H	0930	46.3	13.1	X			FELT/							**	DP
1954	OC11H	1419	46.3	13.1	X			FELT/							**	DP
1954	OC11H	164525	46.3	13.1	C	43	41	6.0/							VENZONE	GC
1954	OC12G	2343	46.3	13.1	X			FELT/							**	DP
1955	JL21F	2132	46.2	12.7	X		31	4.0/							MANIAGO	DP
1955	JL22H	0850	46.2	12.7	X		33	4.5/							**	DP
1955	JL23H	035431	4612	1242	A	42	41	6.0=	6.0 004	5.0 008	4.0 027	3.0 032			**	GC
1955	JL23F	042059	46.1	12.4	X			UNKN*							**	OG
1955	JL23H	044850	46.1	12.4	X			UNKN*							**	OG
1955	JL23H	0925	46.2	12.7	X		36	5.0/							**	DP
1955	JL23H	1929	46.2	12.7	X		36	5.0/							**	DP
1956	JA02A	094207	45.0	13.7	X		36	5.0/							ISTRIA	OG
1956	AU15A	101601	46.3	13.7	X			UNKN*							SLOVENIA	OG
1956	NO05F	194520	46.5	13.1	X		41	6.0/							PALUZZA	GC
1956	NO05H	194525	4632	1301	X	49	41	6.0=	6.0 006	5.0 028	4.0 040	3.0 049			**	OG
1957	JA22H	0715	46.5	13.0	X		25	3.0/							**	FM
1957	FE10H	0015	4626	1302	X		36	5.0=	5.0 004	4.0 018	3.0 031				TOLMEZZO	DP
1957	FE18H	0752	46.4	13.0	X		36	5.0=	5.0 004	4.0 016	3.0 036				**	DP
1957	OC23A	08 D	45.7	12.3	X		31	4.0/							VITTORIO VENETO	FM
1957	OC24A	0632	46.0	12.3	X		20	2.0/							**	BM
1959	AP26H	144514	4628	1301	A		49	7.5/							TOLMEZZO	GC
1959	JU12A	22 D	46.5	12.4	X		31	4.0/							LOZZO DI CADORE	BM
1959	JU13H	2156	4628	1238	X		47	7.0=	7.0 008	6.0 015	5.0 028				FORNI DI SOPRA	GC
1959	JU14H	0100	46.5	12.7	X		41	6.0/							SAPPADA	GC
1959	JU14H	1000	46.5	12.5	X		31	4.0/							VIGO DI CADORE	BM
1959	JU14H	22 D	46.3	12.6	X		41	6.0/							FORNI DI SOPRA	GC
1959	OC16F	0115	46.5	12.5	X		36	5.0/							**	FM
1960	JA06H	151734	4624	1242	X		47	7.0/							SAURIS	GC
1960	JA06H	1520	4624	1242	X		39	5.5/							**	FM
1960	JA06H	1531	4624	1242	X		28	3.5/							**	FM
1960	JA06H	1545	4624	1242	X		28	3.5/							**	FM
1960	JA06H	1830	4624	1242	X		28	3.5/							**	FM
1960	JA06H	2000	4624	1242	X		28	3.5/							**	FM
1960	JA06H	2220	4624	1242	X		25	3.0/							**	FM
1960	JA07H	0140	4624	1242	X		25	3.0/							**	FM
1960	JA07H	0420	4624	1242	X		25	3.0/							**	FM
1960	JA07H	0837	4624	1242	X		25	3.0/							**	FM
1960	JA07H	0915	4624	1242	X		25	3.0/							**	FM
1960	JA07H	15 D	4624	1242	X		25	3.0/							**	FM
1960	JA08H	06 D	4624	1242	X		25	3.0/							**	FM
1960	JA08H	0830	4624	1242	X		36	5.0/							**	FM
1960	JA08H	1050	4624	1242	X		31	4.0/							**	FM

DATE Y	M D C	TIME	COORDINATES LA N	LO E	H	MAGNIT ML	MM	INTENSITY AND MACROSEISMIC RADII EI	I1	I2	I3	I4	I5	I6	MEIZOSEISMAL AREA	REFER SD
1960	JA08H	1440	4624	1242	X		25	3.0/							**	FM
1960	JA08H	1530	4624	1242	X		25	3.0/							**	FM
1960	FE27A	1506	46.4	12.5	X		25	3.0/							FORNI DI SOPRA	FM
1960	MA04A	104642	46.7	12.7	X			UNKN*							PREALPI CARNICHE	OG
1960	JL14F	041751	46.4	13.0	X		36	5.0/							TOLMEZZO	FM
1960	OC26G	1231	46.4	13.0	X		31	4.0/							**	FM
1961	MR03A	0231	46 R	13 D	X		33	4.5/							FRIULI	FM
1961	DE22A	130444	46.4	13.0	X			FELT/							TOLMEZZO	FM
1962	AU13A	2002	46.7	13.0	X			FELT/							**	FM
1963	JA14H	2022	46.5	13.6	X		41	6.0/							**	GC
1963	JA15A	1445	46 A	13 B	X		28	3.5/							REMANZACCO	FM
1963	JA15A	15 A	46.3	13.0	X		20	2.0/							CAVAZZO CARNICO	BM
1963	JA15A	20 B	46.4	13.1	X		20	2.0/							**	BM
1963	MA06H		46.3	13.2	X		25	3.0/							TARCENTO	BM
1963	MA08A	0209	4606	1215	34		44	5.0/							BELLUNO	FM
1963	OC09A	212140	4616	1220	A			UNKN*							LONGARONE	FM
1963	NO30A	0405	46 D	12 A	X		31	4.0/							BELLUNESE	FM
1964	JA29A	13 A	46.1	13.4	X		31	4.0/							CIVIDALE	BM
1964	AU31A	15 B	46.1	13.5	X		25	3.0/							**	OG
1964	NO26A	1633	46.3	13.5	33		42	4.5/							BOVEC	OG
1965	JA04H		46.4	13.1	X		36	5.0/							TOLMEZZO	BM
1965	MR27H	2236	46.4	13.1	33			UNKN*							**	OG
1965	NO13H	1137	46.5	13.5	33			UNKN*							CAVE DEL PREDIL	OG
1966	JA23A	0131	45.9	12.2	33	39	42	4.5/							CONEGLIANO	BM
1966	FE03A	02 B	46.2	12.7	X		31	4.0/							MANIAGO	BM
1966	MA26A	0811	46.4	12.9	X		25	3.0/							TOLMEZZO	BM
1967	MR22A	1914	46.3	12.6	X			FELT/							CLAUT	BM
1968	SE03H	141033	46.5	13.1	X	20	20	2.0/							PAULARO	EN
1969	JA14A	005924	46 B	13 A	C		28	3.5/							TOLMEZZO	BM
1969	JA28A	04 A	46.2	12.2	X			FELT/							BELLUNO	BM
1969	MA24A	113435	46.5	12.9	X	15		FELT/							OVARO	EN
1970	OC13A	161903	46.6	13.1	X	20	17	1.5/							PALUZZA	EN
1971	FE04H	0618	46.3	13.1	X		28	3.5/							GEMONA	BM
1971	FE04A	062456	46.4	13.1	X	23	23	2.5/							TOLMEZZO	EN
1971	MA03H	213040	46.3	13.0	X	33	33	4.5/							GEMONA	EN
1971	SE07A	040224	46.1	12.4	25	42		UNKN*							CANSIGLIO	OG
1971	SE07A	050228	46.2	12.5	X	33	33	4.5/							CLAUT	EN
1971	NO03A	213048	46.5	13.0	X			UNKN*							SUTRIO	OG
1971	DE17A	104725	46.4	12.9	X	23	23	2.5/							VILLA SANTINA	EN
1971	DE18A	201223	46.2	12.5	X	23	52	8.0/							CLAUT	EN
1971	DE23A	191928	46.6	13.3	X			UNKN*							PONTEBBA	OG
1972	MR22A	165555	46.3	12.5	X	23	23	2.5/							CLAUT	EN
1972	JU17A	090048	46.3	12.6	X			UNKN*							**	OG
1972	AU26A	172840	46.3	12.3	X	23	23	2.5/							LONGARONE	EN
1972	OC07A	111445	46.3	12.9	X	17	17	1.5/							TRAMONTI	EN
1973	MA15A	051128	46.4	13.1	X	33	33	4.5/							MOGGIO UDINESE	EN
1974	MA04A	001937	45.1	12.1	X			UNKN*							ADRIA	BC
1974	MA06A	075021	46.3	13.4	X	33		UNKN*							MONTEMAGGIORE	BC
1974	SE09A	125015	46.3	12.6	X			UNKN*							CLAUT	BC
1974	NO20A	151053	45.6	12.2	X			UNKN*							TREVISO	BC

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1974	NO20A	193300	45.8	12.2	X			UNKN*							MONTELLO	BC
1974	DE09A	130140	46.8	12.8	C			UNKN*							LIENZ	OG
1974	DE13	224952	45.7	12.4	33	31	39	4.0/							ODERZO	OG
1975	FE17	092718	4555	1337	X	22	23	2.5/							GORIZIA	OG
1975	FE17	145000	4555	1337	X	23	23	2.5/							**	OG
1975	MR19	132852	46 B	12 C	X			UNKN*							OVARO	OG
1975	MR24	023319	46.3	13.1	X	40	31	4.0/							GEMONA	OG
1975	AP23	161921	46.4	13.1	X	33	33	4.5/							MOGGIO UDINESE	OG
1975	JU08	022859	46.5	13.0	X			UNKN*							PALUZZA	OG
1975	SE16A	100227	4630	1335	X	27	31	4.0/							TARVISIO	OG
1975	SE16	122137	4630	1335	X	34	33	4.5/							**	OG
1975	NO04A	083954	4601	1413	X			UNKN*							SLOVENIA	OG
1975	NO16A	045746	4620	1224	X			UNKN*							CIMOLAIS	OG
1975	NO23A	102458	4546	1259	X	35	36	5.0/							LATISANA	OG
1975	NO23	102811	4542	1257	X	35	36	5.0/							**	OG
1975	DE08A	205958	4521	1420	X	28	28	3.5/							FIUME	OG
1975	DE09A	021546	4536	1432	X			UNKN*							MONTE NEVOSO	OG
1975	DE11A	071511	4524	1428	X			UNKN*							KRANJ	OG
1975	DE19A	144322	4616	1416	X			UNKN*							FIUME	OG
1976	JA03A	173538	4546	1259	X	25	28	3.5/							LATISANA	OG
1976	JA03A	174018	4555	1300	X	29	28	3.5/							**	OG
1976	FE27A	095857	4543	1300	X	34	33	4.5/							**	OG
1976	MR16A	211249	4606	1418	X			UNKN*							SLOPJA LOKA	OG
1976	AP13A	225611	4604	1324	X	29	28	3.5/							CIVIDALE	OG
1976	AP29A	203119	4615	1259	X			UNKN*							GEMONA	OG
1976	MA06F	195902	4619	1316	C	45	44	6.5/							**	OG
1976	MA06H	200009	4617	1307	C	64	63	10.0/	10.0 003	9.0 009	8.0 023	7.0 046	6.0 091	5.0 149	**	OG
1976	MA06H	202210			C	30	33	4.5/							**	OG
1976	MA06H	202415			C	30	33	4.5/							**	OG
1976	MA06H	202457	4618	1305	C	42	41	6.0/							**	OG
1976	MA06H	202920	4616	1302	C	32	33	4.5/							**	OG
1976	MA06H	203110			C	29	31	4.0/							**	OG
1976	MA06H	204505	4622	1303	C	32	33	4.5/							**	OG
1976	MA06H	204659	4612	1307	C	28	31	4.0/							**	OG
1976	MA06H	204803	4613	1306	C	29	31	4.0/							**	OG
1976	MA06H	205009	4612	1308	C	30	33	4.5/							**	OG
1976	MA06H	205215	4617	1301	C	29	31	4.0/							**	OG
1976	MA06H	205659	4614	1306	C	28	31	4.0/							**	OG
1976	MA06H	205757	4615	1308	C	27	31	4.0/							**	OG
1976	MA06H	210233	4613	1306	C	27	31	4.0/							**	OG
1976	MA06H	210419	4612	1308	C	27	31	4.0/							**	OG
1976	MA06H	210716	4619	1306	C	33	33	4.5/							**	OG
1976	MA06H	210734			C	42	41	6.0/							**	OG
1976	MA06H	211501	4618	1300	C	32	33	4.5/							**	OG
1976	MA06H	211836	4614	1305	C	29	31	4.0/							**	OG
1976	MA06H	212640	4610	1306	C	27	31	4.0/							**	OG
1976	MA06H	213103	4619	1304	C	29	31	4.0/							**	OG
1976	MA06H	214210	4616	1305	C	39	39	5.5/							**	OG
1976	MA06H	214849	4612	1304	C	33	33	4.5/							**	OG
1976	MA06H	214936	4614	1307	C	43	41	6.0/							**	OG

DATE			TIME	COORDINATES			MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y	M	D	C	LA N	LO E	H	ML	MM	EI I1	I2	I3	I4	I5	I6		SD
1976	MA	06H	215509	4614	1300	C	27	31	4.0/						**	OG
1976	MA	06H	215813	4620	1259	C	27	31	4.0/						**	OG
1976	MA	06H	220102	4619	1253	C	27	31	4.0/						**	OG
1976	MA	06H	220540	4619	1301	C	27	31	4.0/						**	OG
1976	MA	06H	220946	4621	1258	C	29	31	4.0/						**	OG
1976	MA	06H	221337	4618	1302	C	33	33	4.5/						**	OG
1976	MA	06H	221432	4612	1305	C	34	36	5.0/						**	OG
1976	MA	06H	222039	4614	1312	C	35	36	5.0/						**	OG
1976	MA	06H	223008	4614	1306	C	27	31	4.0/						**	OG
1976	MA	06H	223255	4613	1307	C	32	33	4.5/						**	OG
1976	MA	06H	223435	4610	1307	C	28	31	4.0/						**	OG
1976	MA	06H	223546	4624	1305	C	29	31	4.0/						**	OG
1976	MA	06H	224615	4617	1303	C	30	33	4.5/						**	OG
1976	MA	06H	225050	4610	1312	C	31	33	4.5/						**	OG
1976	MA	06H	225605	4615	1305	C	29	31	4.0/						**	OG
1976	MA	06H	230104			C	28	31	4.0/						**	OG
1976	MA	06H	230144	4616	1303	C	28	31	4.0/						**	OG
1976	MA	06H	230240	4615	1305	C	27	31	4.0/						**	OG
1976	MA	06H	230659	4615	1318	C	39	39	5.5/						**	OG
1976	MA	06H	231002	4612	1307	C	32	33	4.5/						**	OG
1976	MA	06H	232110	4614	1305	C	26	36	5.0/						**	OG
1976	MA	06H	233327	4609	1308	C	30	33	4.5/						**	OG
1976	MA	06H	233506	4612	1307	C	30	33	4.5/						**	OG
1976	MA	06H	233814	4617	1300	C	27	31	4.0/						**	OG
1976	MA	06H	235531	4610	1306	C	30	33	4.5/						**	OG
1976	MA	06H	235807	4616	1303	C	27	31	4.0/						**	OG
1976	MA	06H	235921	4614	1300	C	27	31	4.0/						**	OG
1976	MA	07H	001438	4617	1256	C	31	33	4.5/						**	OG
1976	MA	07H	002247	4619	1253	C	27	31	4.0/						**	OG
1976	MA	07H	002346	4618	1314	C	45	44	6.5/						**	OG
1976	MA	07H	004157			C	29	31	4.0/						**	OG
1976	MA	07H	004221	4622	1255	C	27	31	4.0/						**	OG
1976	MA	07H	004930			C	30	33	4.5/						**	OG
1976	MA	07H	005145	4611	1304	C	32	33	4.5/						**	OG
1976	MA	07H	005824			C	30	33	4.5/						**	OG
1976	MA	07H	010021	4617	1305	C	37	39	5.5/						**	OG
1976	MA	07H	010220			C	32	33	4.5/						**	OG
1976	MA	07H	011147	4617	1256	C	32	33	4.5/						**	OG
1976	MA	07H	012026			C	33	33	4.5/						**	OG
1976	MA	07H	012125			C	31	33	4.5/						**	OG
1976	MA	07H	013242	4612	1308	C	32	33	4.5/						**	OG
1976	MA	07H	020515	4618	1259	C	33	33	4.5/						**	OG
1976	MA	07H	022444			C	29	31	4.0/						**	OG
1976	MA	07H	045759			C	30	33	4.5/						**	OG
1976	MA	07H	052340			C	29	31	4.0/						**	OG
1976	MA	07H	054017	4615	1304	C	35	36	5.0/						**	OG
1976	MA	07H	060201	4613	1311	C	39	39	5.5/						**	OG
1976	MA	07H	063928	4616	1311	C	34	36	5.0/						**	OG
1976	MA	07H	065419			C	28	31	4.0/						**	OG
1976	MA	07H	071835	4613	1305	C	30	33	4.5/						**	OG

DATE	TIME	COORDINATES		MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y M D C		LA N	LO E H	ML	MM	EI	I1	I2	I3	I4	I5	I6		SD
1976 MA07H	073700	4618	1306 C	32	33	4.5/							**	OG
1976 MA07H	075856	4617	1304 C	33	33	4.5/							**	OG
1976 MA07H	094115	4624	1257 C	38	39	5.5/							**	OG
1976 MA07H	100323		C	32	33	4.5/							**	OG
1976 MA07H	101238	4616	1302 C	31	33	4.5/							**	OG
1976 MA07H	102046		C	29	31	4.0/							**	OG
1976 MA07H	111527	4614	1301 C	35	36	5.0/							**	OG
1976 MA07H	114429	4617	1301 C	31	33	4.5/							**	OG
1976 MA07H	124139	4613	1306 C	35	36	5.0/							**	OG
1976 MA07H	132022		C	28	31	4.0/							**	OG
1976 MA07H	134247	4615	1308 C	41	41	6.0/							**	OG
1976 MA07H	134410	4617	1311 C	40	39	5.5/							**	OG
1976 MA07H	135553		C	29	31	4.0/							**	OG
1976 MA07H	145512	4617	1305 C	27	31	4.0/							**	OG
1976 MA07H	154024	4617	1300 C	32	33	4.5/							**	OG
1976 MA07H	155437	4619	1303 C	35	36	5.0/							**	OG
1976 MA07H	162848		C	28	31	4.0/							**	OG
1976 MA07H	165030	4612	1307 C	28	31	4.0/							**	OG
1976 MA07H	183348	4620	1301 C	31	33	4.5/							**	OG
1976 MA07H	191226	4618	1317 C	29	31	4.0/							**	OG
1976 MA07H	201250	4617	1303 C	34	36	5.0/							**	OG
1976 MA07H	205232	4612	1307 C	32	33	4.5/							**	OG
1976 MA08H	013204		C	28	31	4.0/							**	OG
1976 MA08H	013955	4614	1303 C	29	31	4.0/							**	OG
1976 MA08H	021603	4616	1253 C	30	33	4.5/							**	OG
1976 MA08H	031001	4619	1305 C	41	41	6.0/							**	OG
1976 MA08H	033724		C	29	31	4.0/							**	OG
1976 MA08H	041152		C	30	33	4.5/							**	OG
1976 MA08H	041955	4611	1308 C	29	31	4.0/							**	OG
1976 MA08H	082046		C	29	31	4.0/							**	OG
1976 MA08H	095623	4620	1259 C	35	36	5.0/							**	OG
1976 MA08H	113614	4616	1301 C	32	33	4.5/							**	OG
1976 MA08H	114031	4612	1309 C	33	33	4.5/							**	OG
1976 MA08H	133222	4619	1302 C	34	36	5.0/							**	OG
1976 MA08H	150340		C	30	33	4.5/							**	OG
1976 MA08H	155635		C	28	31	4.0/							**	OG
1976 MA08H	173533		C	30	33	4.5/							**	OG
1976 MA08H	204027	4615	1252 C	40	39	5.5/							**	OG
1976 MA08H	220848		C	29	31	4.0/							**	OG
1976 MA09H	003538		C	29	31	4.0/							**	OG
1976 MA09H	005342	4614	1319 C	53	52	8.0/							**	OG
1976 MA09H	022452		C	27	31	4.0/							**	OG
1976 MA09H	030353		C	27	31	4.0/							**	OG
1976 MA09H	033924		C	31	33	4.5/							**	OG
1976 MA09H	060346		C	30	33	4.5/							**	OG
1976 MA09H	123324	4619	1304 C	30	33	4.5/							**	OG
1976 MA09H	180223		C	28	31	4.0/							**	OG
1976 MA09H	200003	4615	1306 C	30	33	4.5/							**	OG
1976 MA10H	021053	4616	1253 C	31	33	4.5/							**	OG
1976 MA10H	043550	4615	1308 C	44	44	6.5/							**	OG

DATE	TIME	COORDINATES		MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y M D C		LA N	LO E H	ML	MM	EI I1	I2	I3	I4	I5	I6		SD
1976 MA10H	050846	4618	1305 C	37	39	5.5/						**	OG
1976 MA10H	160144	4615	1301 C	31	33	4.5/						**	OG
1976 MA11H	005424	4617	1313 C	30	33	4.5/						**	OG
1976 MA11H	053154	4615	1309 C	39	39	5.5/						**	OG
1976 MA11H	095726	4621	1307 C	37	39	5.5/						**	OG
1976 MA11H	100620	4614	1311 C	34	36	5.0/						**	OG
1976 MA11H	204445	4619	1307 C	27	31	4.0/						**	OG
1976 MA11H	221801	4620	1308 C	38	39	5.5/						**	OG
1976 MA11H	224358	4617	1303 C	48	44	6.5/						**	OG
1976 MA11H	225738	4617	1311 C	26	28	3.5/						**	OG
1976 MA11H	232249	4616	1304 C	34	36	5.0/						**	OG
1976 MA11H	233638	4620	1256 C	37	39	5.5/						**	OG
1976 MA12H	000906	4611	1304 C	28	31	4.0/						**	OG
1976 MA12H	022328	4616	1305 C	27	31	4.0/						**	OG
1976 MA12H	023809	4615	1309 C	32	33	4.5/						**	OG
1976 MA12H	030112	4619	1256 C	36	36	5.0/						**	OG
1976 MA12H	030238		C	30	33	4.5/						**	OG
1976 MA12H	061723		C	30	33	4.5/						**	OG
1976 MA12H	090403	4620	1259 C	36	36	5.0/						**	OG
1976 MA12H	144806		C	30	33	4.5/						**	OG
1976 MA12H	180650	4608	1306 C	35	36	5.0/						**	OG
1976 MA12H	201248	4612	1259 C	31	33	4.5/						**	OG
1976 MA12H	205743		C	29	31	4.0/						**	OG
1976 MA12H	220122		C	29	31	4.0/						**	OG
1976 MA13H	015311		C	28	31	4.0/						**	OG
1976 MA13H	031509	4611	1301 C	30	33	4.5/						**	OG
1976 MA13H	032125	4612	1304 C	29	31	4.0/						**	OG
1976 MA13H	033831		C	29	31	4.0/						**	OG
1976 MA13H	130447	4618	1301 C	37	39	5.5/						**	OG
1976 MA14H	004932		C	30	33	4.5/						**	OG
1976 MA14H	123446		C	30	33	4.5/						**	OG
1976 MA14H	211550		C	30	33	4.5/						**	OG
1976 MA15H	042611	4612	1309 C	37	39	5.5/						**	OG
1976 MA15H	084014	4614	1300 C	34	36	5.0/						**	OG
1976 MA15H	085740	4611	1309 C	31	33	4.5/						**	OG
1976 MA15H	090639		C	31	33	4.5/						**	OG
1976 MA15H	094034		C	30	33	4.5/						**	OG
1976 MA15H	102802		C	29	31	4.0/						**	OG
1976 MA15H	142130		C	28	31	4.0/						**	OG
1976 MA15H	152507	4618	1310 C	32	33	4.5/						**	OG
1976 MA15H	160552	4620	1303 C	35	36	5.0/						**	OG
1976 MA15H	165045	4621	1307 C	30	33	4.5/						**	OG
1976 MA15H	165801		C	28	31	4.0/						**	OG
1976 MA15H	183701	4619	1259 C	30	33	4.5/						**	OG
1976 MA15H	192009		C	29	31	4.0/						**	OG
1976 MA15H	201355	4610	1307 C	29	31	4.0/						**	OG
1976 MA15H	204300		C	28	31	4.0/						**	OG
1976 MA15H	211023		C	29	31	4.0/						**	OG
1976 MA15H	221815		C	27	31	4.0/						**	OG
1976 MA15H	223414	4618	1257 C	30	33	4.5/						**	OG

DATE	TIME	COORDINATES		MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y M D C		LA N	LO E H	ML	MM	EI	I1	I2	I3	I4	I5	I6		SQ
1976 MA16H	045659	4617	1301 C	29	31	4.0/							**	OG
1976 MA16H	055920	4615	1316 C	31	33	4.5/							**	OG
1976 MA16H	074423	4619	1257 C	30	33	4.5/							**	OG
1976 MA16H	080005		C	29	31	4.0/							**	OG
1976 MA16H	125615	4611	1310 C	29	31	4.0/							**	OG
1976 MA16H	134828	4611	1305 C	29	31	4.0/							**	OG
1976 MA16H	172646	4606	1312 C	28	31	4.0/							**	OG
976 4116H	200322	4621	1256 C	28	31	4.0/							**	OG
1976 MA16H	201337		C	29	31	4.0/							**	OG
1976 MA17H	025543		C	28	31	4.0/							**	OG
1976 MA17H	091127		C	29	31	4.0/							**	OG
1976 MA17H	161312	4621	1303 C	42	41	6.0/							**	OG
1976 MA17H	162057	4621	1301 C	29	31	4.0/							**	OG
1976 MA17H	172948		C	30	33	4.5/							**	OG
1976 MA17H	173553	4619	1301 C	32	33	4.5/							**	OG
1976 MA17H	195855		C	28	31	4.0/							**	OG
1976 MA18H	013004	4622	1301 C	37	39	5.5/							**	OG
1976 MA18H	013507		C	29	31	4.0/							**	OG
1976 MA18H	023935	4624	1259 C	33	33	4.5/							**	OG
1976 MA18H	070022	4608	1309 C	29	31	4.0/							**	OG
1976 MA18H	080139	4618	1259 C	31	33	4.5/							**	OG
1976 MA18H	143219	4617	1257 C	31	33	4.5/							**	OG
1976 MA18H	152213	4617	1307 C	33	33	4.5/							**	OG
1976 MA18H	025037	4609	1308 C	26	28	3.5/							**	OG
1976 MA18H	201820	4619	1259 C	31	33	4.5/							**	OG
1976 MA18H	234513	4612	1306 C	29	31	4.0/							**	OG
1976 MA19H	151449	4616	1252 C	30	33	4.5/							**	OG
1976 MA19H	151725	4612	1311 C	28	31	4.0/							**	OG
1976 MA19H	185925	4611	1313 C	28	31	4.0/							**	OG
1976 MA20H	085923	4614	1304 C	28	31	4.0/							**	OG
1976 MA20H	144434	4612	1308 C	30	33	4.5/							**	OG
1976 MA20H	172339		C	28	31	4.0/							**	OG
1976 MA22H	060218	4619	1307 C	29	31	4.0/							**	OG
1976 MA22H	095834	4614	1300 C	28	31	4.0/							**	OG
1976 MA22H	103041		C	28	31	4.0/							**	OG
1976 MA23H	005105	4613	1306 C	36	36	5.0/							**	OG
1976 MA23H	015306	4612	1307 C	29	31	4.0/							**	OG
1976 MA23H	124727	4609	1307 C	26	28	3.5/							**	OG
1976 MA25H	190427	4619	1309 C	31	33	4.5/							**	OG
1976 MA25H	194758	4616	1307 C	33	33	4.5/							**	OG
1976 MA26H	043905	4617	1301 C	31	33	4.5/							**	OG
1976 MA26H	074823	4617	1300 C	32	33	4.5/							**	OG
1976 MA26H	112032	4622	1305 C	32	33	4.5/							**	OG
1976 MA27H	034945	4614	1305 C	31	33	4.5/							**	OG
1976 MA27H	065018		C	28	31	4.0/							**	OG
1976 MA27H	181915		C	29	31	4.0/							**	OG
1976 MA29H	125747	4610	1312 C	27	31	4.0/							**	OG
1976 MA29H	125748		C	29	31	4.0/							**	OG
1976 MA29H	144550	4611	1305 C	26	28	3.5/							**	OG
1976 MA29H	145741	4614	1300 C	27	31	4.0/							**	OG

DATE Y	M D C	TIME	COORDINATES LA N LO E	H	MAGNIT ML	MM	INTENSITY AND MACROSEISMIC RADII EI I1 I2 I3 I4 I5 I6	MEIZOSEISMAL AREA	REFER SD
1976	MA29H	145749	4614 1305	C	28	31	4.0/	**	OG
1976	MA30H	211309	4617 1304	C	36	36	5.0/	**	OG
1976	MA31H	040336		C	29	31	4.0/	**	OG
1976	MA31H	072417	4617 1303	C	30	33	4.5/	**	OG
1976	MA31H	072427		C	29	31	4.0/	**	OG
1976	MA31H	215558	4613 1302	C	26	28	3.5/	**	OG
1976	JU01H	032344		C	29	31	4.0/	**	OG
1976	JU01H	100407	4609 1311	C	28	31	4.0/	**	OG
1976	JU01H	154601	4616 1303	C	30	33	4.5/	**	OG
1976	JU01H	172105	4618 1259	C	37	39	5.5/	**	OG
1976	JU01H	191559	4615 1306	C	32	33	4.5/	**	OG
1976	JU02H	092701	4615 1308	C	33	33	4.5/	**	OG
1976	JU03H	035616	4610 1309	C	29	31	4.0/	**	OG
1976	JU03H	114441		C	30	33	4.5/	**	OG
1976	JU03H	154444	4617 1304	C	31	33	4.5/	**	OG
1976	JU03H	193552		C	29	31	4.0/	**	OG
1976	JU03H	202205	4621 1256	C	30	33	4.5/	**	OG
1976	JU03H	231504		C	30	33	4.5/	**	OG
1976	JU04H	074912	4623 1249	C	35	36	5.0/	**	OG
1976	JU04H	115652	4622 1301	C	33	33	4.5/	**	OG
1976	JU06H	081234	4623 1303	C	31	33	4.5/	**	OG
1976	JU06H	123048		C	30	33	4.5/	**	OG
1976	JU07H	031500		C	30	33	4.5/	**	OG
1976	JU07H	123523		C	29	31	4.0/	**	OG
1976	JU07H	223105	4625 1254	C	29	31	4.0/	**	OG
1976	JU08H	004332	4621 1251	C	27	31	4.0/	**	OG
1976	JU08H	021332	4615 1303	C	27	31	4.0/	**	OG
1976	JU08H	120531	4617 1315	C	28	31	4.0/	**	OG
1976	JU08H	121434	4619 1310	C	43	41	6.0/	**	OG
1976	JU08H	121925	4618 1302	C	33	33	4.5/	**	OG
1976	JU08H	214053		C	30	33	4.5/	**	OG
1976	JU09H	184811	4621 1259	C	40	39	5.5/	**	OG
1976	JU09H	191215	4621 1302	C	30	33	4.5/	**	OG
1976	JU10H	130425	4615 1307	C	29	31	4.0/	**	OG
1976	JU11H	123246		C	30	33	4.5/	**	OG
1976	JU11H	171636	4621 1258	C	42	41	6.0/	**	OG
1976	JU11H	173936	4624 1253	C	27	31	4.0/	**	OG
1976	JU11H	175129	4620 1258	C	32	33	4.5/	**	OG
1976	JU11H	201048	4619 1256	C	27	31	4.0/	**	OG
1976	JU12H	060512	4617 1300	C	27	31	4.0/	**	OG
1976	JU12H	180529	4618 1312	C	33	33	4.5/	**	OG
1976	JU13H	011850	4610 1309	C	26	28	3.5/	**	OG
1976	JU13H	084718	4611 1307	C	28	31	4.0/	**	OG
1976	JU14H	001850	4618 1303	C	31	33	4.5/	**	OG
1976	JU15H	054627	4624 1258	C	37	39	5.5/	**	OG
1976	JU16H	015033	4618 1305	C	32	33	4.5/	**	OG
1976	JU16H	032028	4622 1303	C	37	39	5.5/	**	OG
1976	JU17H	132732	4620 1304	C	31	33	4.5/	**	OG
1976	JU17H	142746	4614 1302	C	33	33	4.5/	**	OG
1976	JU17H	142844	4614 1255	C	44	44	6.5/	**	OG

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Y	M	D C		LA N	LO E	H	ML	MM	EI I1	I2	I3	I4	I5	I6		SD
1976	JU	17H	164205	4616	1301	C	35	36	5.0/						**	OG
1976	JU	20H	100405	4616	1302	C	32	33	4.5/						**	OG
1976	JU	21H	185828	4615	1259	C	33	33	4.5/						**	OG
1976	JU	21H	233238	4615	1300	C	27	31	4.0/						**	OG
1976	JU	22H	045709	4620	1257	C	32	33	4.5/						**	OG
1976	JU	25H	044956	4616	1304	C	28	31	4.0/						**	OG
1976	JU	25H	232851	4618	1255	C	31	33	4.5/						**	OG
1976	JU	26H	111343	4620	1305	C	43	41	6.0/						**	OG
1976	JU	26H	113553	4619	1257	C	31	33	4.5/						**	OG
1976	JU	26H	164734	4614	1306	C	32	33	4.5/						**	OG
1976	JU	26H	234053			C	29	31	4.0/						**	OG
1976	JU	27H	140112	4613	1306	C	32	33	4.5/						**	OG
1976	JU	28H	040101	4617	1300	C	29	31	4.0/						**	OG
1976	JU	29H	170323	4620	1259	C	27	31	4.0/						**	OG
1976	JU	30H	190238	4611	1311	C	28	31	4.0/						**	OG
1976	JL	03H	044631	4617	1301	C	30	33	4.5/						**	OG
1976	JL	03H	153607	4613	1310	C	34	36	5.0/						**	OG
1976	JL	03H	165837	4617	1306	C	32	33	4.5/						**	OG
1976	JL	05H	023903	4624	1256	C	27	31	4.0/						**	OG
1976	JL	05H	034131	4617	1304	C	31	33	4.5/						**	OG
1976	JL	05H	095137	4616	1303	C	35	36	5.0/						**	OG
1976	JL	06H	060549	4620	1316	C	26	28	3.5/						**	OG
1976	JL	08H	095600	4614	1301	C	27	31	4.0/						**	OG
1976	JL	10H	041120	4613	1305	C	42	41	6.0/						**	OG
1976	JL	11H	122423	4620	1257	C	31	33	4.5/						**	OG
1976	JL	11H	132340	4617	1258	C	30	33	4.5/						**	OG
1976	JL	12H	080447	4618	1304	C	39	39	5.5/						**	OG
1976	JL	14H	053930	4624	1313	C	42	41	6.0/						**	OG
1976	JL	14H	113105	4619	1303	C	27	31	4.0/						**	OG
1976	JL	14H	164257	4614	1315	C	26	28	3.5/						**	OG
1976	JL	14H	185026	4618	1300	C	27	31	4.0/						**	OG
1976	JL	15H	125845	4620	1308	C	38	39	5.5/						**	OG
1976	JL	17H	065814	4618	1259	C	31	33	4.5/						**	OG
1976	JL	18H	133914	4619	1257	C	35	36	5.0/						**	OG
1976	JL	25H	034506	4612	1305	C	26	28	3.5/						**	OG
1976	JL	25H	093009	4617	1300	C	30	33	4.5/						**	OG
1976	JL	27H	045227	4617	1257	C	30	33	4.5/						**	OG
1976	JL	27H	081944	4622	1259	C	33	33	4.5/						**	OG
1976	JL	30H	073240	4619	1257	C	35	36	5.0/						**	OG
1976	JL	31H	144650	4619	1311	C	37	39	5.5/						**	OG
1976	AU	01H	123859	4616	1302	C	29	31	4.0/						**	OG
1976	AU	01H	144400	4620	1253	C	31	33	4.5/						**	OG
1976	AU	11H	183023	4614	1310	C	29	31	4.0/						**	OG
1976	AU	12H	012210	4623	1257	C	30	33	4.5/						**	OG
1976	AU	14H	053456	4612	1256	C	27	31	4.0/						**	OG
1976	AU	18H	055845	4624	1259	C	27	31	4.0/						**	OG
1976	AU	23H	155125	4620	1302	C	31	33	4.5/						**	OG
1976	AU	24H	144745	4615	1320	C	28	31	4.0/						**	OG
1976	SE	02H	025051	4619	1257	C	29	31	4.0/						**	OG
1976	SE	02H	140422	4619	1302	C	30	33	4.5/						**	OG

DATE			TIME	COORDINATES			MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y	M	D C		LA N	LO E	H	ML	MM	EI I1	I2	I3	I4	I5	I6		SD
1976	SE	05H	070533	4617	1256	C	28	31	4.0/						**	OG
1976	SE	06H	192810	4619	1300	C	37	39	5.5/						**	OG
1976	SE	07H	055349	4622	1300	C	29	31	4.0/						**	OG
1976	SE	07H	110812	4620	1257	C	38	39	5.5/						**	OG
1976	SE	08H	041234	4614	1305	C	31	33	4.5/						**	OG
1976	SE	08H	231006	4617	1319	C	27	31	4.0/						**	OG
1976	SE	09H	172631	4625	1304	C	32	33	4.5/						**	OG
1976	SE	11H	163108	4619	1311	C	51	49	7.5/						**	OG
1976	SE	11H	163457	4620	1310	C	56	57	9.0/						**	OG
1976	SE	11H	164041			C	36	36	5.0/						**	OG
1976	SE	11H	172610	4620	1305	C	29	31	4.0/						**	OG
1976	SE	11H	173458	4620	1302	C	34	36	5.0/						**	OG
1976	SE	11H	474624	4618	1307	C	29	31	4.0/						**	OG
1976	SE	11H	180543	4618	1255	C	29	31	4.0/						**	OG
1976	SE	11H	182312			C	30	33	4.5/						**	OG
1976	SE	11H	182747	4620	1301	C	34	36	5.0/						**	OG
1976	SE	11H	194941	4612	1303	C	30	33	4.5/						**	OG
1976	SE	11H	195711	4614	1301	C	31	33	4.5/						**	OG
1976	SE	11H	210543	4616	1257	C	37	39	5.5/						**	OG
1976	SE	12H	011954	4620	1310	C	40	39	5.5/						**	OG
1976	SE	12H	022544	4614	1302	C	29	31	4.0/						**	OG
1976	SE	12H	034725	4613	1302	C	30	33	4.5/						**	OG
1976	SE	12H	040246	4614	1306	C	28	31	4.0/						**	OG
1976	SE	12H	080828	4613	1304	C	35	36	5.0/						**	OG
1976	SE	12H	081445	4617	1259	C	36	36	5.0/						**	OG
1976	SE	12H	104150	4615	1311	C	32	33	4.5/						**	OG
1976	SE	12H	133146	4614	1307	C	29	31	4.0/						**	OG
1976	SE	12H	195324	4619	1303	C	41	41	6.0/						**	OG
1976	SE	13H	004805	4617	1303	C	32	33	4.5/						**	OG
1976	SE	13H	041050	4619	1259	C	31	33	4.5/						**	OG
1976	SE	13H	051422	4614	1324	C	26	28	3.5/						**	OG
1976	SE	13H	070348	4619	1303	C	34	36	5.0/						**	OG
1976	SE	13H	072958	4611	1312	C	29	31	4.0/						**	OG
1976	SE	13H	141714	4614	1307	C	29	31	4.0/						**	OG
1976	SE	13H	185443	4618	1305	C	43	41	6.0/						**	OG
1976	SE	13H	194210	4617	1305	C	39	39	5.5/						**	OG
1976	SE	13H	204551			C	29	31	4.0/						**	OG
1976	SE	13H	212505	4620	1302	C	31	33	4.5/						**	OG
1976	SE	14H	023028	4617	1300	C	31	33	4.5/						**	OG
1976	SE	14H	082517	4620	1310	C	37	39	5.5/						**	OG
1976	SE	14H	152902	4616	1301	C	32	33	4.5/						**	OG
1976	SE	14H	184655	4617	1254	C	27	31	4.0/						**	OG
1976	SE	14H	203734	4616	1313	C	29	31	4.0/						**	OG
1976	SE	15H	013002	4619	1258	C	31	33	4.5/						**	OG
1976	SE	15H	031517	4619	1311	C	58	57	9.0/						**	OG
1976	SE	15H	032508			C	31	33	4.5/						**	OG
1976	SE	15H	033917			C	35	36	5.0/						**	OG
1976	SE	15H	035233	4622	1300	C	33	33	4.5/						**	OG
1976	SE	15H	035547	4617	1305	C	34	36	5.0/						**	OG
1976	SE	15H	043036			C	32	33	4.5/						**	OG

DATE			TIME	COORDINATES			MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y	M	D C		LA N	LO E	H	ML	MM	EI I1	I2	I3	I4	I5	I6		SD
1976	SE	15H	043849	4622	1301	C	47	44	6.5/						**	OG
1976	SE	15H	045839	4624	1310	C	43	41	6.0/						**	OG
1976	SE	15H	053820	4616	1257	C	33	33	4.5/						**	OG
1976	SE	15H	092116	4619	1309	C	61	60	9.5/						**	OG
1976	SE	15H	093403	4626	1312	C	32	33	4.5/						**	OG
1976	SE	15H	193726	4620	1305	C	34	36	5.0/						**	OG
1976	SE	15H	094552			C	43	41	6.0/						**	OG
1976	SE	15H	095332			C	29	31	4.0/						**	OG
1976	SE	15H	095543	4619	1253	C	35	36	5.0/						**	OG
1976	SE	15H	095813			C	27	31	4.0/						**	OG
1976	SE	15H	101103	1619	1301	C	31	33	4.5/						**	OG
1976	SE	15H	103245	4617	1301	C	31	33	4.5/						**	OG
1976	SE	15H	104810			C	27	31	4.0/						**	OG
1976	SE	25H	105100			C	28	31	4.0/						**	OG
1976	SE	15H	105425	4617	1301	C	32	33	4.5/						**	OG
1976	SE	15H	111108	4620	1308	C	45	44	6.5/						**	OG
1976	SE	15H	111742	4616	1302	C	37	39	5.5/						**	OG
1976	SE	15H	112718	4620	1256	C	30	33	4.5/						**	OG
1976	SE	15H	3857			C	29	31	4.0/						**	OG
1976	SE	15H	115101	4619	1307	C	29	31	4.0/						**	OG
1976	SE	15H	122057			C	29	31	4.0/						**	OG
1976	SE	15H	125041	4617	1301	C	31	33	4.5/						**	OG
1976	SE	15H	132556	4611	1255	C	30	33	4.5/						**	OG
1976	SE	15H	144233	4620	1258	C	37	39	5.5/						**	OG
1976	SE	15H	151952	4621	1303	C	37	39	5.5/						**	OG
1976	SE	15H	152243			C	29	31	4.0/						**	OG
1976	SE	15H	152421	4623	1257	C	35	36	5.0/						**	OG
1976	SE	15H	152629			C	28	31	4.0/						**	OG
1976	SE	15H	155631			C	26	28	3.5/						**	OG
1976	SE	15H	161116	4617	1257	C	33	33	4.5/						**	OG
1976	SE	15H	162421	4616	1259	C	34	36	5.0/						**	OG
1976	SE	15H	164946	4616	1247	C	30	33	4.5/						**	OG
1976	SE	15H	172554	4617	1241	C	37	39	5.5/						**	OG
1976	SE	15H	173555			C	30	33	4.5/						**	OG
1976	SE	15H	174225			C	28	31	4.0/						**	OG
1976	SE	15H	174446	4618	1255	C	34	36	5.0/						**	OG
1976	SE	15H	191811	4615	1305	C	28	31	4.0/						**	OG
1976	SE	15H	193106	4626	1311	C	41	41	6.0/						**	OG
1976	SE	15H	195717	4613	1300	C	31	33	4.5/						**	OG
1976	SE	15H	201145			C	30	33	4.5/						**	OG
1976	SE	15H	201641			C	27	31	4.0/						**	OG
1976	SE	15H	202406	4620	1305	C	39	39	5.5/						**	OG
1976	SE	15H	203008			C	27	31	4.0/						**	OG
1976	SE	15H	203449	4618	1255	C	37	39	5.5/						**	OG
1976	SE	15H	204446	4614	1254	C	33	33	4.5/						**	OG
1976	SE	15H	214044			C	29	31	4.0/						**	OG
1976	SE	15H	222058	4617	1300	C	30	33	4.5/						**	OG
1976	SE	15H	223543	4614	1305	C	31	33	4.5/						**	OG
1976	SE	15H	233334	4617	1301	C	29	31	4.0/						**	OG
1976	SE	16H	013040	4618	1257	C	37	39	5.5/						**	OG

DATE			TIME	COORDINATES			MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y	M	D	C	LA N	LO E	H	ML	MM	EI I1	I2	I3	I4	I5	I6		SD
1976	SE	16	H 020848	4618	1255	C	29	31	4.0/						**	OG
1976	SE	16	H 021737			C	29	31	4.0/						**	OG
1976	SE	16	H 022057	4618	1300	C	27	31	4.0/						**	OG
1976	SE	16	H 024221	4617	1256	C	28	31	4.0/						**	OG
1976	SE	16	H 033032	4614	1302	C	29	31	4.0/						**	OG
1976	SE	16	H 054037	4616	1257	C	33	33	4.5/						**	OG
1976	SE	16	H 090820	4620	1254	C	29	31	4.0/						**	OG
1976	SE	16	H 092753	4622	1255	C	27	31	4.0/						**	OG
1976	SE	16	H 142733	4615	1305	C	30	33	4.5/						**	OG
1976	SE	16	H 143033	4616	1257	C	29	31	4.0/						**	OG
1976	SE	16	H 162635	4619	1302	C	28	31	4.0/						**	OG
1976	SE	16	H 163607			C	28	31	4.0/						**	OG
1976	SE	16	H 171224	4617	1257	C	29	31	4.0/						**	OG
1976	SE	16	H 173925	4619	1253	C	27	31	4.0/						**	OG
1976	SE	16	H 200135	4619	1303	C	31	33	4.5/						**	OG
1976	SE	16	H 202942			C	29	31	4.0/						**	OG
1976	SE	16	H 203705			C	28	31	4.0/						**	OG
1976	SE	16	H 210924	4618	1301	C	29	31	4.0/						**	OG
1976	SE	16	H 231357			C	28	31	4.0/						**	OG
1976	SE	16	H 235033	4618	1301	C	29	31	4.0/						**	OG
1976	SE	16	H 235157	4620	1242	C	34	36	5.0/						**	OG
1976	SE	17	H 003845	4618	1258	C	30	33	4.5/						**	OG
1976	SE	17	H 022732			C	29	31	4.0/						**	OG
1976	SE	17	H 024709	4615	1258	C	30	33	4.5/						**	OG
1976	SE	17	H 041115			C	28	31	4.0/						**	OG
1976	SE	17	H 041138			C	29	31	4.0/						**	OG
1976	SE	17	H 041400	4621	1256	C	39	39	5.5/						**	OG
1976	SE	17	H 063106			C	29	31	4.0/						**	OG
1976	SE	17	H 091752	4619		C	32	33	4.5/						**	OG
1976	SE	17	H 085832	4618	1255	C	29	31	4.0/						**	OG
1976	SE	17	H 110619			C	29	31	4.0/						**	OG
1976	SE	17	H 124415			C	29	31	4.0/						**	OG
1976	SE	17	H 131452	4619	1254	C	32	33	4.5/						**	OG
1976	SE	17	H 141730	4613	1304	C	33	33	4.5/						**	OG
1976	SE	17	H 143516	4612	1249	C	29	31	4.0/						**	OG
1976	SE	17	H 161851			C	29	31	4.0/						**	OG
1976	SE	17	H 162034			C	27	31	4.0/						**	OG
1976	SE	17	H 170734	4616	1257	C	29	31	4.0/						**	OG
1976	SE	17	H 175217			C	28	31	4.0/						**	OG
1976	SE	17	H 225605	4610	1258	C	28	31	4.0/						**	OG
1976	SE	17	H 235257	4621	1248	C	28	31	4.0/						**	OG
1976	SE	18	H 003935	4620	1257	C	36	36	5.0/						**	OG
1976	SE	18	H 010837			C	29	31	4.0/						**	OG
1976	SE	18	H 055016	4619	1255	C	34	33	4.5/						**	OG
1976	SE	18	H 063323	4614	1306	C	28	31	4.0/						**	OG
1976	SE	18	H 162228	4613	1257	C	30	33	4.5/						**	OG
1976	SE	18	H 185337	4630	1306	C	27	31	4.0/						**	OG
1976	SE	18	H 214934	4619	1256	C	31	33	4.5/						**	OG
1976	SE	19	H 012252	4618	1306	C	27	31	4.0/						**	OG
1976	SE	19	H 102648	4616	1301	C	37	39	5.5/						**	OG

DATE			TIME	COORDINATES			MAGNIT		INTENSITY AND MACROSEISMIC RADII						MEIZOSEISMAL AREA	REFER
Y	M	D C		LA N	LO E	H	ML	MM	EI	I_1	I_2	I_3	I_4	I_5	I_6	SD
1976	SE	19H	111307	4620	1252	C	32	33	4.5/							06
1976	SE	20H	022719	4620	1304	C	31	33	4.5/							06
1976	SE	20H	090955	4620	1311	C	40	39	5.5/							06
1976	SE	20H	095124	4616	1258	C	27	31	4.0/							06
1976	SE	20H	155336	4610	1251	C	27	31	4.0/							06
1976	SE	20H	172247	4618	1255	C	27	31	4.0/							06
1976	SE	20H	233414	4622	1256	C	35	36	5.0/							06
1976	SE	21H	063355	4614	1248	C	30	33	4.5/							06
1976	SE	21H	161750	4616	1253	C	31	33	4.5/							06
1976	SE	22H	032713	4620	1314	C	29	31	4.0/							06
1976	SE	22H	152351	4622	1253	C	32	33	4.5/							06
1976	SE	22H	183539	4621	1254	C	27	31	4.0/							06
1976	SE	22H	192947	4614	1253	C	29	31	4.0/							06
1976	SE	22H	203501	4621	1253	C	29	31	4.0/							06
1976	SE	23H	152648	4613	1311	C	29	31	4.0/							06
1976	SE	23H	154907	4612	1254	C	31	33	4.5/							06
1976	SE	23H	222437	4609	1301	C	31	33	4.5/							06
1976	SE	24H	041110	4619	1314	C	26	28	3.5/							06
1976	SE	24H	144602	4614	1241	C	27	31	4.0/							06
1976	SE	24H	161209	4616	1301	C	31	33	4.5/							06
1976	SE	25H	013443			C	29	31	4.0/							06
1976	SE	25H	123231	4622	1303	C	29	31	4.0/							06
1976	SE	25H	133645			C	28	31	4.0/							06
1976	SE	25H	200609	4615	1308	C	29	31	4.0/							06
1976	SE	26H	012659			C	29	31	4.0/							06
1976	SE	26H	015146	4613	1252	C	36	36	5.0/							06
1976	SE	26H	053047	4624	1304	C	31	33	4.5/							06
1976	SE	26H	072436	4620	1257	C	31	33	4.5/							06
1976	SE	26H	073342	4619	1318	C	33	33	4.5/							06
1976	SE	26H	094002	4617	1304	C	30	33	4.5/							06
1976	SE	26H	132756	4614	1301	C	27	31	4.0/							06
1976	SE	26H	145216	4617	1257	C	36	36	5.0/							06
1976	SE	26H	175022	4619	1302	C	27	31	4.0/							06
1976	SE	27H	143726	4615	1306	C	36	36	5.0/							06
1976	SE	28H	001012	4613	1302	C	26	28	3.5/							06
1976	SE	28H	122509	4622	1238	C	30	33	4.5/							06
1976	SE	29H	025928	4620	1302	C	27	31	4.0/							06
1976	SE	29H	065941	4618	1308	C	28	31	4.0/							06
1976	SE	29H	223958	4619	1306	C	27	31	4.0/							06
1976	OC	01H	080624	4618	1308	C		28	3.5/							06
1976	OC	02H	170942	4621	1308	C	27	31	4.0/							06
1976	OC	03H	174945	4622	1300	C	34	36	5.0/							06
1976	OC	05H	073303	4626	1259	C	30	33	4.5/							06
1976	OC	06H	103134			C	29	31	4.0/							06
1976	OC	09H	034105	4616	1301	C	30	33	4.5/							06
1976	OC	09H	050008	4615	1254	C	29	31	4.0/							06
1976	OC	11H	165711			C	32	31	4.0/							06
1976	OC	12H	080139	4616	1254	C	31	33	4.5/							06
1976	OC	12H	102305	4614	1251	C	32	33	4.5/							06
1976	OC	13H	024835	4619	1253	C	44	41	6.0/							06

DATE			TIME	COORDINATES			MAGNIT		INTENSITY AND	MACROSEISMIC RADII					MEIZOSEISMAL AREA	REFER
Y	M	D C		LA N	LO E	H	ML	MM	EI I1	I2	I3	I4	I5	I6		SD
1976	OC	13H	073943	4614	1304	C	34	36	5.0/						**	OG
1976	OC	15H	022829	4619	1253	C	32	33	4.5/						**	OG
1976	OC	15H	055741	4616	1304	C	29	31	4.0/						**	OG
1976	OC	16H	045643	4621	1306	C	29	31	4.0/						**	OG
1976	OC	16H	132639	4620	1304	C	30	33	4.5/						**	OG
1976	OC	17H	162329	4619	1308	C	28	31	4.0/						**	OG
1976	OC	17H	201942	4623	1315	C	29	31	4.0/						**	OG
1976	OC	19H	083125	4620	1304	C	41	39	5.5/						**	OG
1976	OC	19H	225242	4622	1258	C	32	33	4.5/						**	OG
1976	OC	20H	055520	4618	1255	C	29	31	4.0/						**	OG
1976	OC	21H	033022	4621	1302	C	29	31	4.0/						**	OG
1976	OC	21H	033446	4620	1308	C	29	31	4.0/						**	OG
1976	OC	26H	060245	4620	1310	C	32	33	4.5/						**	OG
1976	OC	26H	060956	4619	1309	C	27	31	4.0/						**	OG
1976	OC	27H	042540	4619	1310	C	33	33	4.5/						**	OG
1976	OC	28H	061547			C	31	33	4.5/						**	OG
1976	OC	30H	122841	4619	1305	C	34	36	5.0/						**	OG

STRONG MOTION RECORDS RELATIVE TO THE FRIULI EARTHQUAKE
ACCELEROGRAM PROCESSING AND ANALYSIS

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The instrumentation of the national accelerometric network of ENEL and of the mobile accelerometric stations CNEN and ENEL installed in Friuli, permitted the recording of 203 accelerograms referring to 32 earthquakes.
The data gathered, besides being a remarkable contribution to the study of the seismic event in Friuli and to the investigations of nuclear engineering that CNEN and ENEL are carring on, make available a precious material which can be useful for the development of studies and assessments on seismic engineering.

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(+++) SERVIZIO ANALISI DEL SITO, DISP-AMB, CNEN, ITALY

Accelerogram processing

The location of the mobile accelerometric stations installed in Friuli has been choosen taking into account problems of engineering interest, such as the soil amplification, the dynamic response of structures, the correlations of magnitude with the intensity, the distance from the energy release area and ground motions.

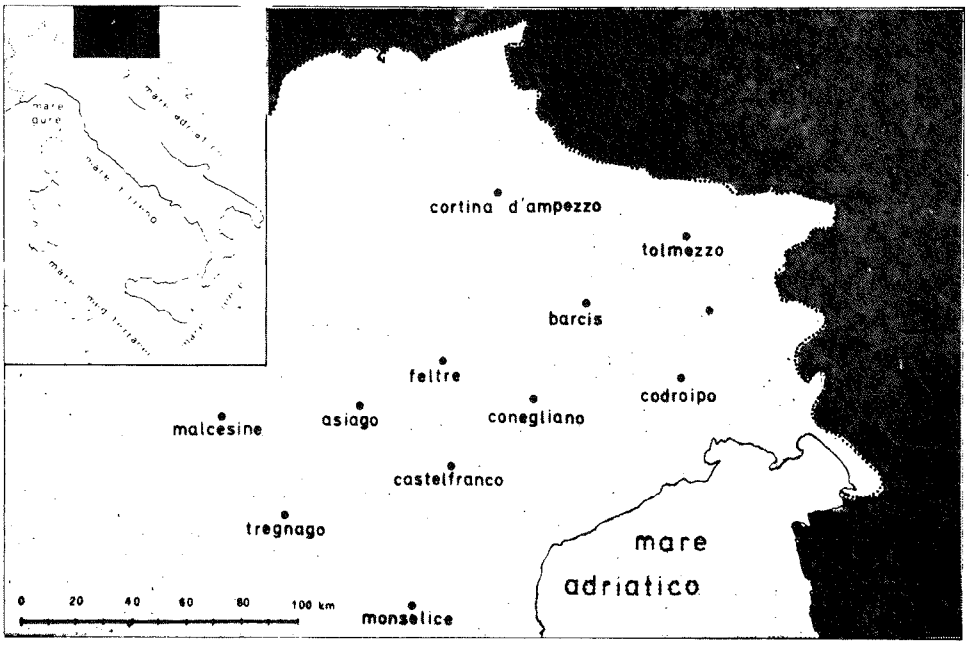


Fig. 1. Stations of accelerometric national network triggered by the main shock of the earthquake of May 6 1976.

The figure 1 shows the locations of the eleven fixed stations of the ENEL network which supplied us with a record we were able to process of the main shock of May 6th.
The asterisk shows the position of the epicenter.
The accelerogram of the Tolmezzo station which, geographically was the nearest to the epicenter is reproduced in figure 2.

Accelerogram processing

The record presents a peak acceleration of 0.37 G on the North -South component and has an instrumental duration of abouth 37 seconds.

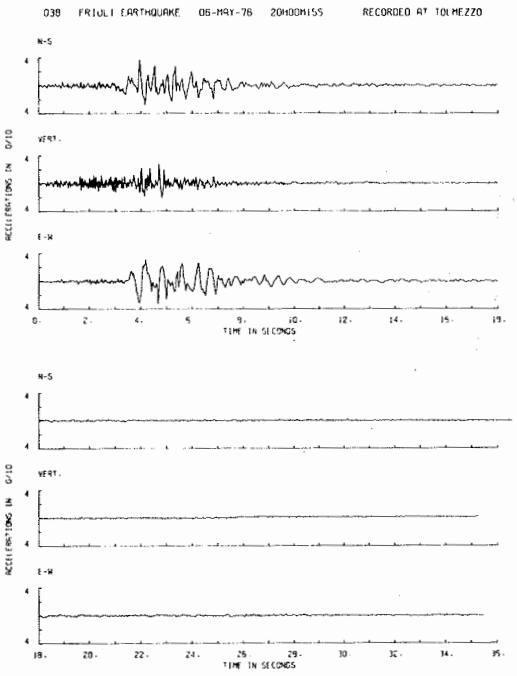
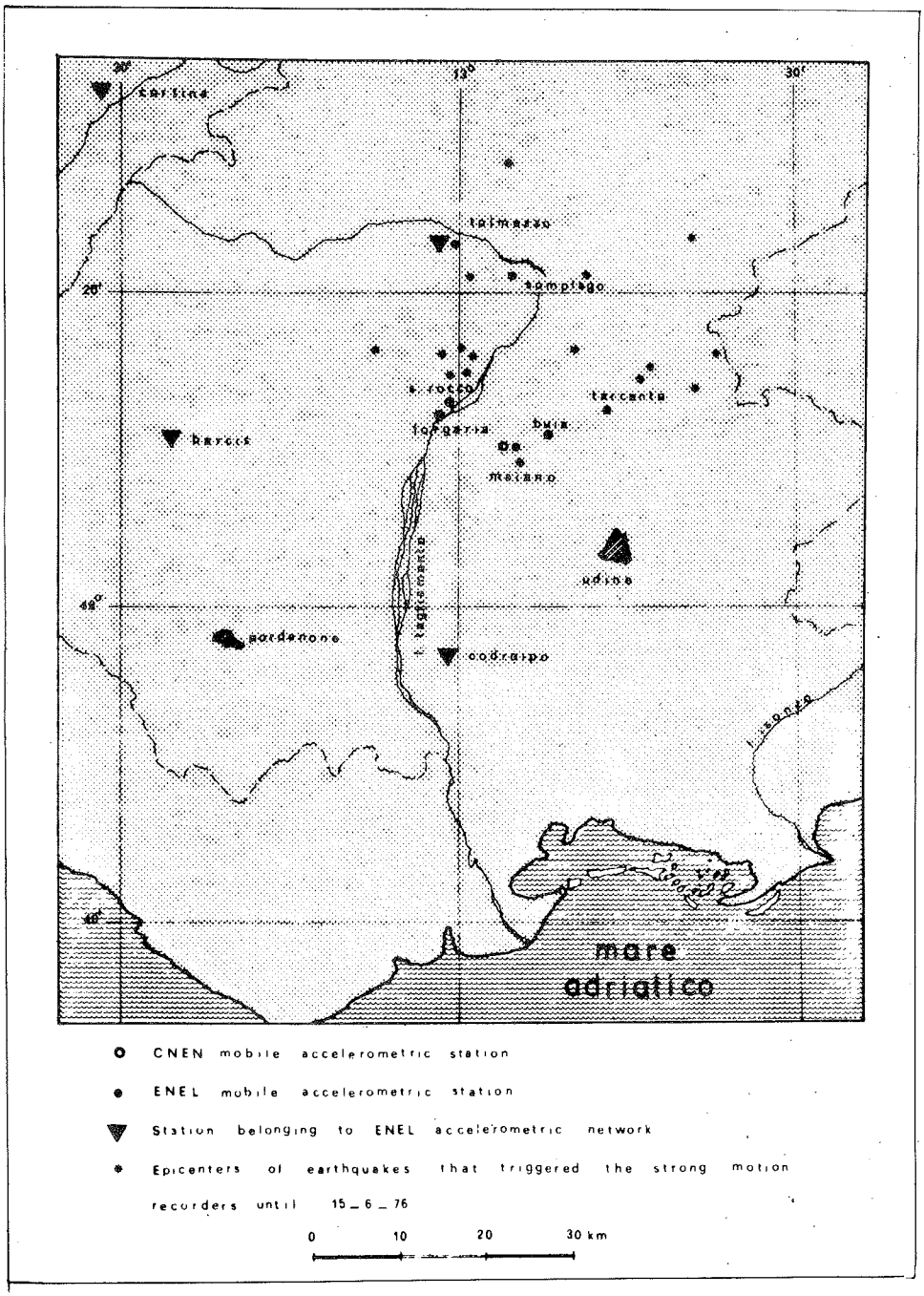


Fig. 2. Tolmezzo strong motion accelerogram.
Friuli earthquake, 6 May 1976, 20h 00m.

Eight mobile stations were added to those of the network, after May 7th. In the figure 3 together with the location of the mobile and fixed stations the epicenters (asterisks) of the earthquakes recorded up to June 15th are shown.
At Somplago three strong-motion accelerographs were installed.
One in the hydroelectric station which is into a cavern located at a depth of about 400 meters one at the entrance of the tunnel to the station, one midway between entrance and the station.

The stations of Forgaria-Cornino and S. Rocco some hundreds of meters one from the other had the purpose, as well as the station at Somplago of studying the dynamic behaviour

Accelerogram processing


20'
30'
40°
tarcento
tolmezzo
tampisago
s. rocco
forgaria
buia
barcis
meiano
udine
gradisca
gemona
sacile
sacile
sacile

of soils; in fact the two stations are different only for the presence, immediately beneath the instrument of Forgaria, of an alluvial deposit of about 15 meters. The station of S. Rocco, on the contrary, is placed directly on the rock. The station of Majano was installed with the aim of studying the behaviour of a reinforced - concrete building; an accelerograph was installed in the free field, another one in the basement, and the third one at the top of the building. The different operations of collection, photographic process classification, digitization and numerical elaboration of the accelerograms were carried out according to a programme established long before, to obtain the following objectives:

- To keep a file of all the records area of the copies used for digitization.
- To carry out an accurate digitization of all the usable accelerograms.
- To compute for all the digitized records the corrected acceleration, the velocity and displacements, the response and Fourier spectra.
- To publish, in a form consistent with similar data available at the international level, the "uncorrected" digitized accelerograms, the corrected acceleration, velocity and displacement, the response and Fourier spectra.

Figure 4 shows the different steps we follow in carrying on the various operations for each accelerogram recorded: from the original film two contact negative prints are produced, one of which is used to obtain the enlargement necessary

Accelerogram processing

for a good digitization.

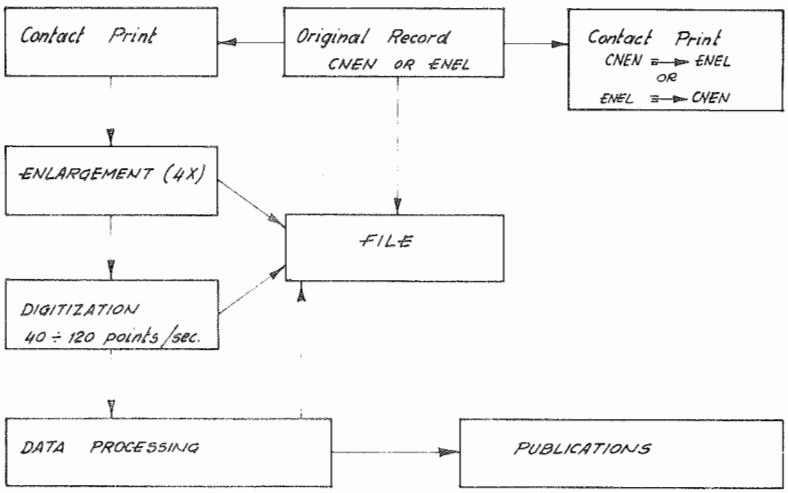


Fig. 4. Procedures for the treatment of the original accelerograms.

A manual digitization is then performed on an unequal time basis. The number of digitized points is increased to 100 - 120 points per second on the most rapidly oscillating section of the accelerograms.

The data thus obtained are then processed.
Each step of the processing is issued in adeguate publications.
The original records and their elaboration are kept in a single file of the CNEN - ENEL Commission.

Accelerogram processing

The processing of the data is substantially carried on in four stages, having the following objectives:

General Check and scaling

Print-outs and plots of the uncorrected accelerograms.

Print-outs and plots of base-line corrected accelerations, velocities and displacements.

Print-outs and plots of the response spectra and Fourier spectra.

The general check and scaling are carried out by means of a computer program which verifies the quality and the acceptability of the digitization, considers the sequence of timing marks in order to form the basic time coordinate, corrects the effects of possible film distortions and of the imperfect alignment of the record in respect of the digitizing table so to define the basic acceleration coordinate. Before scaling acceleration values it also shifts the zero axis of the accelerogram so as to coincide with the axis which zeroes the mean value of the acceleration and minimized the root mean square of the accelerogram with respect to its zero axis so to eliminate the effect of very small rotations of the records with respect to the table.

The "uncorrected" data thus obtained are filed on magnetic tape and issued in volume I of the red series.

For what concerns the Friuli's earthquake the data of the first 25 accelerograms have been published during the month of July, other volumes are printing.

The second stage of the data processing permits to obtain

Accelerogram processing

the values of corrected acceleration, velocity and displacement. During this stage the uncorrected accelerograms are first smoothed by a digital low pass filter (cut off frequency 25 HZ) which aims to eliminate the high frequency components caused by imperfections of the instrument and by errors introduced during the digitization.
The equation:

$$-a(t) = \ddot{x} + 2\omega_0 \xi \dot{x} + \omega_0^2 x$$

is used to correct the effects of the frequency dependance of the instrumental response:
a (t) is the soil acceleration that is to be found; x is the displacement relative to the soil of the mobile equipment of the instrument rapresented by the uncorrected accelerograms.
The accelerograms are then base-line corrected with the procedure shown in figure 5.
This procedure aims to eliminate low frequency components caused both by defects of the instrument and by errors introduced during the stages of photographical process and digitization.
The acceleration function so corrected is then integrated at first time to obtain velocity and a second to obtain the displacement, which are then also smoothed by a low pass filter.
In the last stage of the data processing the Fourier and response spectra of the accelerograms are computed.

Accelerogram processing

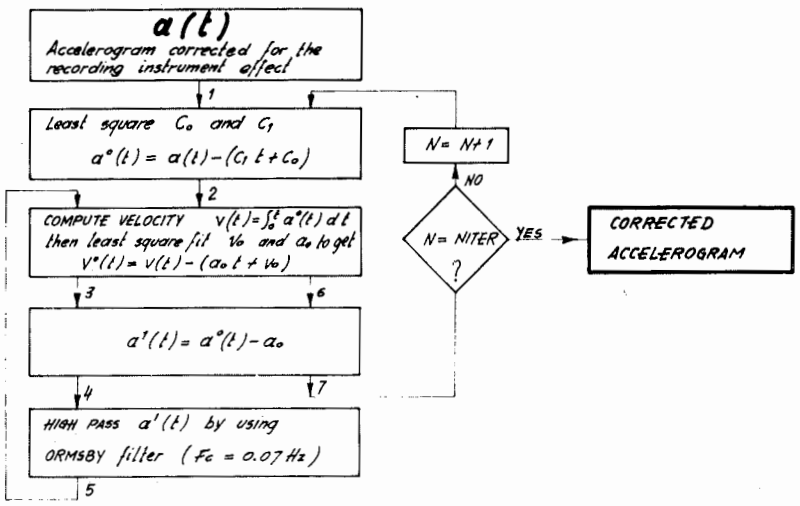


Fig. 5. Flow chart for baseline correction.

The response spectra of acceleration shown in figure 6 are those relative to the second shock of September 15th recorded both at S. Rocco on the left of the figure, and at Forgaria Cornino, on the right. As we have said before the stations are only a few hundred meters far one from another, but the shape and the amplitude of the two spectra are different because the two instruments are installed one on rock, one on alluvial deposit.

We would like now to point out the fact that the data processing technique and the presentation of the results we are using, are world wide utilized and considered the most reliable.

In spite of that, we think that this area needs of further

Accelerogram processing

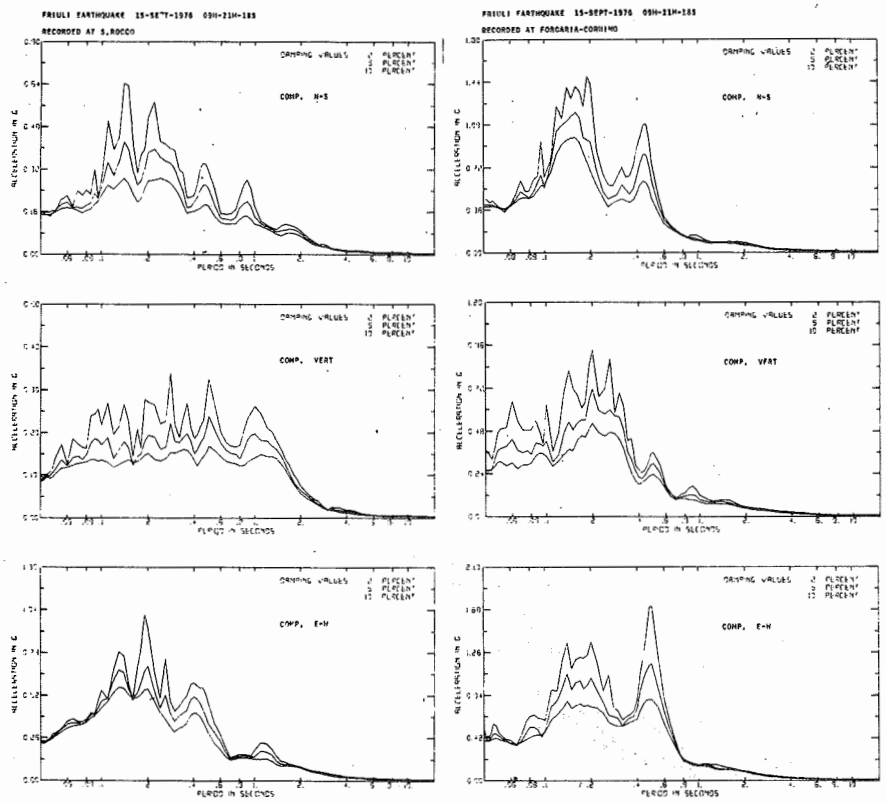


Fig. 6. Acceleration Response Spectra of the earthquake of Spet. 15 1976 recorded at S. Rocco (on the left) and at Forgaria -Cornino (on the right).

research and therefore appropriate studies are being carried out in this direction.

For example using this procedure, the accelerograms may not represent accurately the acceleration of the base of the instrument in all the frequency range between 0.07 and 25 Hz;

Accelerogram processing

the higher frequency of the record could be affected with sensible errors due to pratical limits of the maximum sampling frequency. Because that, very high frequency components present in the original accelerogram or introduced during the photografic process and during the digitization phases could be folded at lower frequency.

The peak ground surface acceleration represents a simple index of the seismic level of an earthquake.

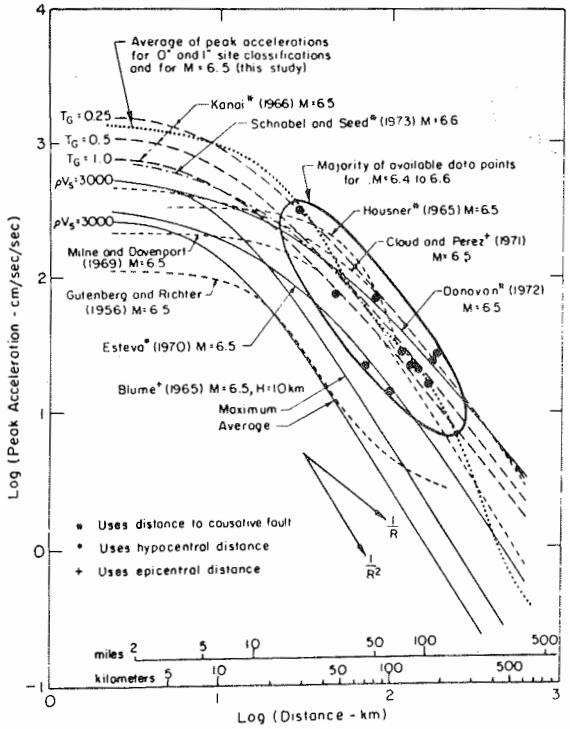


Fig.7. RELATIONSHIPS BETWEEN PEAK ACCELERATION AND DISTANCE FROM SOURCE FOR MAGNITUDE 6.5 EARTHQUAKES (after Trifunac and Brady, 1976)

Accelerogram processing.

It can be used as index of the intensity of the vibratory motion.

For this reason the engineers and the seismologists have shown a great interest towards it; especially in view of possible correlations with other quantities of technical and scientific interest.

In particular many scientists have proposed correlations between the values of the peak acceleration and the distance from the epicenter or from the geological structure that generated an earthquake, or, however from the sources of energy release.

Trifunac and Brady 1976 have re-examined the different proposal of correlation between peak acceleration versus distance suggested by several anthors and have proposed an average correlation.

The issues of this work are summed up in figure 7 in which have been reported with small circles the representative points of the peak acceleration recorded by the instruments of the ENEL network that have been triggered by the main shock of Friuli's earthquake.

It can be noticed that these representative points are in the variability range of analogous data, that they agree with the law proposed in the above mentioned study of Trifunac and Brady, and that the peak acceleration values vary approximately as $1/R^2$

The peak acceleration can not by itself characterize an earthquake for what concerns, for example its destructive

Accelerogram processing

potentiality which is instead better esprimed by the maximum velocity of the motion or by its response spectrum or by the frequency content and the duration of the strong shaking part of the motion.

Not many studies exist to-day for correlating the maximum velocity with the distance of the area of energy release even if, as we have already said, the maximum velocity appears to be an index more significant than the maximum acceleration, this probably depends on the difficulties inherent in the computation of the maximum velocity of an accelerogram.

Ambraseys proposes the correlation among the probable maximum velocity, the distance from the area of energy release

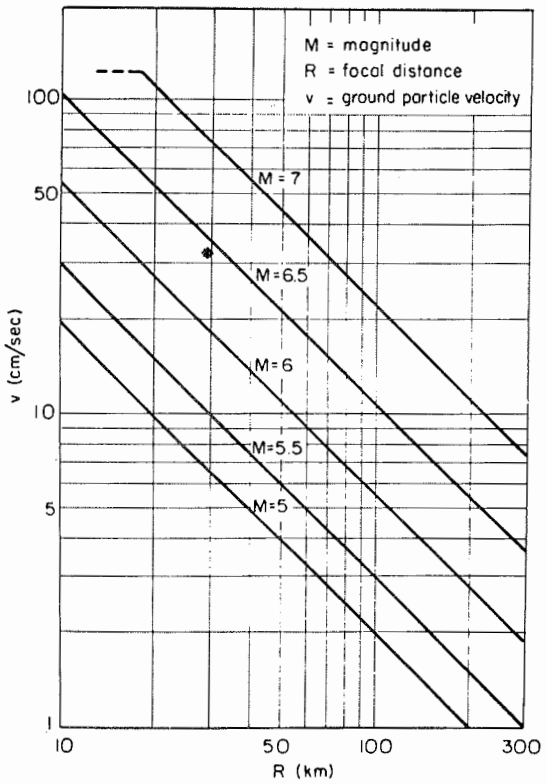


Fig.8. MAXIMUM PROBABLE GROUND VELOCITIES (after Ambraseys, 1973)

Accelerogram processing

and magnitude which is ressumed in figure 8 in which is also reported the representative points of the maximum velocity of the main shock of May 6th recorded at Tolmezzo.
This representative point agrees with Ambraseys law.
In conclusion what has been said points out what large possibilities exist to-day in Italy and abroad, for increasing the knowledge on the correlations among the earthquake engineering parameters.
This thanks to the availability of accelerometric data recorded in occasion of the seismic event of Friuli and not only for the number of data gathered but also for the large variety of these same data in connection with the distance from the sources of energy release, with the magnitude of the shocks recorded and with the local conditions of the soil where the recording stations have been installed.

MACROSEISMIC ASPECTS AND SEISMOLOGICAL AND STATISTICAL CONSIDERATIONS

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C.N.E.N.
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In Italy seismic design parameters for nuclear installations are defined by using methods and correlations developed in foreign countries. It is therefore of great importance to verify the validity of these procedures whenever data and records from Italian seismic events become available.

On the occasion of the Earthquake of May 6 one of the first actions was the definition of its degree of intensity according to both MCS and MM scales. The evaluation of the intensity according to these two scales may prove useful to compare seismic events occurred at different times and at places characterized by different types of constructions.

By examining information concerning both civil and industrial building damages, landslides, soil and road

breakages, and soil liquefaction phoenomena, the May 6 earthquake may be classified as an event of intensity X MCS or VIII-IX MM.

Unfortunately the comparison of the intensity of the Friuli earthquake with the intensity of the known hystoric events is not sufficient for the evaluation of the other seismic parameters.

Instrumental data, such as maximum accelerations, duration spectra, used for design purposes, that are not available for the past earthquakes, can be determined only in a approximate way.

Therefore records and instrumental data of the Friuli earthquake may be compared only with records and instrumental data of similar events occurred in other countries. For no reasons they may be used to define the Italian Design Basis Earthquake.

An analysis has also been performed in the field of statistics in order to obtain information on local tectonics and to determine the yearly probabilities of occurrence of a given intensity earthquake.

By using the so called "strong shocks model", in which occurrence of the events are supposed to be random both in the time and space fields, frequencies of high energy events follow the Posson distribution.

$$p\ (k, \Delta\ t) = \frac{e^{-b} b^{k}}{k!}$$

where $p\ (k, \Delta t)$ indicates the probability of occurrence of k shocks in the unit time internal Δt and b is the average

number of shocks occurred in such interval. The Poisson distribution is characterized only by the average parameter b, whereas the variance coincides with the mean value and the relative variance is equal to 1.

Experimental results obtained from the "strong shocks model" have shown how important is the delimitation of the area over which to perform the statistic analyses and how much these analyses are sensitive to the actual availability of data.

The Poisson distribution is significant in the area included between the Po river and the Calabrian border. In this area the average return period of an event of intensity equal or greater than X MCS, is about 18 years.

In the area delimited by the Vicenza-Schio line at SW, the seismicity has been evaluated by means of the method of the "Gumbel line".

The results indicate that an event of intensity X MCS, as the one occurred in the Friuli region on May 6, 1976, has a ten-year occurrence probability

$$P = 1-0,95$$

and therefore this event has an average return period equal to 200 years.

It has to be remarked that an event of intensity I greater than VIII MCS, which corresponds to the collapse of some bad-built houses, has an average return period of about 34 years.

For the elaboration of the seismic law, it would be necessary to take into account the following considerations,

which, even if they are specifically referred to the seismic risk, can be applied to the whole protection field, from that of the natural events (such as floods), to the field of the accidental events deriving from human activities (such as the accidents caused by chemical, petrochemical, nuclear industries, ecc.).

The application of these considerations will allow both a homogeneous comparison between different dangerous situations and the exact evaluation of the object to be protected, with regard, for instance, to its use as well as to its value not only economical but also social, etc.

The existence of a seismicity highly remarkable for intensity and frequency on almost all the Italian territory, requires the adoption of urgent measures for the safeguard of life and human activities from the natural events under examination.

Unfortunately, we have to admit that an absolute protection is impossible; for this reason, it will be inevitable to have a finite risk. Therefore, the question to be put to ourselves will not be whether a given protection will be safe but the extent of its safety and whether it will be safe enough. The answer to this question may be the criterium on the extent of the risk that a community wants to accept with reference to the value, not only economical but also social, of the object to be protected.

In defining new acceptability criteria, first of all, we must take into consideration the principle that the acceptability of a dangerous situation is strictly connected

to the consequences deriving from this situation and to the possible occurrence of this situation. Namely, the acceptability criteria should be based on the risk evaluation defined as the product of the probability for the consequence of a given event.

In this way, the acceptable risk becomes the objective and uniform element of dangerous situations having the most different characteristics. Moreover, it would be necessary to extend the sphere of the protection interest (very often exclusively focused on the safeguard of human life), to the safeguard of the whole social and economical contect which makes life possible.

Other consequences, besides the loss of human lives, can result considerable to such an extent to be obliged to define the level of the acceptable risk for each of them. An example of this are the accidents occurred in Friuli and Seveso where, in addition to the loss of human lives, heavy social damages have been suffered too from their effects, with regard to buildings, jobs and production whose recovery is thought to be possible at a long term. However, the definition of a standard for every acceptable risk may once again not be sufficient if the proposed action would result inadequate in comparison with the advantages we want be obtain. Consequently, a decision on the acceptable risk may be taken only by making a complete analysis of costs and benefits. Needless to say that such an analysis must take into account all aspects, both social and economical, so that the safeguard of hyman life will be one

of the many social aspects.

Furthermore, it is important to note that, as there are many ways of attaining an aim, and each of them have different costs and benefits, a decision on an acceptable solution would result conditioned, if all alternative solutions at our disposal would not have been considered and, for each of these solutions the acceptability or less would not have been justified, always on the ground of the above mentioned completeness.

Therefore, there is also the need for us to examine all available alternatives. The acceptance of the relation between advantages and disadvantages requires an evaluation involving medical, social, economical and moral factors; this is not a technical evaluation, but essentially a political one, which cannot be absolutely delegated. Therefore, the problem of the safeguard of human lives and social welfare must be examined at political level according to the limits of the acceptable risk, giving to all the social factors involved the right importance. Unfortunately, a significant debate of this kind has not yet been made in Italy up to now in a public way and at the proper political level. It is to be pointed out that accidents like the ones happened in Friuli or of a superior intensity, have occurred in Italy from 1500 till the present time with an average recurrence period of about 11 years. Urgent measures on the whole national territory become necessary because of this high accident frequency, so that future events like the recent earthquake in Friuli will not be any longer national

calamities. And that's why it is necessary to clearly indicate the different responsibilities in the execution of the political choises to be made, so that the activities of making laws, licensing, designing, constructing and controling may be subsequently carried out by the competent organizations (such as Parliament, Regions, Local Bodies, operators, Control Bodies, etc.) with clear views of "safety" for the settlement of a community on the Italian territory.

Note on the seismicity of northeastern Italy (Friuli area)

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The Hague
(The Netherlands)

ABSTRACT

Van Bemmelen, R.W., 1977. Note on the seismicity of northeastern Italy (Friuli area).

The kinematics and mechanics of the seismicity of the Friuli area in northeastern Italy are discussed, especially the focal mechanism of the catastrophic earthquake of May 6, 1976. Alternative solutions are analyzed. A N-S section, down to 60 km below sea-level, across the Alps from the Bavarian foreland to the Adriatic Sea illustrates these possibilities.

INTRODUCTION

The Friuli region of northeastern Italy was stricken by a strong earthquake on May 6, 1976 (magnitude 6.5 on the Richter scale and IX-X on the Mercalli-Sieberg scale). Apart from great material damage, the death-roll amounted to about 1000 victims. This major shock was followed in the past five months by hundreds of aftershocks, some of which were also rather strong, such as those of the 11th and 15th of September which caused renewed damage and the death of two workmen doing repair work on shaken buildings.

Friuli underwent many catastrophic earthquakes in the past, some 17 since

1000 A.D. according to Schneider (1968). Their epicentres are situated on a narrow belt of epicentres which stretches form Verona northeastward to Vienna (Gutdeutsch and Aric,1976).

In this note some remarks on the geodynamic causes of the seismicity in Friuli are advanced.

Plate tectonicists suggest a N-NNW-ward underthrusting of the African plate, which means active subduction (McKenzie,1970,1972;Mueller,1976), whereas the present author suggests a complementary passive subduction of the Adriatic or Dinaric block ('microplate') owing to the gravitational spreading of the isostatically rising Alpine arch (see Fig.1).

Both alternative views are discussed in the following pages.

THE MODEL OF PLATE TECTONICS

The Friuli earthquake of May 6,1976, had its hypocentre at a depth of about 10-11 km below sealevel, according to a personal letter to the author from Dr. J. Drimmel (Zentral Anstalt für Meteorologie und Geodynamik at Vienna). Its focal mechanism has been analyzed by Mueller (1976). It is essentially a thrust-type solution, with compression almost perpendicular to the strike-direction of the Eastern Alps. It is interpretated by him as an active underthrusting of the Adriatic block with an azimuth of 348° and a dip-angle of 13°. This conforms with McKenzie's opinion (1972,fig.13) that the Adriatic block is a northwestward protrusion of the African plate.[x] Its 'collision' with the Alps and the European plate would cause compressive forces in the Friuli region at the southern margin of the Alps. Mueller adds to this picture the remark that at the northern side of the Alps a similar structural situation is found, which might be interpreted as the southward underthrusting of the Eurpean plate under the Northern Calcareous Alps. Such plate movements would result in a broad collision zone of two converging plates, both actively subducting towards the central (crestal) belt of the Alps. Below a certain depth motions would be directed more or less vertically downwards, and above this depth uplift and compressive folding (and/or overthrusting) of the Alps would take place.

According to the model of plate tectonics, the arching up of the Alpine range and its compressive deformations would be the result of external forces exercised by the adjacent lithospheric plates, the margins of which act like the jaws of a benchvice. See also Ahorner (1975) for the intraplate tectonics of Europe, which are interpreted as adjustments to shifting positions of the African plate.

THE UNDATION MODEL

The undation model, advocated by the present author, leads to a reversed

[x]See also the paper by J.E.T. Channel and F. Horvath:"The African/Adriatic promontary as a palaeographic premise for Alpine orogeny and plate movements in the Carpatho-Balkan region", which appeared in October 13,1976 in Tectonophysics, 35(1-3):71-102.

mechanical solution of the Friuli seismicity. The following basic facts of observation are taken into account. The Alps are actively rising in the 'Hohe Tauern' sector at a rate of one millimeter per year. This uplift is concentrated along the southern marging of this structural window' (Senftl and Exner, 1973). Underneath this sector a blister of density reversal has been established by means of geophysical methods at a depth between a few kilometers to 20 km below sea-level (Angenheister et al.,1972). This blister probably originated by physico-chemical processes in the crust after the overthrusting of the Austria alpine nappes into the flysch foredeep (Van Bemmelen,1973). The mechanical interpretation of this situation is that this intra-crustal low-dinsity blister has an isostatic buoyancy, and that it is responsible for the geodetically ascertained arching up of the Alps. This active uplift of the mountain range increases its potential gravitational energy. The structural situation is at present that the Alps are a crustal vault or arch, the crestal part of which (the Hohe Tauern sector) rests on the northern and southern flanks or limbs (the Northern and Southern Alps). The central Alps themselves are underlain by a more ductile core, an 'asthenolith'. This structural situation results in a tendency for spreading under gravity, the Northern Alps overthrusting the Bavarian 'foredeep' and the Southern Alps overthrusting the Lombardic 'backdeep' (Van Bemmelen 1966,1973). The progressive arching up of the Alps during the Cenozoic is called the molasse phase of orogeny, and it is characterized by a series of tectogenetic phases (tectonic events) separated by longer periods of erosional planation (see fig.13 on p. 112 in Van Bemmelen 1974).

The oldest collapse of the Alpine arch occurred northward in Oligocene time, producing the Augenstein landscape of planation (Van Bemmelen, 1960). The spreading under gravity of the southern limb towards the Lombardic backdeep occurred also intermittently during tectogenetic phases (Guicherit, 1964; Vink, 1968; Martinis, 1975). The emerging of the Alpine arch during the molasse phase caused first decollements of the sedimentary 'epiderm' (the non-metamorphic cover of Mesozoic deposits); thereafter, when deeper crustal layers became exposed, also southward movements of the metamorphic basement complex the crustal 'derm' came to the fore.

The seismicity of the Friuli region at the southern margin of the Hohe Tauern sector of the Alps indicates that tis southward movement of the derm in the southern Alps is still in progress.

This southward movement of the crust underneath the Southern Alps occurs under a pile of epidermal nappes and imbricated or folded slices, some 10 km. thick. Instead of lifting this pile upward (for which no clear geodetical data are available) the southward-moving derm apparently finds an outlet for its potential energy by pushing down the underlying bathydermal crustal layers, causing their isostatic subsidence into the sub-Moho lithosphere. This is a process of passive subduction of the adriatic 'microplate'.

This downward flexuring of the bathyderm might lead to sudden ruptures, for instance the formation of a system of featherlike and 'en echelon' arranged fissures. Such sudden kinematic events in the crustal rocks cause earth-quakes. The fissures and their potential voids are rapidly healed by

matter of lateral secretion, which will at that depth probably have a pegmatic composition. Such brittle ruptures, as suggested in the section Fig.1, are of course only one of the manyfold possible reactions of the rocks to the mechanical and kinematical processes going on underneath the southern foot of the Alpine arch. The school of rock mechanics of Bruno Sander has gone deeper into such tectogenetic events. See, for instance, the excellent chapters on rock mechanics in the German-written textbooks of Metz (1967) and Schmidt-Thome (1972)

The focal mechanism of an earthquake by such ruptures in depth has four possible solutions for the *relative* movements with regard to the surrounding frame. The seismological method for the dermination of the focal mechanism cannot distinguish which one of these four possibilities actually occurred, so that the choice of the interpretation depends on the preferred general geodynamic model.

Plate-tectonicists always choose solution (a) out of the four possibilities for the Friuli earthquake of May 6, distinguished by the letters a, b, c, and d on Fig.1 because (a) fits best in their model. The undation model suggests theat the shock was caused by sudden rupture in the sense of (c), whilst the preceding building-up of locally strong stress gradients resulted from the tendency of the Alpine arch to spread southward under gravity (b). It is also possible that drift of the Dinaric block in NNW-ward direction gave a supplementary potential energy for northward underthrusting according to (a). Only solution (d) seems to be less important in the Friuli case, though a minute fraction of the matter expelled by (c) might tend to move up along (d).

Caire(1973,1975) and the present author (1976) both came to the view, that the geological date, supplemented by seismic observations,indeed indicate a N-NNW-ward drift of the Adriatic or Dinaric block in younger Cenozoic time. This drift can be ascribed to geodynamic processes of megadimensions, either in the sense of plate tectonics(McKenzie, 1972; Channel and Horvath,1976) or in response to mega-undations of the terrestrial gravity field (Van Bemmelen, 1976, pp.176-178;Hédervári, 1977). This drift of the Dinaric unit into the mobilized realm of Mediterranean orogeny is at present obstructed by the rising Austro-alpine mountain range. So there is a convergence of crustal movements concentrated under the Friuli region. This concentration of stresses is relieved by intermittant seismic shocks, separated by periods of slower, more plastic deformations, occurring by means of 'hot creep' in the crystalline lithospheric rocks.

The hypocentres of this seismicity are for the greater part shallower than 20 km and never deeper than 40 km (Ritsema, 1975; Gutdeutsch and Aric, 1976) which means that they are intracrustal, occurring above the Moho discontinuity.

CONCLUSION

In conclusion the following interpretation of the causative processes of the Friulian seismicity can be given. The earthquakes of 1976 are situated on a straight line or narrow zone of epicentres which extends form Verona northeastwards to Vienna, forming the SE marging of the East Alpine

mountain range, and extending some 300 km. beyond the extension of the Adriatic-Dinaric 'microplate' or 'spur' of the African shield. Therefore, the cause of this seismicity, which belongs to a genetically coherent group, has to be sought in its relation with the actually rising Alpine arch and not in drift movements of the African plate.

The geodetically observable rise of the Alpine arch increases its potential gravitative energy, which resluts not only in an isostatically pushing-downward of the Moho, but also in a north- and southward spreading of the limbs of the arch (see Fig.1). These are quasi-steady processes of creep, which need not lead directly to seismic relaxations. The same can be said of the underthrusting tendendies of the Adriatic spur. The movements along (a) and (b) in the hypocentre of May6,1976, have probably already been going on since the beginning of the Molassic phase of Alpine orogeny; they cause underneath Friuli accumulating stresses along the southern foot of the East Alps, which are intermittently released by earthquakes.

The *direct cause* of these earthquakes is neither the slow creep along (a) nor that along (b), but has to be sought in the sudden isostatic adjustments along (c), which are accompanied by rifting processes in the crust, as indicated on Fig. 1. In other,more technical and mechanical terms the foot of the southern limb of the Alpine Arch occasionally breaks through the supporting floor, formed by the lower part of the continental crust.

REFERENCES

Ahorner,L., 1975. Present-day stress field and seismotectonic block movements along major fault zones in Central Europe. Tectonophysics, 29: 233-249

Angenheister, G.,Bögel,H.,Gebrande,H.,Giese,P.,Schmidt-Thomé,P.,and Zeil, W.,1972.
Recent investigations of surficial and deeper crustal structures of the Eastern and Southern Alps. Geol.Rundsch.,61 (2):349-395.

Caire,A., 1973. Italy in its Mediterranean setting. Reprinted from C.Squires (editor), Geology of Italy. The Earth Science Society of the Libyan Arab Republic, Triploi, 74p.

Caire,A.,1975. Les règles de la fracturation continentale et le role des géofractures dan l'évolution de l'écorce terrestre. Rev.Geogr.Phys.Géol. Dynam.,(2),17(4):319-354.

Guicherit,R.,1964. Gravity tectonics, gravity field,and palaeomagnetism in NE-Italy.Geologica Ultraiectina(Publ.Geol.Inst.State Univ.Utrecht), no.14,125p.

Gutdeutsch,R. and Aric,K.,1976. Erdbeben im Ostalpinen Raum. Arbeiten Zentral-anstalt für Meteorologie und Geodynamik, Vienna, No.19 23 p.

Hédervári, P.,1977. Anomalies of the terrestrial gravity field and their relations to geodynamics, Tectonophysics (in press).

Marinis, B.,1975. The Friulian and Julian Alps and Pre-Alps. In:L.Ogniben M.Parotto and A. Praturlon (editors), Structural model of Italy, Consiglio Nazionale delle Ricerche, Roma 1975, pp 17-49.

McKenzie,D.,1970. The Plate tectonics of the Mediterranean region. Nature, 224:125.

McKenzie,D.,1972. Active tectonics of the Mediterranean Region.Geophys. J.R. Soc., 30:109-185.
Metz.K.,1967. Lehrbuch der Tektonischen Geologie.Enke,Stuttgart,2nd ed., 356 pp.
Mueller, G.,1976.Fault-plane solution of the earthquake in northern Italy, 6th May, and its implications for the tectonics of the Eastern Alps. Preprint of a lecture at the Amsterdam meeting of the European Geophysical Union, Sept. 1976 (in press in Journal of Geophysics/Zeitschrift für Geophysik).
Ritsema, A.R.,1975, The contribution of the study of seismicity and earthquake mechanism to the knowledge of Mediterranean geodynamics. Progress in Geodynamics, Proc.Dutch Symposium Amsterdam 1975,pp. 142-153. Geodynamics Project Scient.Rep.nr.13.
Schmidt-Thome,P.,1972. In:R. Brinkmann (editor), Lehrbuch der Allgemeinen Geologie, II: Tektonik. Enke, Stuttgart, 578 p.
Schneider,G.,1968. Erdbeben und Tektonik in Sudwest Deutschland. Tectonophysics, 5(6):459-511.
Senftl,E. and Exner,Chr.,1973. Rezente Hebung der Hohe Tauern und geologische Interpretation. Verh.Geol.Bundesanstalt,Vienna,1972,2:209-234.
Van Bemmelen, R.W., 1960. New views on East Alpine orogeny. 21st Int.Geol. Congr.,Copenhagen,Report 18:99-116.
Van Bemmelen, R.W., 1966. The structural evolution of the Southern Alps. Geol.Mijnbouw,45(12):405-444.
Van Bemmelen, R.W. 1973. Test-case II.Geodynamic models for the Alpine type of Orogeny. Tectonophysics, 18: 33-79.
Van Bemmelen, R.W. 1974. Test-case III. Driving forces of orogeny, with emphasis on blue-schist facies of metamorphism. Tectonophysics, 22:83-125.
Van Bemmelen, R.W., 1976. Plate tectonics and the undation model: a comparison. Tectonophysics, 32:145-182.
Vink, B.W.,1968. Gravity tectonics in Eastern Cadore and Western Carnia, NE-Italy. Geologica Ultraiectina (Publ.Geological Institute State Univ. Utrecht), no. 15,64p.

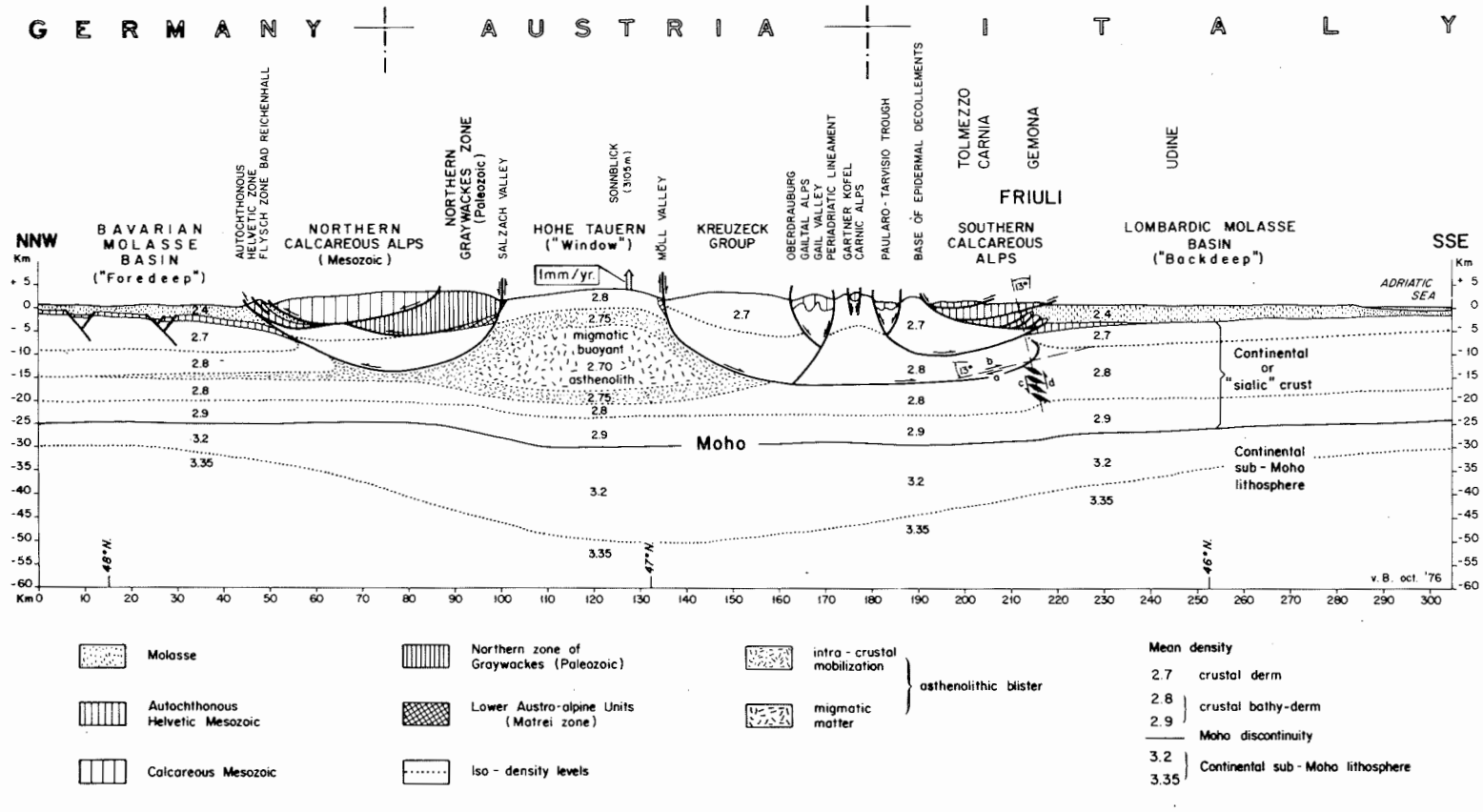

Fig. 1. N–S section across the Eastern Alps (13° E) and the focal mechanism of the Friuli earthquake of May 6, 1976.

SEISMICITY OF THE FRIULI VENEZIA GIULIA REGION

BY

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S U M M A R Y

The first partial results of the research on the seismicity of the Friuli Venezia Giulia region are presented. The research is carried on as part of the C.N.R.'s Geodinamic project.

At first a catalogue of earthquakes which occured in the region from the Roman epoch up to now has been elaborated (Bartole et all., in press). The data of each event have been perforated on computer cards and can be therefore electronically processed.

The spatial distribution of epicenters has been plotted using a CALCOMP Mod. 936 plotter. 28 isoseismal maps have been drawn, 25 of which relative to earthquakes, which hit the region in the last 100 years. These 25 maps served as the basis for the construction of the map of maximum intensity

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felt in the Friuli Venezia Giulia region in the years 1876-1976.

At present research is being conducted on the following topics: curves of macroseismic intensity attenuation with distance, statistical characteristics of earthquake activity, maximum magnitude likely to occur in each source area. A brief outline regardin the work done on each of these topics is presented.

1.- INTRODUCTION

This paper presents the first results of the research carried on by the operative unit 2.4.3.- as part of the C.N.R.'s Geodinamic project. The purpose of the research is to study the seismicity of the Friuli Venezia Giulia region. This study is based on the already available data, but will use also the data in course of elaboration and the results to be obtained thanks to the collaboration of other operative units. The study will lead to define the seismic risk of Friuli Venezia Giulia.

The methodology used in the research is the one recommended by the group 2.3.- Compilation of an operative project to evaluate the seismic risk in Italy.

Our research program has also usefully adopted the techniques, reccomendations and suggestions applied in the "Survey of the Seismicity of the Balkan Region", sponsored by the United Nations Development Programme and the United Nations Educational Scientific and Cultural Organization (Unesco,1976).

The used technique involves the following main steps:

1) Compilation of the catalogue of earthquakes which occured in the area.

2) Delineation of areas of earthquake activity.

3) Evaluation of the statistical characteristics of earthquake activity in each delineated source area.

4) Development of attenuation curves for ground shaking suitable for the area under study.

5) Calculation of the actual seismic risk at each site of interest.

The catalogue of Friuli earthquakes is presented in a separate paper (Bartole et alt., in press). In this paper the work done up to now regarding steps 2, 3 and 4 is briefly discussed.

2.- SPACE DISTRIBUTION OF EARTHQUAKE EPICENTERS FROM THE ROMAN EPOCH UP TO 1976

Data on all major seismic events were looked up in the General Catalogue of Friuli Earthquakes and the earthquake epicenters plotted on a map (see Enclosure 2). The symbols denoting the epicenter location are related to the intensity of the earthquake and to the accuracy of its location.

The epicenters which presented an error $\Delta\lambda, \Delta\varphi \geqslant 0.5°$ in the coordinate determination have not been plotted. Two different kinds of circles distinguish the epicenters determined with coordinate errors $\Delta\lambda, \Delta\varphi \geqslant 0.25°$ and those determined with an error $\Delta\lambda, \Delta\varphi < 0.25°$.

In the map the depth of focus of the earthquakes has not been represented, due to the insufficiency of the available

data. According to these data however, it would seem that all earthquakes in Friuli Venezia Giulia originate in the crust and that most of them have a very shallow focus.

The great amount of historic records exsisting in the region together with the considerable bibliographic material, which is available, lead us to the conclusion, that the events of these last 100 years having and intensity higher than VI are plotted with sufficient accuracy. Many events were localized with a coordinate error $< 0.25°$.

In Friuli the epicenters are distributed along the main Periadriatic thrust fault, along the other major thrust faults to the north of it and along the fractures having a north-south direction (trascurrent faults) (Amato et alt., in press). The most important concentrations are found on the line going from Gemona, Trasaghis to Clauzetto; from Venzone towards Claut; from Tolmezzo to Ampezzo and on the two lines Tolmezzo-Paluzza and Moggio Udinese-Pontebba. Other centers of lower activity are near Cividale and near Tarvisio.

3.- MAXIMUM INTENSITIES FELT IN THE REGION IN THE LAST CENTURY

The map of maximum intensity felt in the region Friuli Venezia Giulia in the last century is based on the analysis of 25 isoseismal maps built according to historic records. The map includes also the May 6, 1976 earthquake data. This earthquake, along with the Venzone (1928) and Cansiglio (1936) ones, determines almost alone, due to its high intensities, the approximate configuration of the isoseismal lines on this

map. (Enclosure 3).

Another contribution of the past seismicity of the Friuli region will be possible when the analysis is extended also to the past centuries. This could modify the map of maximum felt intensity exspecially for what regards some seismic centers in the Carnia, Tarvisio and Cividale areas.

4.- STATISTICAL CHARACTERISTICS OF EARTHQUAKE ACTIVITY

The statistical characteristics of earthquake activity in Friuli Venezia Giulia have been analysed taking into account historic records and the recent seismic activity due to the May 6 and September 15 earthquakes.

The construction of graphs of partial and cumulative earthquake frequencies as functions of magnitude M on one hand and as functions of energy class K (K = log E) on the other, has been initiated (Karnik, 1971).

The empirical relations N(M) and N(K) between the number of earthquakes N and respectively their magnitude M and their energy class K is well known in seismological literature. Various empirical formulae now exist, the simplest ones being respectively:

$$\log N = a - bM \qquad (1)$$

and

$$\log N = \alpha - \beta K \qquad (2)$$

It was obviously tried to fit the catalogue data to these equations and to determine the values of the relative coefficients.

It is important to stress at this point, that the preparatory stages are still under study. Anyway a first analysis has been undertaken in order to get an idea on the goodness of the available data.

For this tentative analysis, magnitude intervals of one degree of the Richter scale have been considered. These intervals are centered on the integer values of the scale. The choice of the most appropriate intervals to be used in the final statistical analysis is one of the problems still to be solved.

The following types of graphs are in course of elaboration:

1) Curve relative to all earthquakes contained in the catalogue
2) Curve relative to the earthquakes of the last 100 years
3) Curve relative to the earthquakes of the period 1928-1976
4) Curve relative to the 1928 earthquake and its aftershocks
5) Curve relative to the 1976 earthquake and its aftershocks

The values of the coefficient b (relating to the ratio of weak and strong shocks) obtained from the cumulative frequency graphs relative to the curves described in points 3), 4), 5), are observed to vary between the values -.63 and -.73.

The values of b and α are also in good agreement. All this in spite of the arbitrary choice of the magnitude interval. One can deduct from these results that the data of the Catalogue, at least for what concerns the last 50 years, are

consistent and reliable.

5.- INTENSITY ATTENUATION AS A FUNCTION OF DISTANCE

In this section the work done up to now regarding attenuation curves is briefly analysed.

In the Catalogue of Friuli earthquakes (Bartole et al., 1976) all the events for which isoseismal maps were available in the literature or for which the maps could be constructed from historic records have been separated out. Successively the areas enclosed by each isoseismal line have been computed and the mean radius of each isoseismal line has been derived from them. Finally the intensity as a function of distance was plotted on a graph. This has been done for every single earthquake.

The attenuation curves relative to the same epicentral intensity I_o were then grouped and approximated by a single mean attenuation curve.

A brief parenthesis is perhaps appropriate at this point. As already mentioned, one of the first steps in the construction of a seismic risk map is the delineation of source areas. A preliminary study of this problem has led to determine several focal areas in the region Friuli Venezia Giulia (e.g. the Cividale area, the Tolmezzo area, the Gemona area, etc.). Unfortunately the amount of macroseismic data relative to several focal areas is very scarce. Only the data relative to the Tolmezzo and Gemona areas have been therefore grouped and tentatively elaborated.

It was then tried to fit these experimental points with

an empirical formula, using Sponheuer's method (Sponheuer, 1960). The formula used was the Kövesligethy one:

$$I_o - I(r) = 3 \log \frac{d}{h} + 1.3 \alpha (d - h) \qquad (3)$$

where:

I_o = epicentral intensity

$I(r)$=intensity at a distance r from the epicenter

d = hypocentral distance ($d^2 = r^2 + h^2$)

h = focal depth

α = attenuation coefficient

The fit gives the following values for the parameters h and α of the mean attenuation curves:

Epicentral intensity	Focal depth h (km)	Attenuation coefficient, α
VII	8	0.001
VI	6	0.005
V	6	0.001

Trying to fit with the Kövesligethy formula also the attenuation curves of the single events, it was noticed that the attenuation coefficient is pretty much stable between the values 0.001 and 0.005. The focal depth though varies between 2 km and 10 km.

Fitting the attenuation data of earthquakes originating in other focal areas, the conclusion was reached that the parameters determined above are not peculiar of the examined source areas, but could be taken to be valid for the whole

region Friuli Venezia Giulia.

It seems therefore to be sufficient to develop mean attenuation curves valid for the whole region.This is a comfortable result,insomuch as there are few macroseismic data relative to other focal areas.

6.- MAXIMUM MAGNITUDE LIKELY TO OCCUR IN THE REGION

In the construction of the seismic risk map it is of great importance to know approximately the largest value the magnitude of an earthquake can have in a certain area.Its determination encounters however serious difficulties,due to the rareness of destructive shocks and the troublesome statistical elaboration of their return periods.Because we are still studying the physical conditions of the focal areas,at present the problem has been approached statistically,trying to infer from the historical records as much as possible.The statistical solution though becomes more difficult for limited areas, as the data available for a small area is usually scarce.

It was noted in the past (Nordquist, 1945; Epstein et alt., 1966; Gumbel, 1945) that Gumbel's theory of largest values can be successfully applied to study the behaviour of maximum earthquake magnitudes.This theory is formulated under the assumptions that the prevailing conditions are valid for the future,that the observed largest earthquakes are independent events,and that the observed behaviour of the largest earthquakes in a given interval in the future will be similar to that of the past (Schenkova, Karnik, 1976). The method has also several other advantages we will not discuss here.

As an attempt a simplified version of the method was used to get a first indicative result.

The maximum yearly magnitudes $y_1, y_2 \cdots y_n$ of the last 105 years were arranged in the order of increasing magnitude. The representative values of y_j were then grouped into classes and associated with a probability:

$$G(y_j) = \frac{j}{n+1} \qquad n=105 \qquad (4)$$

The couples y_j and $G(y_j)$ were plotted on extremal probability paper. According to the theory the points should fit a straight line.

The following results have been obtained:

	M 1%	M 2%	M 10%
M (Richter)	6.5	6.0	5.0
T (years)	100	50	10

This means for example that magnitude 6.5 will be exceeded with a probability of P=1% in a period of T=100 years.

The results obtained are in good agreement with the data in the Catalogue. Let us mention that B.A.Borissoff et al. in a recent work (Borissof et alt., in press) predicted on the basis of geotectonic methods a M_{max}=6.5 for the Friuli Venezia Giulia region.

Other methods to find M_{max} are also under study.

REFERENCES

AMATO A., BARNABA P.F., FINETTI I., GROPPI G., MARTINIS B., MUZZIN A. (1976) - Geodynamic Outline and Seismicity of Friuli Venezia Giulia Region. Proceeding of the meeting on the Friuli Earthquake, 4-5 December 1976, Udine (In press).

BARTOLE R., BERNARDIS G., GIORGETTI F., NIETO D., RUSSI M. (1976) - Earthquake Catalogue of Friuli Venezia Giulia Region. Proceeding of the meeting on the Friuli Earthquake, 4-5 December 1976, Udine (In press).

BORISSOFF B.A., REISNER G.I., SHOLPO U.N. ( ) - A Geotectonic Method of Predicting the Maximum Magnitudes of Expected Earthquakes as Applied to the Northern Italy Area. In press.

EPSTEIN B., LUMNITZ C. (1966) - A Model for the Occurrence of Large Earthquakes. Nature, 211, No 5052, 954.

GUMBEL E.J. (1945) - Simplified Plotting of Statistical Observations. Trans.Am.Geophys.Union, 26, 69.

KARNIK V. (1969) - Seismicity of the European Area. Vol. 1,2 Reidel Publishing Comp. Holland.

NORDQUIST J.M. (1945) - Theory of Largest Values Applied to Earthquake Magnitudes. Trans.Am.Geophys.Union, 26, 29.

SCHENOKOVA Z., KARNIK V. (1976) - Application of the Largest Values Theory to Balkan Earthquakes. Pric. of Seminar on Seismic Zoning Maps, UNESCO.

SPONHEUER W. (1960) - Methoden zur Herdtiefenbestimmung in der Makroseismik. Geophysik C 88, Akad.Verlag., Berling.

UNESCO (1976) - Proceeding of the seminar on seismic zoning maps; vol. I, II; 27 October-4 November 1975, Skopje.

STRESS CORROSION THEORY OF CRACK PROPAGATION APPLIED TO THE EARTHQUAKE MECHANISM. A POSSIBLE BASIS TO EXPLAIN THE OCCURRENCE OF TWO OR MORE LARGE SEISMIC SHOCKS IN A GEOLOGICALLY SHORT TIME INTERVAL.

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Abstract

Previous models of the seismic mechanism, as given by the dislocation theory, the relaxation theory and the elastic rebound theory, are briefly considered and criticized. None of these theories may be profitably employed to explain several features of many earthquakes and their related precursory phenomena. Two alternative models are then proposed, either based on the inclusion theory for dry rock, or based on the stress corrosion theory of crack propagation in a wet environment.

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Both theories are briefly reviewed and their relevance for geophysical phenomena is discussed. When these two theories are combined and applied to the Friuli earthquake sequence, its outstanding features, namely the occurrence of two high magnitude events in a region previously classified as one of low seismic risk and the large aftershock of september 11-th, may be both qualitatively and quantitatively accounted for.

Introduction

Since the very beginning of the study of geophysical phenomena by means of physical and mathematical methods, two major difficulties were recognized in trying to obtain reliable information from laboratory experiments: the ignorance of the materials and their behaviour in the high pressure layers of the interior of the Earth and the difficulties arising from the long time scale typical of geological dynamics. Both problems have been extensively studied in recent years, so that realistic models of geophysical phenomena may be given today. In particular much effort has been devoted recently to the study of earthquakes in the twofold attempt of gaining a better knowledge of the Earth's properties and arriving at a reliable and possibly deterministic description of the seismic mechanism.

The first approach to the description of the source mechanism of an earthquake was based on the consideration of simple point sources and couples within the surface of an elastic

medium. Although inadequate under many respects, this model has been of considerable help in describing the character of a tectonic source and defining many useful concepts and parameters. More recently however, some more elaborate theories have been proposed; they are either based on the dislocation theory, first proposed by Volterra[1] where an earthquake is modeled as a step-like discontinuity in the displacement field over a surface embedded in an elastic medium, or are generalized point source theories (e.g. Ben Menahem[2]), in which propagation of the source describes the phenomenon of rupture. A more general approach was given by Archambeau[3] and Randall[4], who recognized an earthquake as a relaxation phenomenon described mathematically as an initial value problem with moving boundaries. The elastic rebound theory may be considered as a model intermediate between a dislocation model and a moving source model.

The description of an earthquake according to the previous models implies the following common features:

a) an initial shear stress field is considered to be the primary cause of rupture,

b) seismic effects are considered to arise mainly from the pre-stress shear field in the medium, surrounding a region in which the physical properties, principally the rigidity modulus have changed abruptly. The tectonic source is therefore viewed in terms of release of potential strain energy from the elastic zone of the medium.

In this view, earthquakes are localized to those regions of the Earth's crust and upper mantle where large, non-hydro-

static stress fields of tectonic origin exist, that is along plate margins where actually most earthquakes take place. Earthquakes, however, also occur within the plates and this fact cannot be conveniently interpreted according to the previous models. Indeed we intend to show that the previous models of the earthquake mechanism are too simple in order to give a realistic description not only of the seismic radiation, but mainly of the other physical phenomena leading to and accompanying the rupture process. Some of the mentioned models may give a convenient description for some determined purposes or in some particular instances, but none of them is of general applicability.

Restrictions on earthquake models

Elementary conditions of compatibility for any proposed model are:

A-The rupture model and the related dynamical processes must give rise to a net reduction of stored elastic energy within the medium.

B-The rupture mechanism must restore the system to a final state of equilibrium.

C-The mechanism must be more likely to occur under the thermodynamic, chemical and stress condition existing within the Earth, than other competing mechanisms.

The condition termed C above is the most severe restriction to any proposed model. Exploiting its implications ful-

ly, requires a deep knowledge and understanding of slow, long term phenomena of rock chemistry and rock mechanics. Further stringent restrictions in this context are imposed by precursory phenomena which have been extensively studied in recent years. Such phenomena take place in the focal region of an impending earthquake and include the anomalous variations in the ratio of longitudinal to shear seismic velocities V_p/V_s (Semenov[5], Aggarwal et al.[6], Whitecomb et al.[7]), stress axis rotation (Nersesov & Simbireva[8]), anomalous crustal movements and tilt (Sadovsky et al.[9], Sassa & Nichimura[10]), changes in resistivity (Sadovsky et al.[9]), changes in microearthquake frequency (Sholz et al.[11], Wyss[12]), increase in radon emission from deep wells (Ulomov & Mavashev[13]).

Many earth scientists were dubious about the validity of these observations and even more uncertain about whether these effects were characteristic of more than a few earthquakes. Vigorous programs to monitor premonitory effects, particulary in Japan and the USSR during the last 5 years leave little doubt that such effects are real. In view of these observations, the approximation of an earthquake by previous models, in which the sudden formation of a shear discontinuity in rocks occurs over or within a well defined geometrical surface, is an oversimplification. The dislocation model may be considered a good one only for long period waves, particularly for the free oscillations of the Earth. The general relaxation model proposed by Archambeau[3] is limited for practical use, since no model is included of the rupture process and the failure region. In particular it is not possible to inclu-

de in it realistic processes of energy dissipation into heat. Theoretical spectra obtained from the relaxation theory yield unrealistic features when compared with observed spectra, the reason being abscribed mainly to dissipative processes (Molnar et al.[14]). The elastic rebound theory does not suffer from the previous limitations, however Ohnaka[15] showed that, when static and viscous friction along the fault surface are included in the physical processes accompanying fracture propagation, only a minor part, typically less than 1 percent, of the released energy goes into seismic energy. Thus the elastic rebound mechanism is highly inefficient and a huge release of strain energy accompanied by a large stress drop is needed to explain the observed seismic radiation. The dynamically increasing shear stress conditions play the critical role,according to this theory, of determining where and when a seismic event takes place and thus cannot explain the occurrence of an earthquake within the plates. Furthermore the elastic rebound theory requires an extremely long re-charging time so that it is unable to explain the occurrence of two or more seismic events in geologically short time intervals.

It appears then that a re-evaluation of our models of the seismic mechanism is required. A theory of rock failure on the large scale typical of earthquakes is needed, which must provide an explanation of all the precursor phenomena occurring prior to failure. Fracture models and fracture criteria previously employed to describe shear failure of rocks may be briefly reviewed:

A-Coulomb fracture describes cracking and the related

stress drop followed by faulting along the plane of failure. This type of failure occurs when the non-hydrostatic stress τ satisfies the Coulomb-Navier relation

$$\tau \geq \tau_0 + \sigma \operatorname{tg} \phi$$

where τ_0 is the cohesive shear strength of the material, σ is the hydrostatic pressure and $\operatorname{tg}\phi$ is a material costant corresponding to a coefficient of internal friction and is typically of the order of unity. Coulomb fracture thus cannot occur below about 5 km.

B-Orowan[17] devised a failure mechanism by instability in high temperature creep. This hypothetic process cannot be given any direct verification from the limited laboratory experiments, but may constitute the most likely process of sudden energy release at the more extreme end of the depth range for earthquakes (around 700 km).

C-Raleigh & Paterson[18] suggest that a modification of the Coulomb-Navier criterium applies to rocks which have undergone high temperature dehydration at depth in the Earth. Pore pressure of water p, acts then to lower the confining pressure according to the modified relation

$$\tau \geq \tau_0 + (\sigma - p) \operatorname{tg} \phi$$

This model is based on experimental evidences obtained serpentine dehydration. Preferred depth range for the modified Coulomb failure depends on the depth of dehydrated minerals and

probably occurs in the lower part of the crust and upper part of the mantle. A somewhat different explanation of this fracture process will be given later in terms of the stress corrosion crack propagation theory.

All the previous models of fracture are under many respects unsuitable for geophysical application since they were derived from short time scale experiments and cannot give any explanation of precursory phenomena. It appears that a reliable rock failure theory must be developed, first of all, which may account for the manyfold features of the fracture phenomenon, particularly in the long time scale limit, and give them physical interpretation.

The inclusion theory of failure in dry rocks

Brady[19,20] developed a scale indipendent theory of failure in dry rocks, termed inclusion theory, which steps from experimental evidence obtained by the same author in laboratory tests. Such tests were conducted on marble and granite specimens compressed under a confining pressure of 100 bars, loaded at a constant strain rate of 10^{-4} sec^{-1} . According with the inclusion theory, 5 distinct phases may be recognized in a general failure phenomenon:

1-Pre-dilatant phase: pores and microcracks throughout the rock volume close following the application of compressive stresses (which are set up by tectonic movements in an earthquake).

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2-Dilatant phase: microcracks form uniformly throughout the rock and along a preferential direction aligned with the axis of greatest compression. These microcracks contribute a reversible component to the total dilatancy strain.

3-Inclusion phase: clusters of microcracks develop in localized regions within a few percent of rocks' ultimate strength. These microcracks contribute an irreversible component to the dilatancy strain. These regions may be represented physically as low modulus inclusions embedded within a host material of higher modulus. As a result of the elastic contrast over the inclusion boundary there are both a rotation and a change in magnitude of the physical stresses in the focal region, that is the region in the immediate vicinity of the inclusion.

4-Closure phase (only partly assessed): microcracks close as the magnitude of the least principal stress increases in compression.

5-Growth phase: cracks within the inclusion begin to coalesce in response to the increasing tensile stress which is normal to the long axis of the inclusion.

Phases 3 to 5 take very short time; once clusters of microcracks form, rock failure follows immediately. However Brady[19,20] suggests that the closure phase may take a longer time for the large scale phenomena. This theory explains both qualitatively and quantitatively all the premonitory effects previously discussed, although in our views it completely neglects the long time scale problem of strain rate loading.

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The stress corrosion theory of crack propagation

Another limitation of the inclusion theory, with respect to geophysical applications, stands in the chemically inactive environment in which failure occurs. The stress corrosion theory of crack propagation yields the required completion of rock failure theories, particularly when the phenomenon of fracture is considered on a relatively long time scale.

Stress corrosion cracking may be defined as low or stable crack growth resulting from the combined effects of corrosion and stress. It applies specifically to static stress configurations. Sholz[21] suggested that static fatigue due to stress corrosion is the mechanism of brittle creep in rocks and, on a large scale, may be the mechanism of earthquake triggering by water injection through intrinsic, chemical weakening by stress corrosion, whereas strictly mechanical pore pressure effects had been previously assumed (Raleigh & Paterson[18]).

According to the "cohesive zone" model, the crack system may be divided into two zones:

1-a relatively small, inner zone immediately surrounding the crack tip, in which the non-linear separation processes operate,

2-the surrounding outer zone in which the linear elastic material serves the function of a medium for transmitting the applied forces to the inner regions.

The non-linear crack tip zone extends over several molecular spacings along the crack interface and cohesive forces attract the two sides of the crack together. The region of

the cohesive zone is thus very small compared to the crack length.

The work done in separating the material at the crack tip is expressed in terms of a surface energy U_S, elastic energy U_E and the work done by external loads W_L. The crack growth criterium, referred to the unit crack width, is then

$$\frac{d\,U_S}{da} \leq \frac{d(-W_L+U_E)}{da}$$

where da is an infinitesimal increment in crack length. U_S contains a reversible contribution, typical of ideal brittle solids, plus a dissipative component which is always present in real solids while creating a new fracture surface.

If surface active chemicals are present in the environment, a part of the energy required to form a new surface is supplied by a chemical reaction. The rate of chemical reactions or the rate of diffusion of chemical agents to and from the crack tip, determine the time dependence observed in the fracture process. The previous relation may then be interpreted as saying that the crack is in thermodynamic equilibrium when, for a virtual increment in area, the work done by applied forces, elastically transmitted through the medium to the crack tip, just balances the increase in the fracture surface energy which corresponds to a reduced, interfacial value for the solid in contact with a solid environment.

The overall process at the crack tip consists of several steps:

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1-transport of reactants to the surface,

2-adsorption of the reactants,

3-reactions on the surface,

4-desorption of the products.

The stress concentration at the end of an open crack is proportional to the square root of the ratio of crack length a to crack width w.

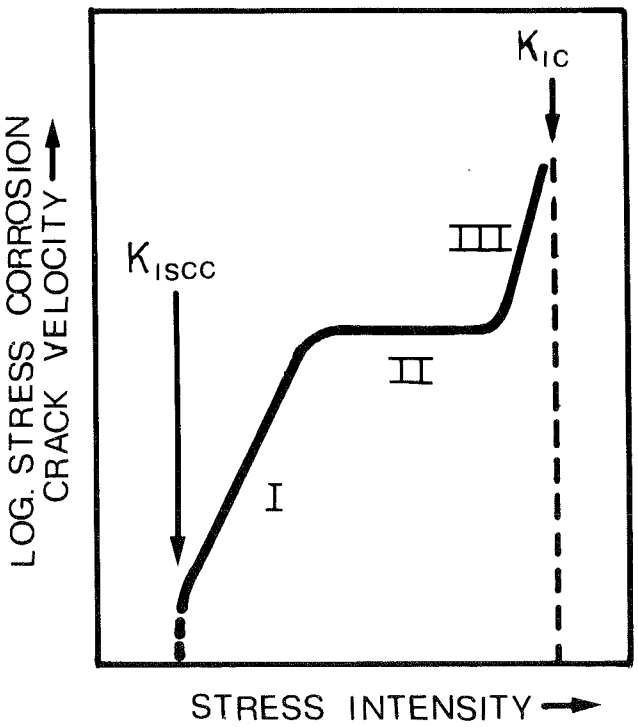

Figure 1- Generalized representation of effect of the stress intensity factor on kinetics of stress corrosion cracking. The ordinate scale has been adjusted; the origin represents zero crack growth rate. Some systems show an apparent zero growth rate at a certain limiting value of K denoted K_{ISCC} (from Brown[22] and Evans[23]).

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Figure 1 is a commonly used graph for displaying stress corrosion cracking data. The logarithm of stress corrosion crack velocity is plotted versus the stress intensity factor at the crack tip. In region I there is a linear relation between the logarithm of the crack velocity and the stress intensity factor; crack propagation is controlled by the kinetics of chemical reactions between the solid and the environment that fills the crack and is strongly dependent on stress intensity. In the plateau region II the crack velocity is indipendent of stress. Mass transport, i.e. diffusion, of corrosive reactants to the crack tip is the rate limiting process. In this region a crack cannot propagate faster than the maximum velocity at which the damaging species can move to the crack tip. Region III represents a mixture of corrosive and mechanical failure and leads to the fast, catastrofic fracture propagation of region IV, beyond the critical stress intensity factor K_{IC}.

Stuart & Anderson[22] derived an expression for crack velocity in terms of the net rate of breaking chemical bonds

$$\frac{dN}{dt} = \frac{NkT}{h} \exp\left[\frac{-\Delta F^* + F_S/2}{RT}\right] 2 \sinh\left(\frac{c\,\sigma\,\lambda A}{2NkT} - \frac{f_S}{2kT}\right)$$

where k is the Boltzmann constant, T the absolute temperature, h Planck constant, λ is the average distance particle must separate to go from the unfractured to the fractured state, ΔF^* is the average free energy of activation per mole of particles, R is the gas constant, c is a stress concentration

factor, σ is the average macroscopic stress and f_s is the effective average surface energy per particle. A choice of appropriate empirical constant in the Stuart-Anderson equation yields a "stress vs. time-to-failure" behaviour which fits experimental data.

Another equation to fit data for static fatigue was proposed by Elliot[25] on the basic assumption that the slow growth rate of a crack in a corrosive environment is controlled by diffusion of the corrosive agents through fissured corrosion products to the root of the crack.

In experimental studies of the mechanism of slow crack growth in quartz, Martin & Durham[26] found that the controlling mechanism of crack growth was the partial pressure of water at the crack tip; the water at the tip reduces the stress necessary to rupture bonds by approximatively an order of magnitude below that with no water available. The same explanation may be also assumed to hold in order to explain the analogous results obtained by Raleigh & Paterson[18] for serpentine dehydration weakening. Increased humidity increases the rate of stress corrosion crack growth by shifting region II to higher velocities and region I to lower stress intensity.

Experiments by Charles[27] and Sholz[21] on quartz and granite suggest that stress corrosion cracking may be an important process in the fracture of rock-forming silicates. The fabric of rocks is a variable influencing the kinetics of stress corrosion cracking along preferred directions.

Macro-branching, that is crack separation into two or more macroscopic components that tend to diverge, appears to

be confined to region II of Fig. 1.

Microseismic emission during the slow growth of a crack is correlated with propagation of fractures through and between mineral grains (Lange[28]). The rate of microfracturing in quartz crystals is proportional to the crack velocity (Sholz[20]).

The stress corrosion phenomena and the related theory, it should be clearly emphasized, is no longer a matter of temptative speculations, such a large amount of experimental evidences existing to support them. Stress corrosion cracking must be considered as a fundamental phenomenon of nature, taking place in brittle materials whenever pre-existing flaws and a favourable chemical environment exists. Stress corrosion phenomena may be safely neglected only in the short time scale problems, which clearly is not the case in geophysics.

Application of the stress corrosion theory to Earthquake phenomena

Sholz[20] suggests that stress corrosion in slow crack propagation may be a controlling process in time dependent geological processes, in particular in earthquake aftershocks. The time sequence in aftershocks is caused, in his view, by a time dependent rock strength, as determined by weakening through stress corrosion. The primary reactions which weaken silicates are hydration reactions. Sholz furthermore pointed out that there was no scale problem in his experimental results of fracture in the Earth, in agreement with Brady's[19] failure

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theory in dry rocks.

Anderson & Grew[29] argued that the effect of a major earthquake might be to redistribute the groundwater in vicinity of the fault so that some cracks would be immersed in water whereas they were dry before the earthquake. This is reflected in changes in water levels of wells and springs which take place after earthquakes. Anderson & Grew[29] furthermore suggest that stress corrosion cracking controls the induction time of subcritical crack growth (region I of Fig. 1), but that, at higher values of the stress intensity factor and higher crack propagation velocities, fluid transport becomes the dominant factor. Then at the critical stress intensity, fast cracking progresses in the catastrofic fashion typical of earthquake events. Injecting fluid into an inactive fault could result in substantially increasing the crack velocity by changing the kinetics of chemical reactions at the crack tip. Water weakening could reduce the breaking strength of the chemical bonds at the crack tip.

Martin & Durham[26] attribute to water an important role in upper crustal deformation and failure; it reduces the stress at the crack tip necessary to break bonds by approximately an order of magnitude below that for a silicate with no water available. They go on to propose that the chemical effect of water may suggest a mechanism whereby deformation may proceed without requiring a continuous augmentation of the stress field. Such a time dependent dilatancy may be particularly important in earthquake regions. According to the dilatancy-diffusion hypothesis (Nur[30], Aggarwal et al.[6], Sholz et

al.[11], Whitecomb et al.[7], Hanks[31]), the following events precede an earthquake:

1-accumulation of tectonic strain and increasing effective stress,

2-production of dilatancy at a rate faster than pore water can flow into volumes created by newly formed cracks,

3-undersaturation of rocks and decrease in pore pressure as crack volume exceeds fluid volume and strength of rocks against fracture increases

4-return to saturated state by fluid flow from the external areas and diffusion through the focal region (Rikitake[32]),

5-rising pore pressure triggers an earthquake.

The increased radon content in well water prior to earthquakes has been attributed to increased fresh surface area in cracks and to an increase in the flowrate of pore water.

A possible mechanism for the anomalous earthquake sequence in Friuli

Two outstanding features have been generally recognized in the Friuli earthquake. First, the region was previously considered not very active seismically on a statistical basis so that the seismic event prompted a modification of the existing seismic risk maps; second, the large aftershocks of September 11th and 12th were of the same magnitude of the main shock of May 6th, so that it appears difficult to consider them as simple aftershock events, neither may they be interpre-

ted as entirely different earthquakes, too short being the time interval between the two main shocks in order for tectonic movements to have elastically re-charged the region up to the critical threshold for rupture (as required by the elastic rebound theory or Brady's[20] theory). Actually stick-slip sliding might account for a similar behaviour in the framework of the elastic rebound theory (e.g. Ohnaka[33]), but a continuous augmentation of the tectonic stress would be required so that this mechanism can only apply to pre-existing, sharply defined faults along plate margins.

In view of the previous considerations however, the interpretation for the Friuli earthquake is very simple and almost immediate.

1-st phase: tectonic stresses slowly but continuously increase in the course of hundred of years. Indeed there is great evidence from seismic maps and tectonic studies of an Adriatic microplate which is responsible for such an elastic "charging". Owing to the large hydrostatic pressure, rock in the lower crust and upper mantle may be assumed compact, i.e. with no porosity.

2-nd phase: microcracks develop uniformly within the focal region according to Brady's[19] theory and the dilatancy theory. Alternatively with this hypothesis, the extremely long loading rate of tectonic origin allows low temperature creep to develop without any crack generation. In both cases stress corrosion phenomena do not apply at this stage since water can only come from desaturation of hydrated rocks following a temperature rise, while little heating is expected at this stage.

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If water however, does penetrate into the dilatant region from the environmental area, stress corrosion may enhance the crack growth process and determine foreshocks occurrence or even trigger the major earthquake. This is even more plausible for high seismicity regions where cracks or microcracks are always present. This however seems not to be the case for the 1st Friuli seismic shock of May, 6th.

3-rd phase: clusters of microcracks form in relatively localized regions within a few percent of the ultimate strength of the medium.

4-th phase: a weakened zone, depicted as an elastic inclusion in Brady's[19] theory, develops in which microcracks rise and grow until the threshold for catastrofic rupture is reached, thus leading to the first seismic event of May, 6th. The stress drop accompanying an earthquake is only a small fraction of the total pre-stress field. A stress drop amounting to 10% of the pre-stress field has been estimated in many instances (e.g. Wyss & Molnar[34], Healey[35]). Stress corrosion cracking plays again no role since the cluster formation and the macrocrack growth take place in a short time interval so that Brady's failure theory may be applied without the time scale objection. Surrounding the macrocracks, the focal region is highly microfractured. High temperatures are raised locally by dissipative processes, particularly when sliding takes place. Dehydration of hydrated silicates takes place and steam or water begin to diffuse into the focal region and to fill cracks.

5-th phase: stress corrosion crack growth takes place

within the focal region. The residual stress still present is a considerable fraction of the initial pre-stress. Water present in the microcracks of the focal region considerably lowers the threshold for subcritical crack growth. While cracks grow, more and more water diffuses within the focal region. The threshold for catastrofic propagation may be reached locally sooner than elsewhere and consistently aftershocks are observed of considerable magnitude.

6-th phase: the stress intensity threshold for catastrofic crack growth is reached in most of the focal region. Catastrofic crack growth enhanced by cohalescence takes place along various branches leading to the large seismic events of September, 11th.

Did this second catastrofic phase develop new cracked regions or did the cracks remain wholly confined within the focal region of the previous earthquake? The answer to this question, together with the knowledge of the stress drop associated with both major shock sequences might tell us wether new destructive shocks are to be expected or not on the basis of the previous model.

What has been proposed up to now may however sound as a suggestive but too qualitative description of the seismic mechanism for the Friuli earthquake. Unfortunately precursory phenomena have not been monitored, as far as we know, during the interval between the two main shocks. Indeed most of them must be necessarily present during the mentioned interval if the present description is meaningful.

There are however two "a posteriori" restriction to our

model: the 128 days delay between the two major events and the 6.1 magnitude of the second event. If these data fit with the semiempirical relations based on the interpretation of many previous earthquakes in the light of the dilatancy diffusion theory, the previous description may be considered with a better confidence.

Figure 2 represents the relation between precursor time and the length of the aftershock zone. The proportionality between time and L^2 desumed from this figure, is perhaps the most convincing prove of the importance of diffusive processes as leading to destructive fracture.

A semiempirical relation furthermore holds between magnitude M and aftershock area A in the form:

$$M = a \log A + b$$

where a and b are empirical constants. Utsu[36] gives the following values:

$$a = 1 \qquad b = 3.7$$

when A is measured in km^2. In an approximate calculation we may assume $A \sim L^2$. Then from the magnitude 6.2 of the first major event the area of the aftershock region may be derived and from this the time needed for diffusion of water into the focal region may be derived from Fig. 2. It appears then that a delay time of approximately 100-200 days was to be expected and that the magnitude of the second major shock comes out to

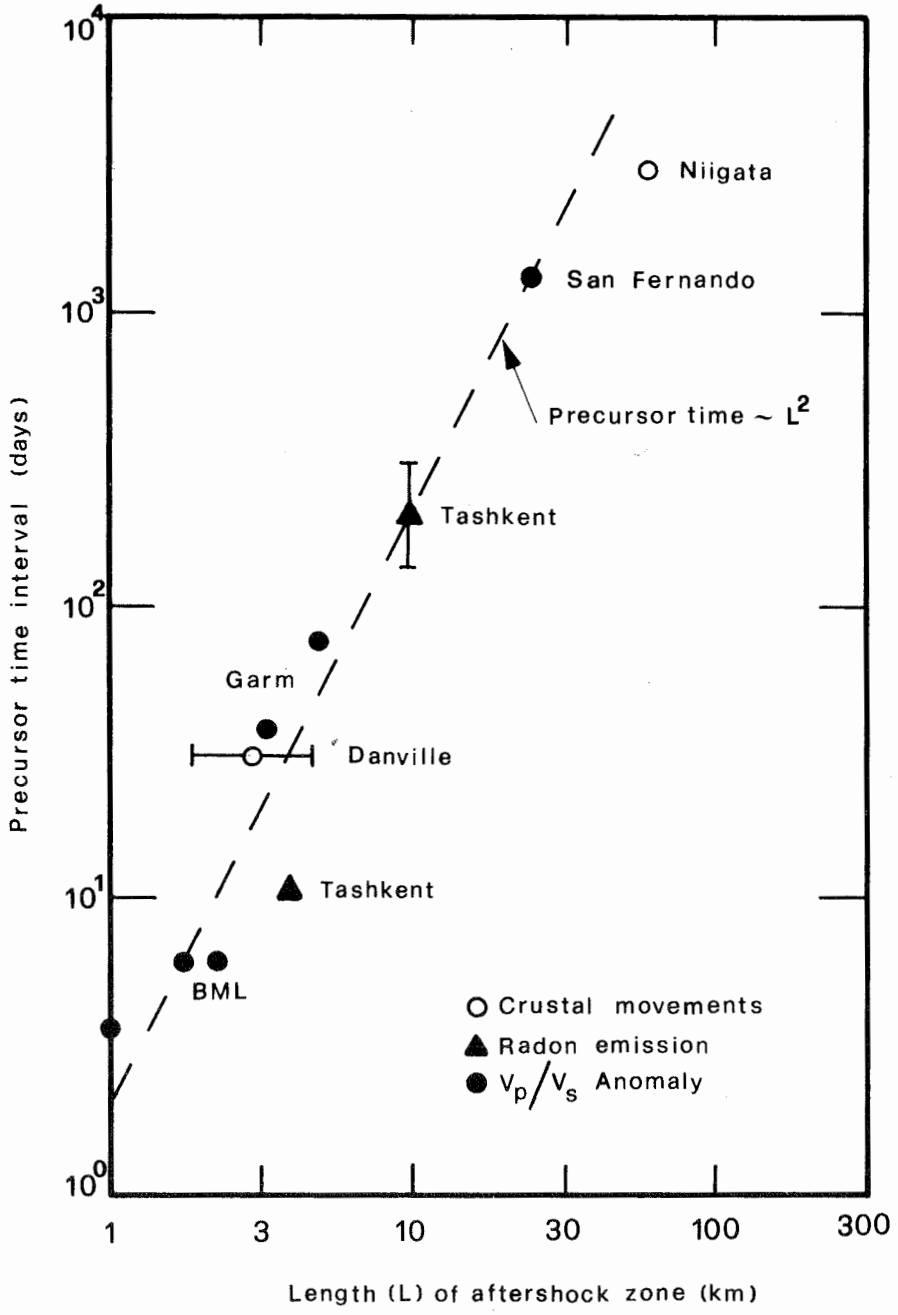

Figure 2. Precursor time interval as a function of the length of the aftershock zone for a variety of earthquakes and types of physical observations (from Scholz et al.[11]).

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be the same as for the first shock.

This must not be taken as implying that the shock sequence of September in Friuli might have been forecasted. Actually the present model was developed "a posteriori" with the specific aim of trying to explain the two mentioned outstanding features of the Friuli earthquake: its localization in a region of low seismic activity and its anomalous time behaviour.

The present model however suggests that stress corrosion cracking may be a fundamental mechanism of earthquake triggering in pre-cracked regions, while a different machanism with a higher stress threshold must be invoked to explain sudden fracture occurrence in a compact medium. In the latter case high aftershock activity and new large shocks must be expected.

The present model furthermore suggests that premonitory phenomena may well occur prior to both types of earthquakes but they surely occur before the first type earthquakes.

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References

1. Volterra, V., Sur l'equilibre des corps elastiques multiplement connexes, Ann. Ec. Norm., ser. 3, Paris, 24, 401, 1907.
2. Ben Menhaem, A., Radiation of seismic surface waves from finite moving sources, Bull. Seismol. Soc. Am., 51 (3), 401, 1961.
3. Archambeau, C.B., Elastodynamic source theory, Ph.D. thesis, California Institute of Technology, Pasadena, 1964.
4. Randall, M.J., On the mechanism of earthquakes, Bull. Seismol. Soc. Am., 54, 1283, 1964.
5. Semenov, A.M., Variations in the travel time of transverse and longitudinal waves before violente earthquakes, Isv. Earth Physics, 4, 245, 1969.
6. Aggarwal, Y.P., Sykes, L.R., Armbruster, J. and Sbar, M.L., Premonitory changes in seismic velocities and prediction of earthquakes, Nature, 241, 1973.
7. Whitcomb, J., Garmany, J., and Anderson, D., Earthquake prediction: variation of seismic velocities before the San Fernando earthquake, Science, 180, 632, 1973.
8. Nersesov, I.L., and Simbireva, I.G., Regularities in the distribution of stresses in the foci of weak earthquakes in the Garm area and their relationship to seismicity,

Third All-Union Symposium of the seismic regime, June 3-7, 1968, Part I, pp. 147-181.

9. Sadovsky, M.A., Nersesov, I.L., Nigmatullaev, S.K., Latynina, L.A., Lukk, A.A., Semenov, A.N., Simbireva, I.G., and Ulomov, R.I., The processes preceding strong earthquakes in some regions of middle Asia, Tectonophysics, 14, 296, 1972.
10. Sassa, K., and Nichimura, E., On phenomena forerunning earthquakes, Bull. Disast. Prev. Res. Inst., Kyoto Univ., 13, (1), 1, 1956.
11. Scholz, C.H., Sykes, L.R., and Aggarwal, Y.P., The physical basis for earthquake prediction, Science, 181, 803, 1973.
12. Wyss, M., Toward a physical understanding of the earthquake frequency distribution, J. Geophys. Res., 31, 341, 1973.
13. Ulomov, V.I., and Mavashev, B.Z., in The Tashkent Earthquake of 26 April 1966,Akademiia Nauk Uzbekskoi, S.S.R., FAN, Tashkent, 1971, p. 188.
14. Molnar,P., Jacob, K.H., and McCamy, K., Implications of Archambeau's earthquake source theory for slip on faults, Bull. Seismol. Soc. Am., 63, 101, 1973.
15. Ohnaka,M., A physical understanding of the earthquake source mechanism, J. Phys. Earth, 21,39, 1973.
16. Ohnaka, M., A physiaal basis for earthquakes based on the elastic rebound theory, Bull. Seismol. Soc. Am., 66, 433, 1976.
17. Orowan, E., Dilatancy and the seismic focal mechanism, Rev. Geophys., 4, 395, 1966.

18. Raleigh, C.B., and Paterson, M.S., Experimental deformation of serpentinite and its tectonic implications, J. Geophys. Res., 70, 3965, 1965.
19. Brady, B.T., Theory of earthquakes-Part I- A scale independent theory of rock failure, Pageoph., 112, 701, 1974.
20. Brady, B.T., Theory of earthquakes-Part II- Inclusion theory of crustal earthquakes, Pageoph., 113, 149, 1975.
21. Scholz, C.H., Static fatigue of quartz, J. Geophys. Res., 77, 2104, 1972.
22. Brown, B.F., A preface to the problem of stress corrosion cracking, in Stress corrosion cracking of metals-A state of the art, edited by H.L. Craig, Jr., ASTM Special Technical Publication 518, Philadelphia, 1972, page 3.
23. Evans, A.G., A method for evaluating the time dependent failure characteristics of brittle materials and its application to polycrystalline alumina, J. Mat. Sci., 7, 1137, 1972.
24. Stuart, D.A., and Anderson, O.L., Dependence of ultimate strength of glass under constant load on temperature, ambient atmosphere and time, J. Am. Cer. Soc., 36, 416, 1953.
25. Elliott, H.A., Stress rupture in glass, J. Appl. Phys., 29, 224, 1958.
26. Martin, R.J., and Durham, W.B., Mechanism of crack growth in quartz, J. Geophys. Res., 80, 4837, 1975.
27. Charles, R.J., The strength of silicate glasses and some crystalline oxides, in Fracture: Proceedings of an international conference on the atomic mechanism of fracture, Swampscott, Massachusetts, MIT Press, Cambridge, 1959, 225.

28. Lange, F.F., Origin and use of fracture mechanics, in Fracture mechanics of ceramics, Vol. 1: Concepts, Flaws and Fractography, edited by R.C. Bradt, D.P.H. Hasselman and F.F. Lange, Plenum Press, New York, 1974, page 3.

29. Anderson, O.L., and Grew, P.C., Stress corrosion theory of crack propagation with applications to geophysics, Rev. Geophys. Space Phys., in press, 1977.

30. Nur,A., Dilatancy, pore fluids and premonitory variations in t_s/t_p travel times, Bull. Seismol. Soc. Am., 62, 1217, 1972.

31. Hanks, T.C., Constraints on the dilatancy diffusion model of the earthquake mechanism, J. Geophys. Res., 79, 3023, 1974.

32. Rikitake, T., Dilatancy model and empirical formulas for an earthquake area, Pageoph., 113, 141, 1975.

33. Ohnaka, Experimental studies of stick-slip and their application to the earthquake source mechanism, J. Phys. Earth, 21, 285, 1973.

34. Wyss, M., and Molnar, P., Efficiency, sress drop, apparent stress, effective stress and frictional stress of Denver, Colorado, earthquakes, J. Geophys. Res., 77, 1433, 1972.

35. Healey, J.H., Rubey, W.W., Griggs, D.T., and C.B. Raleigh, The Denver earthquakes, Science, 161, 1301, 1968.

36. Utsu, T., Aftershocks and earthquake statistic (I), J. Fac. Sci. Hokkaido Univ., ser. 7, 3, 129, 1969.

THE AREA OF THE FAULT, THE DISLOCATION, THE STRESS DROP AND THE SEISMIC MOMENT OF THE FRIULI EARTHQUAKE OF MAY 6TH 1976

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The values of the dislocation, of the stress drop and of the seismic of the May 6th 1976 Friuli earthquake are estimated with three different methods and four different indipendent data.

The computations are based on estimates of the area of the fault which caused the esrthquake and on the fault plane solution.

The average value of the parameters is

Area of fault	800 km^2	800
Stress drop	10 bars	13

Dislocation	32 cm	54
Seismic moment	$10^{25.9}$	$10^{26.1}$
Magnitude	6.2	6.4

Of allthe parameters obtained in this note the most interesting for our purpose is the stress drop. From this value we may deduct two important conclusions, one on the possibility to forecast the earthquake of May 6th and another on the consequences of such stress drop at the focal depth of the eartquake which was estimated about 26 $\pm$ 6 Km. (ING 1976).

The first nodal plane found by Console (1976) has azimuth 168° and dip angle 75°5, the slip direction has the same angles. In this solution the Northern Alps would have sinked with respect to the Eastern Alps; this mechanims is unlikely because lateral forces could not cause the slip on such an angle (Caputo 1976), vertical lift associated with isostatic adjustement would prefer to lift the Northern Alps perhaps. The second nodal plane has azimuth of 350° and dip of 14°, the slip directions are 350° and 13°. This solution in which the Eastern Alps would have thrusted under the Northern Alps is more acceptable; in this case the angle berween the direction of the faults and that of the major tectonic forces is 77°. This is the angle to be used in the method of Caputo (1976); unfortunately this angle is critical and not too reliable. However

inspite of this circumstance even this method gives results which are not unreasonable. The formula is

$$\frac{10^{11.22}}{\frac{\sin 2\vartheta}{2} - 0.6\cos^2\vartheta}$$

which gives directly the stress drop.

A second method is based on the area of the distribution of the epicenters of the aftershocks (Gasparini 1976).

A third method is based on the area of the isoseismal of intensity IX (Console 1976) and also on an average formula by Caputo et al. (1773). From this formula one also obtains for the italian area the average radius R of the fault, stress drop p, dislocation s and seismic moment as functions of the Magnitude

$$R = 10^{0.40M + 3.72}$$

$$p = 10^{0.13M + 6.26}$$

$$s = 10^{0.52M + 1.65}$$

$$M_0 = 10^{1.31M + 17.76}$$

According to the focal mechanism accepted and the dire ction af the major tectonic force the dislocation could have been detected with standard geodetic instruments if it had occurred on the surface of the Earth and not at depth.
The possibility to find precursoty phoenomena of the Friuli event of May 6th 1976 was limited only by the response of the upper layers to the contraction of the lower layers; if there was a proper response of the upper layers the modern standard geodetic instruments could have easily detected the precursory phenomena.
Observations of this type are being made by the Istituto di Geofisica of the Università di Bologna in the area of Ancona (In cooperation with that University), in the area of Pozzuoli and across the Messina Straits.
The displocation computed here shows that the equilibrium of the upper layers of the crust were upset on a wide area and that it was not too surprising that another large event at shallow depth occurred in September very near that of May.

On the basis of these considerations it is very advisable that geodetic measurements (of distance and heights) begin in Friuli as soon as possible.

REFERENCES

Caputo,M., Tables for the Deformation of an Earth model by surface mass. distribution, "Journ.Geophys. Res". 67,4, 1611-1616, 1962.

Caputo, M., Keilis-Borok, V.I. Kronrod,T.,Molchan,G., Panza,G.F., Piva, A., Podgaezkaya, V.,Postpischl,D., Model of earthquake occurrance and isoseismals in Italy."Annali di Geofisica".XXVI,2-3,421-443, 1973.

Caputo,M.,A mechanical model for the statistics of earthquakes magnitude moment and fault distribution; presented at the Symposium on Mathematical Geophysics. Frankfurt, 1976.

Console,R., Meccanismo focale di alcuni terremoti del Friuli nel 1976. (In preparation).

Keilis-Borok,V.I., On the estimation of the displacement in an earthquake source and of source dimension. "Annali di Geofisica". XII,2, 205-213, 1959.

Gasparini,C., Andamento spazio-temporale dei fenomeni sismici in Friuli nel 1976. (In preparation).

I.N.G.,Supplemento al Bollettino Sismico definitivo, Maggio-Giugno 1976, Friuli (I^ parte). Istituto Nazionale di Geofisica, Roma, Settembre 1976.

LINEARS STUDY IN FRIULI BY MEANS OF LANDSAT-2 IMAGES

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ABSTRACT

The aim of this work is the study of linears from Landsat-2 images recorded over Friuli during I975.
Methodology and results are described with special reference to the comparison of several passes analyzed in different bands, scales and photographic support.
A particular attention is devoted to the selection of the most significant data in connection with the geology of the examined areas.

FOREWORD

As soon as they were available in I972 the Landsat (formerly ERTS) images gave a large contribution in the field of structural geology.
Up to day, after about four years of applications, the major scientific relevance continues to be the exceptional ability to show large geologi

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cal linear features such as faults, folds, lithologic boundaries, etc. of regional or subcontinental size.

Landsat images, such as the ones utilized in our research, proved to be remarkably effective in revealing new "linears", many of which, upon field investigation, were classified as faults, joints, or fracture zones. [oo]

Since the first studies the meaning of these linear features has been analyzed both from theoretical and practical point of view.

Uncontrolled mosaic, multispectral and multitemporal images have recognized linears ranging from few kilometers to hundreds of kilometers in lenght which were known only in part or completely unmapped before.

For the above mentioned experiences, testified by several researches yet performed both in several foreign countries and in Italy also by us we decided to utilize for studies of this kind some Landsat-2 images covering North Italy (East-side).

The goal is to obtain for the Friuli area a complete analysis of large linears by means of photointerpretative techniques. For a better level of accuracy different passes, scales, spectral bands and photographic supports have been employed.

This was done also to select the best configuration of these three elements (passes, spectral bands and scales) for tectonic studies in Alpine environment.

We are aware from our direct experience, of the high level of accuracy reached by more sophisticated interpretation techniques such as the digi

[oo] Linears are defined as those phenomena which in satellite images exhibit a continuous "about linear" trend
Lineaments are those linears which upon an appropriate control show a clear geologic source of the phenomenon

tal and analogic electronic processing and up to day (Dicember I976) we are working on two researches in this field but, nevertheless, we think that the thematic maps obtained from this stage of the work are a good standpoint and can be utilized by geologist and geophisicist as an aid to the studies they are performing in this region.

LANDSAT 2 SATELLITE (Formerly ERTS-B)

The two Landsat satellites (previously named ERTS-Earth Resources Technology Satellites) were launched by NASA respectively on July 23rd I972 and January 22nd I975.

Landsat 2, in the same way of Lansat I, operates in a circular, sun synchronous, near polar orbit at an altitude of about 900 Km. The orbit has been selected so that the satellite ground trace repeats it earth coverage at the same local time every I8 day period.

Satellite surveying sistems record data from a ground belt I85 Km wide and include one Return Beam Vidicon Camera (R.B.V.), one Multispectral Scanner (MSS), one Data Collection System.

The Multispectral Scanner is the system which up to day has been operating with the highest level of reliability. MSS is a line scanning device which uses an oscillating mirror to continuously scan the earth surphace perpendicular to the spacecraft orbit. Optical energy is sensed simultaneously by an array of detectors in four spectral bands, i.e.: green (0.5-0.6 micron), red (0.6-0.7 micron) red-near infrared (0.7-0.8 and 0.8-I.I micron).

Nominal ground resolution of the system is 80 meters.

The detector outputs are sampled, encoded and formatted and can be transmitted to the ground receiving station directly or after recording.

The ground station equipment in connection with the NASA Data Processing Facility generates both Computer Compatible Tapes (C.C.T.) and photographic images.

In our work we have been utilizing Landsat 2 photographic images corresponding to September 10th, December 9th and 27th 1975 passes (Fig.1a,b; 2a,b; 3a,b).

IMAGE ANALYSIS

The space images we studied include the four spectral bands mentioned before and different types of NASA photographic material.

For this reason we had the opportunity to analyze the Landsat 2 images in a very detailed way in order to obtain:

1) The most objective methods to recognize and classify linears
2) The best image properties, from bands and scales point of view, for the analysis of linear phenomena
3) A reliable evaluation of geologic significance of the mapped linears

The first step of the work was the selection of the spectral bands which could better fit with the study.

From our experience in the framework of applications in structural geology and also in applied geomorphology, red (0.6-0.7 micron) and near infrared (0.8-1.1 micron) bands seem to be generally the most meaningful ones. Moreover near infrared band (MSS7) in our environmental conditions is also more useful because, due to its wavelenght, it shows clearly phenomena not detectable in visible portion of the spectrum and in addition exhibits sharper contrasts in function of a less atmospheric attenuation of the energy reflected by the earth surphace.

The study of our images was done following these steps:

a) Analysis and drawing of linears (from Landsat 2 frames)

1 - From I:I.000.000 positive film of band 7 (Fig.4 a,b)

2 - From I:500.000 print of band 7 (Fig.5)

3 - From I:250.000 prints (B&W) bands 7 and 5 (Fig.6 a,b)

b) Rose diagrams compilation for lenght distribution of linears referred to the whole area of the image (Fig.8 a,b,c,d)

1 - For angular grouping of 10°

2 - For angular grouping of 22.5°

c) Rose diagrams compilation for lenght distribution of linears (angular grouping:10°) referred to structurally homogeneous blocks

1 - From I:I.000.000 positive film (Fig.9 a,b,c,d)

2 - From I:500.000 print (Fig.10 a,b,c,d)

d) Rose diagrams compilation (angular grouping: 10°) referred to the lenght of lineaments of inferred tectonic source.

1 - From I:I.000.000 positive film in the whole geologically controlled area (Fig.11)

2 - Idem for each single block (Fig.12 a,b,c,d)

e) Lineaments map in the area geologically controlled

1 - From I:I.000.000 band 7 positive film of 9/10/'75 (Fig.7)

f) Comparison of these data with the ones coming from geologic lectera ture.

The results of the above mentioned steps (a-e) are in Fig.4÷12.

FIRST CONSIDERATIONS

a) In the field of interpretation

From the analysis of the Landsat 2 images we are able to present the following considerations:

1 - Band 7 exhibits a structural information content higher qualitative

ly than band 5; example:

b7 Dec. '75 linears n.262 total lenght Km 2989

b5 Dec. '75 linears n.234 total lenght Km 2II9

(From I:250.000 print)

2- The b7 image recorded on IOth Sept.(AZ I4I° EL 42°) exhibits a total number of linears higher than the 27th Dec.'75 one (AZ I52° EL I5°) partly due to change in snow cover; example:

b7 Sept '75 linears n.470 total lenght Km 438I

b7 Dec '75 linears n.2I8 total lenght Km 2I49

(From I:I.000.000 positive film)

3- The informations derived from positive film (scale I:I.000.000) seem to be better detectable expecially from a regional point of view in comparison with the corrisponding prints also in a more detailed scale. In fact we have noted that the "linear phenomena"have in general a lower level of comprehensive detectability in the larger scales.

This is also partly due to the fact that the images recorded on positive films have more detailed contours and more accuracy in gray levels scale than the corresponding prints.

The rose diagrams of density and lenght of linears of two different periods (September and December '75) enhance in September the trends connected with WNW-ESE components while in December have no particular prevailing direction.

b) In the field of geology

Friuli region, located in the Eastern of Southern Alps, was affected by alpinic and ercinic orogeny.There is a number of faults and overthrusts and some folds in the Prealps.

The principal structural elements strike E-W (Fig.I3) while faults system have NW-SE, NE-SW and N-S strike. NW-SE fault system in related with Di

narides belt, which is in the south-eastern side of the studied area. Faults, with NE-SW strike, are "alpine" and related with "giudicarie" fault system.

Total field linears, which are the result of the analysis of Sep '75 I.I.000.000 positive film, were "filtered" in order to draw the lineaments of the area. It was not possible to classify the whole area, in fact the eastern portion (Jugoslavia) was lacking from the point of wiew of geological map resources.

Moreover, due to the geologic complexity of the territory, the area interested at the highest level by May 6th '76 earthquake was divided into 4 blocks having homogeneous structural charachteristics.

The four blocks correspond to: A block-Tolmezzo Alps p.p.; B block - Julian Alps p.p.; C block-Julian Prealps; D block-Carnic Prealps p.p.

Density and lenght of linears and lineaments are computed and draft by means of rose diagrams, which gave rise to the following comparison:

I - Total field of lineaments (Fig.II) towards total field of linears (band 7 of Sept IOth and Dic 27th passes, Fig.8).

It is noticeable a certain analogy between the total field of linears in Dic 75 (Fig.8d) and the total field of lineaments of Sept. '75 (Fig. II). This fact may be due to the E-W component of the geological structures in the area that could be enhanced by sun azimut and elevation during the mounth of December.

2 - Total field linears towards total field of lineaments in the four blocks (Fig.9-IO-I2).

In fact in the four blocks the comparison linears-lineaments shows about equal values in C, a lower agreement in A and B, and a very different behaviour in D.

This event may be due to the concourse of three main factors:

I) Methodology in drawing linears

2) Type and age of the dislocations in the area

3) Uncorrect evaluation of the rank of the dislocations in the area.

Obviously from our point of view the highest interest is focused where the difference is significant and the evidence of the information in the images may suggest the presence of phenomena till now not well known in their"regional" meaning.

A clear example of this fact appears from the western connection of Fella-Sava Line with the Comeglians- Ravascletto Line.

CONCLUSIONS

Our work seems to suggest the following interesting considerations:

I) In our zones and in particular, but not only, in the Alpine belt the study of linear features provides a basic chartography to be utilized in two ways:

a) As a support for other data of different kind to which it furnishes the capability of a better comprehension and of a better synthesis of large scale phenomena.

b) As a basis for structural geology researches to which refer those new hypotheses or those confirmations that derive from this new way of looking at the regional nature of some phenomena. In certain cases this fact may give rise to a systematic completion of the structural knowledges which are based, it has to be noted once again, on the integrate understanding in a regional scale of those phenomena known only separately at a local level.

2) This study, moreover, offers the possibility of framing in a correct and operative way the utilization of semi-authomatic technologies for satellite images interpretation.

This is due to the fact that the authomatic portion of the interpretation both analogic and digital (Fourier spectra, edge enhancement, derivative function, etc.) has to be driven by the geological characteristics of a certain area as seen also from their response in space coming images. In this way it will possible to achieve the best objective results to be compared with those detailed information coming from different levels (surveys on ground and airplane imaging) which are the normal complement of space satellite imaging systems.

REFERENCES

ASSERETO R. et Al.: "Carta geologica d'Italia Foglio I4 A, Tarvisio" Scala I:I00.000, Roma,I968.

BOZZO G.P., SEMENZA E.: "Nuovi elemnti tettonici del vallone di Fadalto e loro inquadramento nella struttura del Veneto nord-orientale", Boll.Mus.Ven. suppl.24,pp.II-25, Venezia, (I973).

CANTELLI C. et Al.: "Carta geologica d'Italia Foglio 4-I3, Monte Cavallino-Ampezzo." Scala I:I00.000, Bergamo (I97I).

CARDAMONE P., CASSINIS R., CASNEDI R., CASSINIS G., MARCOLONGO B., TONELLI A.: "Study of regional linears in central Sicily by satellite imagery", Tectonophysics, 33(I976).

CAVALLIN A.: "Osservazioni sulla tettonica nella conca di Tramonti (Prealpi Carniche)" Riv.Ital.Paleont.Strat., V.82, n.2, pp.285-292, Milano, I976

DAINELLI G.: "La struttura delle Prealpi Friulane", Mem. Geogr., pp.I-220, I03 Fig., I schizzo tett., Firenze (I92I)

DE NARDI A.: "Schema tettonico del Massiccio Cansiglio-Cavallo nelle Prealpi Friulane Occidentali", Mem. Acc.Patav. SS.LL.AA., Cl.Sc.Mat.

Mat. Nat.,v.77, pp.I36-I48, 3 Fig., Padova (I965).

FERASIN F.: "Geologia dei dintorni di Cimolais", Ist.Geol.Miner. Univ.Padova, v.20-3I pp., 3 tav., II Fig., I carta geol. I.25.000, Padova, I956

FERASIN F., BRAGA G.P., CORSI M., LOCATELLI D,: " La linea dell'alto Tagliamento fra la Val Cimoliana ed il gruppo del Verzegnis in Carnia" Mem. Ist. Geol. Miner. Univ. Padova, I3 pp. n.I Fig., I Carta Geol., I:50.000, Padova, I969.

FERUGLIO E.: "Le Prealpi fra l'Isonzo e l'Arzino (Descrizione geologica)", Bull., Ass., Agr. Friuli, s.7, v.39-40, 30I pp., 20 tav., Udine, I925.

GORTANI M.: "Alpi Carniche e stili tettonici", Atti Accad. Sci. Vol. 4, pp. II2-I35, Bologna, (I957).

LOCATELLI D.:"Primi risultati di uno studio geologico sulle Prealpi dell'Arzino in Friuli. (Nota preliminare), Mem. Acc. Patav. SS.LL.AA.CL. Sc.Mat.Nat., v.73 pp.I-I6, 2 tav. Padova, (I96I).

MARINO C.M.:"L'Italia ripresa da satelliti automatici (ERTS-I) e abitati (SKylab): analisi delle caratteristiche operative delle due piattaforme in base allo studio di aree osservate da entrambi i sistemi". Convegno Internazionale Tecnico Scientifico sullo Spazio, I974 , Roma.

MARTINIS B.:"Prove di ampi sovrascorrimenti nelle Prealpi Friulane e Venete", Mem.Ist.Geol.Miner.Univ.Padova, v.25,3I pp., 8 tav., I2 Fig., Padova (I966).

MARTINIS B.:"Geologia generale e geomorfologia del Friuli Venezia Giulia", In : Enciclopedia monografica del Friuli Venezia Giulia Vol.I, parteI, Ist.per l'Enciclopedia del Friuli Venezia Giulia, Udine (I97I).

MARTINIS B.: "The friulian and Julian Alps and Prealps", In: Structural maps of Italy explanatory notes. Quaderni de "La Ricerca Scientifica", C.N.R., pp.I7-48, Roma, I975.

MELVIN H., PODWYSOCKI: "Quantification of geologic lineaments by manual and machine processing techniques", Proceedings of the Nasa Earth Resources Survey Symposium, Houston Texas, June I975, Vol.I-B.

PICCOLI G.:"Studio aerogeologico strutturale del Carso Goriziano - Triestino della Slovenia Occidentale e dell'Istria", Memorie degli Istituti di Geologia e Mineralogia dell'Università di Padova, Vol. XXXI(I975).

SALVINI G.:"Osservazioni geologiche sui dintorni di Bàrcis (Prealpi Friulane)", Riv. Ital.Paleont.Strat., v.75, n.I, pp.I07-I2I, Milano (I969).

SAWATZKY DON L. et Al.: "Geological significance of features observed in Colorado from orbital altitudes ", Proceedings of the Nasa Earth Resources Survey Symposium, Houston Texas, June I975, Vol.I-B.

SELLI R.: "La geologia dell'alto bacino dell'Isonzo (stratigrafia e tettonica)", G.Geol., n.I9, pp.3-I53, Bologna, (I953).

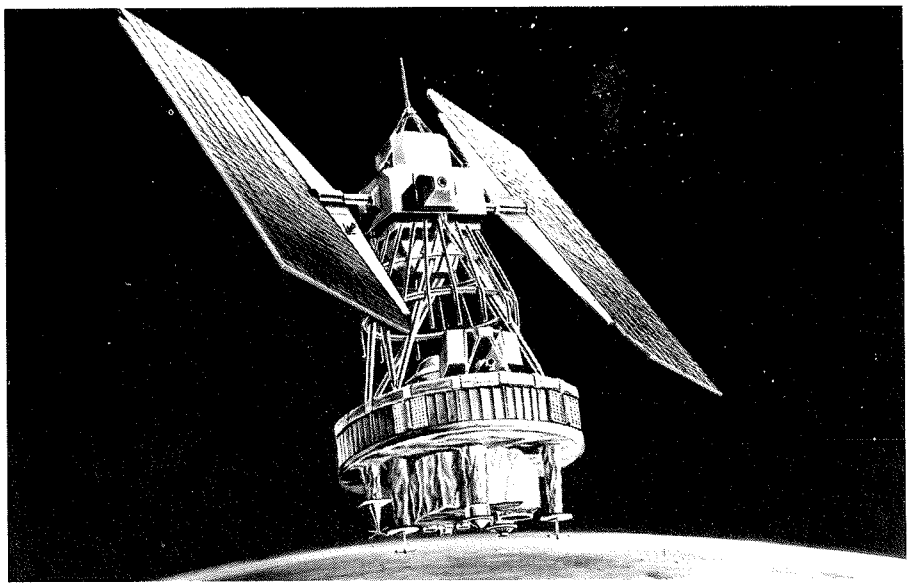
SELLI R.:"Schema geologico delle Alpi Carniche e Giulie Occidentali", Giorn. Geol. s.2,v.30, I2I pp.,7tav., I carta geol.: I/I00.000, Bologna, I963.

SEMENZA E(I974):"La fase giudicariense, nel quadro di una nuova ipotesi sull'orogenesi alpina nell'area Italo-Dinarica", Mem.Soc.Geol.It;Vol. I3, pp.I87-226, I2 ff., Pisa (I974).

ZANFERRARI A.:" Sulla terminazione occidentale del sovrascorrimento, periadriatico (piega-faglia periadriatica auct.) nelle Prealpi carniche", Boll.Soc.Geol.It., v.93, pp.33-46,4 ff., 2 tavv., Roma, '74.

ZENARI S.:" Note illustrative della carta Geologica delle Tre Venezie, Foglio "Maniago", Uff. Idrogr.R.Mag.Acque, v.di I02 pp., 3 tav., Padova, I929.

LANDSAT (ERTS).



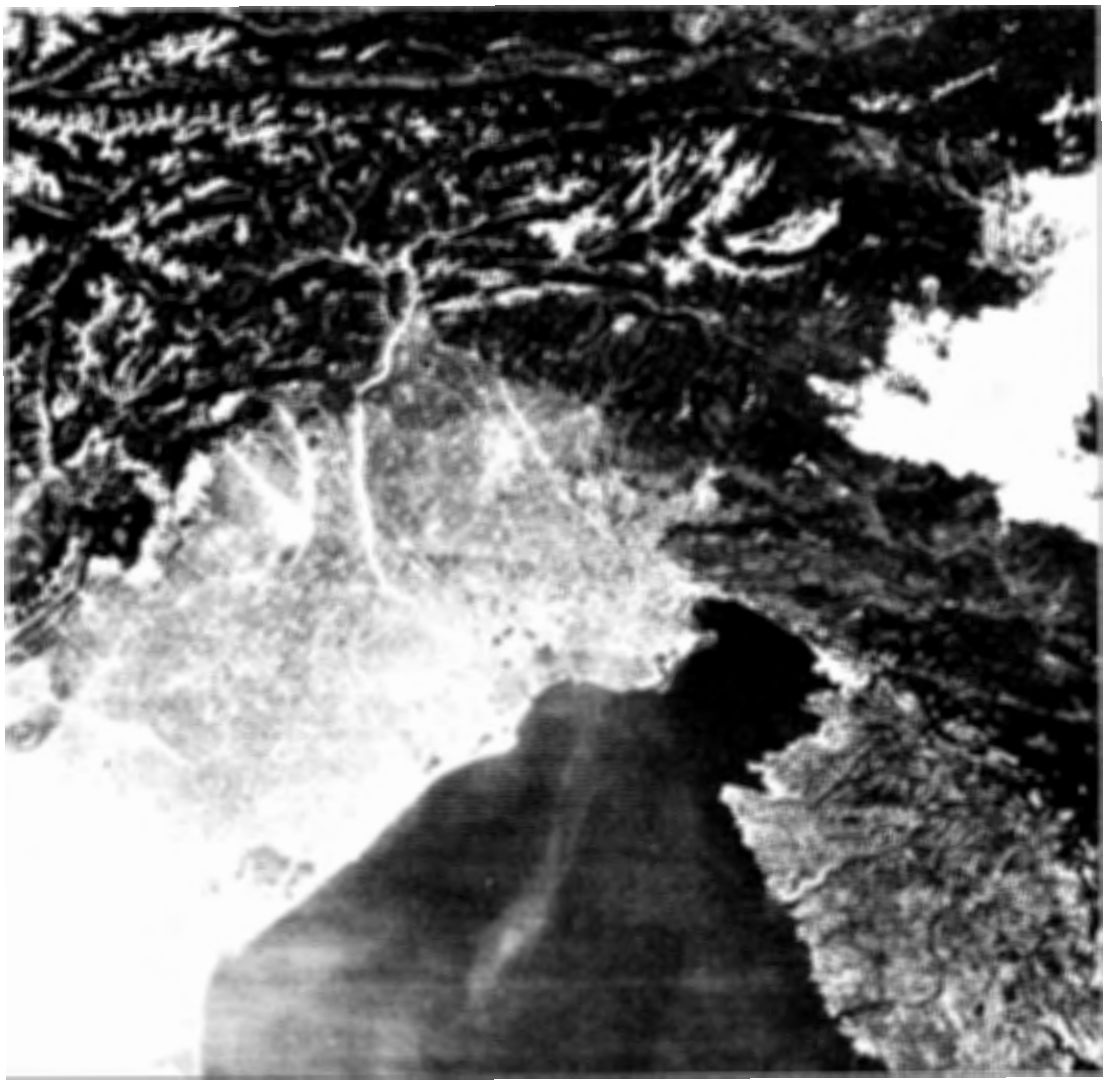


Fig.Ia - MSS5 (9.IO.75 orbit) Landsat 2 image printed from standard 70 mm negative film (swath: I85 km about)

Fig.Ib - MSS7 Landsat 2 image (9.IO.75 orbit) printed from standard 70 mm negative film

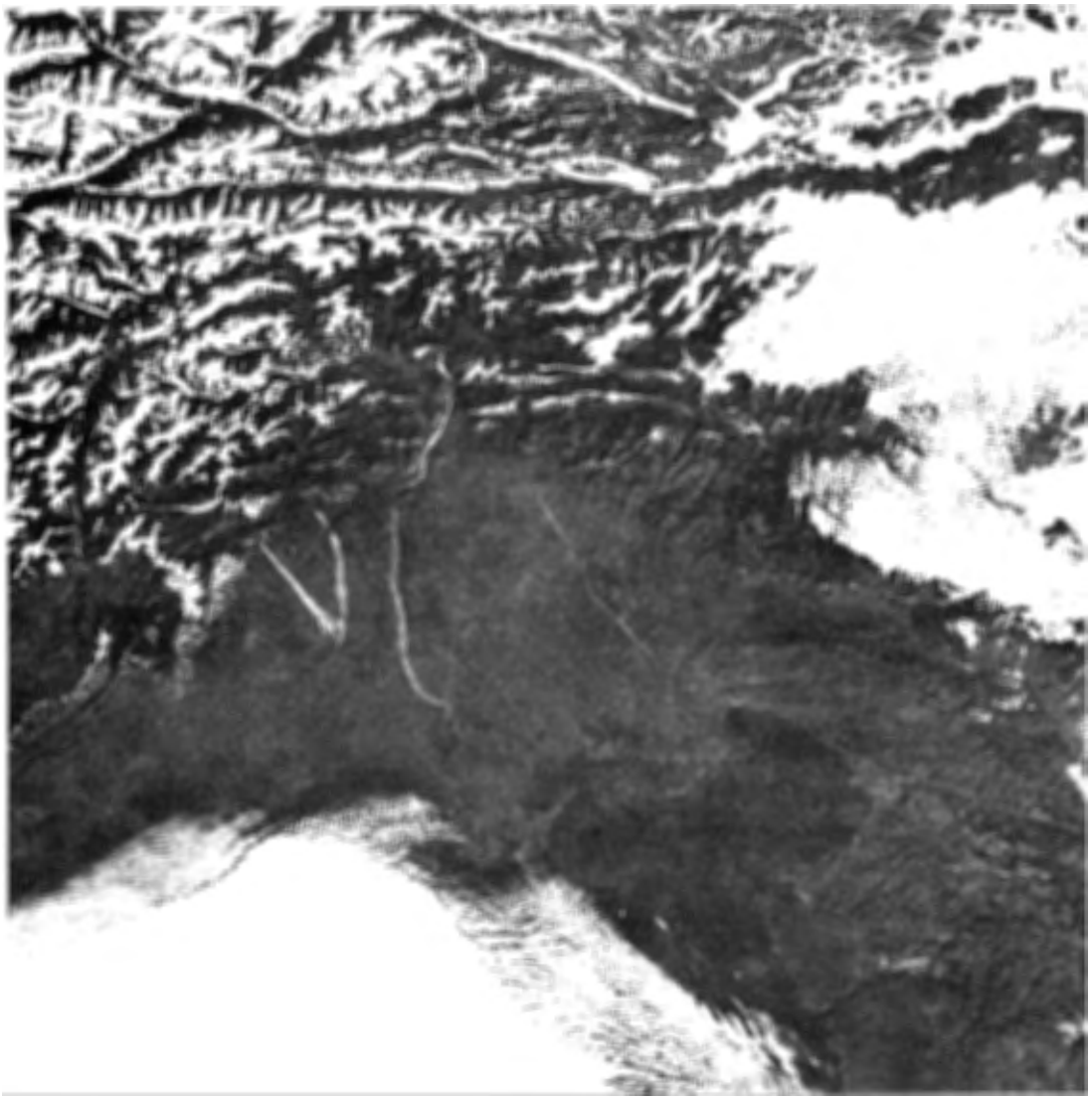


Fig.2a - MSS5 Landsat 2 image (I2. 9 .75 orbit) printed from standard 70mm negative film (swath I85 km about)

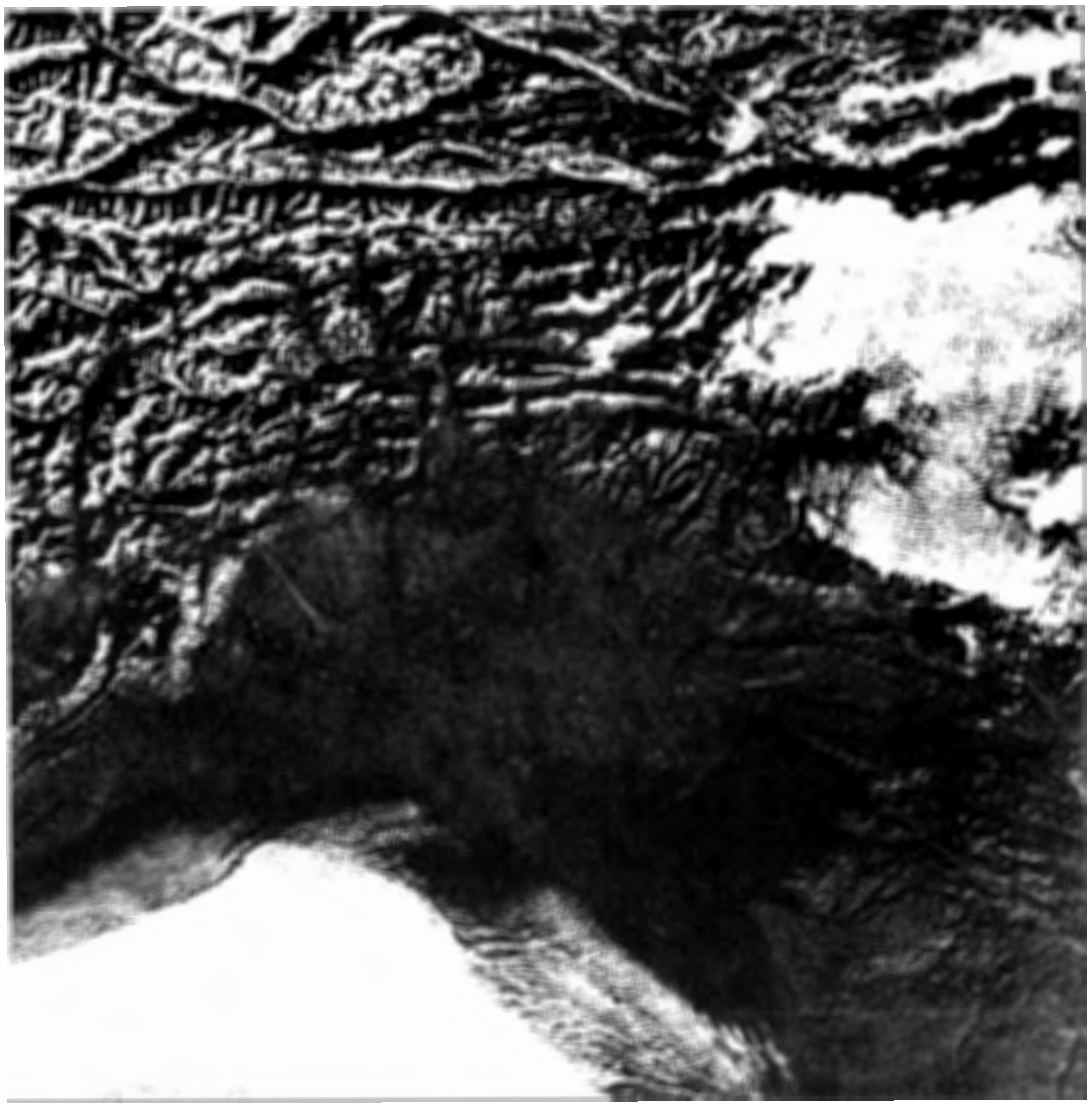


Fig.2b - MSS7 Landsat 2 image (I2.9.75 orbit) printed from standard 70 mm negative film

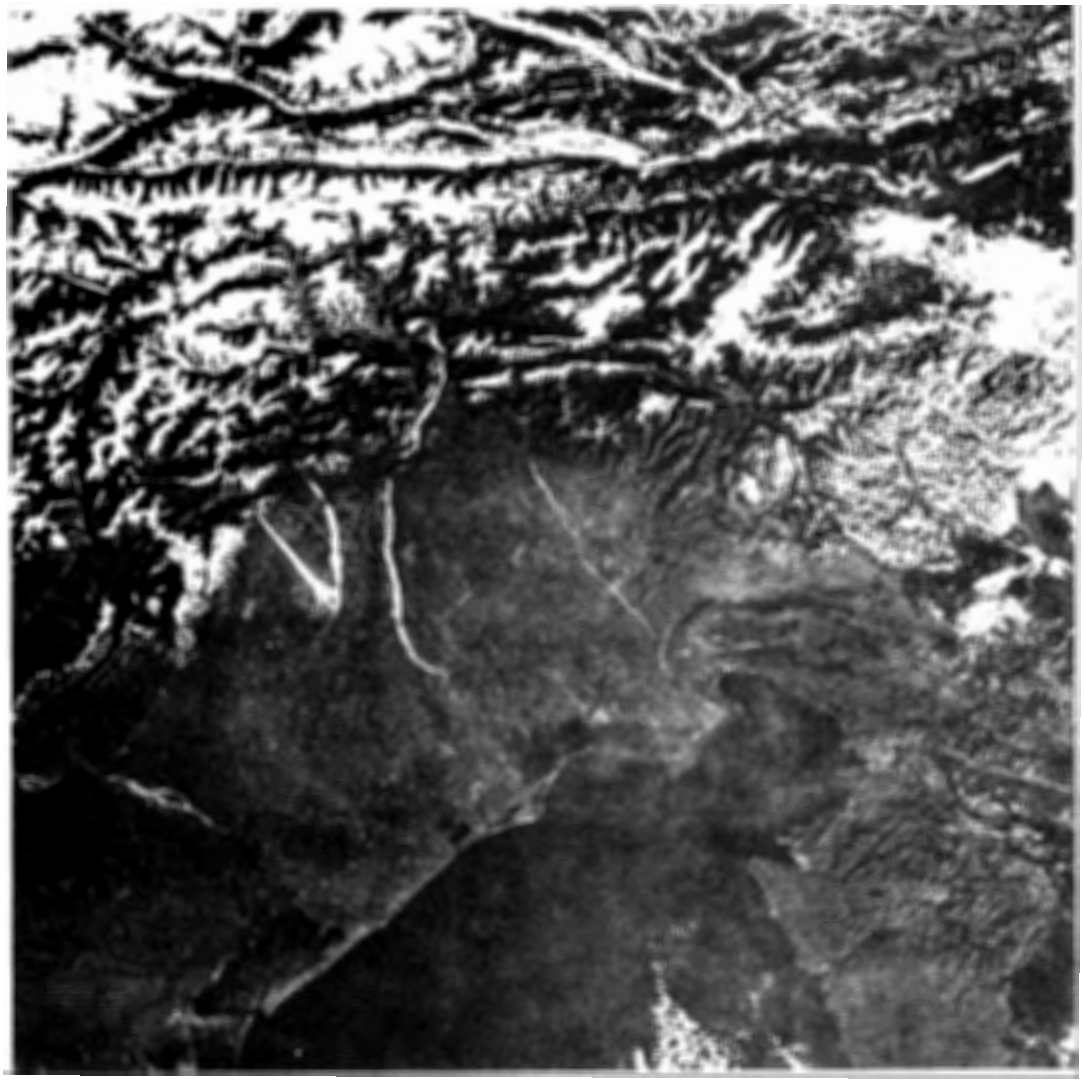


Fig.3a - MSS5 Landsat 2 image (I2.27.75 orbit) printed from standard 70 mm negative (swath: I85 Km about)

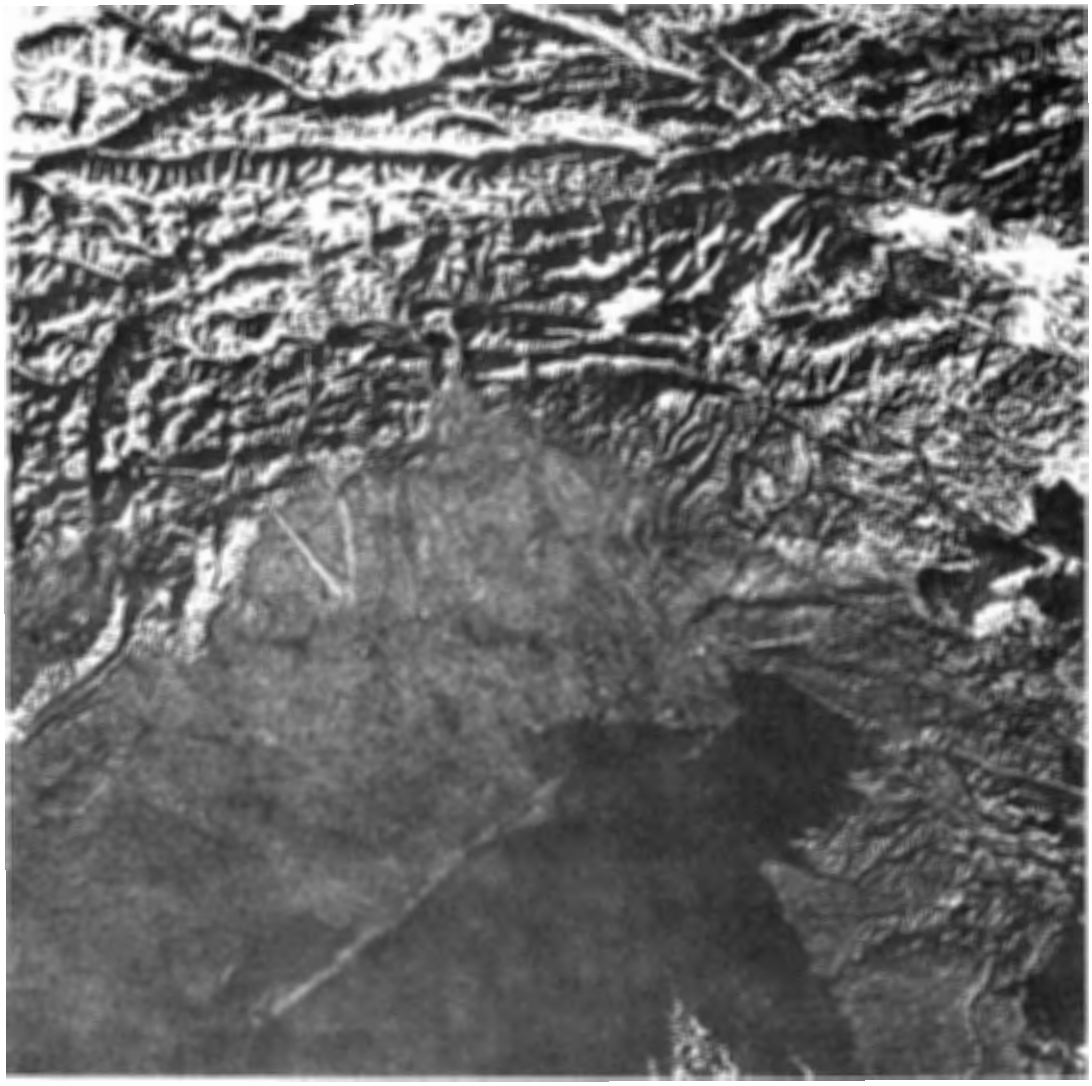


Fig.3b - MSS7 Landsat 2 image (I2.27.75 orbit) printed from 70 mm negative film

Fig. 4a - Linears drawn from b7 1:1.000.000 positive film(9.10.75 orbit) for the whole area of the image (draft)

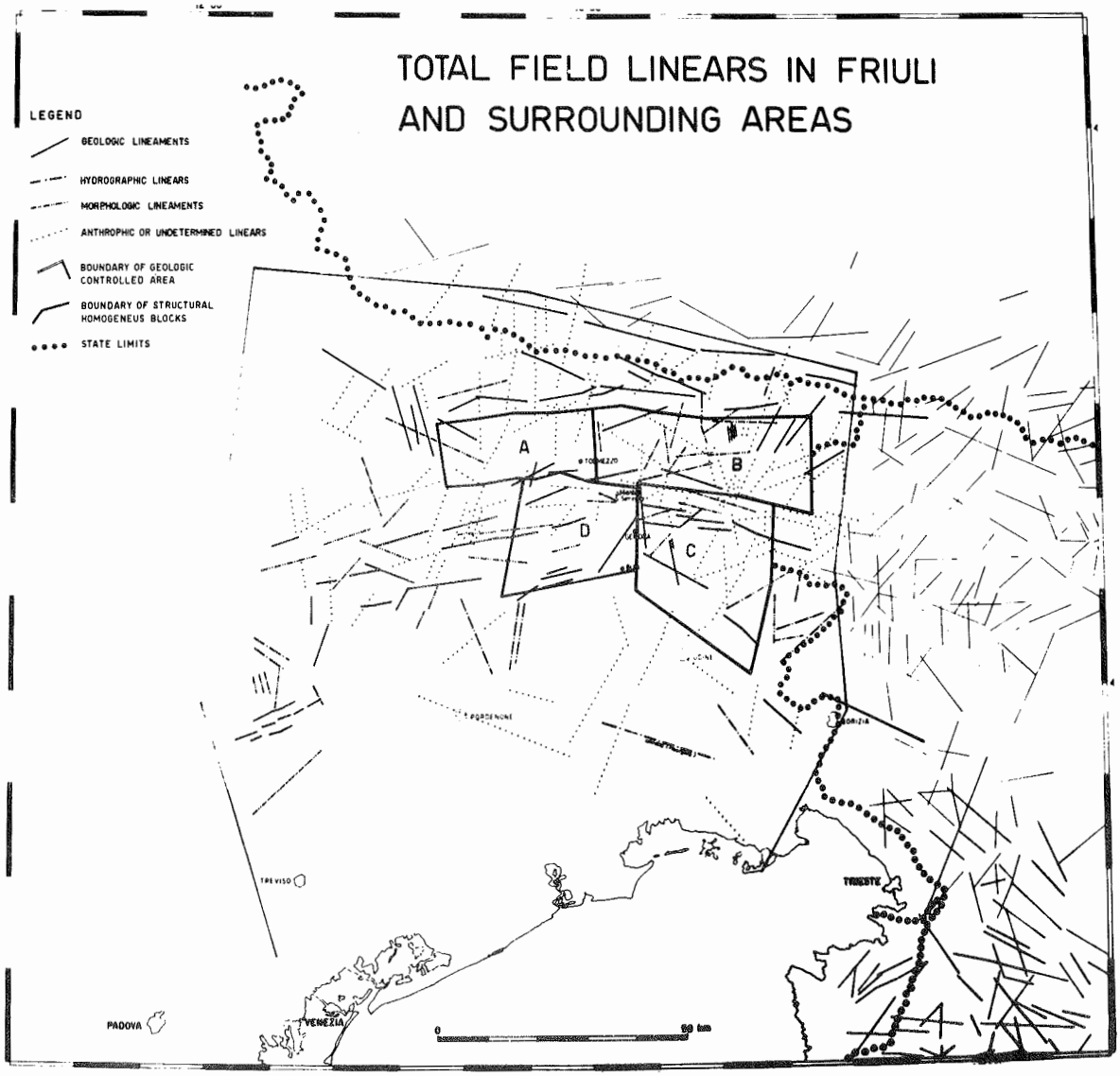


Fig. 4b - Total field linears and their classification (from the same image of Fig.4a) printed on I:250.000 Friuli-Venezia Giulia official regional map

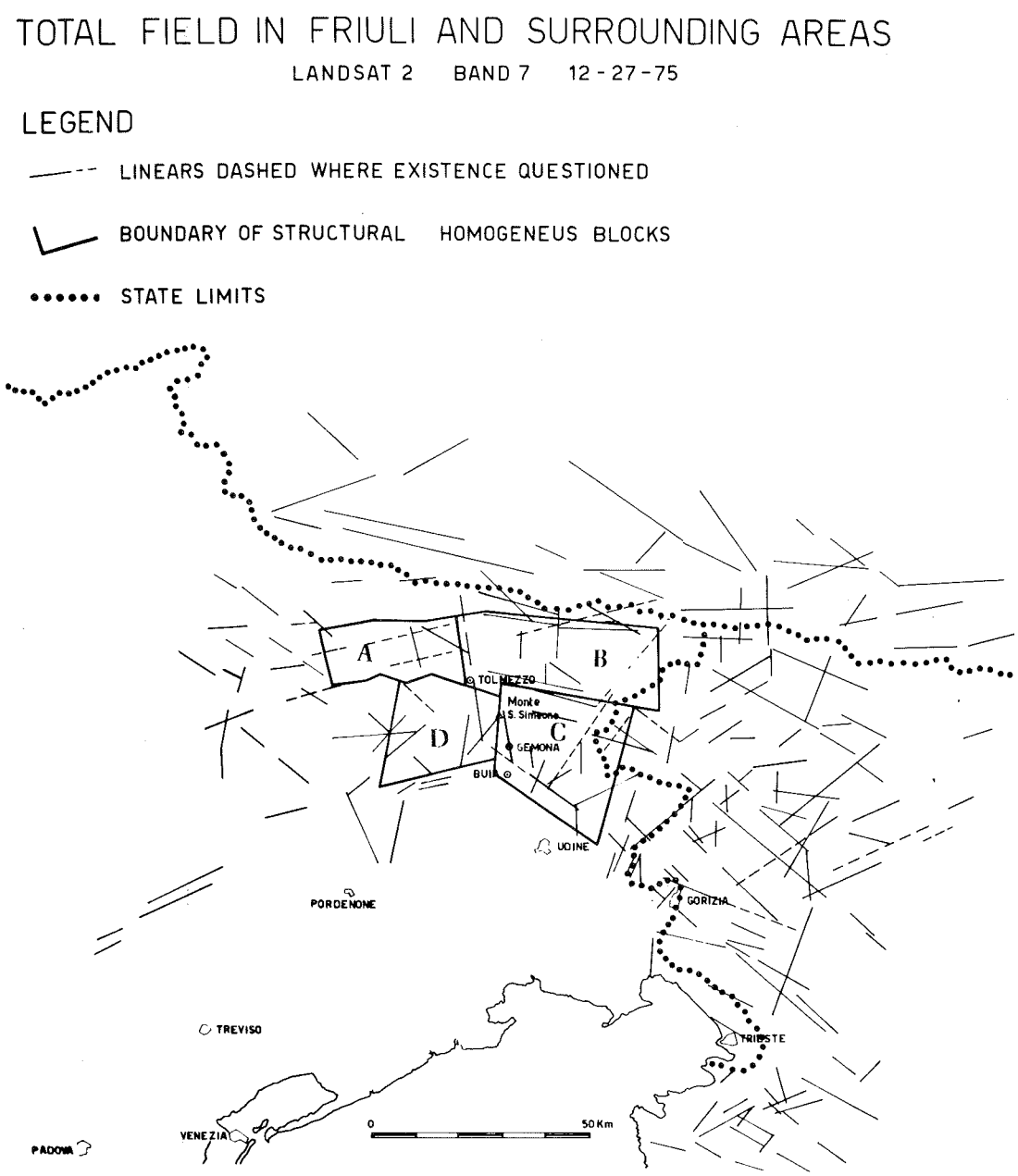


Fig.5 - Total field linears from b7 I:500.000 print (I2.27.75 orbit)

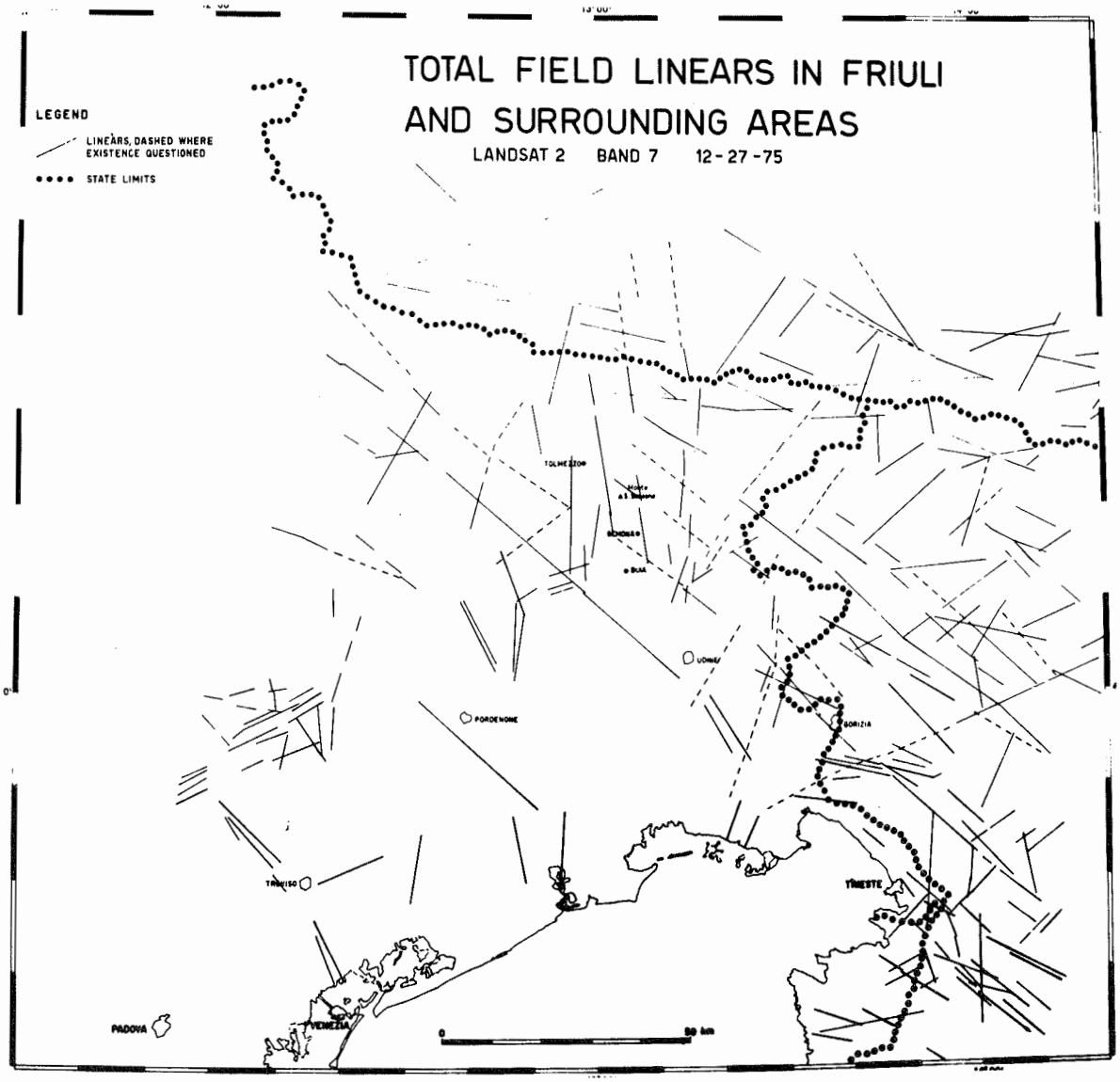


Fig.6a - Total field linears in Friuli and surrounding areas from b7 I:250.000 print (I2.27.75 orbit)

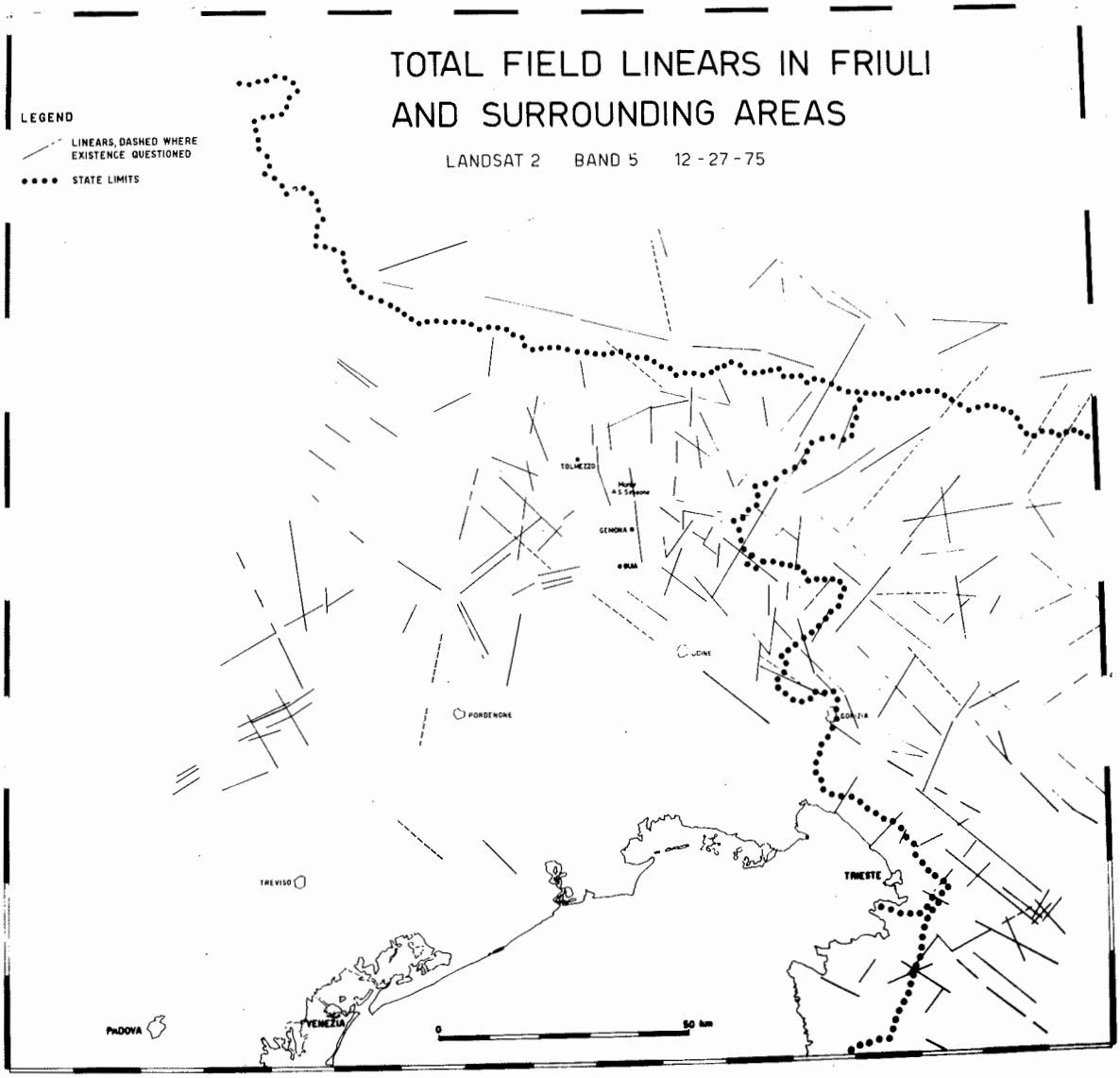


Fig.6b - Total field in Friuli and surrounding areas from b5 I:250.000 print (I2.27.75 orbit)

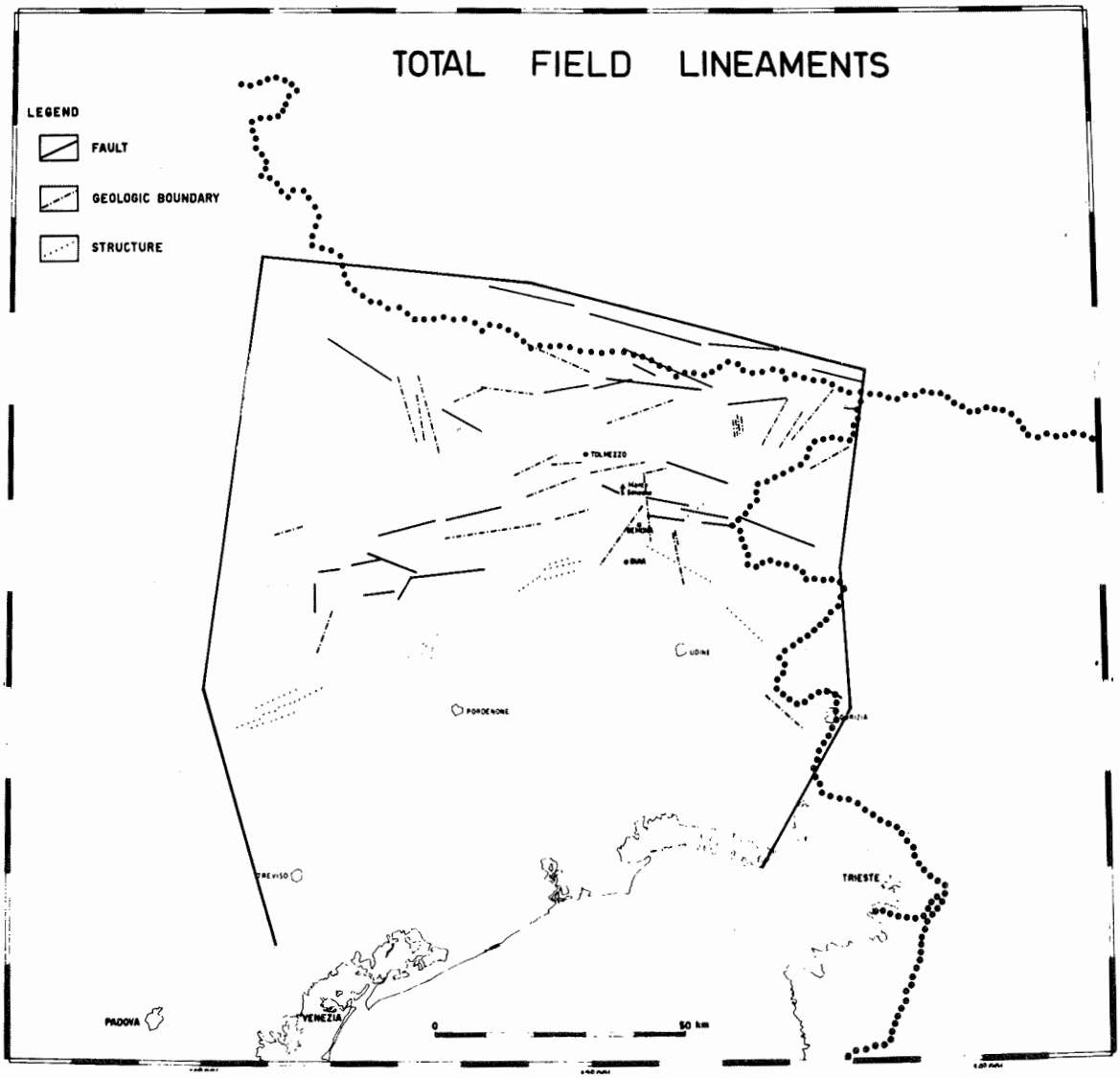


Fig.7 - Total field lineaments map in the geologically controlled area (from b7 I:I.000.000 positive film, 9.I0.75 orbit)

a : from b7 I:1.000.000 positive film (9.10.75)
b : " " b7 I.250.000 print (12.27.75)
c : " " b5 I:250.000 print (12.27.75)
d : " " b7 I:500.000 print (12.27.75)

Fig.8 - Rose diagrams (lenght distribution) of linears referred to the whole area of the image

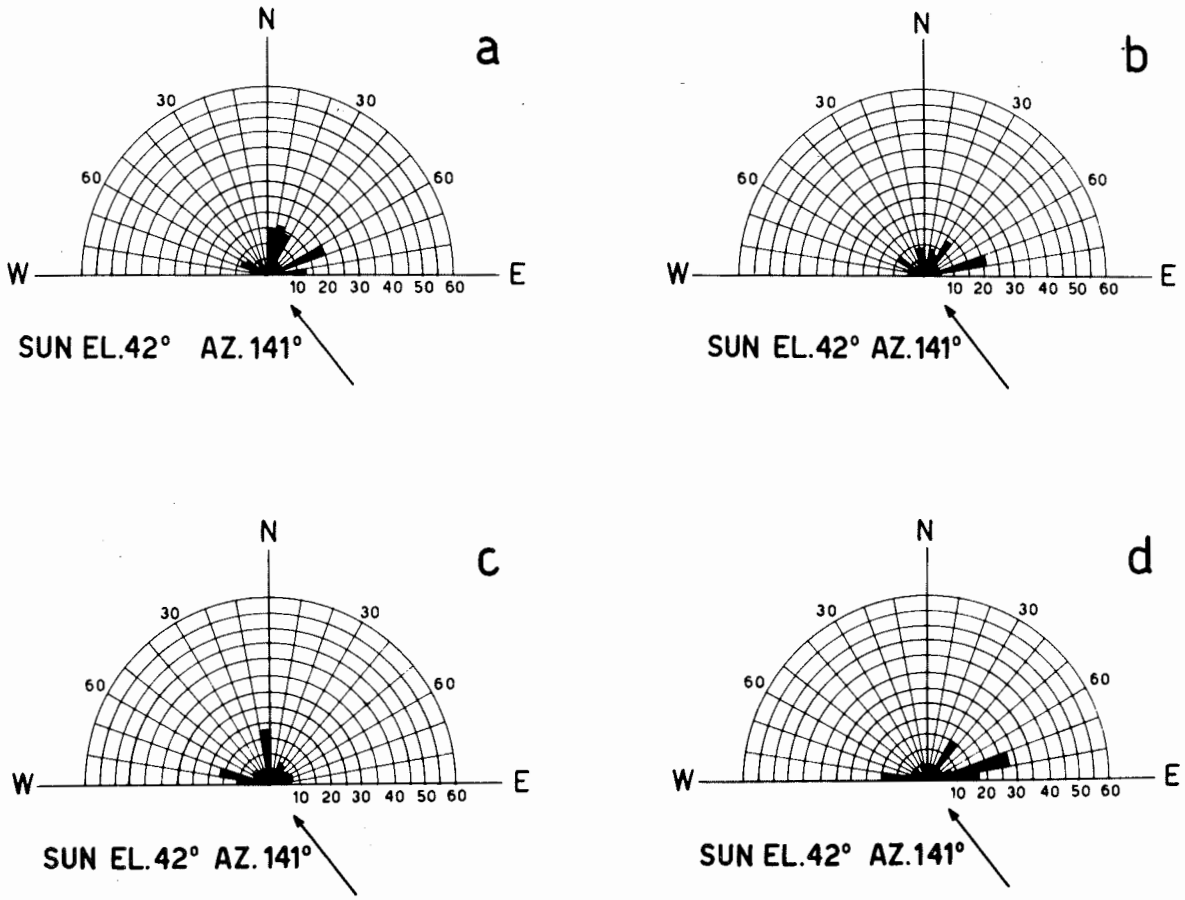


Fig.9 - Rose diagrams (lenght distribution) of linears referred to structurally homogeneous blocks (a,b,c,d correspond to A,B,C,D blocks of Fig.5). The diagrams are derived from I:I.000.000 positive film (9.IO.75 orbit)

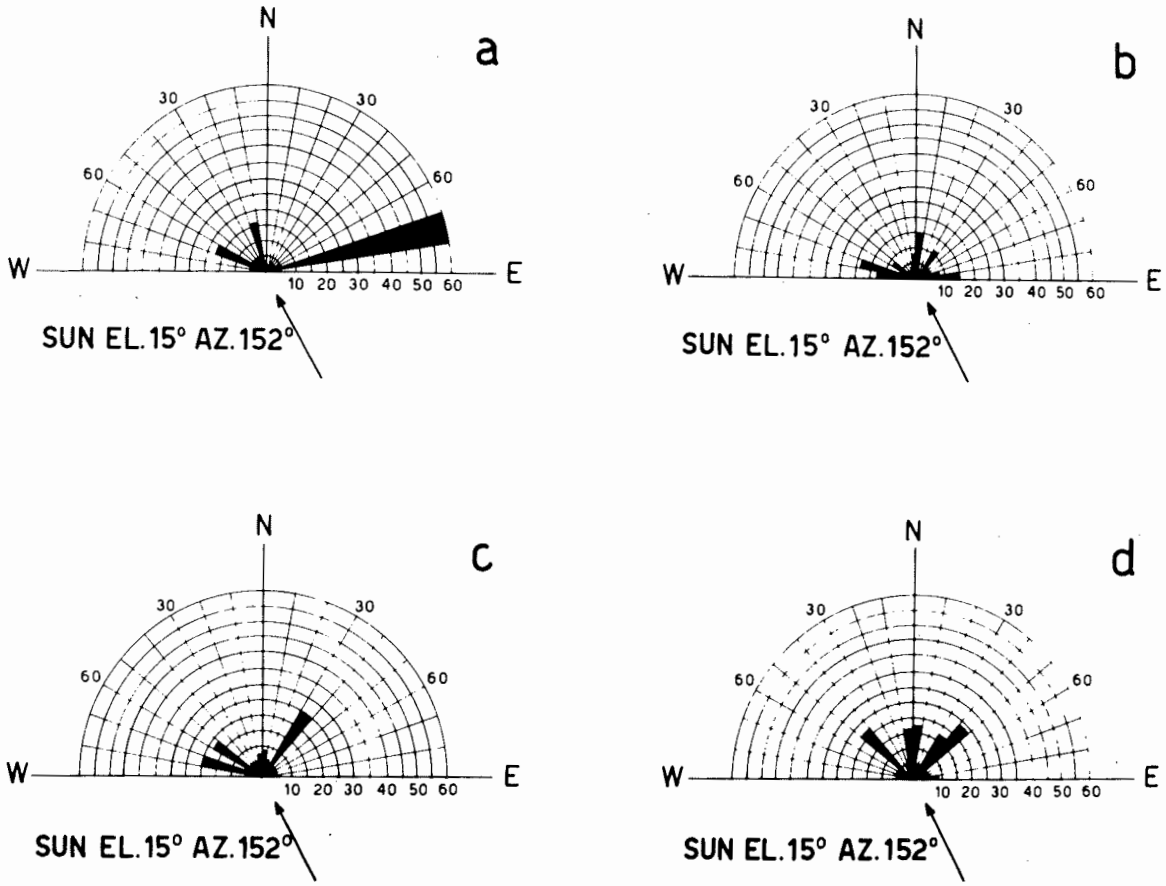


Fig. IO - Rose diagrams (lenght distribution) of linears referred to structurally homogeneous blocks (a,b,c,d correspond to A,B,C,D blocks of Fig.5). The diagrams are derived from I:500.000 prints (I2.27.75 orbit)

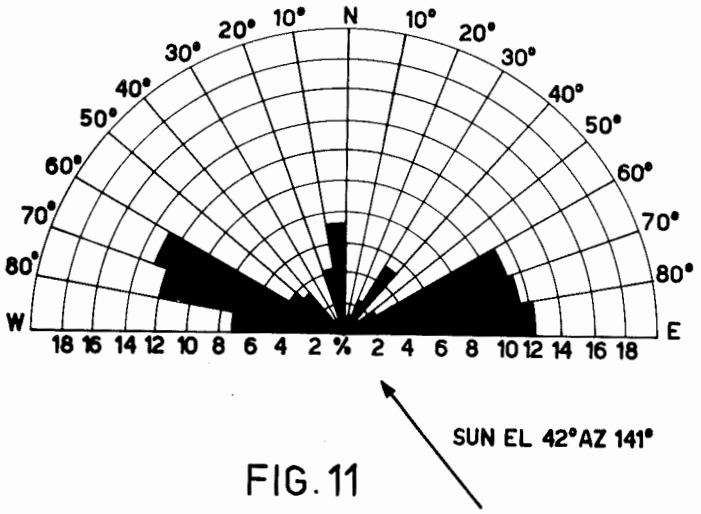


FIG. 11

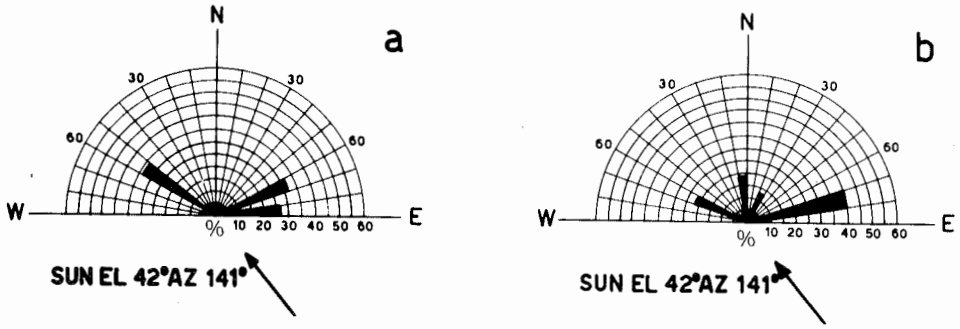


FIG. 12

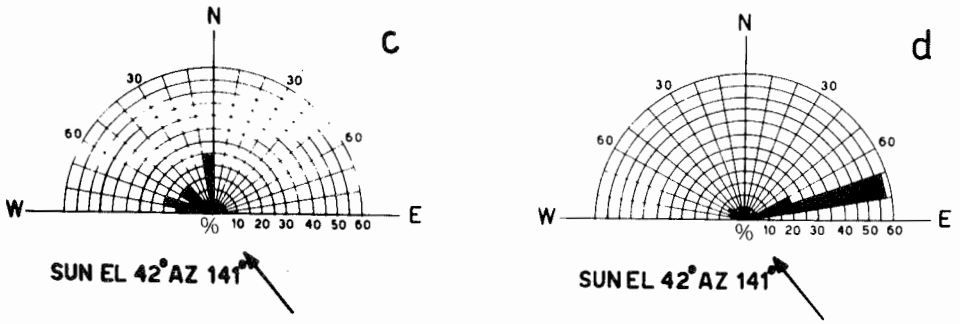


Fig. II and I2

Fig.II - Rose diagram lineaments from b7 positive film (9.I0.75 orbit) drawn for the whole geologically controlled area

Fig.I2 - idem for each single block

TECTONIC SKETCH-MAP OF FRIULI

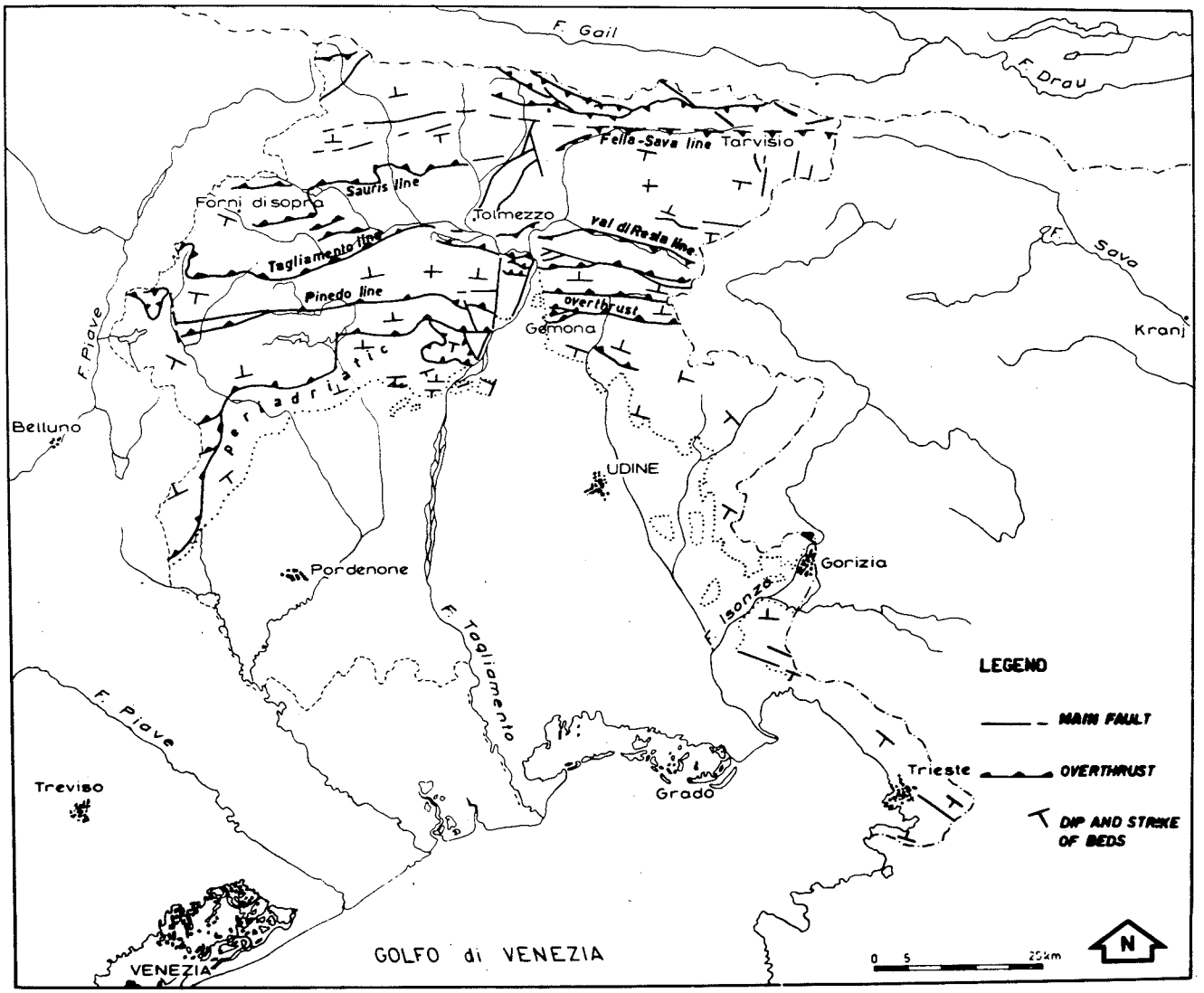


Fig.I3

HORIZONTAL PENDULUM OBSERVATIONS AT TRIESTE

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Abstract.

The Trieste Earth Tide Station equipped with a pair of horizontal pendulums of big dimensions is recording continuously rare interruptions apart, from 1959. Starting from beginning of 1973 jumps as well as oscillatory perturbations have been recorded by both components which appear as forerunning events of the recent Friuli earthquakes. A discussion of the phenomenon is presented.

Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 18.

1. The Trieste Earth Tide Station was installed in 1958, in occasion of the International Geophysical Year, when the International Association of Geodesy promoted the installation of a wide network of Earth Tide Stations around the world.

The Station is located in a big cave (Grotta Gigante) in the Carst near Trieste (Marussi, 1959) and is equipped with a pair of Marussi horizontal pendulums having exceptional mechanical and geometrical characteristics. Owing to such characteristics the instruments are extremely stable in time, they are able to work at very long eigenperiods and their critical damping can be easily reached. The stability has been checked by analysing the annual drift for several years (Zadro, 1972). From the installation the eigenperiod has been of 6 min, except for a short period of time when an eigenperiod of 10 min was preferred in order to get a greater amplification requested by special research (Caputo, 1962). The instruments have always had a critical damping. Their recording device is photographic.

The Station is operating almost continuously since 1959. In the past the analyses carried out on the pendulum records shown the following relevant results:

a) The loading and newtonian effects of water masses (commonly called indirect effects) are of the same order of magnitude as the theoretical Earth Tide itself; a change of

1 cm of sea level recorded in the Trieste harbour corresponds to about .25 msec of apparent deflection of the vertical recorded by the horizontal pendulums (Marussi, 1960; Zadro, 1966; Zadro, 1972; Chiaruttini, 1976).

b) Deflections of the apparent vertical as large as 100 msec of arc with a yearly periodicity are recorded (Zadro, 1972); their origin is unexplicable: the hypotheses of astronomical tide effects as well as snow loading effects in the Alps have to be rejected due to the largeness of the observed deflections; meteorological and temperature effects seem improbable owing to the characteristics of the cave.

c) Due to their long eigenperiod and to the critical damping the instruments gave the best horizontal pendulum records of the free oscillations of the Earth obtained till now in the world (Bolt & Marussi, 1962; Caputo & Zadro, 1968; Pekeris, 1964; Bolt & Currie, 1975). Similarly long surface waves following big earthquakes have been clearly recognized in several occasions (Bernetti & Zadro, 1975). It is interesting to note that the recorded surface waves cover a frequency band lower then the frequency band covered by other kind of instruments.

2. Owing to the critical damping smoothed curves have always been recorded in the past; meteorological perturbations, seiches effects of the Adriatic, underground water effects have been studied (Marussi, 1960; Zadro, 1964; 1966;

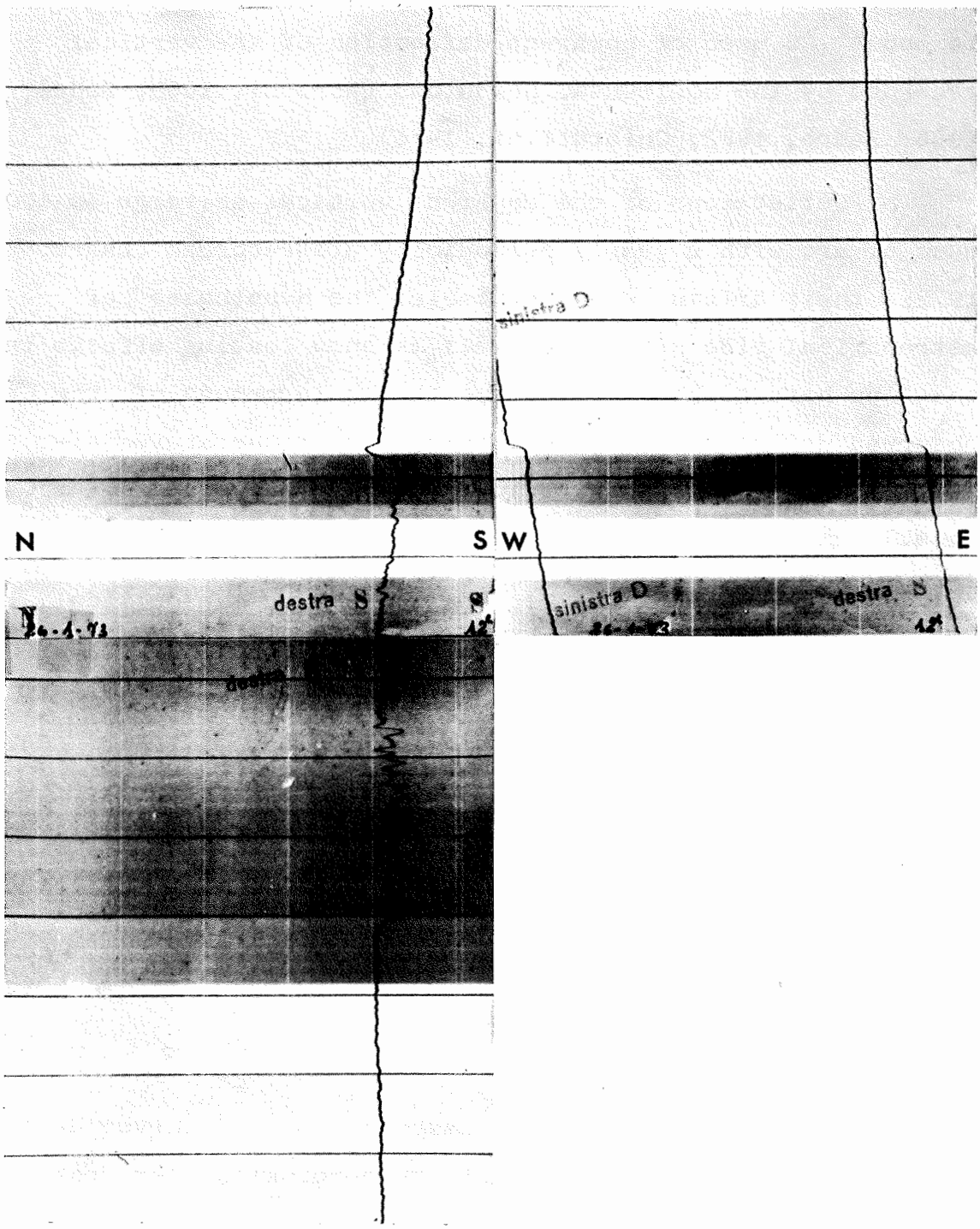

Fig.1 Beginning of perturbations. Parallel lines correspond to hours.

1972) and appear with well-known characteristics.

At the beginning of 1973 (January, 26) a jump large some msec of arc appears on both components (fig. 1), the E-W component shows a permanent deflection towards east while the N-S component shows a permanent deflection towards south after an initial jump towards north. Perturbations of completely new kind are growing after the jump expecially on the N-S component; they disappear after 6 hours. For the E-W component only few hours of records are available due to a damage in the recording device.

During 1973 rare perturbations of the same kind, without evident initial jumps appear simultaneously on both components. In the following years the perturbations are present more and more often. In fig. 2 the sequence duration of perturbations in hours per day is plotted for the E-W component from 1973 till September 1976 (analogous results are given by the other component).

The situation of May 6, before and after the main shock is represented in fig. 3. Following the shock a permanent deflection towards south is recorded by the N-S component after an initial jump in the Northern direction; on the E-W component after the initial impulse no permanent deflections are recorded. It is noteworthy that after the shock the perturbations disappear almost completely for several days. Only on May 20 weak disturbances start being again recorded. In August the records are almost quiet whereas in September

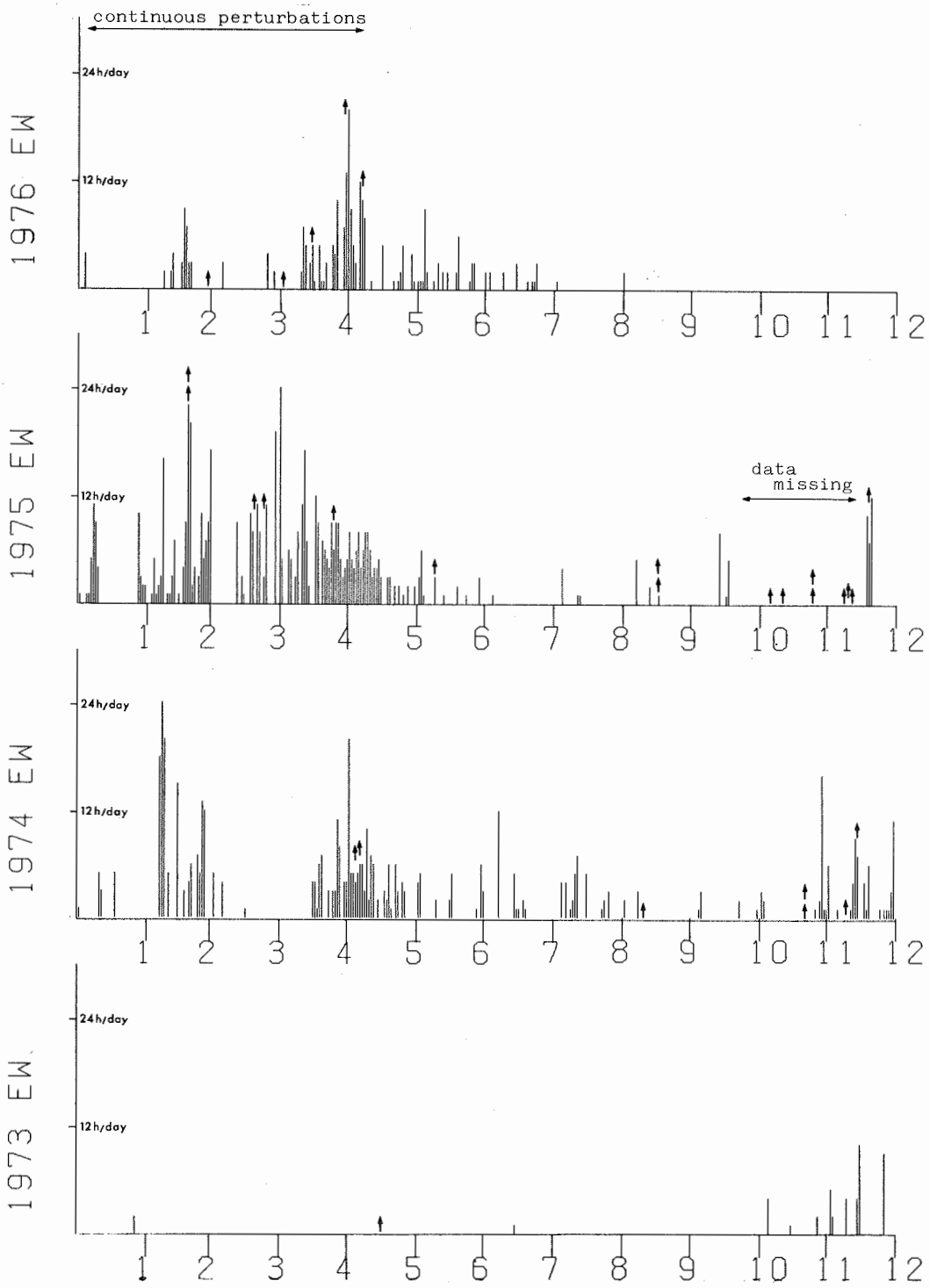

fig.2 Hours of perturbation per day from 1973 till September 1976. Arrows indicate earthquakes; recent earthquakes after May 6 , are missing.

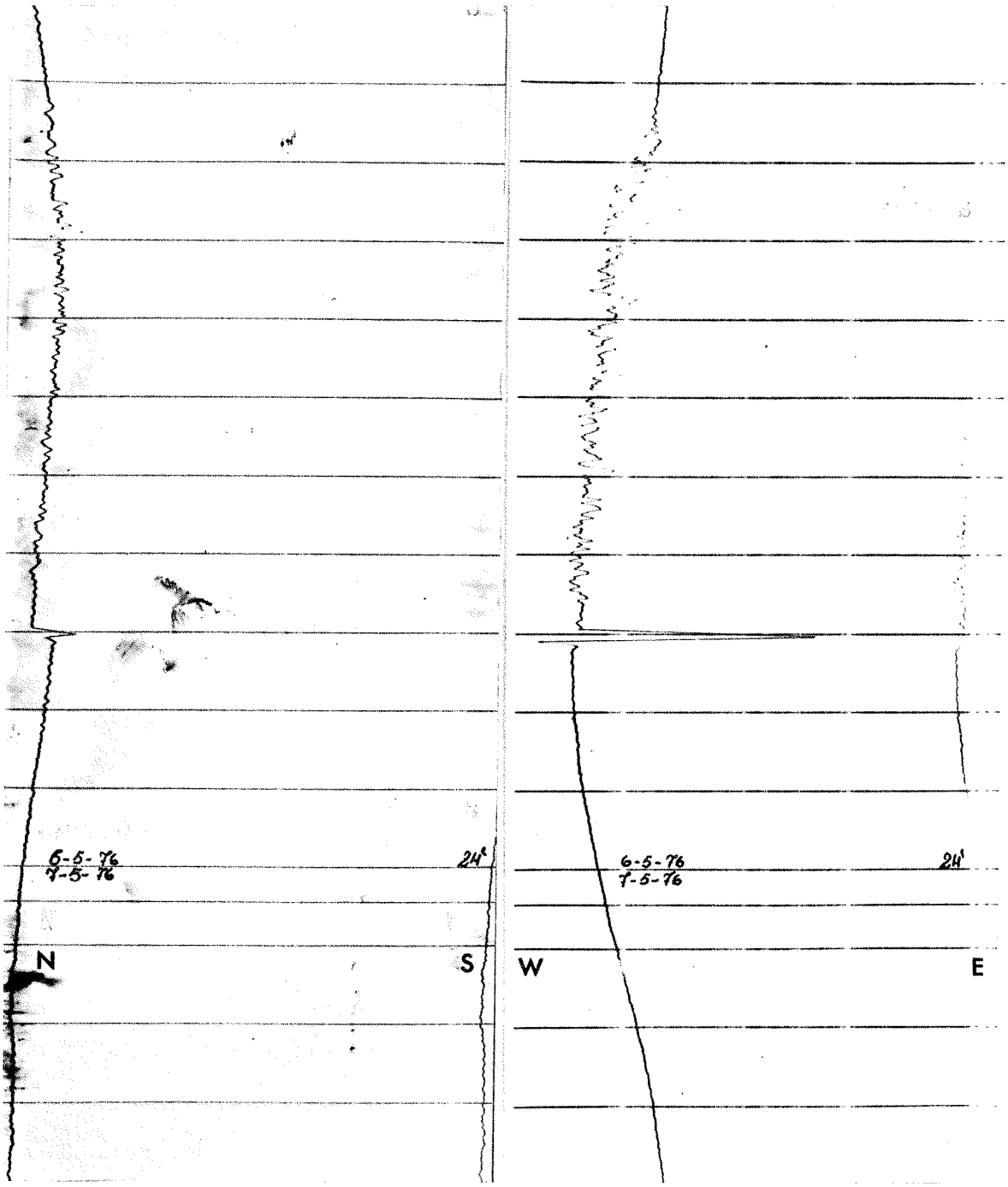

Fig.3 Records of May 6,1976, with the impulse of the shock.

weak continuous perturbations are again present. The earthquake of September 15 has been recorded as jumps by the two components, with a permanent deflection towards west. After that shock till now the records do not present strong perturbations; the greatest perturbation recorded after September is represented in fig. 4.

3. Starting from May 1 the hourly readings for both components have been analysed in order to investigate the jumps and slow drift in the deflection of the apparent vertical. The ideal passband filter with 1/30 and 1/6 cph as cut-off frequencies has been applyed in order to reject tidal effects. The residual curves for August and September are represented for both components in fig. 5. May, June and July are missing since without evident drift effects, a continuous slow deflection toward south and west apart. In order to avoid as much as possible the loss of data at the extremes of the analyzed section a short lag (48 hours) of the filter has been used. For that reason a feable tide still appears in the residual curve. A large drift is visible before the main shock of September (between 3 and 6 of September); since deflections of the same kind have already been observed in the past (Zadro, 1972) any inference on earthquake mechanism is doubtful. Analysis are now in progress on the residual curves starting from the year 1972: their comparison will give more information on the observed drift.

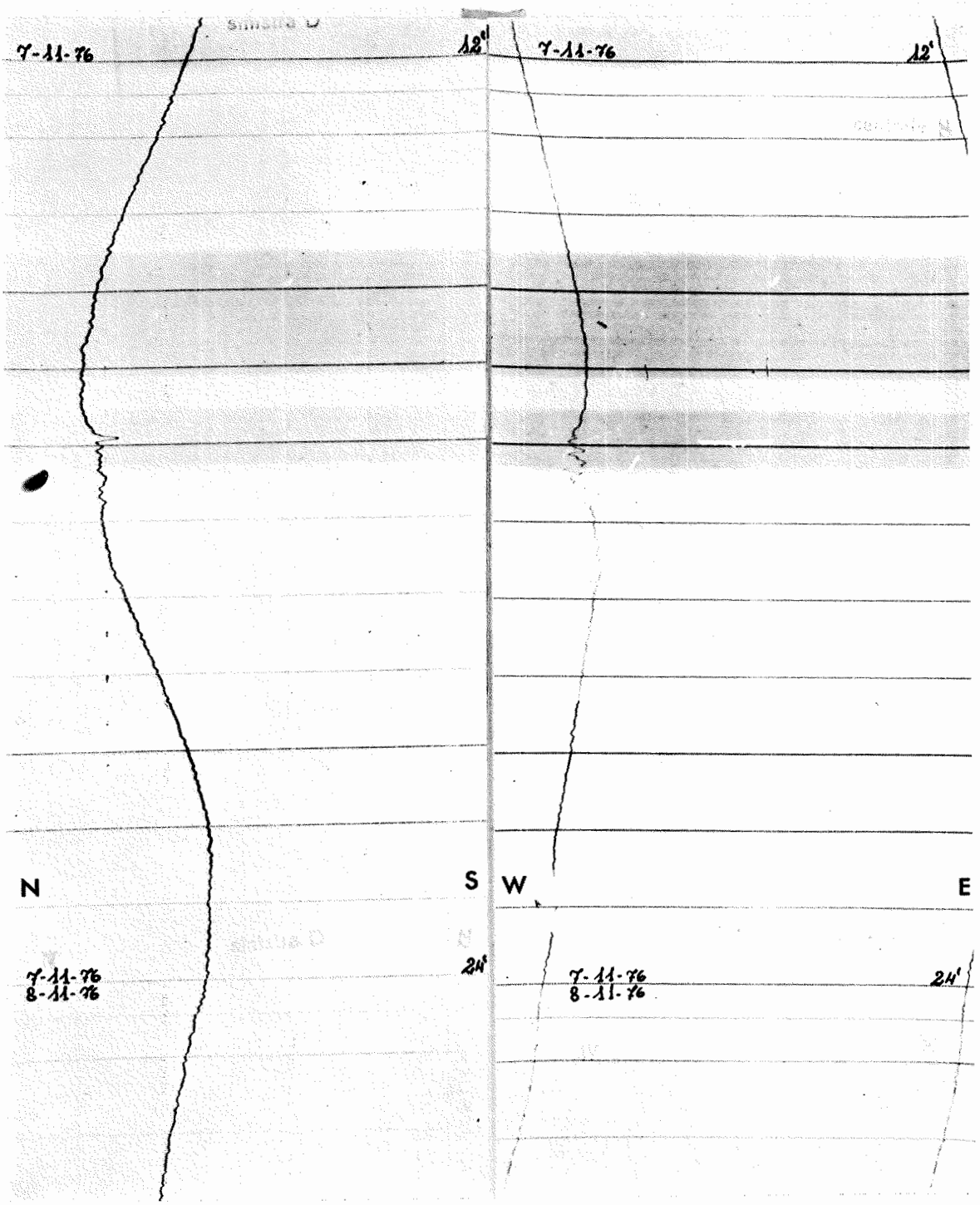

Fig.4 Example of recent perturbation.

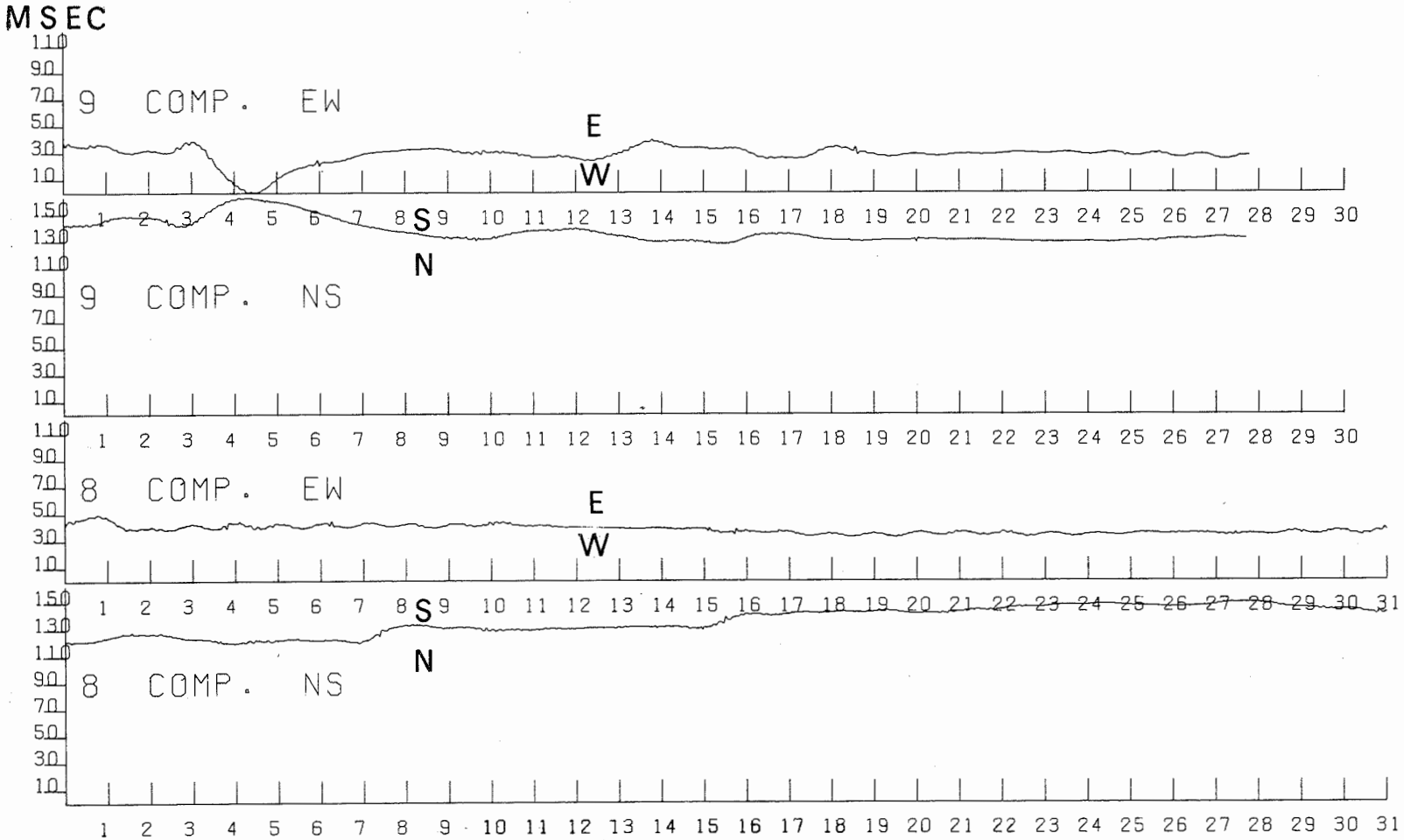

fig.5 Drift of August and September.

4. It is well-known from the current bibliography (see for instance Press, 1965; Fitch & Scholz, 1971; Goulty, 1976; Rikitake, 1976) that crustal deformations are forerunning events of earthquakes also at large distances from the thrust plane. Dilatancy uplift theory as well as creep phenomena added to elastic buildup and rebound are explanations of the time history of the deformations connected with the earthquake mechanism. The jumps and the drift recorded by tiltmeters before the earthquake occurrence have already been observed in many places around the world, and they are analogous to the permanent deflections recorded by the horizontal pendulums of the Trieste Station. For comparison, the records of the Costozza Earth Tide Station (kindly supplyed by Prof. Norinelli, University of Padova) equipped with a pair of Melchior pendulums have been examined for the shock of May 6. There a permanent deflection of some msec of arc towards south and east is recorded. Notwithstanding the lower degree of stability of that kind of instruments, the south deflection of the apparent vertical seems to be also confirmed in that area.

A privileged southern deflection is evident from all the jumping effects recorded, whereas the other cardinal direction appears unperturbed or weakly perturbed. This could be explained by the compressional low which generates the thrusting effect mostly responsible of the actual earthquakes and which is directed roughly N-S.

The sea level records in the Trieste harbour, which in the hypothesis of dilatancy phenomena (Goulty, 1976) should show variations before and during earthquakes, do not appear perturbed as far as the May 6 earthquake is concerned. More detailed analyses of the mean level from the previous records are needed and will be carried out in order to test the dilatancy hypothesis.

The particular kind of perturbations recorded by both pendulums of the Trieste Station since 1973 appear as forerunning events connected with creep or dilatancy phenomena. A confirmation of their connection with earthquakes is given by the correlation of the Friuli earthquakes occurrence with the days of greater perturbations recorded from 1973 till now, as visible in fig. 2, where the Friuli earthquakes occurrence (kindly supplyed by the Osservatorio Geofisico Sperimentale di Trieste) is represented by arrows. Owing to the characteristics of the instruments, unique in the world, the recorded perturbations were unexplained till now, since no other examples could be found in the literature. Recently, Caloi (1976) with shorter-period classical tiltmeters, found in the Friuli region analogous responses before earthquakes. Due to the characteristics of the instruments as well as to the usual high perturbations and drift on those stations (ENEL stations, installed near dams) forerunning events could not be clearly recognized as early as in the case of the Trieste station.

The low of precursor times of earthquakes as given by Scholz and other (1973), states a linear relation between the logarithm of the precursor time and the magnitude of the earthquake; it indicates for the actual case of the Friuli earthquakes a precursor time of less than 1000 days. Taking the jump of January 26, 1973 as the first precursor time we get a slightly bigger precursor time. But it has to be noted that the precursor times given in the common literature are related to effects detectable by different kind of instruments.

In order to detect privileged frequencies and orientations the statistical analysis on the perturbation periods with characteristics similar to the records of surface waves with periods between 6 and 10 minutes is now in progress. Up till now their theoretical explanation seems rather difficult. Their correlation with other effects which could act as triggering effects as tides or loading effects of snow and underground and surface waters is still under examination.

References:

Bernetti, L. & M. Bozzi Zadro, 1975, Free oscillations of the Earth and Surface Waves; Preliminary report on the research carried out at the Geodetic Institute of the Uppsala University.

Bolt, B.A. & A. Marussi, 1962, Eigenvibrations of the Earth observed at Trieste; Goephysical Journal, vol.6, n.3.

Bolt, B.A. & R. G. Currie, 1975, Maximun entropy estimates of earth torsional eigenperiods from 1960 Trieste data; Geophysical Journal R.A.S., 40.

Bozzi Zadro, M., 1966, Maree terrestri ed effetti di carico; Boll. di Geof. Teorica ed Appl., vol. VIII, n. 31.

Bozzi Zadro, M., & M. Caputo, 1968, Spectral, Bispectral Analysis and Q of the Free Oscillations of the Earth; Suppl. al "Nuovo Cimento", n. 1 Serie I, vol.6, 1968.

Bozzi Zadro, M., 1972, Earth tides and ocean load effects recorded at Trieste; Boll. di Geof. Teorica ed Appl., vol. XIV, n. 55.

Caloi, P., 1976, Sulle possibilità di previsione dei terremoti; Acc. Naz. dei Lincei, Roma, vol. XIV.

Caputo, M., 1962, Un nuovo limite superiore per il coefficiente di assorbimento della gravitazione; Rend. Acc. Naz. dei Lincei, Cl. Sc. Fis., Mat. Nat., Serie VIII, vol. XXXII, fasc. 4.

Chiaruttini, C., 1976, Tidal loading on the Italian Peninsula; Geophysical Journal R.A.S., vol. 46.

Goulty, N. R., 1976, Strainmeters and tiltmeters in geophysics; Tectonophysics, vol. 34.

Marussi, A., 1959, The University of Trieste station for the study of the tides of the vertical in the Grotta Gigante; Proceedings of the Third International Symposium on Earth Tides, Trieste.

Marussi, A., 1960, I primi risultati ottenuti nella stazione per lo studio delle maree della verticale della Grotta Gigante; Boll. di Geod. e Sc. Affini, anno XIX, n. 4.

Pekeris, C., 1965, Terrestrial Spectroscopy; Suppl. al Nuovo Cimento, Sc. Ital. di Fisica, vol. III, n. 4.

Press, F., 1965, Displacements, Strains, and Tilts at Teleseismic Distance; Journal of Geophysical Research, vol. 70, n. 10.

Rikitake, T., 1976, Earthquake Prediction; Elsevier Scientific Publishing Company, Amsterdam.

Scholz, C. H., L. R. Sykes & Y. P. Aggarwal, 1973, Earthquake Prediction: a physical basin; Science, vol. 181.

Wiss, M., 1976, Local Changes of Sea Level before Large Earthquakes in South America; Bulletin of the Seismological Society of America, vol. 66, n. 3.

Zadro, M., 1964, On the frequency dependance of the loading effects due to ocean tides and seiches; Communications n. 236 de l'Observatoire Royal de Belgique, Série Géophysique, n. 69, V° Symp. Int. sur les Marées Terrestres. Bruxelles.

EPICENTER DISTRIBUTION AND ANALYSIS OF 1976 EARTHQUAKES AND AFTERSHOCKS OF FRIULI

BY

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P.SUHADOLC*

S U M M A R Y

An earthquake catalogue is presented for the 1976 destructive shock and aftershocks in Friuli area. It concerns 695 shocks of magnitude range 2.6 to 6.4, recorded by the OGS's seismological station of Borgo Grotta Gigante, Trieste during the period May 6 to end of October. The epicenter succession from May to September shows a progressive northward migration. The frequency-magnitude relationship and the cumulative calculated average displacement are obtained from these data. Some comparisons of the Trieste data with those obtained by a teleseismic network installed in Friuli are made and the results are reported in the paper.

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* OGS - Osservatorio Geofisico Sperimentale - Trieste

O.G.S. - Osservatorio Geofisico Sperimentale - Trieste - Contrib. n. 256.
Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 19.

1.- INTRODUCTION

On May 6 Friuli was destroyed by a strong earthquake having a magnitude of about 6.4 degrees of the Richter scale. This earthquake was felt all over Europe and many strong aftershocks followed it especially during the months of May, June and September (see Table 1). The OGS's seismological station of Borgo Grotta Gigante, Trieste is the nearest one at about 80 kilometers from the epicentral area (see Fig. 1). All shocks of magnitude ≥ 2.7 degrees of the Richter scale were therefore well recorded. The purpose of this paper is to give the time-space epicenter distribution of all recorded shocks.

2.- SOURCES OF DATA

The data in this paper were obtained from the only seismological station of the Osservatorio Geofisico Sperimentale of Borgo Grotta Gigante, Trieste (see Fig. 2). The station belongs to the World Wide Standardized Seismograph Stations Network (WWSSS - TRI). It started to operate in 1963. Before 1963 the Osservatorio Geofisico Sperimentale operated the seismological station of Campo Marzio, which existed since 1890. During the seismic period the following seismographs were operating in the station:

a) Benioff: three components with magnification 50.000 and free period 1.0 sec.

b) Ewing-Press: three components with magnification 3.000 and free period 15 sec.

c) Wood-Anderson: horizontal components with magnifica

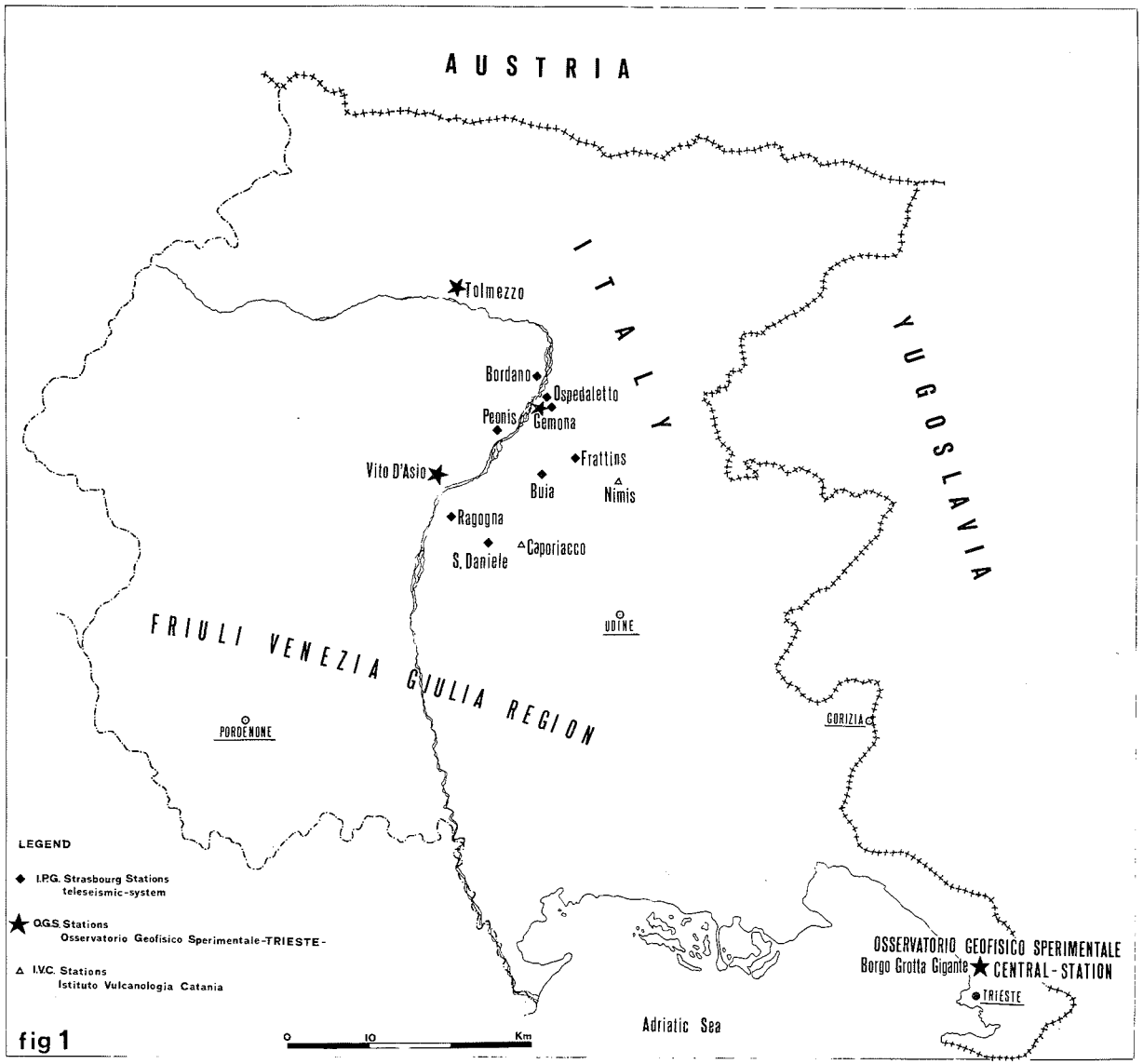

AUSTRIA
ITALY
YUGOSLAVIA
Tolmezzo
Bordano
Ospedaletto
Peonis
Gemona
Vito D'Asio
Frattins
Buia
Nimis
Ragogna
S. Daniele
Caporiacco
UDINE
FRIULI VENEZIA GIULIA REGION
PORDENONE
GORIZIA
LEGEND
I.P.G. Strasbourg Stations
teleseismic-system
O.G.S. Stations
Osservatorio Geofisico Sperimentale-TRIESTE-
I.V.C. Stations
Istituto Vulcanologia Catania
0
10
Km
Adriatic Sea
OSSERVATORIO GEOFISICO SPERIMENTALE
Borgo Grotta Gigante
CENTRAL-STATION
TRIESTE

fig 1

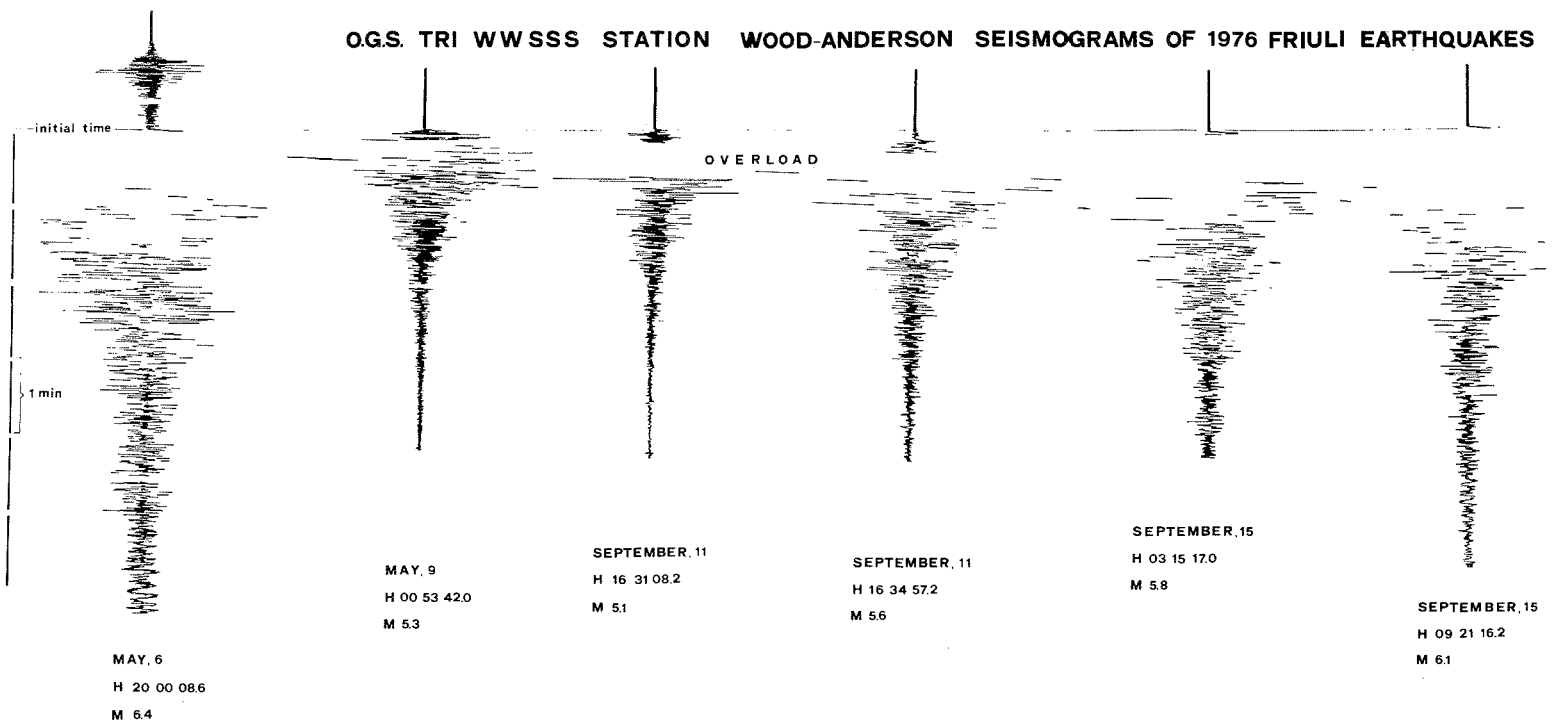

O.G.S. TRI WWSSS STATION WOOD-ANDERSON SEISMOGRAMS OF 1976 FRIULI EARTHQUAKES
initial time
1 min
OVERLOAD
MAY, 6
H 20 00 08.6
M 6.4
MAY, 9
H 00 53 42.0
M 5.3
SEPTEMBER, 11
H 16 31 08.2
M 5.1
SEPTEMBER, 11
H 16 34 57.2
M 5.6
SEPTEMBER, 15
H 03 15 17.0
M 5.8
SEPTEMBER, 15
H 09 21 16.2
M 6.1

fig 2

tion 2.800 and free period 0.8 sec.

To calculate the epicenter position the following velocities were assumed:

velocity of P waves = 5.69 km/sec

velocity of S waves = 3.35 km/sec

Vp to Vs ratio: 1.69

The hypocentral depth is obviously not determinable. Since the epicentral distance depends on it, we have to assume a certain hypocentral depth range. The epicentral distances though do not vary sensibly, if we take the hypocentral depth to vary between 7÷20 km.

The coordinates of the epicenters are obtained from the distances and the azimuths calculated from the seismograms using the transformation formulas. The value of the azimuths not determinable from the Trieste station seismograms was obtained using two different methods:

1) Use of the first arrival time recorded by the portable stations of the Istituto di Vulcanologia of Catania placed in Nimis and Caporiacco. A Wadati sphere was constructed. Knowing the distance of the epicenter from Trieste its location was thus determinated.

2) The Carnot theorem applied to the Gauss plane knowing the epicentral distance of Ljubljana and Trieste.

All values of magnitude presented were calculated in Trieste using the Wood-Anderson records and the procedure reported in "Finetti-Morelli: Earthquake magnitude determination for Trieste WWSS station".

Table 1 - LIST OF 1976 DESTRUCTIVE EARTHQUAKES OF FRIULI

Date	Origin Time	Magnitude (Richter)	Provisional average estimated intensity (Mercalli)
May 6	20 00 08.6	6.4	$9\frac{1}{2}$ - 10
May 9	00 53 42.0	(5.3)	$7\frac{1}{2}$ - 8
Sept.11	16 31 08.2	5.1 *	$7\frac{1}{2}$
Sept.11	16 34 57.2	5.6 *	8
Sept.15	03 15 17.0	5.8 *	$8\frac{1}{2}$
Sept.15	09 21 16.2	6.1 *	9

3.- COMPARISON OF TRIESTE STATION DETERMINATIONS WITH THOSE OF THE TELESEISMIC NETWORK

During the months of May, September and October a teleseismic network of "Institut du Physique du Globe" of Strasbourg was operating in the epicentral area. The network was formed by seven stations placed near Ragogna, San Daniele, Frattins, Peonis, Gemona, Ospedaletto, Bordano and by the head-station near Buia (see Fig. 1). Very good determinations of the hypocenters were obtained ($\pm$ 250 m) from the recordings and these data have been compared with the Trieste ones. Two sets of twelve determinations regarding May and October events have been compared. The following results have been obtained:

* calculated on later arrivals

Mean $|\Delta d|$ = 2.8 km

Standard Deviation $|\Delta d|$ = 1.6 km

Mean Δd = - 1.8 km

Standard Deviation Δd = 2.6 km

Mean $|\Delta A|$ = 4.5°

Standard Deviation $|\Delta A|$ = 2.2°

Mean ΔA = 3.5°

Standard Deviation ΔA = 3.7°

Where Δd is the difference between epicentral distances from Trieste determined by Strasbourg and by Trieste and ΔA is the difference between the azimuths.

The smaller precision in azimuth determination of the Trieste station is due to the difficulty to measure the amplitude of the first arrival for the earthquakes of magnitude ≤ 3.0. As the Strasbourg data is more reliable, a correction of +2° in the azimuth has been applied to all Trieste station data. The correction is somehow arbitrary but it can be justified taking it to represent a general station correction.

The distances obtained from the data of the seismological station of Trieste are normally bigger than those obtained from the plots of IPG hypocenters, but an applicable standard correction was not found.

4.- EPICENTER DISTRIBUTION

For many recorded earthquakes it was possible to determine the epicenter fairly well. In general the Trieste data alone were used. The epicenter was therefore determined from the distance and the azimuth, obtained from the seismograms.

In this procedure the sphericity of the earth has been also taken into account. The epicenters were plotted on a map, which shows a time migration from the South to the North (see Fig. 3). This migration of the epicenters was noticed as there has been a general increase in the distance of the shocks from Trieste since the September events. With one station data alone is in fact quite difficult to follow a small epicenter migration rigorously, especially since the earthquakes occurred at random over the whole seismic area.

The full circles represent the epicenters of the first month after May 6. One can see that they are roughly placed around Gemona. The gray squares representing the events occurred in the month after September 11, are distributed on the other hand over an area aound Venzone.

5.- FREQUENCY-MAGNITUDE ANALYSIS

During the period from May 6 to October 31 the seismological station of Trieste recorded 407 aftershocks having a magnitude $\geqslant 2.9$. These data have been used to obtain the values of a and b that appear in the empiric relation:

$$\log N(M) = a - bM \qquad (1)$$

where $N(M)$ represents the number of earthquakes with magnitude $M \geqslant M_o$ (cumulative frequency: a_1, b_1) or the number of earthquakes within the magnitude range $M \pm \delta M$ (non cumulative frequency: a_2, b_2). The coefficients a and b of the cumulative frequency and of the non-cumulative frequency were calcula

ted using the least squares method.

The earthquakes were divided into three categories according to the magnitude:

1) small aftershocks: $2.9 \leq M \leq 3.4$

2) moderate aftershocks: $3.5 \leq M \leq 4.5$

3) strong aftershocks: $M > 4.5$

For δM the value of 0.05 has been chosen. This is the approximation normally used in magnitude determination.

In the catalogue there are also about 80 aftershocks of magnitude range $2.7 \leq M < 2.9$. This number is however surely lesser than the true number because the magnitude of many small shocks has not been calculated. The value of the coefficients obtained is reported in Tab. 2.

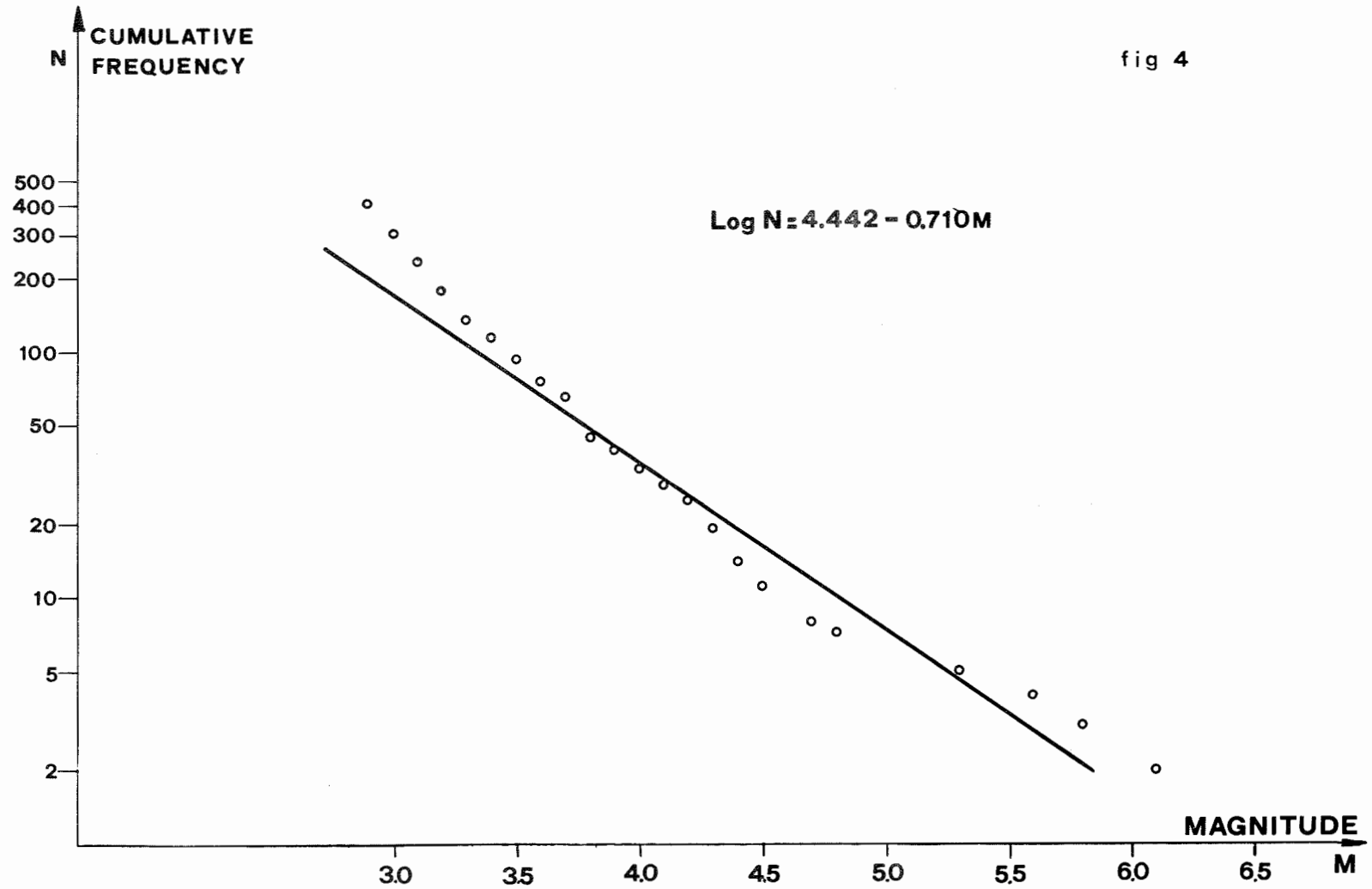
The cumulative frequency graphs are represented in Fig.s 4, 5, 6 & 7. The non-cumulative frequency graphs are represented in Fig.s8, 9 & 10.

The value of the coefficient b changes according to the magnitude range. It is smaller for the strong aftershocks. One can also notice that the small and moderate aftershocks have almost the same slope. The slope of the strong aftershocks on the other hand is very mild. It is the abundance of strong shocks which causes the final graph to be come less steep. It is interesting to note therefore that the recorded small shock activity did not imply the occurrence of so many large shocks.

6.- Vp TO Vs RATIO

The hypocenter determinations obtained from the IPG's seismic network records were also used to obtain the P and S

fig 4


N
CUMULATIVE FREQUENCY
500
400
300
200
100
50
20
10
5
2
Log N = 4.442 - 0.710M
MAGNITUDE
M
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5

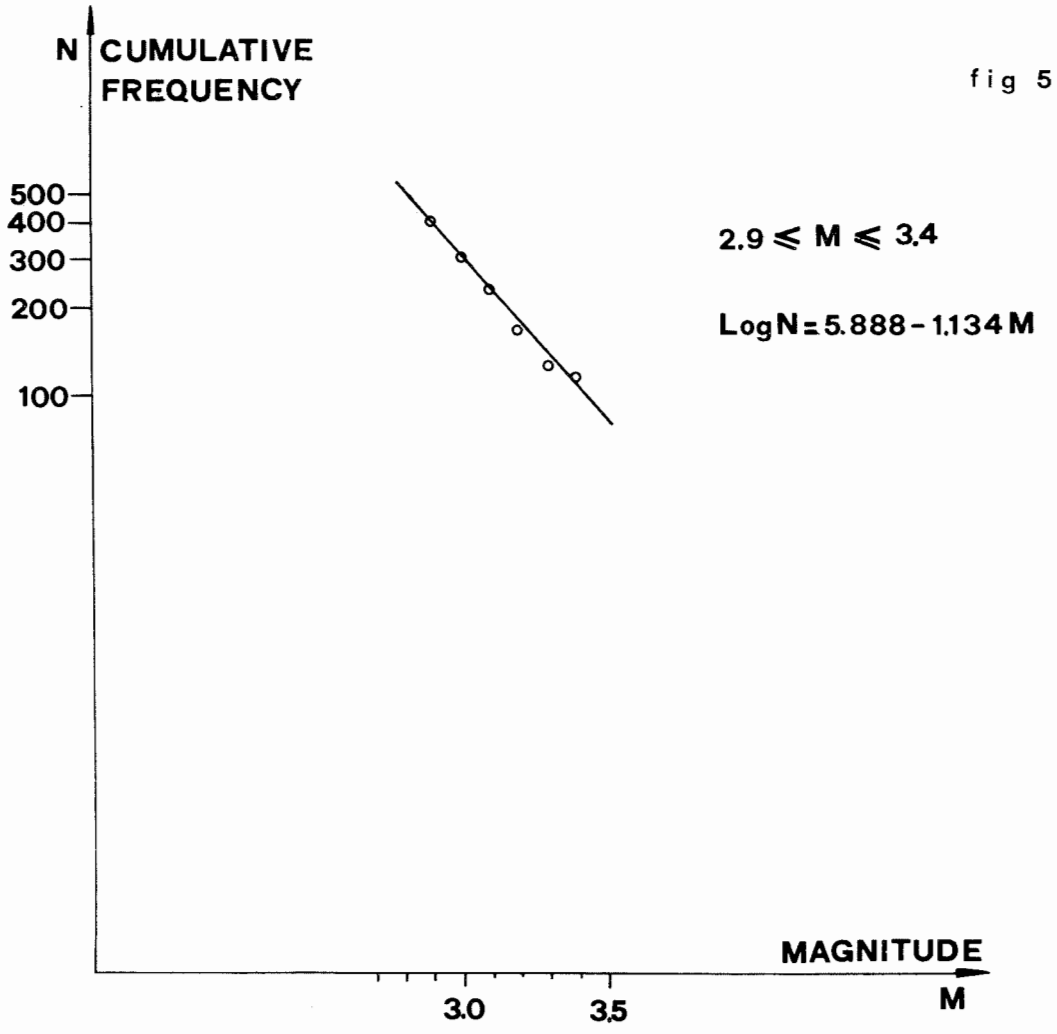

N
CUMULATIVE
FREQUENCY
500
400
300
200
100
2.9 ≤ M ≤ 3.4
LogN = 5.888 - 1.134 M
MAGNITUDE
M
3.0
3.5

fig 5

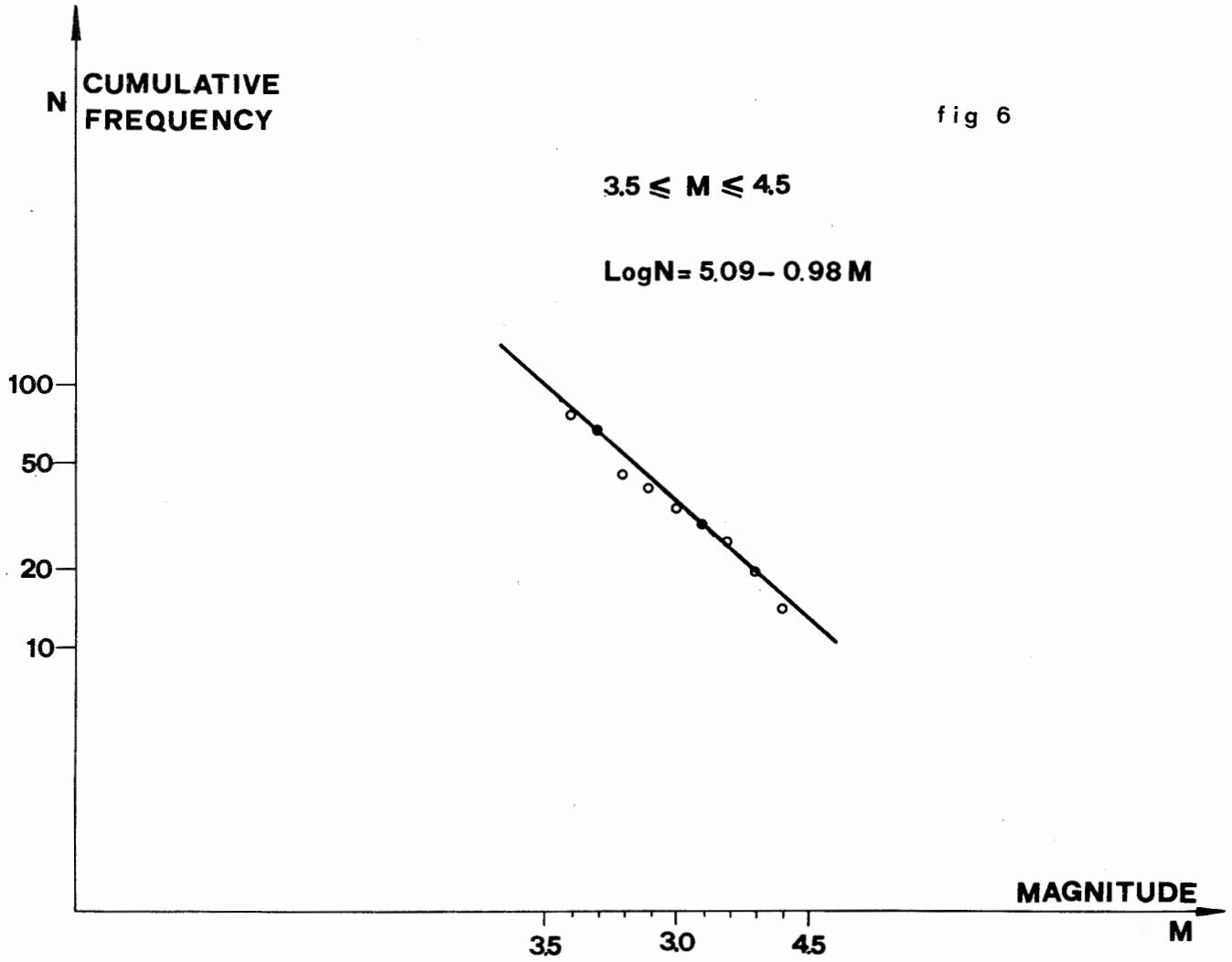

N
CUMULATIVE
FREQUENCY
3.5 ≤ M ≤ 4.5
LogN= 5.09 – 0.98 M
100
50
20
10
MAGNITUDE
M
3.5
3.0
4.5

fig 6

fig 7

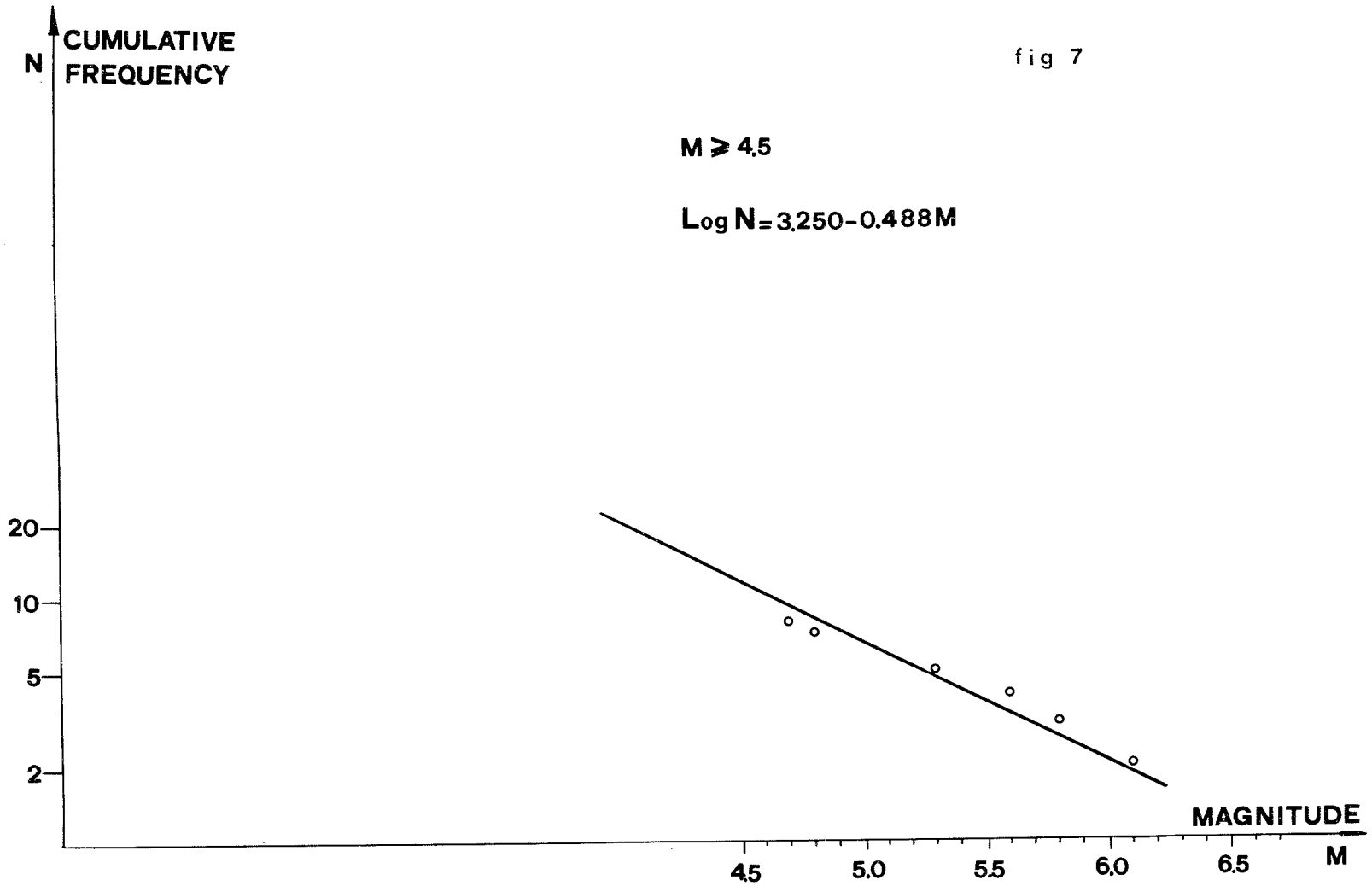

N
CUMULATIVE FREQUENCY
M ≥ 4.5
Log N = 3.250 - 0.488M
20
10
5
2
MAGNITUDE
4.5
5.0
5.5
6.0
6.5
M

fig 8

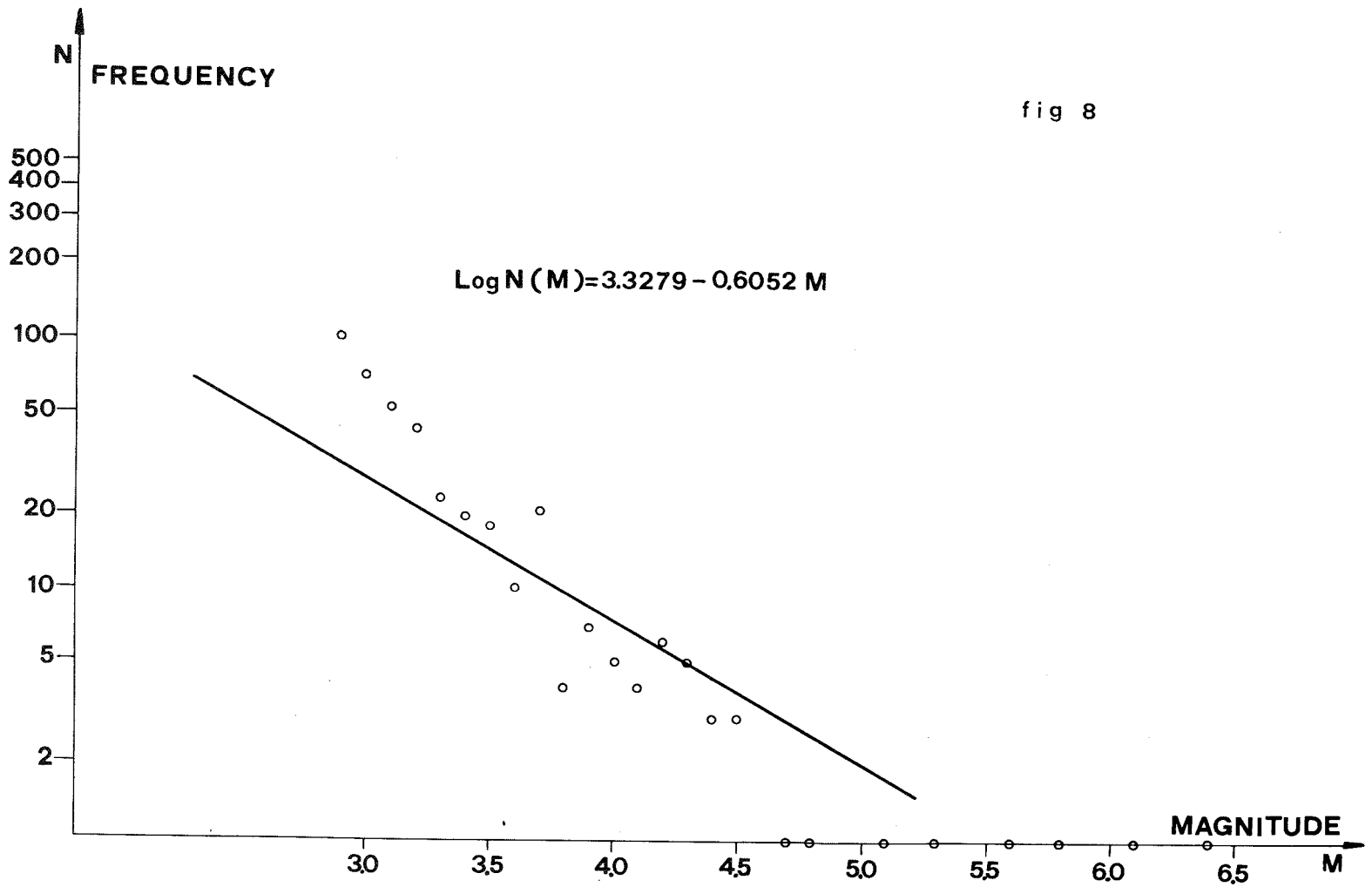
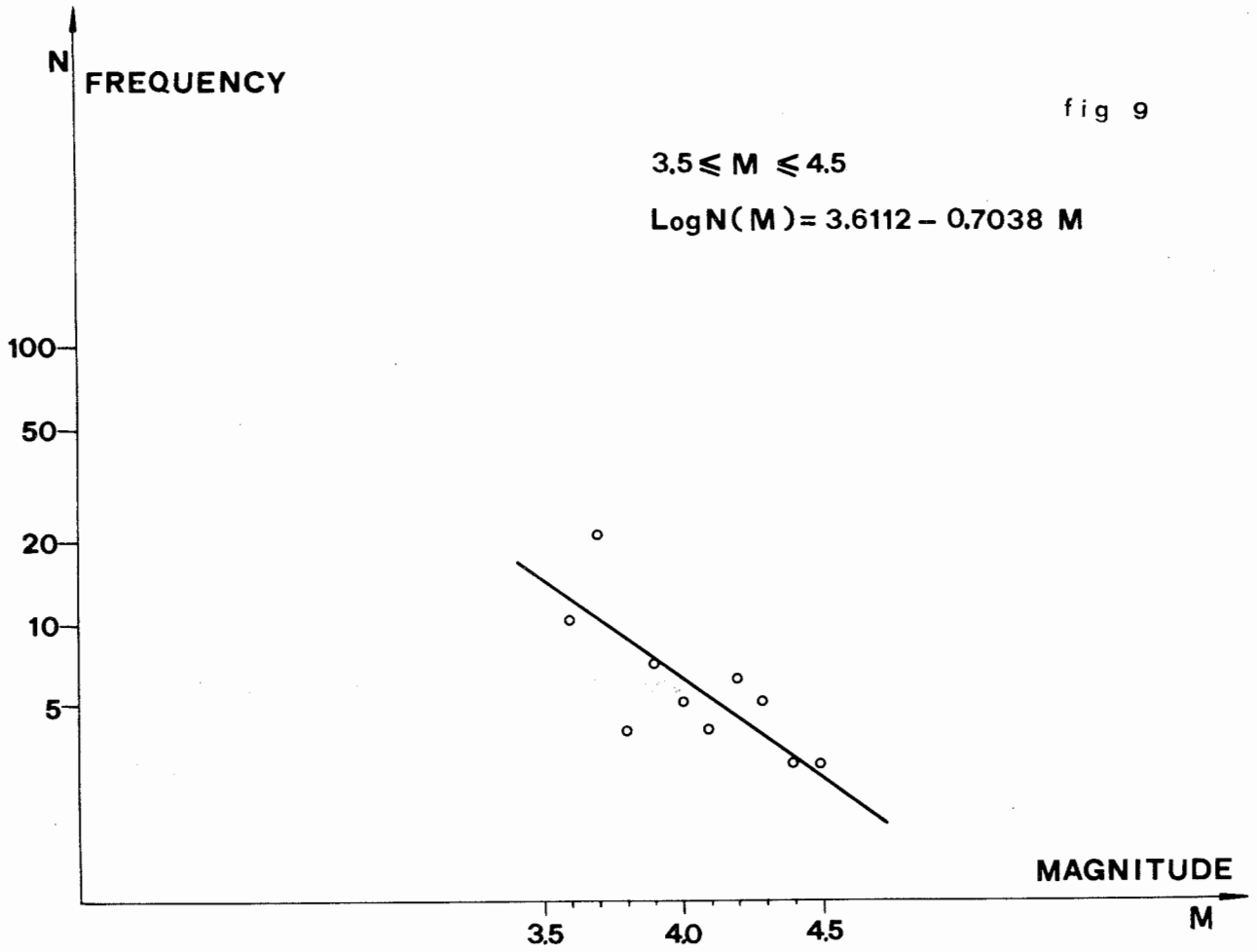

N
FREQUENCY
500
400
300
200
100
50
20
10
5
2
Log N (M)=3.3279 - 0.6052 M
MAGNITUDE
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
M

fig 9


N
FREQUENCY
3.5 ≤ M ≤ 4.5
Log N (M) = 3.6112 – 0.7038 M
100
50
20
10
5
MAGNITUDE
M
3.5
4.0
4.5

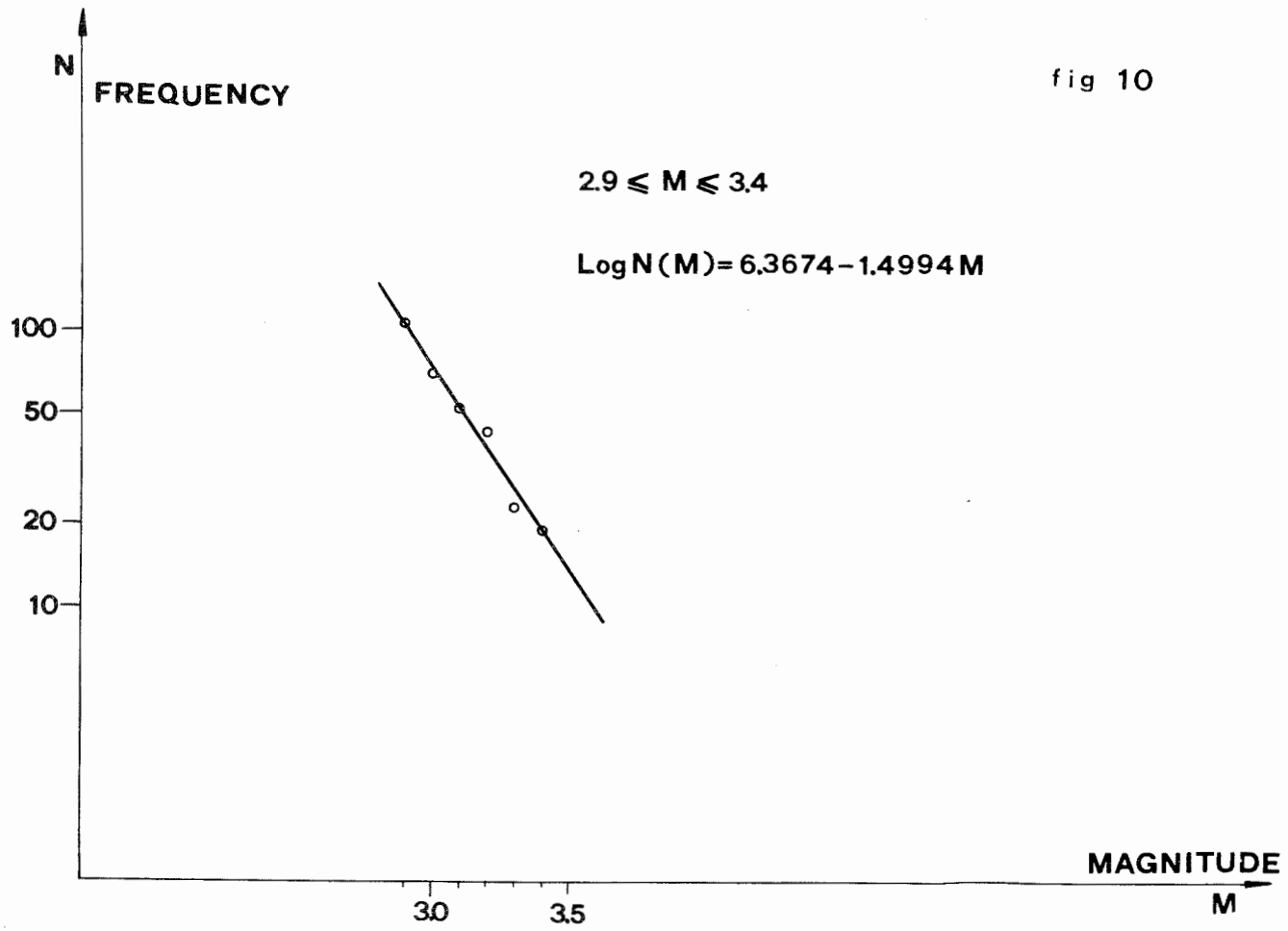

N
FREQUENCY
2.9 ≤ M ≤ 3.4
Log N (M) = 6.3674 – 1.4994 M
100
50
20
10
3.0
3.5
MAGNITUDE
M

fig 10

Tab. 2 - FREQUENCY-MAGNITUDE RELATION OF AFTERSHOCKS

Category	ΔM	N(M)	a_1	b_1	a_2	b_2
Total	$2.9 \leq M \leq 6.4$	407	4.442	0.710	3.3279	0.6052
Small	$2.9 \leq M \leq 3.4$	313	5.888	1.1343	6.3674	1.4994
Moderate	$3.5 \leq M \leq 4.5$	86	5.1043	0.8945	3.6112	0.7038
Strong	$M > 4.5$	8	3.25	0.488		

Remarks: N(M) = number of earthquakes used for calculating the coefficients a and b

a_1, b_1 = least squares method for cumulative frequency

a_2, b_2 = least squares method for non-cumulative frequency

wave velocities. These values are presented in Table 3 and they are related to May and October events. The mean velocities assume the following values:

$Vp = 6.43$ km/sec

$Vs = 3.45$ km/sec

giving a ratio

$Vp/Vs = 1.86$

The ratio decreases slightly in the second period. It has in fact a mean value of 1.88 in May and a mean value of 1.84 in October. The value of Vp is fairly higher than the one used in Trieste. In applying it in the formula for the epicentral distance a small difference of about 1 km is introduced with respect to the $Vp = 5.69$ km/sec values. The data has not been corrected for this Vp to Vs ratio anomaly recently remarked.

7.- INDICATIVE AVERAGE FAULT DISPLACEMENTS OF THE FRIULI EARTHQUAKES

The graphs presented in this section have been constructed in order to give a rough indication on the displacements of the faults interested by the May 6 seismic event and by those of September 11 and September 15.

The curves have been calculated using the Wyss & Smith (1969) relation:

$$\Sigma \bar{u} = \frac{\Sigma M_o}{A_o \mu} \qquad (2)$$

where $\bar{u}$ is the average slip of the area A_o, due to an earth

Tab. 3 - LIST OF Vp, Vs AND Vp TO Vs RATIO VELOCITIES OF SOME SHOCKS HAVING CAREFUL HYPOCENTRAL DETERMINATIONS MADE BY THE TELESEISMIC SYSTEM

Date	H	Tp	Ts	Vp	Vs	Vp to Vs
May 11	00 54 28.8	54 39.6	54 49.7	6.971	3.607	1.933
May 11	09 57 29.9	57 42.6	57 53.9	6.435	3.399	1.893
May 11	10 06 22.5	06 34.7	06 44.4	6.311	3.516	1.795
May 11	22 18 05.5	18 17.4	18 28.5	6.802	3.512	1.937
May 11	22 44 01.5	44 14.4	44 25.4	6.434	3.469	1.855
May 11	23 22 52.2	23 05.3	23 16.1	6.379	3.495	1.825
May 12	01 34 13.7	38 24.8	38 34.5	7.580	3.866	1.960
Oct. 16	04 56 46.6	57 00.3	57 11.7	6.279	3.402	1.846
Oct. 16	13 26 42.2	26 56.0	27 07.5	6.240	3.269	1.909
Oct. 17	16 23 31.1	23 45.0	23 55.9	5.970	3.343	1.786
Oct. 17	20 19 46.0	19 58.6	20 09.8	6.408	3.394	1.888
Oct. 17	22 52 45.7	53 00.4	53 12.9	6.280	3.389	1.853
Oct. 21	03 30 25.9	30 39.8	30 51.7	6.294	3.388	1.858
Oct. 21	03 34 49.5	35 03.0	35 14.0	6.085	3.348	1.817
Oct. 26	06 02 48.7	03 01.2	03 12.1	6.396	3.412	1.875

Tab. 3 (continued)

Date	H	Tp	Ts	Vp	Vs	Vp to Vs
Oct. 26	06 10 00.0	10 12.4	10 23.3	6.405	3.406	1.880
Oct. 27	04 25 42.6	25 56.5	26 07.2	6.020	3.398	1.771

Where: H = origin time obtained from I.P.G. data

Tp = first arrival time in Trieste

Ts = second arrival time in Trieste

Vp = velocity of P waves obtained from the epicentral I.P.G. distance

Vs = velocity of S waves obtained from the epicentral I.P.G. distance

quake of seismic momento M_o. μ is the rigidity of the rock brocken by the fault. The value of the rigidity μ is 3.0×10^{11} dyne/cm^2. This value and the values of the coefficients of the formula $\log M_o = 1.5M + 16$ used to calculate the seismic moment, have been arbitrarily selected from the studies conducted by Aki (1969), Wyss (1968), Smith (1968), Eaton (1970). We have assumed $A_o = 200$ km^2 for the period May 6 - September 10, $A_o = 270$ km^2 for the period September 15 - October 30.

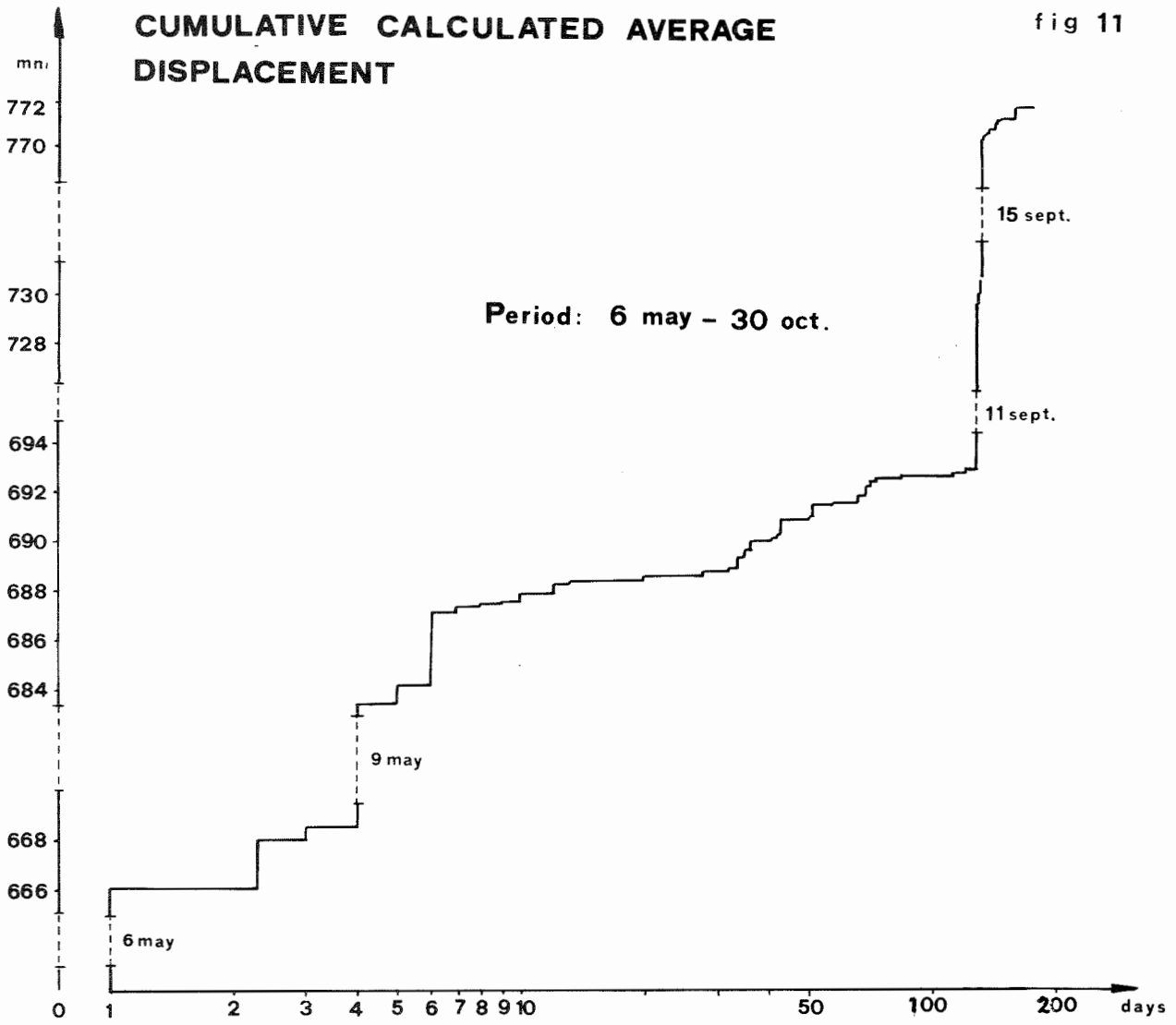
The theoretical average cumulative displacements ($\Sigma \bar{u}$) of the faults against time have been reported in the graphs of Fig.s 11, 12 & 13.

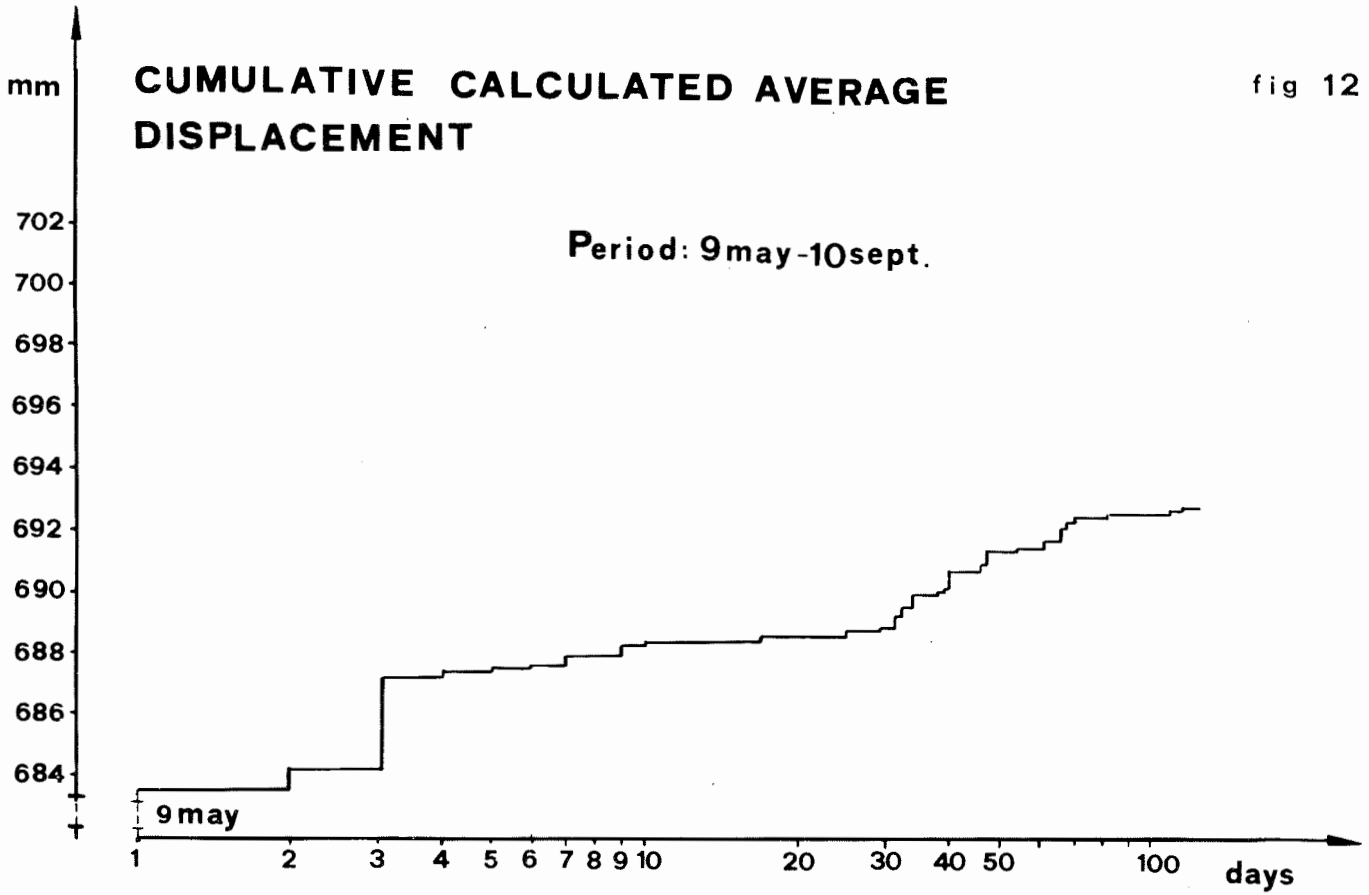
The curves refer, respectively,to all the seismic period that started with the great earthquake of May 6, to the period from May 9 to September 10 and to the period from September 15 to October 30.

In the graph of Fig. 11 the total effects of the main shock and of the aftershocks have been considered together. In the others only the effect of the aftershocks has been considered.

A simple analysis of Fig. 13 concerning the period from Sept. 15 to Oct. 30 shows that the effect of the aftershocks follows a linear law (in semilogarithmic scale). This trend of the diagram is in accordance to the behaviour of a logarithmic decay of seismic activity after a single main shock.

The first four months of seismic activity after the strong aftershock of May 9 (Fig. 12) shows on the other hand, an increase in the slope at about one month after the origin point. This fact could be interpreted as an increase of seismic


CUMULATIVE CALCULATED AVERAGE DISPLACEMENT
fig 11
mn
772
770
730
728
694
692
690
688
686
684
668
666
Period: 6 may - 30 oct.
15 sept.
11 sept.
9 may
6 may
0
1
2
3
4
5
6
7
8
9
10
50
100
200
days


mm
CUMULATIVE CALCULATED AVERAGE DISPLACEMENT
fig 12
Period: 9may-10sept.
702
700
698
696
694
692
690
688
686
684
9may
1
2
3
4
5
6
7
8
9
10
20
30
40
50
100
days

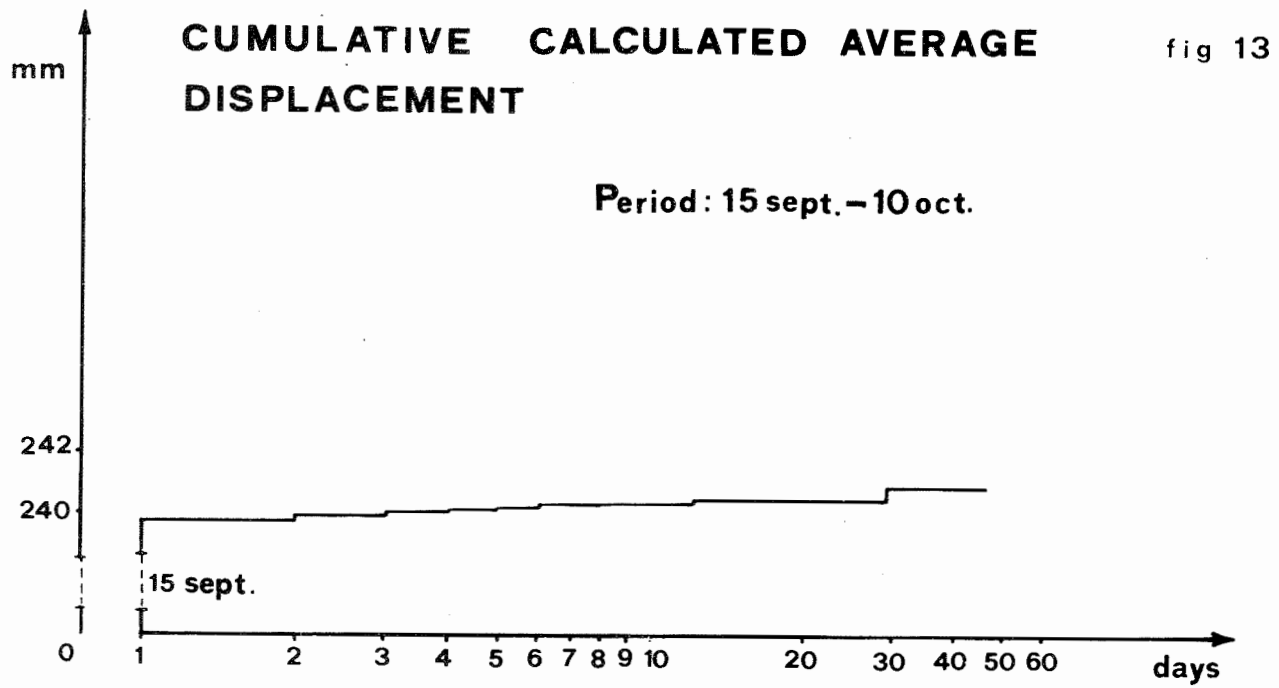

CUMULATIVE CALCULATED AVERAGE DISPLACEMENT
Period : 15 sept. – 10 oct.
mm
242
240
15 sept.
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
days

fig 13

smic activity due to the foreshocks of the strong September earthquakes.

Explanation of the abbreviation of the shock listing:

All elaborated data are reported in twelve colums. The symbols have the following meaning:

NUMB: progressive numeration of the earthquakes recorded by the Osservatorio Geofisico Sperimentale in the Seismological Station of Borgo Grotta Gigante (Trieste).

YEAR, MONTH, DAY: date of the shock.

HR, MN, SEC: time of the event in hours, minutes, seconds and tenths of a second according to Greenwich Medium Time. The first line gives the origin time of the shock, the second the first arrival (P) time recorded by O.G.S., the third line the second arrival (S) time in Trieste (O.G.S.).

NORTH, EAST: coordinates of the epicenter in degrees, minutes and tenths of a minute.

MAG: magnitude of the shock.

DIST: distance between the epicenter and the Seismological Station of O.G.S. in Borgo Grotta Gigante.

AZI: azimuth in degrees between the epicenter and the station, pointing 360° = 0° to the North.

N after the number for azimuths obtained from Nimis and Caporiacco data;

L from Ljubljana data;

S from Strasbourg data.

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F I G U R E S

Fig. 1 : Seismic stations location map.

Fig. 2 : O.G.S. TRI WWSS station Wood-Anderson seismograms of 1976 Friuli earthquakes.

Fig. 3 : Epicenter distribution of 1976 Friuli earthquakes and aftershocks. (Enclosure 4).

Fig. 4 : Cumulative frequency-magnitude graph, $2.9 \leq M \leq 6.4$

Fig. 5 : Cumulative frequency-magnitude graph $2.9 \leq M \leq 3.4$

Fig. 6 : Cumulative frequency-magnitude graph $3.4 < M \leq 4.5$

Fig. 7 : Cumulative frequency-magnitude graph $M \geq 4.5$

Fig. 8 : Non-cumulative frequency-magnitude graph $2.9 \leq M \leq 6.4$.

Fig. 9 : Non-cumulative frequency-magnitude graph $2.9 \leq M \leq 3.4$

Fig. 10 : Non-cumulative frequency-magnitude graph $3.5 \leq M \leq 4.5$

Fig. 11 : Cumulative calculated average displacement period: 6 May - 30 October (Rough indication).

Fig. 12 : Cumulative calculated average displacement period: 9 May - 10 September (Rough indication).

Fig. 13 : Cumulative calcolated average displacement period: 15 September - 10 October (Rough indication).

REFERENCES

AKI K. (1969) - Analysis of seismic coda of local earthquakes as scattered waves. J. Geophs. Res. 74, 615-631.

EATON J.P. (1970) - Aftershocks of the 1966 Parkfield-Cholame, California, earthquakes:A detailed study. Bull.of the Seism.Society of America Vol.60 n°4, pp. 1151-1197.

FINETTI I., MORELLI C. (1972) - Deep seismic refraction exploration of eastern Alps. Boll.Geof.Teor.ed Appl.OGS - Trieste.

FINETTI I., MORELLI C. (1972) - Earthquakes determination for Trieste WWSS station. Boll.Geof.Teor.ed Appl.OGS-Trieste

KARNIK V. (1969) - Seismicity of the European Area. Part. I, Part. II, Academia, Praha.

KARNIK V.et al. (1976) - Proceedings of the Seminar on Seismic Zoning maps. Vol. I, Vol. II, UNESCO, Skopje.

RICHTER C. (1958) - Elementary Seismology, California Institute of Technology,S. Francisco.

RIZNICHENKO et al. (1969) - Seismic Activity and Skakeability of the Appenninian region. Boll.Geof.Teor.ed Appl. Vol. XI, n° 43-44.

SMITH W., WYSS M. (1968)) Displacement on the San Andreas Fault subsequent to the 1966 Parkfield earthquake. Boll.Seism.Soc.Am. 58, 1955-1973.

WYSS M., BRUNE J. (1968) - Seismic moment , stress and source dimensionsfor earthquakes in the California Nevada region. J. Geophs. Res. 73, 4681-4694.

8. CATALOGUE

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
1	1976	5	6	19	59	2.2	46 18.6	13 15.8	4.5	77.2	330	
				19	59	17.6D						
				19	59	27.8						
2	1976	5	6	20	0	8.6	46 16.7	13 6.1	6.4	81.4	321	L
				20	0	24.8D						
				20	0	35.5						
3	1976	5	6	20	20	26.3				80.5		
				20	20	42.3D						
				20	20	52.9						
4	1976	5	6	20	22	10.2			3.0	76.4		
				20	22	25.5C						
				20	22	35.6						
5	1976	5	6	20	24	14.7			3.0	73.9		
				20	24	29.5D						
				20	24	39.3						
6	1976	5	6	20	24	57.4	46 18.7	13 6.6	4.2	83.8	323	
				20	25	14.0D						
				20	25	25.0						
7	1976	5	6	20	29	19.9	46 17.2	13 4.0	3.2	83.8	320	
				20	29	36.5D						
				20	29	47.5						
8	1976	5	6	20	31	9.7			2.9	75.6		
				20	31	24.8D						
				20	31	34.8						
9	1976	5	6	20	45	5.1	46 23.3	13 4.8	3.2	92.1	325	
				20	45	23.2D						
				20	45	35.2						
10	1976	5	6	20	46	59.4	46 12.6	13 8.2	2.8	73.9	319	
				20	47	14.2D						
				20	47	24.0						
11	1976	5	6	20	48	2.8	46 14.1	13 7.7	2.9	76.4	320	
				20	48	18.1D						
				20	48	28.2						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
12	1976	5	6	20	50	9.0	46 12.8	13 9.4	3.0	73.1	320
				20	50	23.7D					
				20	50	33.4					
13	1976	5	6	20	52	15.4	46 17.9	13 3.1	2.9	85.5	320
				20	52	32.3D					
				20	52	43.5					
14	1976	5	6	20	56	58.7	46 15.3	13 7.7	2.8	78.0	321
				20	57	14.3D					
				20	57	24.6					
15	1976	5	6	20	57	57.4	46 16.2	13 9.4	2.7	78.0	323
				20	58	13.0D					
				20	58	23.3					
16	1976	5	6	21	2	33.4	46 14.5	13 7.3	2.7	77.2	320
				21	2	48.8D					
				21	2	59.0					
17	1976	5	6	21	4	19.4	46 12.8	13 9.4	2.7	73.1	320
				21	4	34.1D					
				21	4	43.8					
18	1976	5	6	21	7	15.7	46 20.0	13 8.1	3.3	84.7	325
				21	7	32.4D					
				21	7	43.5					
19	1976	5	6	21	7	33.6			4.2	92.1	
				21	7	51.7D					
				21	8	3.7					
20	1976	5	6	21	15	1.0	46 19.3	13 1.5	3.2	88.8	320
				21	15	18.5D					
				21	15	30.1					
21	1976	5	6	21	18	35.9	46 15.1	13 6.5	2.9	78.9	320
				21	18	51.6D					
				21	19	2.0					
22	1976	5	6	21	26	40.2	46 11.1	13 7.6	2.7	72.3	317
				21	26	54.8D					
				21	27	4.4					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
23	1976	5	6	21	31	2.7	46 20.2	13 6.4	2.9	86.3	324
				21	31	19.7D					
				21	31	31.0					
24	1976	5	6	21	42	9.6	46 17.1	13 6.9	3.9	81.4	322
				21	42	25.8D					
				21	42	36.5					
25	1976	5	6	21	48	48.6	46 12.7	13 5.4	3.3	76.4	317
				21	49	3.9D					
				21	49	14.0					
26	1976	5	6	21	49	36.5	46 15.4	13 8.9	4.3	77.2	322
				21	49	51.9D					
				21	50	2.1					
27	1976	5	6	21	55	9.2	46 15.6	13 1.4		83.8	317
				21	55	25.8D					
				21	55	36.8					
28	1976	5	6	21	58	13.0	46 20.8	13 1.2		91.3	321
				21	58	30.9D					
				21	58	42.8					
29	1976	5	6	22	1	2.2	46 20.5	12 54.8		96.3	317
				22	1	21.0D					
				22	1	33.5					
30	1976	5	6	22	5	40.1	46 19.8	13 2.4		88.8	321
				22	5	57.6D					
				22	6	9.2					
31	1976	5	6	22	9	46.2	46 21.9	12 60.0	2.9	93.8	321
				22	10	4.5D					
				22	10	16.7					
32	1976	5	6	22	13	37.3	46 18.7	13 3.6	3.3	86.3	321
				22	13	54.3D					
				22	14	5.6					
33	1976	5	6	22	14	32.5	46 12.8	13 6.6	3.4	75.6	318
				22	14	47.6D					
				22	14	57.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
34	1976	5	6	22	20	38.6	46 14.8	13 13.3	3.5	73.1	325
				22	20	53.3C					
				22	21	3.0					
35	1976	5	6	22	30	7.6	46 15.3	13 7.7	2.7	78.0	321
				22	30	23.2D					
				22	30	33.5					
36	1976	5	6	22	32	54.8	46 14.2	13 8.9	3.2	75.6	321
				22	33	9.9D					
				22	33	19.9					
37	1976	5	6	22	34	35.4	46 10.7	13 8.0	2.8	71.4	317
				22	34	49.8D					
				22	34	59.3					
38	1976	5	6	22	35	46.0	46 25.5	13 7.2	2.9	93.8	328
				22	36	4.3C					
				22	36	16.5					
39	1976	5	6	22	46	14.7	46 17.7	13 4.8	3.0	83.8	321
				22	46	31.3D					
				22	46	42.3					
40	1976	5	6	22	50	49.6	46 11.2	13 13.7	3.1	67.3	322
				22	51	3.3D					
				22	51	12.3					
41	1976	5	6	22	56	4.9	46 16.3	13 6.5	2.9	80.5	321
				22	56	20.9D					
				22	56	31.5					
42	1976	5	6	23	1	4.3			2.8	84.7	
				23	1	21.0D					
				23	1	32.1					
43	1976	5	6	23	1	44.0	46 16.9	13 4.4	2.8	83.0	320
				23	2	.4D					
				23	2	11.3					
44	1976	5	6	23	2	40.4	46 16.0	13 6.9	2.7	79.7	321
				23	2	56.3D					
				23	3	6.8					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
45	1976	5	6	23	6	59.3	46 16.2	13 20.1	3.9	70.6	332
				23	7	13.6D					
				23	7	23.0					
46	1976	5	6	23	10	1.6	46 13.1	13 9.0	3.2	73.9	320
				23	10	16.4C					
				23	10	26.2					
47	1976	5	6	23	21	9.6	46 14.8	13 6.9		78.0	320
				23	21	25.2D					
				23	21	35.5					
48	1976	5	6	23	33	26.7	46 10.1	13 8.9	3.0	69.8	317
				23	33	40.8D					
				23	33	50.1					
49	1976	5	6	23	35	6.4	46 13.1	13 9.0	3.0	73.9	320
				23	35	21.2D					
				23	35	31.0					
50	1976	5	6	23	38	13.8	46 18.6	13 2.3		87.2	320
				23	38	31.0D					
				23	38	42.4					
51	1976	5	6	23	47	36.7				78.0	
				23	47	52.3D					
				23	48	2.6					
52	1976	5	6	23	55	31.1	46 11.4	13 7.2	3.0	73.1	317
				23	55	45.8C					
				23	55	55.5					
53	1976	5	6	23	58	6.8	46 17.4	13 5.3		83.0	321
				23	58	23.2D					
				23	58	34.1					
54	1976	5	6	23	59	20.8	46 15.3	13 1.9		83.0	317
				23	59	37.2D					
				23	59	48.1					
55	1976	5	7	0	14	38.2	46 18.2	12 57.9	3.1	90.5	317
				0	14	56.0D					
				0	15	7.8					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
56	1976	5	7	0	22	47.1	46 20.5	12 54.8		96.3	317
				0	23	5.9D					
				0	23	18.4					
57	1976	5	7	0	23	45.6	46 18.6	13 15.8	4.5	77.2	330
				0	24	1.0D					
				0	24	11.2					
58	1976	5	7	0	41	57.0			2.9	81.4	
				0	42	13.2D					
				0	42	23.9					
59	1976	5	7	0	42	21.1	46 23.0	12 56.9		97.9	320
				0	42	40.2D					
				0	42	52.9					
60	1976	5	7	0	49	30.5			3.0	76.4	
				0	49	45.8D					
				0	49	55.9					
61	1976	5	7	0	51	44.9	46 12.4	13 5.8	3.2	75.6	317
				0	52	.0D					
				0	52	10.0					
62	1976	5	7	0	58	24.1			3.0	86.3	
				0	58	41.1D					
				0	58	52.4					
63	1976	5	7	1	0	21.5	46 18.3	13 7.0	3.7	83.0	323
				1	0	37.9C					
				1	0	48.8					
64	1976	5	7	1	2	20.2			3.2	76.4	
				1	2	35.5D					
				1	2	45.6					
65	1976	5	7	1	11	47.3	46 18.2	12 57.9	3.2	90.5	317
				1	12	5.1C					
				1	12	16.9					
66	1976	5	7	1	20	25.6			3.3	97.9	
				1	20	44.7C					
				1	20	57.4					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
67	1976	5	7	1	21	25.5			3.1	78.0	
				1	21	41.1C					
				1	21	51.4					
68	1976	5	7	1	32	42.3	46 12.8	13 9.4	3.2	73.1	320
				1	32	57.0D					
				1	33	6.7					
69	1976	5	7	2	5	15.3	46 18.7	13 .6	3.3	88.8	319
				2	5	32.8D					
				2	5	44.4					
70	1976	5	7	2	24	43.6			2.9	84.7	
				2	25	.3C					
				2	25	11.4					
71	1976	5	7	2	48	8.5				72.3	
				2	48	23.1					
				2	48	32.7					
72	1976	5	7	2	48	46.2				83.0	
				2	49	2.6					
				2	49	13.5					
73	1976	5	7	2	54	10.1				69.8	
				2	54	24.2					
				2	54	33.5					
74	1976	5	7	4	6	2.6				73.9	
				4	6	17.4					
				4	6	27.2					
75	1976	5	7	4	23	13.0				85.5	
				4	23	29.9D					
				4	23	41.1					
76	1976	5	7	4	32	.3				82.2	
				4	32	16.6					
				4	32	27.4					
77	1976	5	7	4	57	58.6			3.0	88.0	
				4	58	15.9D					
				4	58	27.4					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
78	1976	5	7	5	16	32.1				94.6	
				5	16	50.6C					
				5	17	2.9					
79	1976	5	7	5	23	39.7			2.9	84.7	
				5	23	56.4D					
				5	24	7.5					
80	1976	5	7	5	40	17.5	46 15.8	13 5.6	3.5	80.5	320
				5	40	33.5C					
				5	40	44.1					
81	1976	5	7	6	2	.8	46 14.1	13 12.9	3.9	72.3	324
				6	2	15.4D					
				6	2	25.0					
82	1976	5	7	6	39	27.9	46 16.7	13 12.7	3.4	76.4	326
				6	39	43.2C					
				6	39	53.3					
83	1976	5	7	6	54	18.7			2.8	77.2	
				6	54	34.1D					
				6	54	44.3					
84	1976	5	7	7	1	4.1				85.5	
				7	1	21.0D					
				7	1	32.2					
85	1976	5	7	7	18	34.6	46 13.7	13 6.9	3.0	76.4	319
				7	18	49.9D					
				7	19	.0					
86	1976	5	7	7	36	60.0	46 18.8	13 7.9	3.2	83.0	324
				7	37	16.4D					
				7	37	27.3					
87	1976	5	7	7	47	22.1				78.0	
				7	47	37.7					
				7	47	48.0					
88	1976	5	7	7	58	56.4	46 18.2	13 5.7	3.3	83.8	322
				7	59	13.0D					
				7	59	24.0					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
89	1976	5	7	8	5	7.1				89.6	
				8	5	24.7					
				8	5	36.4					
90	1976	5	7	9	41	15.2	46 25.1	12 59.6	3.8	98.7	323
				9	41	34.4D					
				9	41	47.2					
91	1976	5	7	9	58	55.5				86.3	
				9	59	12.5					
				9	59	23.8					
92	1976	5	7	10	3	22.9			3.2	82.2	
				10	3	39.2					
				10	3	50.0					
93	1976	5	7	10	12	38.3	46 17.5	13 3.6	3.1	84.7	320
				10	12	55.0D					
				10	13	6.1					
94	1976	5	7	10	20	46.1			2.9	83.0	
				10	21	2.5D					
				10	21	13.4					
95	1976	5	7	11	15	26.8	46 15.0	13 2.3	3.5	82.2	317
				11	15	43.1D					
				11	15	53.9					
96	1976	5	7	11	44	29.2	46 18.2	13 2.7	3.1	86.3	320
				11	44	46.2D					
				11	44	57.5					
97	1976	5	7	12	41	38.9	46 14.1	13 7.7	3.5	76.4	320
				12	41	54.2C					
				12	42	4.3					
98	1976	5	7	13	20	21.9			2.8	77.2	
				13	20	37.3C					
				13	20	47.5					
99	1976	5	7	13	42	46.6	46 15.8	13 9.7	4.1	77.2	323
				13	43	2.0C					
				13	43	12.2					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
100	1976	5	7	13	44	10.2	46 18.2	13 12.5	4.0	78.9	327	L
				13	44	25.9D						
				13	44	36.3						
101	1976	5	7	13	55	53.2			2.9	83.8		
				13	56	9.8						
				13	56	20.8						
102	1976	5	7	14	43	39.0				85.5		
				14	43	55.9D						
				14	44	7.1						
103	1976	5	7	14	50	.9				68.1		
				14	50	14.7						
				14	50	23.8						
104	1976	5	7	14	55	12.4	46 18.3	13 7.0		83.0	323	
				14	55	28.8D						
				14	55	39.7						
105	1976	5	7	15	40	24.0	46 18.6	13 2.3	3.2	87.2	320	
				15	40	41.2D						
				15	40	52.6						
106	1976	5	7	15	54	37.2	46 20.5	13 4.7	3.5	88.0	323	
				15	54	54.5D						
				15	55	6.0						
107	1976	5	7	16	28	48.2			2.8	71.4		
				16	29	2.6D						
				16	29	12.1						
108	1976	5	7	16	50	29.9	46 13.4	13 8.5	2.8	74.7	320	
				16	50	44.9D						
				16	50	54.8						
109	1976	5	7	18	33	47.8	46 20.7	13 2.9	3.1	89.6	322	
				18	34	5.4D						
				18	34	17.1						
110	1976	5	7	19	12	26.0	46 18.9	13 19.2	2.9	75.6	333	L
				19	12	41.1D						
				19	12	51.1						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
111	1976	5	7	20	12	50.2	46 18.1	13 4.4	3.4	84.7	321	
				20	13	6.9D						
				20	13	18.0						
112	1976	5	7	20	52	32.4	46 13.1	13 9.0	3.2	73.9	320	
				20	52	47.2D						
				20	52	57.0						
113	976	5	7	21	42	22.8				88.8		
				21	42	40.3						
				21	42	51.9						
114	1976	5	8	1	21	3.3				79.7		
				1	21	19.2C						
				1	21	29.7						
115	1976	5	8	1	32	4.4			2.8	74.7		
				1	32	19.4						
				1	32	29.3						
116	1976	5	8	1	39	55.5	46 15.3	13 4.8	2.9	80.5	319	
				1	40	11.5D						
				1	40	22.1						
117	1976	5	8	2	16	3.1	46 17.7	12 55.2	3.0	92.1	315	L
				2	16	21.2D						
				2	16	33.2						
118	1976	5	8	3	10	1.5	46 19.9	13 6.8	4.1	85.5	324	
				3	10	18.4D						
				3	10	29.6						
119	1976	5	8	3	37	23.6			2.9	91.3		
				3	37	41.5D						
				3	37	53.4						
120	1976	5	8	4	11	52.2			3.0	82.2		
				4	12	8.5						
				4	12	19.3						
121	1976	5	8	4	19	55.1	46 11.6	13 9.5	2.9	71.4	319	
				4	20	9.5D						
				4	20	19.0						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
122	1976	5	8	6	0	14.8				65.6	
				6	0	28.2					
				6	0	37.0					
123	1976	5	8	8	20	46.3			2.9	78.9	
				8	21	2.0D					
				8	21	12.4					
124	1976	5	8	9	56	22.9	46 21.2	13 .8	3.5	92.1	321
				9	56	41.0D					
				9	56	53.0					
125	1976	5	8	11	36	14.2	46 16.7	13 3.1	3.2	83.8	319
				11	36	30.8D					
				11	36	41.8					
126	1976	5	8	11	40	31.3	46 13.2	13 10.1	3.3	73.1	321
				11	40	46.0D					
				11	40	55.7					
127	1976	5	8	13	32	21.9	46 20.0	13 3.7	3.4	88.0	322
				13	32	39.2D					
				13	32	50.7					
128	1976	5	8	15	3	39.7			3.0	107.0	
				15	4	.4					
				15	4	14.2					
129	1976	5	8	15	56	34.6			2.8	65.6	
				15	56	48.0D					
				15	56	56.8					
130	1976	5	8	17	35	33.1			3.0	93.8	
				17	35	51.4D					
				17	36	3.6					
131	1976	5	8	18	53	14.9				83.8	
				18	53	31.5					
				18	53	42.5					
132	1976	5	8	20	40	27.5	46 16.4	12 53.5	4.0	92.1	313
				20	40	45.6C					
				20	40	57.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
133	1976	5	8	22	8	47.7			2.9	73.9	
				22	9	2.5					
				22	9	12.3					
134	1976	5	9	0	35	38.3			2.9	83.0	
				0	35	54.7					
				0	36	5.6					
135	1976	5	9	0	53	42.0	46 14.4	13 19.4	5.3	68.1	330
				0	53	55.8D					
				0	54	4.9					
136	1976	5	9	2	24	51.9			2.7	67.3	
				2	25	5.6					
				2	25	14.6					
137	1976	5	9	3	11	6.8				74.7	
				3	11	21.8D					
				3	11	31.7					
138	1976	5	9	3	14	31.7				83.0	
				3	14	48.1					
				3	14	59.0					
139	1976	5	9	3	39	24.3			3.1	79.7	
				3	39	40.2D					
				3	39	50.7					
140	1976	5	9	3	52	60.0			2.7	77.2	
				3	53	15.4					
				3	53	25.6					
141	1976	5	9	6	3	46.5			3.0	78.9	
				6	4	2.2D					
				6	4	12.6					
142	1976	5	9	12	33	24.5	46 19.7	13 5.5	3.0	86.3	323
				12	33	41.5D					
				12	33	52.8					
143	1976	5	9	18	2	22.8			2.8	71.4	
				18	2	37.2D					
				18	2	46.7					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
144	1976	5	9	20	0	3.5	46 16.1	13 8.1	3.0	78.9	322	
				20	0	19.2D						
				20	0	29.6						
145	1976	5	10	2	10	53.5	46 17.7	12 55.2	3.1	92.1	315	L
				2	11	11.6D						
				2	11	23.6						
146	1976	5	10	4	35	49.6	46 15.5	13 10.1	4.4	76.4	323	
				4	36	4.9D						
				4	36	15.0						
147	1976	5	10	5	8	46.1	46 18.7	13 6.6	3.7	83.8	323	
				5	9	2.7D						
				5	9	13.7						
148	1976	5	10	5	53	50.2				83.8		
				5	54	6.8						
				5	54	17.8						
149	1976	5	10	7	21	47.4				72.3		
				7	22	2.0D						
				7	22	11.6						
150	1976	5	10	16	1	44.1	46 15.8	13 2.7	3.1	83.0	318	L
				16	2	.5D						
				16	2	11.4						
151	1976	5	10	16	8	26.8				84.7		
				16	8	43.5D						
				16	8	54.6						
152	1976	5	10	16	44	14.6				69.8		
				16	44	28.7D						
				16	44	38.0						
153	1976	5	10	20	49	14.3				83.0		
				20	49	30.7						
				20	49	41.6						
154	1976	5	10	21	54	49.1				75.6		
				21	55	4.2						
				21	55	14.2						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
155	1976	5	11	0	54	24.3	46 17.1	13 13.5	3.0	76.4	327 S
				0	54	39.6D					
				0	54	49.7					
156	1976	5	11	2	0	49.4				83.8	
				2	1	6.0					
				2	1	17.0					
157	1976	5	11	2	25	35.4				105.4	
				2	25	55.8					
				2	26	9.4					
158	1976	5	11	4	25	5.7				75.6	
				4	25	20.8					
				4	25	30.8					
159	1976	5	11	5	31	53.6	46 15.4	13 8.9	3.9	77.2	322 S
				5	32	9.0D					
				5	32	19.2					
160	1976	5	11	9	57	25.6	46 20.7	13 7.4	3.7	86.3	325 S
				9	57	42.6					
				9	57	53.9					
161	1976	5	11	10	5	43.9				75.6	
				10	5	59.0					
				10	6	9.0					
162	1976	5	11	10	6	20.0	46 13.6	13 10.9	3.4	73.1	322 S
				10	6	34.7					
				10	6	44.4					
163	1976	5	11	20	44	44.9	46 19.5	13 7.2		84.7	324 S
				20	45	1.6					
				20	45	12.7					
164	1976	5	11	22	18	.7	46 20.0	13 8.1	3.8	84.7	325 S
				22	18	17.4C					
				22	18	28.5					
165	1976	5	11	22	43	57.8	46 16.7	13 3.1	4.8	83.8	319 S
				22	44	14.4C					
				22	44	25.4					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
166	1976	5	11	22	57	38.3	46 17.4	13 10.7		78.9	325	S
				22	57	54.0D						
				22	58	4.4						
167	1976	5	11	23	22	49.0	46 16.0	13 4.0	3.4	82.2	319	S
				23	23	5.3C						
				23	23	16.1						
168	1976	5	11	23	36	38.2	46 21.1	12 57.6	3.7	94.6	319	
				23	36	56.7D						
				23	37	9.0						
169	1976	5	12	0	9	5.6	46 11.9	13 5.1	2.8	75.6	316	L
				0	9	20.7						
				0	9	30.7						
170	1976	5	12	2	23	28.5	46 16.5	13 4.8	2.7	82.2	320	S
				2	23	44.8						
				2	23	55.6						
171	1976	5	12	2	38	8.9	46 14.9	13 8.1	3.2	77.2	321	S
				2	38	24.3D						
				2	38	34.5						
172	1976	5	12	3	1	12.3	46 19.8	12 57.5	3.6	92.9	318	
				3	1	30.5D						
				3	1	42.6						
173	1976	5	12	3	2	38.1			3.0	84.7		
				3	2	54.8D						
				3	3	5.9						
174	1976	5	12	6	17	23.5			3.0	74.7		
				6	17	38.5						
				6	17	48.4						
175	1976	5	12	7	17	58.7				75.6		
				7	18	13.8D						
				7	18	23.8						
176	1976	5	12	8	47	49.4				78.0		
				8	48	5.0D						
				8	48	15.3						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
177	1976	5	12	9	4	2.9	46 21.2	13 .8	3.6	92.1	321	
				9	4	21.0D						
				9	4	33.0						
178	1976	5	12	14	48	5.7			3.0	93.8		
				14	48	24.0D						
				14	48	36.2						
179	1976	5	12	18	6	49.6	46 9.5	13 7.1	3.5	70.6	315	
				18	7	3.9C						
				18	7	13.3						
180	1976	5	12	20	12	48.4	46 13.0	13 .4	3.1	81.4	314	
				20	13	4.6C						
				20	13	15.3						
181	1976	5	12	20	57	42.8			2.9	97.1		
				20	58	1.7						
				20	58	14.3						
182	1976	5	12	22	1	22.2			2.9	88.0		
				22	1	39.5						
				22	1	51.0						
183	1976	5	13	1	53	11.5			2.8	80.5		
				1	53	27.5						
				1	53	38.1						
184	1976	5	13	3	15	8.6	46 12.3	13 3.0	3.0	78.0	315	
				3	15	24.2C						
				3	15	34.5						
185	1976	5	13	3	21	24.8	46 12.7	13 5.4	2.9	76.4	317	
				3	21	40.1C						
				3	21	50.2						
186	1976	5	13	3	38	31.1			2.9	101.2		
				3	38	50.8						
				3	39	3.9						
187	1976	5	13	13	4	46.6	46 18.4	13 1.0	3.7	88.0	319	S
				13	5	3.9D						
				13	5	15.4						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
188	1976	5	14	0	49	32.2			3.0	82.2	
				0	49	48.5D					
				0	49	59.3					
189	1976	5	14	12	34	45.7			3.0	91.3	
				12	35	3.6					
				12	35	15.5					
190	1976	5	14	21	15	49.7			3.0	102.9	
				21	16	9.6					
				21	16	22.9					
191	1976	5	15	4	26	11.4	46 13.2	13 10.1	3.7	73.1	321
				4	26	26.1D					
				4	26	35.8					
192	1976	5	15	8	40	13.9	46 15.3	13 1.9	3.4	83.0	317
				8	40	30.3C					
				8	40	41.2					
193	1976	5	15	8	57	39.8	46 12.1	13 10.2	3.1	71.4	320
				8	57	54.2D					
				8	58	3.7					
194	1976	5	15	9	6	39.0			3.1	78.9	
				9	6	54.7D					
				9	7	5.1					
195	1976	5	15	9	40	33.8			3.0	81.4	
				9	40	50.0D					
				9	41	.7					
196	1976	5	15	10	28	1.6			2.9	85.5	
				10	28	18.5					
				10	28	29.7					
197	1976	5	15	14	21	29.6			2.8	80.5	
				14	21	45.6					
				14	21	56.2					
198	1976	5	15	15	17	25.4				68.9	
				15	17	39.4					
				15	17	48.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
199	1976	5	15	15	25	7.5	46 19.0	13 11.8	3.2	80.5	327
				15	25	23.5D					
				15	25	34.1					
200	1976	5	15	16	5	52.3	46 21.3	13 5.3	3.5	88.8	324
				16	6	9.8D					
				16	6	21.4					
201	1976	5	15	16	50	44.7	46 21.6	13 9.3	3.0	86.3	327
				16	51	1.7C					
				16	51	13.0					
202	1976	5	15	16	58	1.1			2.8	71.4	
				16	58	15.5					
				16	58	25.0					
203	1976	5	15	18	37	1.4	46 19.9	13 .6	3.0	90.5	320
				18	37	19.2C					
				18	37	31.0					
204	1976	5	15	19	20	8.9			2.9	83.8	
				19	20	25.5					
				19	20	36.5					
205	1976	5	15	20	13	55.2	46 10.7	13 8.0	2.9	71.4	317
				20	14	9.6					
				20	14	19.1					
206	1976	5	15	20	43	.5			2.8	79.7	
				20	43	16.4					
				20	43	26.9					
207	1976	5	15	21	10	23.4			2.9	73.9	
				21	10	38.2C					
				21	10	48.0					
208	1976	5	15	22	18	14.8			2.7	67.3	
				22	18	28.5					
				22	18	37.5					
209	1976	5	15	22	34	14.0	46 19.2	12 58.4	3.0	91.3	318
				22	34	31.9D					
				22	34	43.8					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
210	1976	5	16	4	56	58.7	46 17.9	13 3.1	2.9	85.5	320
				4	57	15.6C					
				4	57	26.8					
211	1976	5	16	4	58	14.3				78.0	
				4	58	29.9					
				4	58	40.2					
212	1976	5	16	5	58	42.5				74.7	
				5	58	57.5					
				5	59	7.4					
213	1976	5	16	5	59	19.7	46 15.9	13 18.1	3.1	71.4	330
				5	59	34.1D					
				5	59	43.6					
214	1976	5	16	7	44	23.4	46 20.1	12 58.9	3.0	92.1	319
				7	44	41.5C					
				7	44	53.5					
215	1976	5	16	8	0	5.3			2.9	84.7	
				8	0	22.0C					
				8	0	33.1					
216	1976	5	16	10	50	12.1				77.2	
				10	50	27.5					
				10	50	37.7					
217	1976	5	16	12	56	15.2	46 12.1	13 11.4	2.9	70.6	321
				12	56	29.5C					
				12	56	38.9					
218	1976	5	16	13	48	28.4	46 11.7	13 6.7	2.9	73.9	317
				13	48	43.2C					
				13	48	53.0					
219	1976	5	16	17	26	46.2	46 7.1	13 12.9	2.8	62.3	317
				17	26	59.0D					
				17	27	7.4					
220	1976	5	16	20	3	21.9	46 22.0	12 58.2	2.8	95.4	320
				20	3	40.5D					
				20	3	52.9					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
221	1976	5	16	20	13	37.1			2.9	87.2	
				20	13	54.3					
				20	14	5.7					
222	1976	5	16	21	31	57.5				78.0	
				21	32	13.1					
				21	32	23.4					
223	1976	5	17	2	55	43.4			2.8	78.9	
				2	55	59.1					
				2	56	9.5					
224	1976	5	17	9	11	26.7			2.9	92.9	
				9	11	44.9					
				9	11	57.0					
225	1976	5	17	13	30	1.5				73.9	
				13	30	16.3					
				13	30	26.1					
226	1976	5	17	16	13	12.4	46 22.5	13 5.5	4.2	90.5	325
				16	13	30.2D					
				16	13	42.0					
227	1976	5	17	16	20	56.9	46 22.2	13 2.7	2.9	92.1	323
				16	21	15.0D					
				16	21	27.0					
228	1976	5	17	17	29	48.5			3.0	91.3	
				17	30	6.4D					
				17	30	18.3					
229	1976	5	17	17	35	52.9	46 19.8	13 2.4	3.2	88.8	321
				17	36	10.4					
				17	36	22.0					
230	1976	5	17	19	58	55.1			2.8	69.8	
				19	59	9.2D					
				19	59	18.5					
231	1976	5	17	21	56	18.1				71.4	
				21	56	32.5					
				21	56	42.0					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
232	1976	5	18	1	30	4.5	46 23.1	13 3.4	3.7	92.9	324
				1	30	22.7D					
				1	30	34.8					
233	1976	5	18	1	35	6.9			2.9	81.4	
				1	35	23.1D					
				1	35	33.8					
234	1976	5	18	2	39	35.1	46 24.9	13 1.5	3.3	97.1	324
				2	39	54.0D					
				2	40	6.6					
235	1976	5	18	2	50	36.8	46 9.8	13 9.4		68.9	317
				2	50	50.8D					
				2	51	.0					
236	1976	5	18	7	0	21.9	46 9.1	13 10.2	2.9	67.3	317
				7	0	35.6C					
				7	0	44.6					
237	1976	5	18	8	1	39.3	46 19.6	13 1.1	3.1	89.6	320
				8	1	56.9D					
				8	2	8.6					
238	1976	5	18	9	59	43.1				67.3	
				9	59	56.8					
				10	0	5.8					
239	1976	5	18	14	32	18.7	46 17.9	12 58.3	3.1	89.6	317
				14	32	36.3D					
				14	32	48.0					
240	1976	5	18	15	22	12.9	46 17.7	13 9.1	3.3	80.5	324
				15	22	28.9D					
				15	22	39.5					
241	1976	5	18	20	18	20.1	46 19.9	13 .6	3.1	90.5	320
				20	18	37.9D					
				20	18	49.7					
242	1976	5	18	23	45	12.6	46 13.0	13 7.8	2.9	74.7	319
				23	45	27.6C					
				23	45	37.5					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
243	1976	5	19	15	14	48.7	46 17.7	12 53.4	3.0	93.8	314
				15	15	7.0C					
				15	15	19.2					
244	1976	5	19	15	17	25.0	46 13.3	13 12.5	2.8	71.4	323
				15	17	39.4D					
				15	17	48.9					
245	1976	5	19	18	59	24.6	46 11.9	13 14.0	2.8	68.1	323
				18	59	38.4C					
				18	59	47.5					
246	1976	5	19	22	55	7.6				96.3	
				22	55	26.4					
				22	55	38.9					
247	1976	5	20	8	59	23.5	46 15.5	13 6.1	2.8	79.7	320
				8	59	39.4D					
				8	59	49.9					
248	1976	5	20	14	44	34.4	46 12.8	13 9.4	3.0	73.1	320
				14	44	49.1C					
				14	44	58.8					
249	1976	5	20	17	23	38.7			2.8	83.0	
				17	23	55.1C					
				17	24	6.0					
250	1976	5	21	1	48	16.7				92.1	
				1	48	34.8D					
				1	48	46.8					
251	1976	5	21	5	3	39.4				81.4	
				5	3	55.6					
				5	4	6.3					
252	1976	5	21	9	12	57.4				75.6	
				9	13	12.5D					
				9	13	22.5					
253	1976	5	22	6	2	18.2	46 19.6	13 8.5	2.9	83.8	325
				6	2	34.8D					
				6	2	45.8					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
254	1976	5	22	9	58	34.4	46 15.6	13 1.4	2.8	83.8	317
				9	58	51.0C					
				9	59	2.0					
255	1976	5	22	10	30	41.4			2.8	79.7	
				10	30	57.3D					
				10	31	7.8					
256	1976	5	23	0	51	5.4	46 14.1	13 7.7	3.6	76.4	320
				0	51	20.7D					
				0	51	30.8					
257	1976	5	23	1	25	43.1				97.1	
				1	26	2.0					
				1	26	14.6					
258	1976	5	23	1	53	5.8	46 13.4	13 8.5	2.9	74.7	320
				1	53	20.8C					
				1	53	30.7					
259	1976	5	23	2	11	10.2				86.3	
				2	11	27.2					
				2	11	38.5					
260	1976	5	23	12	47	27.1	46 10.4	13 8.5		70.6	317
				12	47	41.4C					
				12	47	50.8					
261	1976	5	23	19	20	29.7				106.2	
				19	20	50.2					
				19	21	3.9					
262	1976	5	25	19	4	26.7	46 19.7	13 11.1	3.1	82.2	327
				19	4	43.0C					
				19	4	53.8					
263	1976	5	25	19	47	57.9	46 16.5	13 9.0	3.3	78.9	323
				19	48	13.6D					
				19	48	24.0					
264	1976	5	25	22	35	13.0				80.5	
				22	35	29.0					
				22	35	39.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
265	1976	5	26	4	39	5.1	46 17.9	13 3.1	3.1	85.5	320
				4	39	22.0C					
				4	39	33.2					
266	1976	5	26	7	48	23.0	46 18.6	13 2.3	3.2	87.2	320
				7	48	40.2D					
				7	48	51.6					
267	1976	5	26	9	46	22.2				93.8	
				9	46	40.5					
				9	46	52.7					
268	1976	5	26	11	20	31.9	46 22.6	13 6.9	3.2	89.6	326
				11	20	49.5C					
				11	21	1.2					
269	1976	5	26	13	53	42.3				70.6	
				13	53	56.6					
				13	54	6.0					
270	1976	5	26	14	39	21.7				68.9	
				14	39	35.7					
				14	39	44.9					
271	1976	5	26	20	29	13.8				92.9	
				20	29	32.0					
				20	29	44.1					
272	1976	5	27	3	49	44.7	46 15.1	13 6.5	3.1	78.9	320
				3	50	.4D					
				3	50	10.8					
273	1976	5	27	6	50	17.9			2.8	74.7	
				6	50	32.9					
				6	50	42.8					
274	1976	5	27	18	19	15.1			2.9	74.7	
				18	19	30.1					
				18	19	40.0					
275	1976	5	29	12	57	46.9	46 10.8	13 13.0	2.7	67.3	321
				12	58	.6D					
				12	58	9.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH		EAST		MAG	DIST	AZI
276	1976	5	29	12	57	47.6					2.9	79.7	
				12	58	3.5							
				12	58	14.0							
277	1976	5	29	14	45	50.5	46	12.0	13	6.3		74.7	317
				14	46	5.5D							
				14	46	15.4							
278	1976	5	29	14	57	41.1	46	15.3	13	1.9		83.0	317
				14	57	57.5D							
				14	58	8.4							
279	1976	5	29	14	57	48.7	46	15.1	13	6.5	2.8	78.9	320
				14	58	4.4D							
				14	58	14.8							
280	1976	5	30	11	3	27.1						83.8	
				11	3	43.7							
				11	3	54.7							
281	1976	5	30	21	13	8.7	46	18.5	13	5.3	3.6	84.7	322
				21	13	25.4C							
				21	13	36.5							
282	1976	5	31	4	3	36.3					2.9	85.5	
				4	3	53.2D							
				4	4	4.4							
283	1976	5	31	7	24	16.6	46	17.7	13	4.8	3.0	83.8	321
				7	24	33.2C							
				7	24	44.2							
284	1976	5	31	7	24	27.1					2.9	68.1	
				7	24	40.9D							
				7	24	50.0							
285	1976	5	31	16	9	43.5						79.7	
				16	9	59.4							
				16	10	9.9							
286	1976	5	31	21	55	58.3	46	14.0	13	3.6		79.7	317
				21	56	14.2D							
				21	56	24.7							

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
287	1976	6	1	3	23	43.6			2.9	70.6	
				3	23	57.9D					
				3	24	7.3					
288	1976	6	1	10	4	6.8	46 10.4	13 12.3	2.8	67.3	320
				10	4	20.5C					
				10	4	29.5					
289	1976	6	1	15	46	1.1	46 16.9	13 4.4	3.0	83.0	320
				15	46	17.5C					
				15	46	28.4					
290	1976	6	1	17	21	4.9	46 19.6	13 1.1	3.7	89.6	320
				17	21	22.5D					
				17	21	34.2					
291	1976	6	1	19	15	58.9	46 16.1	13 8.1	3.2	78.9	322
				19	16	14.6C					
				19	16	25.0					
292	1976	6	1	21	29	34.6				72.3	
				21	29	49.2					
				21	29	58.8					
293	1976	6	2	9	27	.8	46 15.8	13 9.7	3.3	77.2	323
				9	27	16.2C					
				9	27	26.4					
294	1976	6	3	3	56	15.8	46 10.6	13 10.7	2.9	68.9	319
				3	56	29.8D					
				3	56	39.0					
295	1976	6	3	11	44	41.4			3.0	88.8	
				11	44	58.9					
				11	45	10.5					
296	1976	6	3	15	44	43.8	46 18.2	13 5.7	3.1	83.8	322
				15	45	.4D					
				15	45	11.4					
297	1976	6	3	19	35	52.0			2.9	82.2	
				19	36	8.3D					
				19	36	19.1					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
298	1976	6	3	20	22	4.8	46 22.0	12 58.2	3.0	95.4	320
				20	22	23.4D					
				20	22	35.8					
299	1976	6	3	22	32	59.1				76.4	
				22	33	14.4					
				22	33	24.5					
300	1976	6	3	23	15	4.0			3.0	94.6	
				23	15	22.5					
				23	15	34.8					
301	1976	6	4	7	49	11.6	46 24.5	12 51.4	3.5	104.5	318
				7	49	31.8C					
				7	49	45.3					
302	1976	6	4	11	56	52.5	46 23.5	13 3.0	3.3	93.8	324
				11	57	10.8C					
				11	57	23.0					
303	1976	6	5	12	20	47.2				88.0	
				12	21	4.5D					
				12	21	16.0					
304	1976	6	6	8	12	34.1	46 24.5	13 5.1	3.1	93.8	326
				8	12	52.4D					
				8	13	4.6					
305	1976	6	6	11	27	29.9				82.2	
				11	27	46.2D					
				11	27	57.0					
306	1976	6	6	12	30	47.6			3.0	86.3	
				12	31	4.6D					
				12	31	15.9					
307	1976	6	6	14	47	30.8				65.6	
				14	47	44.2					
				14	47	53.0					
308	1976	6	6	15	27	32.3				85.5	
				15	27	49.2					
				15	28	.4					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
309	1976	6	7	3	15	.2			3.0	102.0		
				3	15	20.0						
				3	15	33.2						
310	1976	6	7	12	35	22.6			2.9	78.0		
				12	35	38.2						
				12	35	48.5						
311	1976	6	7	22	31	4.6	46 26.6	12 56.2	2.9	103.7	322	L
				22	31	24.7D						
				22	31	38.1						
312	1976	6	8	0	43	32.5	46 22.2	12 52.6		100.4	317	
				0	43	52.0						
				0	44	5.0						
313	1976	6	8	2	13	32.3	46 15.7	13 4.4		81.4	319	L
				2	13	48.5						
				2	13	59.2						
314	1976	6	8	4	29	26.9				88.8		
				4	29	44.4						
				4	29	56.0						
315	1976	6	8	12	5	31.1	46 17.5	13 16.8	2.8	74.7	330	
				12	5	46.1D						
				12	5	56.0						
316	1976	6	8	12	14	33.9	46 19.8	13 12.3	4.3	81.4	328	
				12	14	50.1D						
				12	15	.8						
317	1976	6	8	12	19	25.3	46 18.7	13 3.6	3.3	86.3	321	
				12	19	42.3D						
				12	19	53.6						
318	1976	6	8	13	25	17.0				95.4		
				13	25	35.6						
				13	25	48.0						
319	1976	6	8	21	26	56.3				81.4		
				21	27	12.5						
				21	27	23.2						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
320	1976	6	8	21	40	53.3			3.0	84.7	
				21	41	10.0					
				21	41	21.1					
321	1976	6	9	0	47	52.4				75.6	
				0	48	7.5					
				0	48	17.5					
322	1976	6	9	7	42	2.6				73.9	
				7	42	17.4					
				7	42	27.2					
323	1976	6	9	18	48	10.7	46 22.4	13 1.0	4.0	93.8	322
				18	48	29.0D					
				18	48	41.2					
324	1976	6	9	19	12	15.4	46 22.0	13 4.5	3.0	90.5	324
				19	12	33.2C					
				19	12	45.0					
325	1976	6	10	7	29	48.0				80.5	
				7	30	4.0C					
				7	30	14.6					
326	1976	6	10	13	4	25.1	46 15.7	13 8.5	2.9	78.0	322
				13	4	40.7D					
				13	4	51.0					
327	1976	6	10	21	33	55.5				94.6	
				21	34	14.0					
				21	34	26.3					
328	1976	6	11	4	19	54.9				90.5	
				4	20	12.7					
				4	20	24.5					
329	1976	6	11	12	32	46.2			3.0	81.4	
				12	33	2.4					
				12	33	13.1					
330	1976	6	11	17	16	35.8	46 22.2	12 59.6	4.2	94.6	321
				17	16	54.3D					
				17	17	6.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
331	1976	6	11	17	39	36.4	46 25.7	12 55.5		102.9	321	
				17	39	56.3D						
				17	40	9.6						
332	1976	6	11	17	51	28.7	46 21.5	13 .4	3.2	92.9	321	
				17	51	46.9C						
				17	51	59.0						
333	1976	6	11	18	17	35.3				86.3		
				18	17	52.3						
				18	18	3.6						
334	1976	6	11	20	10	48.5	46 19.8	12 57.5		92.9	318	
				20	11	6.7C						
				20	11	18.8						
335	1976	6	11	21	3	57.8				91.3		
				21	4	15.7						
				21	4	27.6						
336	1976	6	12	6	5	12.2	46 18.6	13 2.3		87.2	320	
				6	5	29.4						
				6	5	40.8						
337	1976	6	12	18	5	28.9	46 19.0	13 14.3	3.3	78.9	329	
				18	5	44.6C						
				18	5	55.0						
338	1976	6	13	1	18	49.7	46 11.0	13 10.3		69.8	319	L
				1	19	3.8						
				1	19	13.1						
339	1976	6	13	8	47	17.7	46 11.5	13 8.3	2.8	72.3	318	
				8	47	32.3						
				8	47	41.9						
340	1976	6	13	13	8	23.4				90.5		
				13	8	41.2						
				13	8	53.0						
341	1976	6	13	19	0	41.8				88.0		
				19	0	59.1						
				19	1	10.6						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
342	1976	6	14	0	18	49.6	46 18.9	13 4.9	3.1	85.5	322
				0	19	6.5D					
				0	19	17.7					
343	1976	6	15	5	46	26.6	46 24.7	13 .0	3.7	97.9	323
				5	46	45.7D					
				5	46	58.4					
344	1976	6	16	1	50	32.8	46 18.7	13 6.6	3.2	83.8	323
				1	50	49.4C					
				1	51	.4					
345	1976	6	16	3	20	27.7	46 23.3	13 4.8	3.7	92.1	325
				3	20	45.8C					
				3	20	57.8					
346	1976	6	17	13	27	32.2	46 21.0	13 5.6	3.1	88.0	324
				13	27	49.5D					
				13	28	1.0					
347	1976	6	17	14	27	46.3	46 15.2	13 3.6	3.3	81.4	318
				14	28	2.5D					
				14	28	13.2					
348	1976	6	17	14	28	44.4	46 14.0	12 53.8	4.4	88.8	311
				14	29	1.9D					
				14	29	13.5					
349	1976	6	17	14	52	39.5				85.5	
				14	52	56.4					
				14	53	7.6					
350	1976	6	17	16	42	5.0	46 16.7	13 3.1	3.5	83.8	319
				16	42	21.6C					
				16	42	32.6					
351	1976	6	19	22	0	1.8				90.5	
				22	0	19.6					
				22	0	31.4					
352	1976	6	20	10	4	5.0	46 17.2	13 4.0	3.2	83.8	320
				10	4	21.6D					
				10	4	32.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
353	1976	6	20	18	0	1.3				77.2	
				18	0	16.7D					
				18	0	26.9					
354	1976	6	21	18	58	27.8	46 16.0	13 1.0	3.3	84.7	317
				18	58	44.5D					
				18	58	55.6					
355	1976	6	21	23	32	37.7	46 16.5	13 1.8		84.7	318
				23	32	54.4D					
				23	33	5.5					
356	1976	6	22	0	13	42.3				68.9	
				0	13	56.3					
				0	14	5.5					
357	1976	6	22	3	8	47.3				92.1	
				3	9	5.4					
				3	9	17.4					
358	1976	6	22	4	57	8.8	46 21.3	12 59.0	3.2	93.8	320
				4	57	27.1D					
				4	57	39.3					
359	1976	6	22	8	25	31.4				68.9	
				8	25	45.4					
				8	25	54.6					
360	1976	6	22	13	5	33.4				92.1	
				13	5	51.5					
				13	6	3.5					
361	1976	6	23	18	31	54.8				74.7	
				18	32	9.8					
				18	32	19.7					
362	1976	6	24	10	57	21.4				78.0	
				10	57	37.0					
				10	57	47.3					
363	1976	6	25	4	49	56.2	46 16.7	13 6.1	2.8	81.4	321
				4	50	12.4D					
				4	50	23.1					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
364	1976	6	25	20	6	10.4				72.3	
				20	6	25.0					
				20	6	34.6					
365	1976	6	25	22	9	2.7				75.6	
				22	9	17.8					
				22	9	27.8					
366	1976	6	25	23	28	50.8	46 19.2	12 56.6	3.1	92.9	317
				23	29	9.0C					
				23	29	21.1					
367	1976	6	26	11	13	43.3	46 21.1	13 7.0	4.3	87.2	325
				11	14	.5D					
				11	14	11.9					
368	1976	6	26	11	35	53.3	46 19.7	12 59.3	3.1	91.3	319
				11	36	11.2D					
				11	36	23.1					
369	1976	6	26	16	47	34.1	46 14.9	13 8.1	3.2	77.2	321
				16	47	49.5D					
				16	47	59.7					
370	1976	6	26	23	40	52.6			2.9	85.5	
				23	41	9.5D					
				23	41	20.7					
371	1976	6	27	11	4	49.8				73.9	
				11	5	4.6					
				11	5	14.4					
372	1976	6	27	14	1	12.3	46 14.5	13 7.3	3.2	77.2	320
				14	1	27.7D					
				14	1	37.9					
373	1976	6	27	19	3	8.3				74.7	
				19	3	23.3					
				19	3	33.2					
374	1976	6	27	19	47	40.2				90.5	
				19	47	58.0					
				19	48	9.8					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
375	1976	6	28	4	1	1.5	46 18.0	13 1.4	2.9	87.2	319
				4	1	18.7D					
				4	1	30.1					
376	1976	6	29	17	3	23.1	46 21.2	13 .8	2.7	92.1	321
				17	3	41.2D					
				17	3	53.2					
377	1976	6	30	19	2	38.1	46 12.2	13 12.5	2.8	69.8	322
				19	2	52.2D					
				19	3	1.5					
378	1976	7	1	21	27	4.9				96.3	
				21	27	23.7					
				21	27	36.2					
379	1976	7	3	4	46	30.9	46 17.9	13 3.1	3.0	85.5	320
				4	46	47.8D					
				4	46	59.0					
380	1976	7	3	15	36	7.0	46 13.7	13 12.1	3.4	72.3	323
				15	36	21.6D					
				15	36	31.2					
381	1976	7	3	16	58	37.0	46 17.6	13 7.8	3.2	81.4	323
				16	58	53.2D					
				16	59	3.9					
382	1976	7	3	23	40	6.3				91.3	
				23	40	24.2D					
				23	40	36.1					
383	1976	7	5	2	39	2.9	46 25.2	12 57.8		100.4	322
				2	39	22.4D					
				2	39	35.4					
384	1976	7	5	3	41	30.8	46 18.2	13 5.7	3.1	83.8	322
				3	41	47.4D					
				3	41	58.4					
385	1976	7	5	9	51	36.8	46 16.9	13 4.4	3.5	83.0	320
				9	51	53.2D					
				9	52	4.1					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
386	1976	7	6	6	5	48.9	46 20.9	13 17.7		79.7	333
				6	6	4.8C					
				6	6	15.3					
387	1976	7	6	23	8	28.9				82.2	
				23	8	45.2					
				23	8	56.0					
388	1976	7	8	9	56	.2	46 15.0	13 2.3		82.2	317
				9	56	16.5D					
				9	56	27.3					
389	1976	7	10	3	14	58.9				87.2	
				3	15	16.1					
				3	15	27.5					
390	1976	7	10	4	11	20.4	46 13.7	13 6.9	4.2	76.4	319
				4	11	35.7D					
				4	11	45.8					
391	1976	7	11	12	24	23.0	46 21.0	12 59.4	3.1	92.9	320
				12	24	41.2D					
				12	24	53.3					
392	1976	7	11	13	23	40.0	46 17.8	13 .1	3.0	88.0	318
				13	23	57.3C					
				13	24	8.8					
393	1976	7	12	8	4	46.9	46 19.4	13 5.9	3.9	85.5	323
				8	5	3.8D					
				8	5	15.0					
394	1976	7	14	5	39	29.9	46 24.5	13 15.1	4.2	87.2	333
				5	39	47.1D					
				5	39	58.5					
395	1976	7	14	11	31	5.0	46 20.5	13 4.7		88.0	323
				11	31	22.3D					
				11	31	33.8					
396	1976	7	14	16	42	57.1	46 14.9	13 16.8		70.6	328
				16	43	11.4					
				16	43	20.8					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
397	1976	7	14	18	50	25.8	46 18.9	13 1.9		88.0	320
				18	50	43.1D					
				18	50	54.6					
398	1976	7	15	3	37	18.5				102.0	
				3	37	38.3					
				3	37	51.5					
399	1976	7	15	12	58	45.5	46 20.5	13 10.4	3.8	83.8	327
				12	59	2.1D					
				12	59	13.1					
400	1976	7	15	15	21	54.1				71.4	
				15	22	8.5					
				15	22	18.0					
401	1976	7	16	15	39	27.9				73.1	
				15	39	42.6					
				15	39	52.3					
402	1976	7	17	6	58	14.1	46 19.6	13 1.1	3.1	89.6	320
				6	58	31.7D					
				6	58	43.4					
403	1976	7	18	13	39	13.7	46 20.4	12 58.4	3.5	92.9	319
				13	39	31.9D					
				13	39	44.0					
404	1976	7	25	3	45	6.5	46 12.5	13 7.0		74.7	318
				3	45	21.5D					
				3	45	31.4					
405	1976	7	25	9	30	8.6	46 18.0	13 1.4	3.0	87.2	319
				9	30	25.8D					
				9	30	37.2					
406	1976	7	27	4	52	27.3	46 17.9	12 58.3	3.0	89.6	317
				4	52	44.9D					
				4	52	56.6					
407	1976	7	27	8	19	43.6	46 22.8	13 .6	3.3	94.6	322
				8	20	2.1D					
				8	20	14.4					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
408	1976	7	30	7	32	40.4	46 20.1	12 58.9	3.5	92.1	319	
				7	32	58.5C						
				7	33	10.5						
409	1976	7	31	14	46	50.0	46 20.2	13 13.3	3.7	81.4	329	
				14	47	6.2D						
				14	47	16.9						
410	1976	8	1	12	38	58.8	46 17.5	13 3.6	2.9	84.7	320	
				12	39	15.5D						
				12	39	26.6						
411	1976	8	1	14	43	59.9	46 21.5	12 55.3	3.1	97.1	318	
				14	44	18.8D						
				14	44	31.4						
412	1976	8	11	18	30	23.4	46 14.8	13 12.1	2.9	73.9	324	L
				18	30	38.2						
				18	30	48.0						
413	1976	8	12	1	22	9.7	46 24.2	12 59.0	3.0	97.9	322	L
				1	22	28.8						
				1	22	41.5						
414	1976	8	14	5	34	56.4	46 12.8	12 57.5	2.7	83.8	312	L
				5	35	13.0						
				5	35	24.0						
415	1976	8	18	5	58	44.9	46 24.9	13 1.5		97.1	324	
				5	59	3.8C						
				5	59	16.4						
416	1976	8	23	15	51	25.5	46 20.8	13 4.3	3.1	88.8	323	
				15	51	43.0D						
				15	51	54.6						
417	1976	8	24	14	47	45.1	46 15.3	13 21.8	2.8	68.1	333	L
				14	47	58.9						
				14	48	8.0						
418	1976	9	2	2	50	51.2	46 20.1	12 58.9	2.9	92.1	319	
				2	51	9.3D						
				2	51	21.3						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
419	1976	9	2	14	4	22.5	46 20.0	13 3.7	3.0	88.0	322	
				14	4	39.8D						
				14	4	51.3						
420	1976	9	5	7	5	33.3	46 18.6	12 57.5	2.8	91.3	317	
				7	5	51.2C						
				7	6	3.1						
421	1976	9	6	19	28	10.3	46 20.1	13 2.0	3.7	89.6	321	
				19	28	27.9D						
				19	28	39.6						
422	1976	9	7	5	53	48.9	46 23.3	13 1.6	2.9	94.6	323	
				5	54	7.4C						
				5	54	19.7						
423	1976	9	7	11	8	12.4	46 21.3	12 59.0	3.8	93.8	320	
				11	8	30.7D						
				11	8	42.9						
424	1976	9	8	4	12	33.9	46 15.1	13 6.5	3.1	78.9	320	
				4	12	49.6D						
				4	13	.0						
425	1976	9	8	23	10	6.4	46 17.3	13 20.4	2.7	72.3	333	L
				23	10	21.0						
				23	10	30.6						
426	1976	9	9	17	26	31.0	46 26.2	13 6.5	3.2	95.4	328	L
				17	26	49.6C						
				17	27	2.0						
427	1976	9	11	16	31	8.2	46 18.6	13 10.9	5.1	80.5	326	
				16	31	24.2D						
				16	31	34.8						
428	1976	9	11	16	34	57.2	46 19.7	13 9.8	5.6	83.0	326	
				16	35	13.6D						
				16	35	24.5						
429	1976	9	11	16	40	41.3			3.6	81.4		
				16	40	57.5						
				16	41	8.2						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
430	1976	9	11	16	46	9.0				95.4		
				16	46	27.6						
				16	46	40.0						
431	1976	9	11	17	2	11.9				92.1		
				17	2	30.0						
				17	2	42.0						
432	1976	9	11	17	26	10.1	46 21.1	13 7.0	2.9	87.2	325	
				17	26	27.3C						
				17	26	38.7						
433	1976	9	11	17	34	57.7	46 21.2	13 3.9	3.4	89.6	323	L
				17	35	15.3C						
				17	35	27.0						
434	1976	9	11	17	46	24.5	46 18.9	13 9.2	2.9	82.2	325	
				17	46	40.8C						
				17	46	51.6						
435	1976	9	11	17	47	31.7				91.3		
				17	47	49.6C						
				17	48	1.5						
436	1976	9	11	18	5	43.1	46 18.9	12 57.0	2.9	92.1	317	
				18	6	1.2C						
				18	6	13.2						
437	1976	9	11	18	23	12.2			3.0	92.1		
				18	23	30.3D						
				18	23	42.3						
438	1976	9	11	18	27	46.8	46 20.7	13 2.9	3.4	89.6	322	L
				18	28	4.4D						
				18	28	16.1						
439	1976	9	11	19	9	7.4				85.5		
				19	9	24.3						
				19	9	35.5						
440	1976	9	11	19	49	41.1	46 13.0	13 5.0	3.0	77.2	317	
				19	49	56.5D						
				19	50	6.7						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
441	1976	9	11	19	50	56.2				88.0	
				19	51	13.5D					
				19	51	25.0					
442	1976	9	11	19	57	10.6	46 14.7	13 2.8	3.1	81.4	317
				19	57	26.8D					
				19	57	37.5					
443	1976	9	11	21	5	42.9	46 17.3	12 59.2	3.7	88.0	317
				21	6	.2D					
				21	6	11.7					
444	1976	9	11	22	49	6.4				88.0	
				22	49	23.7					
				22	49	35.2					
445	1976	9	12	1	19	54.5	46 20.5	13 11.7	4.0	83.0	328
				1	20	10.9D					
				1	20	21.8					
446	1976	9	12	2	25	43.6	46 15.2	13 3.6	2.9	81.4	318
				2	25	59.8D					
				2	26	10.5					
447	1976	9	12	3	47	25.4	46 14.0	13 3.6	3.0	79.7	317
				3	47	41.3C					
				3	47	51.8					
448	1976	9	12	4	2	46.2	46 14.9	13 8.1	2.8	77.2	321
				4	3	1.6D					
				4	3	11.8					
449	1976	9	12	4	44	.7				83.8	
				4	44	17.3					
				4	44	28.3					
450	1976	9	12	5	33	27.6				78.9	
				5	33	43.3					
				5	33	53.7					
451	1976	9	12	8	8	27.9	46 14.3	13 6.1	3.5	78.0	319
				8	8	43.5C					
				8	8	53.8					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
452	1976	9	12	8	14	45.2	46 18.4	13 1.0	3.6	88.0	319	
				8	15	2.5D						
				8	15	14.0						
453	1976	9	12	10	41	49.6	46 15.6	13 12.5	3.2	74.7	325	
				10	42	4.6D						
				10	42	14.5						
454	1976	9	12	13	31	45.9	46 15.4	13 8.9	2.9	77.2	322	
				13	32	1.3C						
				13	32	11.5						
455	1976	9	12	18	8	25.0				97.1		
				18	8	43.9						
				18	8	56.5						
456	1976	9	12	19	53	23.8	46 20.5	13 4.7	4.1	88.0	323	
				19	53	41.1D						
				19	53	52.6						
457	1976	9	12	21	19	54.1				71.4		
				21	20	8.5						
				21	20	18.0						
458	1976	9	13	0	48	4.7	46 18.1	13 4.4	3.2	84.7	321	L
				0	48	21.4						
				0	48	32.5						
459	1976	9	13	0	58	4.0				73.1		
				0	58	18.7						
				0	58	28.4						
460	1976	9	13	4	10	49.6	46 19.9	13 .6	3.1	90.5	320	
				4	11	7.4D						
				4	11	19.2						
461	1976	9	13	5	14	22.4	46 14.5	13 25.4		64.8	336	L
				5	14	35.6						
				5	14	44.3						
462	1976	9	13	7	3	48.1	46 20.5	13 4.7	3.4	88.0	323	
				7	4	5.4C						
				7	4	16.9						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
463	1976	9	13	7	29	58.3	46 11.5	13 13.3	2.9	68.1	322	L
				7	30	12.1D						
				7	30	21.2						
464	1976	9	13	14	17	14.2	46 15.4	13 8.9	2.9	77.2	322	
				14	17	29.6D						
				14	17	39.8						
465	1976	9	13	18	54	42.6	46 19.5	13 7.2	4.3	84.7	324	L
				18	54	59.3D						
				18	55	10.4						
466	1976	9	13	19	42	9.8	46 18.3	13 7.0	3.9	83.0	323	
				19	42	26.2D						
				19	42	37.1						
467	1976	9	13	20	45	51.3			2.9	88.8		
				20	46	8.8						
				20	46	20.4						
468	1976	9	13	21	25	4.7	46 21.5	13 3.5	3.1	90.5	323	
				21	25	22.5D						
				21	25	34.3						
469	1976	9	13	23	10	47.6				68.1		
				23	11	1.4						
				23	11	10.5						
470	1976	9	14	2	30	28.0	46 18.6	13 2.3	3.1	87.2	320	
				2	30	45.2D						
				2	30	56.6						
471	1976	9	14	6	24	4.8				86.3		
				6	24	21.8						
				6	24	33.1						
472	1976	9	14	8	25	16.9	46 20.5	13 11.7	3.7	83.0	328	
				8	25	33.3C						
				8	25	44.2						
473	1976	9	14	15	29	2.0	46 16.7	13 3.1	3.2	83.8	319	
				15	29	18.6C						
				15	29	29.6						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
474	1976	9	14	18	46	54.9	46 18.3	12 56.1		92.1	316	L
				18	47	13.0						
				18	47	25.0						
475	1976	9	14	20	37	34.3	46 17.1	13 14.7	2.9	75.6	328	L
				20	37	49.4						
				20	37	59.4						
476	1976	9	15	1	30	1.7	46 20.6	12 59.8	3.1	92.1	320	
				1	30	19.8D						
				1	30	31.8						
477	1976	9	15	3	15	17.0	46 18.6	13 10.9	5.8	80.5	326	
				3	15	33.0D						
				3	15	43.6						
478	1976	9	15	3	25	8.4			3.1	78.0		
				3	25	24.0						
				3	25	34.3						
479	1976	9	15	3	26	30.1				79.7		
				3	26	46.0						
				3	26	56.5						
480	1976	9	15	3	39	16.8			3.5	94.6		
				3	39	35.3D						
				3	39	47.6						
481	1976	9	15	3	42	43.6				83.8		
				3	43	.2						
				3	43	11.2						
482	1976	9	15	3	52	32.7	46 23.3	13 1.6	3.3	94.6	323	L
				3	52	51.2D						
				3	53	3.5						
483	1976	9	15	3	55	47.5	46 18.3	13 7.0	3.4	83.0	323	L
				3	56	3.9D						
				3	56	14.8						
484	1976	9	15	4	15	.4				73.9		
				4	15	15.2						
				4	15	25.0						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
485	1976	9	15	4	30	36.1			3.2	81.4		
				4	30	52.3D						
				4	31	3.0						
486	1976	9	15	4	38	49.1	46 23.5	13 3.0	4.7	93.8	324	L
				4	39	7.4D						
				4	39	19.6						
487	1976	9	15	4	49	28.4				80.5		
				4	49	44.4						
				4	49	55.0						
488	1976	9	15	4	58	38.7	46 25.2	13 11.7	4.3	90.5	331	L
				4	58	56.5D						
				4	59	8.3						
489	1976	9	15	5	38	20.0	46 17.6	12 58.8	3.3	88.8	317	L
				5	38	37.5D						
				5	38	49.1						
490	1976	9	15	5	58	23.7				83.0		
				5	58	40.1						
				5	58	51.0						
491	1976	9	15	9	21	16.2	46 19.2	13 8.8	6.1	83.0	325	
				9	21	32.6D						
				9	21	43.5						
492	1976	9	15	9	34	2.7	46 27.2	13 14.4	3.2	92.1	334	
				9	34	20.8D						
				9	34	32.8						
493	1976	9	15	9	37	25.8	46 21.4	13 6.6	3.4	88.0	325	
				9	37	43.1C						
				9	37	54.6						
494	1976	9	15	9	45	51.7			4.3	85.5		
				9	46	8.6						
				9	46	19.8						
495	1976	9	15	9	53	32.1			2.9	85.5		
				9	53	49.0						
				9	54	.2						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
496	1976	9	15	9	54	29.1				79.7		
				9	54	45.0						
				9	54	55.5						
497	1976	9	15	9	55	43.1	46 20.2	12 55.3	3.5	95.4	317	
				9	56	1.7D						
				9	56	14.1						
498	1976	9	15	9	58	13.5			2.7	83.0		
				9	58	29.9						
				9	58	40.8						
499	1976	9	15	10	11	3.2	46 20.3	13 3.3	3.1	88.8	322	
				10	11	20.7C						
				10	11	32.3						
500	1976	9	15	10	32	45.5	46 17.9	13 3.1	3.1	85.5	320	
				10	33	2.4D						
				10	33	13.6						
501	1976	9	15	10	48	10.3			2.7	78.0		
				10	48	25.9						
				10	48	36.2						
502	1976	9	15	10	50	60.0			2.8	107.8		
				10	51	20.8						
				10	51	34.7						
503	1976	9	15	10	54	24.8	46 18.2	13 2.7	3.2	86.3	320	
				10	54	41.8C						
				10	54	53.1						
504	1976	9	15	11	11	7.7	46 21.2	13 9.6	4.5	85.5	327	L
				11	11	24.6D						
				11	11	35.8						
505	1976	9	15	11	17	41.6	46 17.2	13 4.0	3.7	83.8	320	
				11	17	58.2C						
				11	18	9.2						
506	1976	9	15	11	27	18.1	46 21.1	12 57.6	3.0	94.6	319	
				11	27	36.6C						
				11	27	48.9						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
507	1976	9	15	11	38	57.5			2.9	88.0		
				11	39	14.8						
				11	39	26.3						
508	1976	9	15	11	51	.6	46 20.4	13 9.0	2.9	84.7	326	L
				11	51	17.3D						
				11	51	28.4						
509	1976	9	15	12	20	57.3			2.9	79.7		
				12	21	13.2						
				12	21	23.7						
510	1976	9	15	12	50	41.2	46 18.2	13 2.7	3.1	86.3	320	
				12	50	58.2C						
				12	51	9.5						
511	1976	9	15	13	12	52.7				73.9		
				13	13	7.5D						
				13	13	17.3						
512	1976	9	15	13	25	56.4	46 12.5	12 56.2	3.0	84.7	311	
				13	26	13.1D						
				13	26	24.2						
513	1976	9	15	14	42	32.6	46 21.5	13 .4	3.7	92.9	321	
				14	42	50.8						
				14	42	2.9						
514	1976	9	15	15	19	51.7	46 21.7	13 4.9	3.7	89.6	324	
				15	20	9.3D						
				15	20	21.0						
515	1976	9	15	15	22	43.1			2.9	73.1		
				15	22	57.8D						
				15	23	7.5						
516	1976	9	15	15	24	21.1	46 23.8	12 59.4	3.5	97.1	322	
				15	24	40.0C						
				15	24	52.6						
517	1976	9	15	15	26	28.6			2.8	74.7		
				15	26	43.6						
				15	26	53.5						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
518	1976	9	15	15	56	30.6			2.6	71.4	
				15	56	45.0					
				15	56	54.5					
519	1976	9	15	16	11	15.8	46 17.9	12 58.3	3.3	89.6	317
				16	11	33.4C					
				16	11	45.1					
520	1976	9	15	16	24	21.1	46 17.5	13 .5	3.4	87.2	318
				16	24	38.3C					
				16	24	49.7					
521	1976	9	15	16	49	46.1	46 17.3	12 59.2	3.0	88.0	317
				16	50	3.4C					
				16	50	14.9					
522	1976	9	15	17	22	35.2				75.6	
				17	22	50.3					
				17	23	.3					
523	1976	9	15	17	25	53.7	46 19.1	12 43.1	3.7	105.4	310
				17	26	14.1D					
				17	26	27.7					
524	1976	9	15	17	35	55.5			3.0	83.8	
				17	36	12.1					
				17	36	23.1					
525	1976	9	15	17	42	25.2			2.8	86.3	
				17	42	42.2					
				17	42	53.5					
526	1976	9	15	17	44	46.5	46 19.2	12 56.6	3.4	92.9	317
				17	45	4.7C					
				17	45	16.8					
527	1976	9	15	18	17	23.6				80.5	
				18	17	39.6					
				18	17	50.2					
528	1976	9	15	18	23	17.4				90.5	
				18	23	35.2					
				18	23	47.0					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
529	1976	9	15	18	36	44.7				94.6	
				18	37	3.2					
				18	37	15.5					
530	1976	9	15	19	18	11.3	46 16.3	13 6.5	2.8	80.5	321
				19	18	27.3					
				19	18	37.9					
531	1976	9	15	19	31	5.8	46 27.2	13 13.0	4.1	92.9	333
				19	31	24.0D					
				19	31	36.1					
532	1976	9	15	19	52	28.7				93.8	
				19	52	47.0					
				19	52	59.2					
533	1976	9	15	19	57	17.5	46 14.4	13 1.5	3.1	82.2	316
				19	57	33.8C					
				19	57	44.6					
534	1976	9	15	20	8	2.5				77.2	
				20	8	17.9					
				20	8	28.1					
535	1976	9	15	20	11	45.2			3.0	83.0	
				20	12	1.6D					
				20	12	12.5					
536	1976	9	15	20	16	41.2			2.7	75.6	
				20	16	56.3					
				20	17	6.3					
537	1976	9	15	20	24	6.1	46 21.4	13 6.6	3.9	88.0	325
				20	24	23.4C					
				20	24	34.9					
538	1976	9	15	20	30	8.1			2.7	78.0	
				20	30	23.7					
				20	30	34.0					
539	1976	9	15	20	34	49.3	46 19.2	12 56.6	3.7	92.9	317
				20	35	7.5D					
				20	35	19.6					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
540	1976	9	15	20	44	46.3	46 14.9	12 55.9	3.3	88.0	313	L
				20	45	3.6						
				20	45	15.1						
541	1976	9	15	21	40	43.9			2.9	68.9		
				21	40	57.9						
				21	41	7.1						
542	1976	9	15	22	20	57.8	46 18.0	13 1.4	3.0	87.2	319	
				22	21	15.0D						
				22	21	26.4						
543	1976	9	15	22	35	43.2	46 15.1	13 6.5	3.1	78.9	320	
				22	35	58.9						
				22	36	9.3						
544	1976	9	15	23	33	33.6	46 18.2	13 2.7	2.9	86.3	320	L
				23	33	50.6						
				23	34	1.9						
545	1976	9	16	1	30	40.0	46 19.2	12 58.4	3.7	91.3	318	
				1	30	57.9C						
				1	31	9.8						
546	1976	9	16	2	8	47.9	46 19.2	12 56.6	2.9	92.9	317	
				2	9	6.1D						
				2	9	18.2						
547	1976	9	16	2	17	36.7			2.9	91.3		
				2	17	54.6						
				2	18	6.5						
548	1976	9	16	2	20	57.3	46 19.3	13 1.5		88.8	320	
				2	21	14.8						
				2	21	26.4						
549	1976	9	16	2	42	21.4	46 18.6	12 57.5	2.8	91.3	317	L
				2	42	39.3C						
				2	42	51.2						
550	1976	9	16	3	30	32.5	46 14.8	13 4.0	2.9	80.5	318	
				3	30	48.5D						
				3	30	59.1						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
551	1976	9	15	5	20	3.7				91.3	
				5	20	21.6					
				5	20	33.5					
552	1976	9	16	5	40	36.7	46 17.3	12 59.2	3.3	88.0	317
				5	40	54.0					
				5	41	5.5					
553	1976	9	16	8	45	13.6				73.9	
				8	45	28.4					
				8	45	38.2					
554	1976	9	16	9	8	20.5	46 21.1	12 55.8	2.9	96.3	318
				9	8	39.3					
				9	8	51.8					
555	1976	9	16	9	27	53.1	46 23.0	12 56.9	2.7	97.9	320
				9	28	12.2D					
				9	28	24.9					
556	1976	9	16	11	21	7.4				77.2	
				11	21	22.8					
				11	21	33.0					
557	1976	9	16	11	33	26.7				82.2	
				11	33	43.0					
				11	33	53.8					
558	1976	9	16	12	49	49.7				76.4	
				12	50	5.0					
				12	50	15.1					
559	1976	9	16	14	27	33.1	46 16.0	13 6.9	3.0	79.7	321
				14	27	49.0					
				14	27	59.5					
560	1976	9	16	14	30	32.6	46 17.3	12 59.2	2.9	88.0	317
				14	30	49.9C					
				14	31	1.4					
561	1976	9	16	15	33	5.4				95.4	
				15	33	24.0					
				15	33	36.4					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
562	1976	9	16	16	26	35.5	46 20.0	13 3.7	2.8	88.0	322	
				16	26	52.8C						
				16	27	4.3						
563	1976	9	16	16	36	6.6			2.8	94.6		
				16	36	25.1						
				16	36	37.4						
564	1976	9	16	17	12	23.9	46 17.9	12 58.3	2.9	89.6	317	L
				17	12	41.5						
				17	12	53.2						
565	1976	9	16	17	18	15.9				92.1		
				17	18	34.0						
				17	18	46.0						
566	1976	9	16	17	39	25.4	46 20.5	12 54.8	2.7	96.3	317	
				17	39	44.2C						
				17	39	56.7						
567	1976	9	16	19	14	26.2				97.9		
				19	14	45.3						
				19	14	58.0						
568	1976	9	16	20	1	34.8	46 20.1	13 5.1	3.1	87.2	323	
				20	1	52.0C						
				20	2	3.4						
569	1976	9	16	20	29	42.5			2.9	111.2		
				20	30	3.9						
				20	30	18.2						
570	1976	9	16	20	37	4.7			2.8	91.3		
				20	37	22.6						
				20	37	34.5						
571	1976	9	16	21	9	24.3	46 19.4	13 2.8	2.9	88.0	321	
				21	9	41.6D						
				21	9	53.1						
572	1976	9	16	22	0	20.6				97.9		
				22	0	39.7						
				22	0	52.4						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
573	1976	9	16	22	50	31.8				88.0		
				22	50	49.1						
				22	51	.6						
574	1976	9	16	23	13	56.8			2.8	93.8		
				23	14	15.1						
				23	14	27.3						
575	1976	9	16	23	50	33.4	46 19.1	13 3.2	2.9	87.2	321	L
				23	50	50.6						
				23	51	2.0						
576	1976	9	16	23	51	56.6	46 21.2	12 44.0	3.4	107.0	312	
				23	52	17.3C						
				23	52	31.1						
577	1976	9	17	0	38	44.9	46 19.4	12 59.7	3.0	90.5	319	
				0	39	2.7D						
				0	39	14.5						
578	1976	9	17	1	56	25.8				78.0		
				1	56	41.4						
				1	56	51.7						
579	1976	9	17	2	27	31.7			2.9	106.2		
				2	27	52.2						
				2	28	5.9						
580	1976	9	17	2	47	9.5	46 16.1	12 59.3	3.0	86.3	316	
				2	47	26.5C						
				2	47	37.8						
581	1976	9	17	3	24	34.1				78.0		
				3	24	49.7						
				3	25	.0						
582	1976	9	17	4	11	15.4			2.8	73.9		
				4	11	30.2						
				4	11	40.0						
583	1976	9	17	4	11	38.1			2.9	92.9		
				4	11	56.3						
				4	12	8.4						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
584	1976	9	17	4	14	.5	46 22.0	12 58.2	3.9	95.4	320	
				4	14	19.1D						
				4	14	31.5						
585	1976	9	17	6	31	6.3			2.9	79.7		
				6	31	22.2D						
				6	31	32.7						
586	1976	9	17	6	50	46.4				84.7		
				6	51	3.1						
				6	51	14.2						
587	1976	9	17	8	58	32.5	46 19.2	12 56.6	2.9	92.9	317	L
				8	58	50.7D						
				8	59	2.8						
588	1976	9	17	9	17	52.3	46 20.3	13 7.7	3.2	85.5	325	
				9	18	9.2						
				9	18	20.4						
589	1976	9	17	9	36	32.6	46 16.7	12 56.6	3.0	89.6	315	
				9	36	50.2D						
				9	37	1.9						
590	1976	9	17	11	6	18.9			2.9	92.1		
				11	6	37.0						
				11	6	49.0						
591	1976	9	17	12	44	15.1			2.9	91.3		
				12	44	33.0						
				12	44	44.9						
592	1976	9	17	13	14	51.7	46 19.9	12 55.7	3.2	94.6	317	
				13	15	10.2C						
				13	15	22.5						
593	1976	9	17	14	17	30.3	46 13.8	13 5.3	3.3	78.0	318	
				14	17	45.9C						
				14	17	56.2						
594	1976	9	17	14	35	16.1	46 13.5	12 50.8	2.9	91.3	309	L
				14	35	34.0						
				14	35	45.9						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
595	1976	9	17	15	29	20.9				82.2		
				15	29	37.2						
				15	29	48.0						
596	1976	9	17	16	18	51.4			2.9	84.7		
				16	19	8.1						
				16	19	19.2						
597	1976	9	17	16	20	34.2			2.7	78.9		
				16	20	49.9						
				16	21	.3						
598	1976	9	17	17	7	34.0	46 17.3	12 59.2	2.9	88.0	317	
				17	7	51.3D						
				17	8	2.8						
599	1976	9	17	17	52	16.8			2.8	95.4		
				17	52	35.4						
				17	52	47.8						
600	1976	9	17	22	48	33.0				72.3		
				22	48	47.6						
				22	48	57.2						
601	1976	9	17	22	56	4.6	46 11.6	12 59.4	2.8	80.5	312	
				22	56	20.6D						
				22	56	31.2						
602	1976	9	17	23	52	57.5	46 22.8	12 49.8	2.8	103.7	316	
				23	53	17.6D						
				23	53	31.0						
603	1976	9	17	23	54	29.7				100.4		
				23	54	49.2D						
				23	55	2.2						
604	1976	9	18	0	39	35.0	46 21.7	12 58.6	3.6	94.6	320	L
				0	39	53.5						
				0	40	5.8						
605	1976	9	18	1	8	36.8			2.9	83.0		
				1	8	53.2						
				1	9	4.1						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
606	1976	9	18	5	50	16.5	46 20.2	12 57.1	3.4	93.8	318	
				5	50	34.8D						
				5	50	47.0						
607	1976	9	18	6	33	23.1	46 15.3	13 7.7	2.8	78.0	321	
				6	33	38.7C						
				6	33	49.0						
608	1976	9	18	14	27	57.0				83.8		
				14	28	13.6						
				14	28	24.6						
609	1976	9	18	16	22	27.6	46 14.0	12 59.0	3.0	83.8	314	L
				16	22	44.2						
				16	22	55.2						
610	1976	9	18	18	53	37.3	46 30.8	13 8.8		101.2	332	L
				18	53	57.0						
				18	54	10.1						
611	1976	9	18	21	49	34.5	46 19.8	12 57.5	3.1	92.9	318	
				21	49	52.7C						
				21	50	4.8						
612	1976	9	19	1	22	51.9	46 18.8	13 7.9		83.0	324	L
				1	23	8.3						
				1	23	19.2						
613	1976	9	19	10	26	47.8	46 17.0	13 2.7	3.7	84.7	319	
				10	27	4.5D						
				10	27	15.6						
614	1976	9	19	11	13	7.3	46 21.5	12 53.5	3.2	98.7	317	
				11	13	26.5C						
				11	13	39.3						
615	1976	9	19	17	21	26.9				90.5		
				17	21	44.7						
				17	21	56.5						
616	1976	9	19	22	33	59.3				74.7		
				22	34	14.3						
				22	34	24.2						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
617	1976	9	20	2	27	18.9	46 20.6	13 6.0	3.1	87.2	324	
				2	27	36.1C						
				2	27	47.5						
618	1976	9	20	2	46	15.6				88.8		
				2	46	33.1						
				2	46	44.7						
619	1976	9	20	6	18	48.2				79.7		
				6	19	4.1						
				6	19	14.6						
620	1976	9	20	8	5	9.5				87.2		
				8	5	26.7D						
				8	5	38.1						
621	1976	9	20	9	9	55.2	46 20.9	13 12.6	4.0	83.0	329	
				9	10	11.6D						
				9	10	22.5						
622	1976	9	20	9	51	23.6	46 16.9	12 59.7		87.2	317	
				9	51	40.8D						
				9	51	52.2						
623	1976	9	20	15	53	36.2	46 11.5	12 52.5		87.2	308	L
				15	53	53.4						
				15	54	4.8						
624	1976	9	20	17	22	47.0	46 18.9	12 57.0		92.1	317	
				17	23	5.1D						
				17	23	17.1						
625	1976	9	20	23	34	14.4	46 23.3	12 58.3	3.5	97.1	321	
				23	34	33.3D						
				23	34	45.9						
626	1976	9	21	0	29	5.6				64.8		
				0	29	18.8						
				0	29	27.5						
627	1976	9	21	6	33	55.0	46 15.4	12 49.6	3.0	94.6	310	L
				6	34	13.5						
				6	34	25.8						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
628	1976	9	21	16	17	50.2	46 17.7	12 55.2	3.1	92.1	315	
				16	18	8.3C						
				16	18	20.3						
*629	1976	9	22	0	7	33.4				73.1		
				0	7	48.1						
				0	7	57.8						
630	1976	9	22	3	27	13.0	46 20.6	13 15.5	2.9	80.5	331	L
				3	27	29.0D						
				3	27	39.6						
631	1976	9	22	15	23	51.5	46 23.4	12 54.6	3.2	100.4	319	
				15	24	11.0D						
				15	24	24.0						
632	1976	9	22	18	35	38.9	46 22.1	12 56.3		97.1	319	
				18	35	57.8C						
				18	36	10.4						
633	1976	9	22	19	29	47.4	46 15.5	12 54.9	2.9	89.6	313	
				19	30	5.0C						
				19	30	16.7						
634	1976	9	22	19	47	23.8				100.4		
				19	47	43.3						
				19	47	56.3						
635	1976	9	22	20	1	10.9				94.6		
				20	1	29.4						
				20	1	41.7						
636	1976	9	22	20	35	1.4	46 22.8	12 55.5	2.9	98.7	319	
				20	35	20.6D						
				20	35	33.4						
637	1976	9	22	22	20	20.5				92.9		
				22	20	38.7D						
				22	20	50.8						
638	1976	9	23	15	26	47.9	46 14.1	13 12.9	2.9	72.3	324	L
				15	27	2.5						
				15	27	12.1						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
639	1976	9	23	15	49	6.9	46 13.1	12 55.3	3.1	86.3	311	L
				15	49	23.9D						
				15	49	35.2						
640	1976	9	23	18	55	5.3				78.9		
				18	55	21.0						
				18	55	31.4						
641	1976	9	23	22	24	37.3	46 9.8	13 2.3	3.1	75.6	312	
				22	24	52.4D						
				22	25	2.4						
642	1976	9	24	4	11	9.3	46 20.2	13 15.8		79.7	331	L
				4	11	25.2						
				4	11	35.7						
643	1976	9	24	14	46	2.4	46 15.4	12 43.1		101.2	307	L
				14	46	22.1						
				14	46	35.2						
644	1976	9	24	16	12	8.8	46 16.7	13 3.1	3.1	83.8	319	
				16	12	25.4D						
				16	12	36.4						
645	1976	9	24	16	20	60.0				98.7		
				16	21	19.2						
				16	21	32.0						
646	1976	9	25	1	34	43.1			2.9	83.0		
				1	34	59.5D						
				1	35	10.4						
647	1976	9	25	12	32	30.7	46 23.3	13 4.8	2.9	92.1	325	
				12	32	48.8						
				12	33	.8						
648	1976	9	25	13	36	45.3			2.8	97.1		
				13	37	4.2						
				13	37	16.8						
649	1976	9	25	20	6	9.4	46 15.8	13 9.7	2.9	77.2	323	
				20	6	24.8C						
				20	6	35.0						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
650	1976	9	26	1	26	59.5			2.9	92.9		
				1	27	17.7D						
				1	27	29.8						
651	1976	9	26	1	51	45.8	46 14.0	12 53.8	3.6	88.8	311	
				1	52	3.3D						
				1	52	14.9						
652	1976	9	26	5	30	47.0	46 25.4	13 5.8	3.1	94.6	327	
				5	31	5.5C						
				5	31	17.8						
653	1976	9	26	7	24	36.5	46 21.7	12 58.6	3.1	94.6	320	L
				7	24	55.0D						
				7	25	7.3						
654	1976	9	26	7	33	41.6	46 19.6	13 19.8	3.3	76.4	334	L
				7	33	56.9						
				7	34	7.0						
655	1976	9	26	9	40	1.9	46 18.2	13 5.7	3.0	83.8	322	L
				9	40	18.5D						
				9	40	29.5						
656	1976	9	26	13	27	56.4	46 15.0	13 2.3		82.2	317	
				13	28	12.7D						
				13	28	23.5						
657	1976	9	26	14	52	15.7	46 18.5	12 59.2	3.6	89.6	318	
				14	52	33.3D						
				14	52	45.0						
658	1976	9	26	17	50	21.7	46 20.0	13 3.7		88.0	322	
				17	50	39.0C						
				17	50	50.5						
659	1976	9	27	14	37	26.5	46 16.4	13 7.7	3.6	79.7	322	
				14	37	42.4D						
				14	37	52.9						
660	1976	9	28	0	10	11.6	46 13.7	13 4.1		78.9	317	L
				0	10	27.3						
				0	10	37.7						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
661	1976	9	28	13	25	8.6	46 23.6	12 40.2	3.0	113.6	312	
				13	25	30.4D						
				13	25	45.0						
662	1976	9	29	2	59	28.1	46 20.5	13 1.6		90.5	321	N
				2	59	45.9						
				2	59	57.7						
663	1976	9	29	6	59	40.7	46 17.6	13 7.8	2.8	81.4	323	N
				6	59	56.9						
				7	0	7.6						
664	1976	9	29	22	39	58.3	46 19.4	13 5.9		85.5	323	N
				22	40	15.2						
				22	40	26.4						
665	1976	9	30	21	27	44.9				82.2		
				21	28	1.2						
				21	28	12.0						
666	1976	10	1	8	6	24.6	46 17.6	13 7.8		81.4	323	N
				8	6	40.8						
				8	6	51.5						
667	1976	10	2	17	9	42.2	46 20.7	13 7.4	2.7	86.3	325	N
				17	9	59.2						
				17	10	10.5						
668	1976	10	3	17	49	45.4	46 23.3	13 1.6	3.4	94.6	323	
				17	50	3.9D						
				17	50	16.2						
669	1976	10	5	7	33	2.8	46 25.8	12 58.8	3.0	100.4	323	N
				7	33	22.3D						
				7	33	35.3						
670	1976	10	6	10	31	34.4			2.9	99.6		
				10	31	53.8D						
				10	32	6.7						
671	1976	10	9	3	41	4.5	46 17.0	13 2.7	3.0	84.7	319	
				3	41	21.2D						
				3	41	32.3						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI	
672	1976	10	9	5	0	8.4	46 16.1	12 55.8	2.9	89.6	314	
				5	0	26.0D						
				5	0	37.7						
673	1976	10	11	16	57	11.2			3.2	89.6		
				16	57	28.8						
				16	57	40.5						
674	1976	10	12	8	1	39.1	46 17.4	12 55.7	3.1	91.3	315	
				8	1	57.0D						
				8	2	8.9						
675	1976	10	12	10	23	4.7	46 15.5	12 53.1	3.2	91.3	312	
				10	23	22.6C						
				10	23	34.5						
676	1976	10	12	12	5	30.1				79.7		
				12	5	46.0D						
				12	5	56.5						
677	1976	10	12	12	13	49.0				73.9		
				12	14	3.8						
				12	14	13.6						
678	1976	10	13	2	48	35.4	46 20.2	12 55.3	4.4	95.4	317	
				2	48	54.0D						
				2	49	6.4						
679	1976	10	13	7	39	43.0	46 15.0	13 5.2	3.4	79.7	319	
				7	39	58.9C						
				7	40	9.4						
680	1976	10	15	2	28	29.1	46 20.2	12 55.3	3.2	95.4	317	
				2	28	47.7C						
				2	29	.1						
681	1976	10	15	5	57	41.0	46 16.7	13 6.1	2.9	81.4	321	
				5	57	57.2D						
				5	58	7.9						
682	1976	10	16	4	56	42.9	46 21.0	13 5.6	2.9	88.0	324	S
				4	57	.2						
				4	57	11.7						

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
683	1976	10	16	13	26	38.7	46 20.0	13 3.7	3.0	88.0	322 S
				13	26	56.0C					
				13	27	7.5					
684	1976	10	17	16	23	28.6	46 18.8	13 7.9	2.8	83.0	324 S
				16	23	45.0					
				16	23	55.9					
685	1976	10	17	20	19	41.7	46 23.3	13 14.6	2.9	85.5	332 S
				20	19	58.6C					
				20	20	9.8					
686	1976	10	19	8	31	24.9	46 20.6	13 6.0	3.0	87.2	324
				8	31	42.1D					
				8	31	53.5					
687	1976	10	19	22	52	41.6	46 22.3	12 57.7	3.2	96.3	320 S
				22	53	.4D					
				22	53	12.9					
688	1976	10	20	5	55	19.6	46 18.9	12 57.0	2.9	92.1	317
				5	55	37.7D					
				5	55	49.7					
689	1976	10	21	3	30	21.9	46 21.4	13 2.2	2.9	91.3	322 S
				3	30	39.8D					
				3	30	51.7					
690	1976	10	21	3	34	46.4	46 19.6	13 8.5	2.9	83.8	325 S
				3	35	3.0D					
				3	35	14.0					
691	1976	10	26	6	2	44.8	46 19.7	13 9.8	3.2	83.0	326 S
				6	3	1.2D					
				6	3	12.1					
692	1976	10	26	6	9	56.0	46 19.2	13 8.8	2.7	83.0	325 S
				6	10	12.4C					
				6	10	23.3					
693	1976	10	27	4	25	40.3	46 18.9	13 10.5	3.3	81.4	326 S
				4	25	56.5D					
				4	26	7.2					

NUMB	YEAR	MONTH	DAY	HR	MN	SEC	NORTH	EAST	MAG	DIST	AZI
694	1976	10	28	6	15	47.4			3.1	82.2	
				6	16	3.7D					
				6	16	14.5					
695	1976	10	30	12	28	41.4	46 19.9	13 6.8	3.4	85.5	324
				12	28	58.3C					
				12	29	9.5					

FOCAL MECHANISM OF SOME FRIOUL EARTHQUAKES (1976)

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Abstract. By classical methods the focal mechanism solutions for some strong earthquakes of May and September in Frioul has been determined. The data in our possess didn't allow us to fix the nodal plane positions with high precision for all the events. The most significative result of this work is the solution obtained for the three strongest shocks, as they show very similar mechanisms. The solutions are consistent with a dip slip mechanism. The fault plane is dipping towards NNW with a dip angle of about 15-30 degrees.

Introduction

The seismic events happened in Frioul during the 1976 were sharply distinguished into two phases in which we could record the greatest magnitude shocks as well as the greatest number of aftershocks. Such phases were respectively comprised between May 6 and 11, and September 11 and 15.

As well known, earthquake focal mechanisms are chiefly studied by the first pulse sense recorded at the seismic stations. For this purpose good quality records are requested, in which the polarity of the P wave motion can be recognized without any doubt. Moreover the recording stations must be distributed as uniformly as possible in azimuth and in distance from the epicenter. These conditions limit the shocks of which mechanisms can be usefully studied to those of great magnitude only.

Other circumstances can give uncertainty to seismogram analysis. So, for example, some difficulties was found with short period near stations for the M_l = 6.2 (RMP) earthquake of May 6 because of the M_l = 4.5 foreshock which masked its first pulse.

The method

To determine focal mechanism solutions, we used a computer program drawn by that one published by Wickens and Hodgson in 1967 (1). Such program assumes a double couple source and determines three characteristic parameters for

orientation of the nodal planes in order to fit the actual data in the best way.

In the first step azimuth and distance of the stations with respect to the epicenter are computed. Then, by the use of Jeffreys-Bullen travel time tables, the angle i at which the wave left the focus to emerge at the station is determined.

In the following steps a special function is estimated by the sum of the single contributions furnished by the stations according to the weight related to their position between the nodal planes. The position of the planes corresponding to the maximum value of the function is retained as the problem solution.

For the graphic representation of the solution we used the Wulff's stereographic projection of the lower focal emisphere. On such projection the compressions and dilatations are separated by two nodal lines that follow the course of two meridional lines perpendicular to each other (2).

Applicaton to Frioul earthquakes

For the focal mechanism solution, all the informations about first arrival polarity were used, without discrimination between short and long period seismograms.

The hypocentral parameters used in the program, were obtained in the Central Observatory of Monte Porzio (Rome). As every shock in this seismic period was located in the earth's crust, P wave velocity at the focus, determined by

the program itself, was usually comprised between 6 and 7 km/sec.

The events for which we tried the determination of the focal mechanism were twelve. They had all magnitude not much less than 5.0. We noticed, however, that for some of them the solution didn't show the requested reliability, either for the small number of the stations or their bad geographic distribution.

A remarkable persistence of the polarity in the different earthquakes for the same station allows us to think that the general feature of the mechanisms, although some light variation, should not be strongly changed during the seismic period. We are of opinion that a noticeable alteration in the fault-plane solution could derive from lack of data from stations near the nodal planes. In agreement with this fact, we noticed that the program solution for the main shock of May 6 was considerably modified by the addition of some far stations to the data used in the computation.

In table I the hypocentral parameters of the events for which we had a suitable number of data are reported, together their relative nodal-plane solutions. The same solutions are graphically reproduced in figg. 1, 2 and 3 in a polar stereographic projection.

Discussion of the results

As well known, the focal mechanism solution of an earthquake is ambiguos, from the physical point of view, in the

identification of the actual fault plane between the two nodal planes. Sometimes such ambiguity can be resolved by geological argumentations.

In our case the solutions show principally a dip-slip mechanism, in which one of the planes is always near to the vertical. The azimuth of this plane, well determined by the station distribution, ranges from E-W to NE-SW.

The events 2,7 and 8 of table I show very similar solutions. As they have the greatest magnitudes, and therefore also the greatest number of station data, they furnished of course the most reliable solutions. For these three earthquakes the choice of the fault plane between the two nodal planes has clearly to be done in agreement with the circumstance that the northern block (the Alps) is uplifted in respect to the southern one (the Padan Valley). It is possible only taking as slipping plane the second nodal plane. Therefore it should be either a movement for which Alps overthrust towards south or Italy underthrust towards north.

Concerning in particular the event 2 (the main shock of May 6), the present result is in very good agreement with a previous paper of G. Muller (3), who studied a lot of WWNSS long period records.

TABLE I

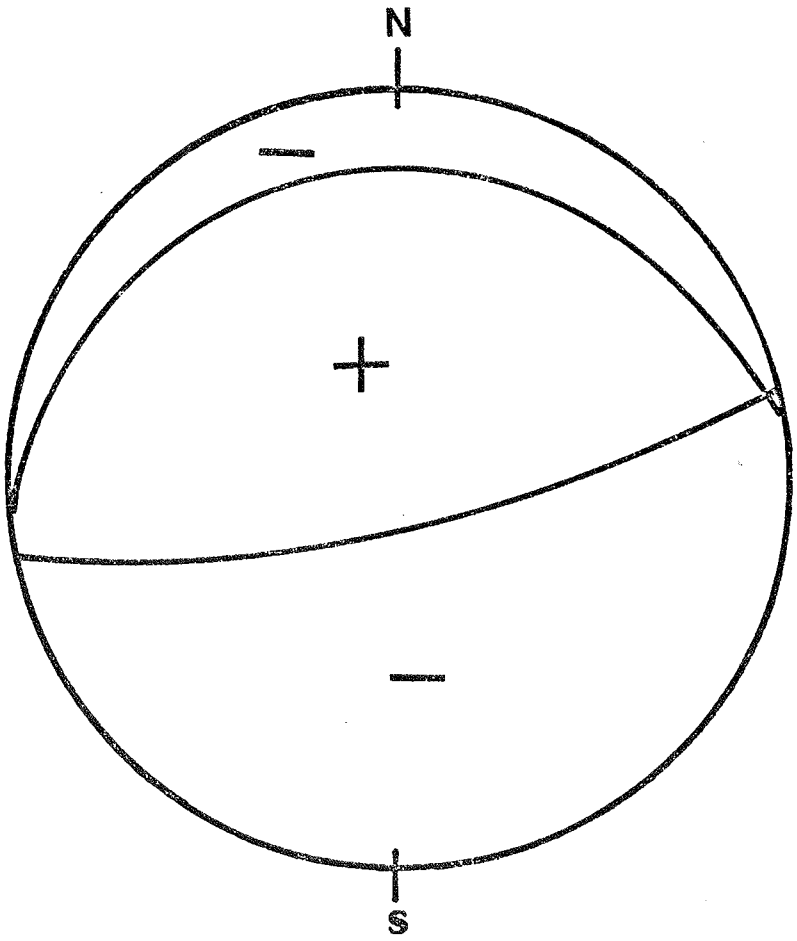
N	Date	Time (GMT)	M_L (RMP)	φ	λ	h (km)	Plane A azimuth	Plane A dip	Plane C azimuth	Plane C dip
1	May 6 1976	19.59	4.5	46°14'	13°15'	24	83°	19°	334°	84°
2	May 6 1976	20.00	6.2	46°10'	13°07'	25	350°	14°	168°	75°
3	May 7 1976	00.24	4.9	46°16'	13°20'	29	112°	15°	327°	78°
4	May 9 1976	00.53	5.5	46°16'	13°23'	20	105°	28°	311°	64°
5	May 11 1976	22.44	5.3	46°16'	13°00'	18	159°	61°	51°	62°
6	Sep 11 1976	16.31	5.5	46°15'	13°07'	15	323°	62°	179°	33°
7	Sep 15 1976	03.15	6.1	46°16'	13°12'	17	312°	31°	160°	62°
8	Sep 15 1976	09.21	6.0	46°19'	13°10'	20	305°	21°	127°	68°

References

(1) Wickens, A.J. and Hodgson, J.H.
Computer revaluation of earthquake mechanism solutions
Publications of the Dominion Observatory. Ottawa.
Vol. XXXIII n. 1, 1967.

(2) The mechanics of faulting, with special refernce to the fault plane work.
Publications of the Dominion Observatory. Ottawa.
Vol. XX n. 2, 1957

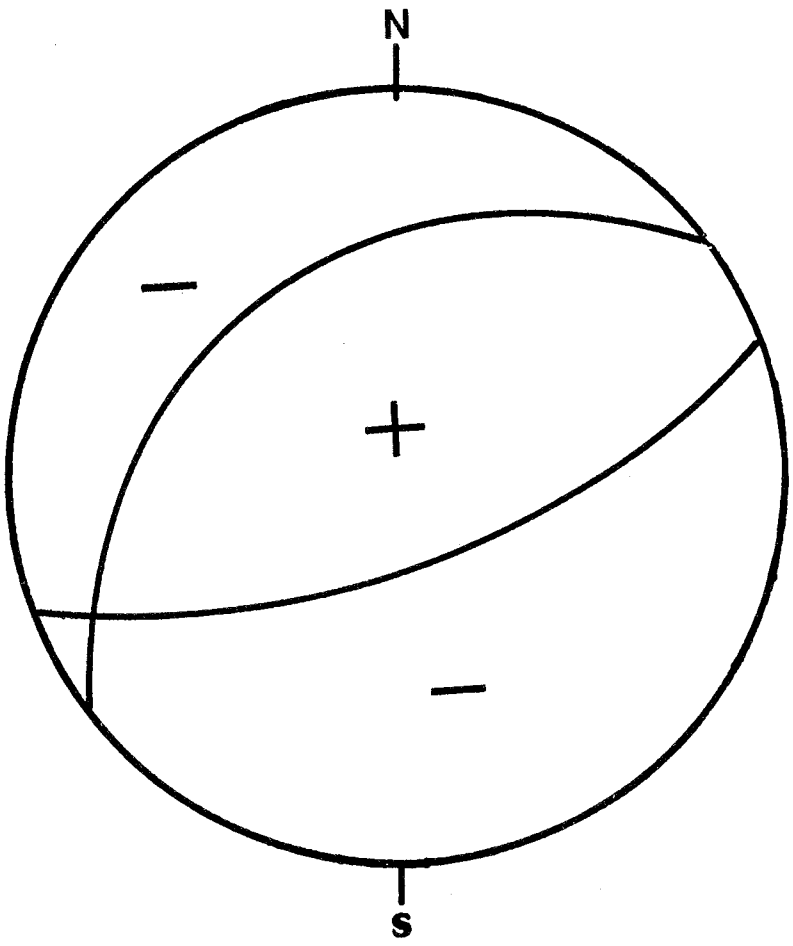
(3) Muller, G.
Fault-plane solution of the earthquake in Northern Italy, 6 May 1976, and implications for the tectonics of the Eastern Alps.
Journal of Geophysics. 1976.



6 · 5 · 76

H = 20 00

fig. 1



15·9·76
H=03 15

fig. 2

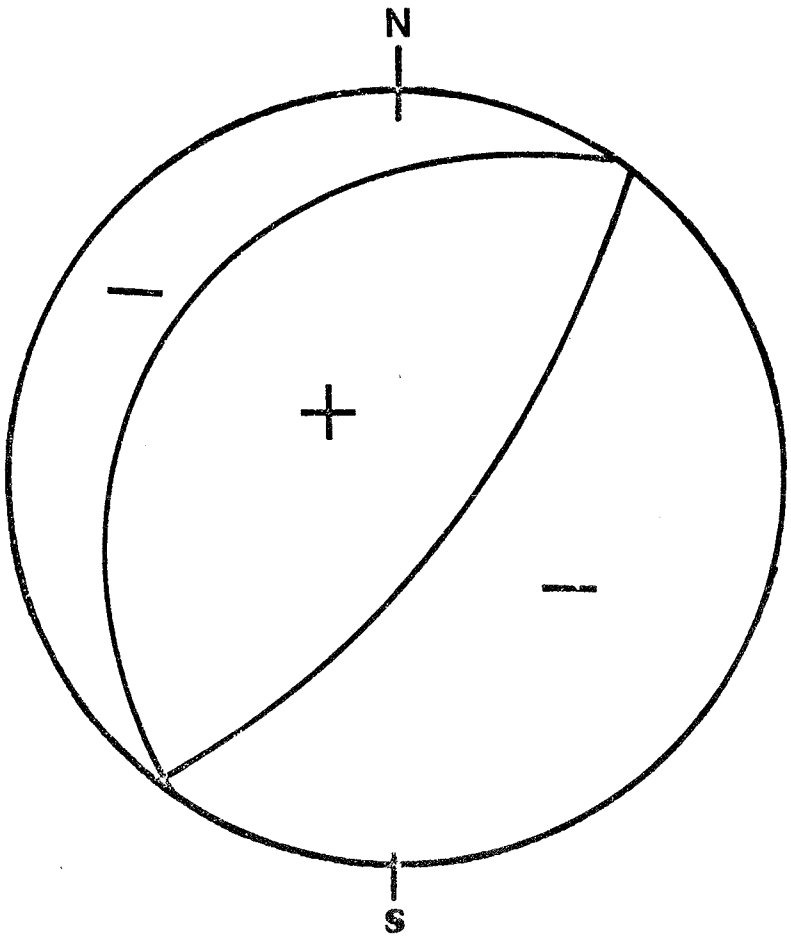


fig. 3

ORIENTATION OF STRESSES AND STRAINS IN THE PIEDMONT AREA OF EASTERN FRIULI, NE ITALY

by

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Abstract.

The fault-plane solutions of some shocks of the 1976 Friuli earthquake are found and compared with the solutions of earlier earthquakes in the same area. An analysis of the geological structures of the Eocenic rocks in the epicentral area shows that the youngest strains can be related to the stresses presently acting in the area. Such Alpine stresses have caused diverse types of deformations at different places: irrotational just outside the border of the Alpine chain and rotational just inside it. Hence the folds in the latter area are shown to be true shear folds.

Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 20.

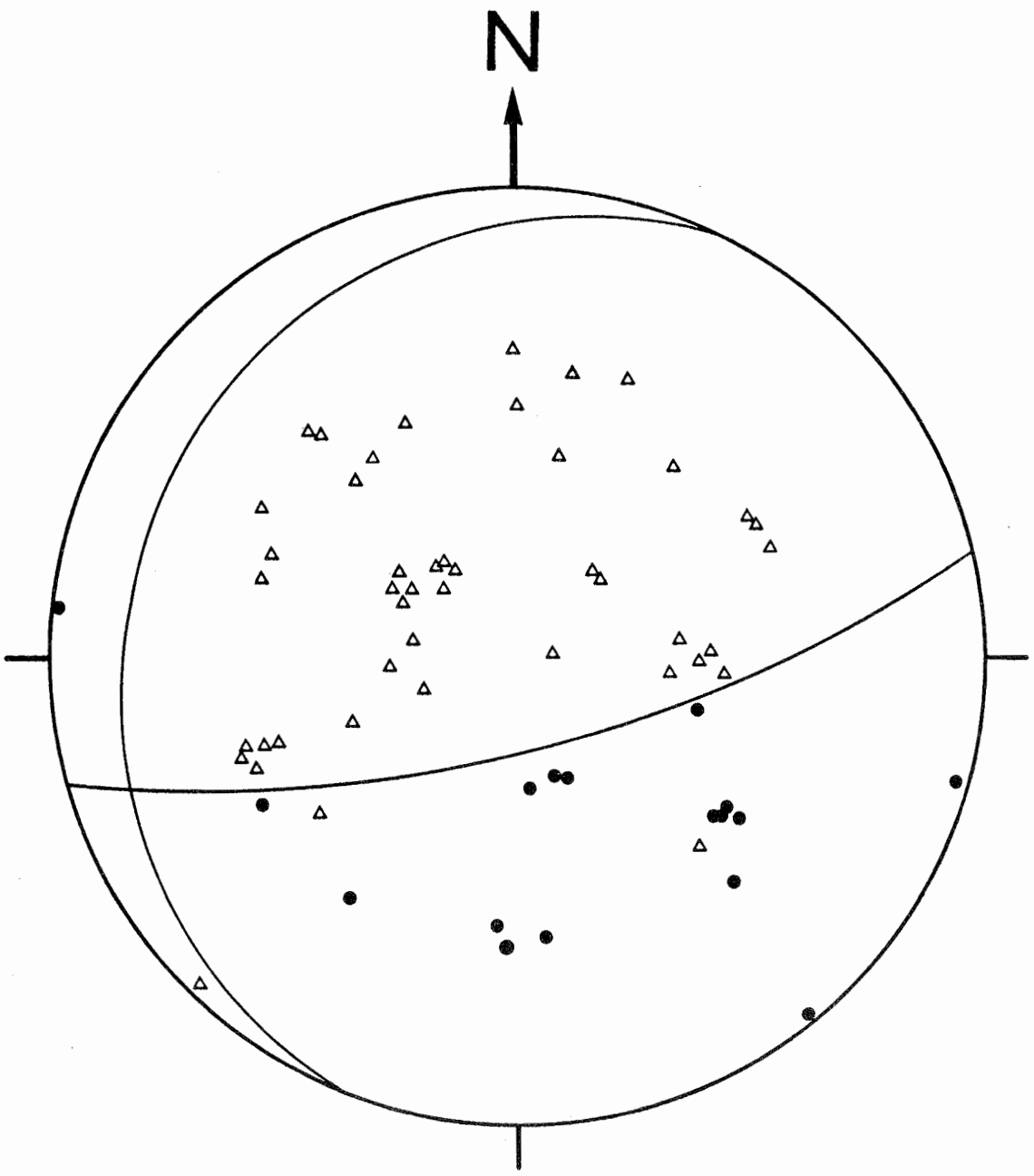

Fig. 1a

Fault-plane solution of the shock of May 6 at 20 00 10 of the 1976 Friuli earthquake. Stereographic projection, equal-area net, lower hemisphere. Solid circles: dilations; open triangles: compressions.

Introduction.

From the tectonic standpoint the epicentres of the 1976 Friuli earthquake are located in a particularly interesting area where the typical E-W trend of the Alps swings to the SE into the Dinaridies.

The intent of the present work is to find the orientation of the principal stresses by means of the fault-plane solutions and to compare them with the principal axes of finite strains of the youngest deformational stage deduced from an analysis of the geological structures observed in the area.

The Fault-Plane Solutions.

The data used for the following fault-plane solutions are the polarizations of P-waves obtained from long-period seismographs of different European observatories. Hypocentral coordinates have been taken to be those of 46.31°N, 13.31°E and shallow depth given for the main shock by the Centre Séismologique Européo-Méditerranéen. The directions of seismic rays at the focus have been calculated on the base of the seismic model of the area (Finetti and Morelli, 1972).

The solution of the main shock of May 6 (fig. 1a) is in excellent agreement with previous results based on first-arrivals of P- and S-waves at distant stations (Müller, written communication). The compressional wave recorded at the Padova station only would suggest that the fault plane dip more to the west than it appeared in the quoted reconstruction. Nevertheless it is clear that the faulting connected with the main shock was of the thrusting type and that the direction of movement was plunging shallowly toward the north.

The large shock of May 7 at 00 23 44.5 (fig. 1b) already displayed a change of polarity at the Kajaama station, the Prato station and the Zagreb station and its solution suggests that the type of faulting related to this second shock was strike-slip. However interestingly in spite of this modification the change in orientation of the

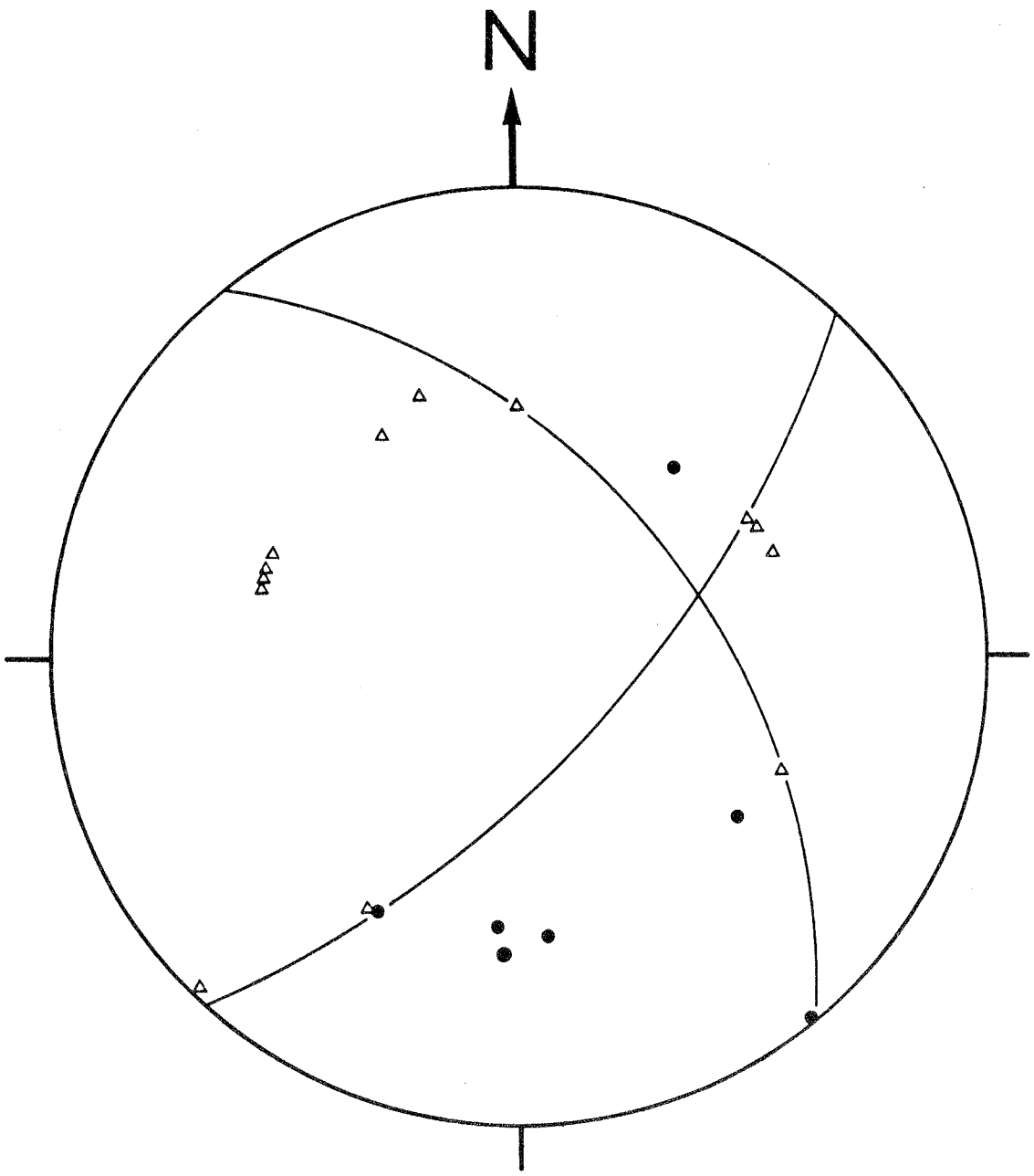

Fig. 1b

Fsult-plane solution of the shock of May 7 at 00 23 44.5.

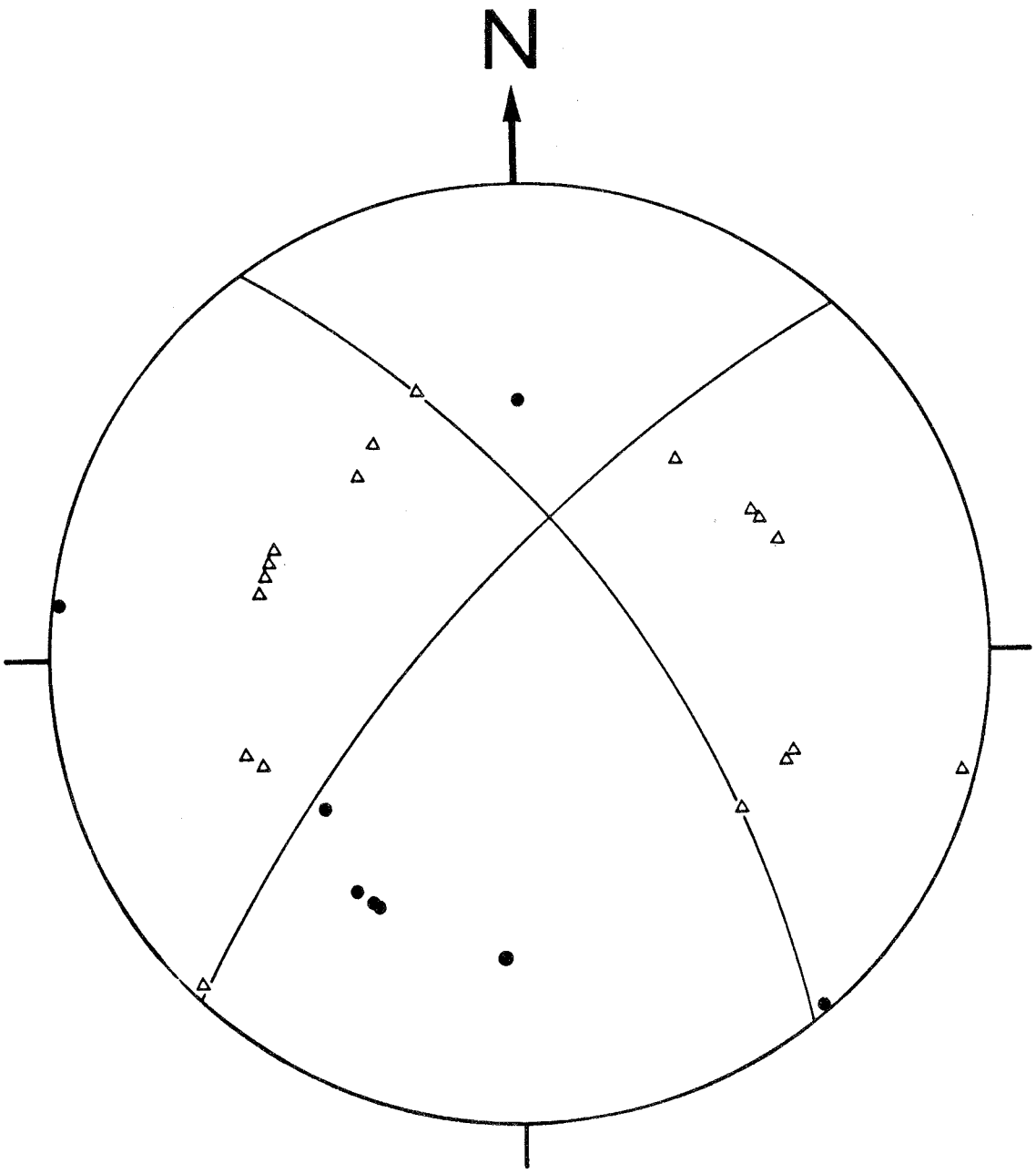

Fig. 1c

Fault-plane solution of the shock of May 9 at 00 53 40.

principal axes of stress has occurred with a simple rotation about the axis of maximum compression.

The polarity of first-arrivals of the shock of May 9 felt at the Trieste station at 00 53 55.8 (fig. 1c) confirmed the rotation of the principal axes of stress. Indeed the Ljubljana station, the Zagreb station and the Sarajevo station all recorded a compressional wave while the Copenhagen station recorded a dilational one. Similarly to both previous shocks the axis of maximum compressional stress was still dipping shallowly to the south.

Although scanty the data of the later shocks of May 11 at 22 43 58.7 (fig. 1d) and of May 23 at 00 51 04.4 (fig. 1e) are in agreement with the interpretation of strike-slip faulting and even in these cases the orientation of maximum compressive stress can be assumed to dip to the south.

The same can be said about the shock of September 12 at 08 09 (fig. 1f) felt at Trieste with a compressional wave just like at the Ljubljana, Zagreb and Sarajevo stations.

Finally in spite of the different polarity of the first-arrivals of P-waves at Bensberg, Almeria and Prato the fault-plane solutions of the two large shocks of September 15 at 03 15 17 (fig. 1g) and at 09 21 16.6 (fig. 1h) also reveal similar characteristics.

Thus of investigated shocks only the main one of May 6 was connected with thrust-type faulting. All the rest of them were characterized by strike-slip motions.

The latter type of faulting also is the one resulting from the fault-plane solution of earlier earthquakes in the region (fig. 2) (Di Filippo and Peronaci, 1962a). Thus the main shock of May 6 may be considered anomalous with respect to all other shocks taken into consideration. Nevertheless even that seismic event has in common with the other shocks the orientation of the axis of maximum compressive stress which plunges shallowly to the south or SSE.

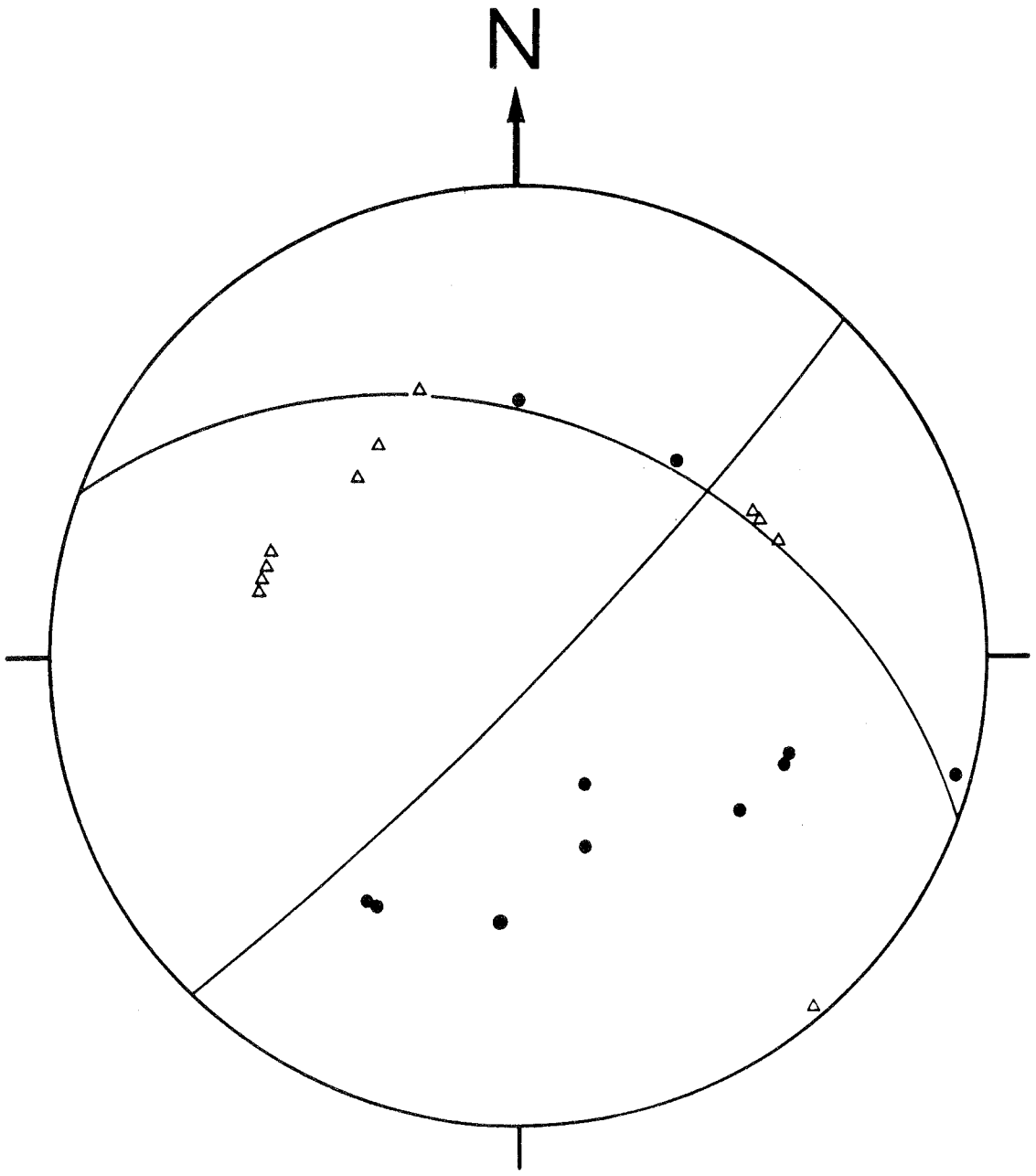

Fig. 1d

Fault-plane solution of the shock of May 11 at 22 43 58.7.

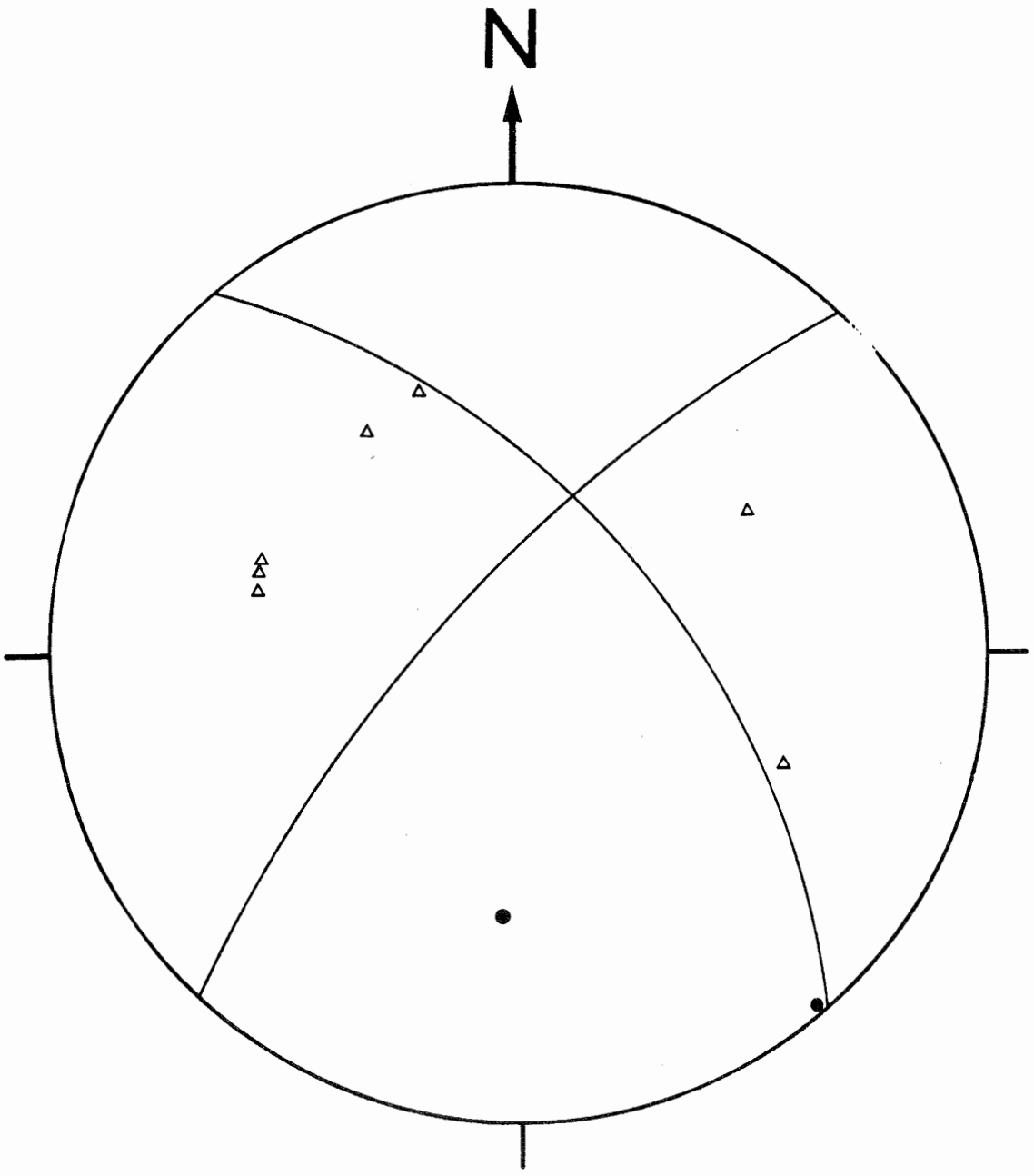

Fig. 1e

Fault-plane solution of the shock of May 23 at 00 51 04.4.

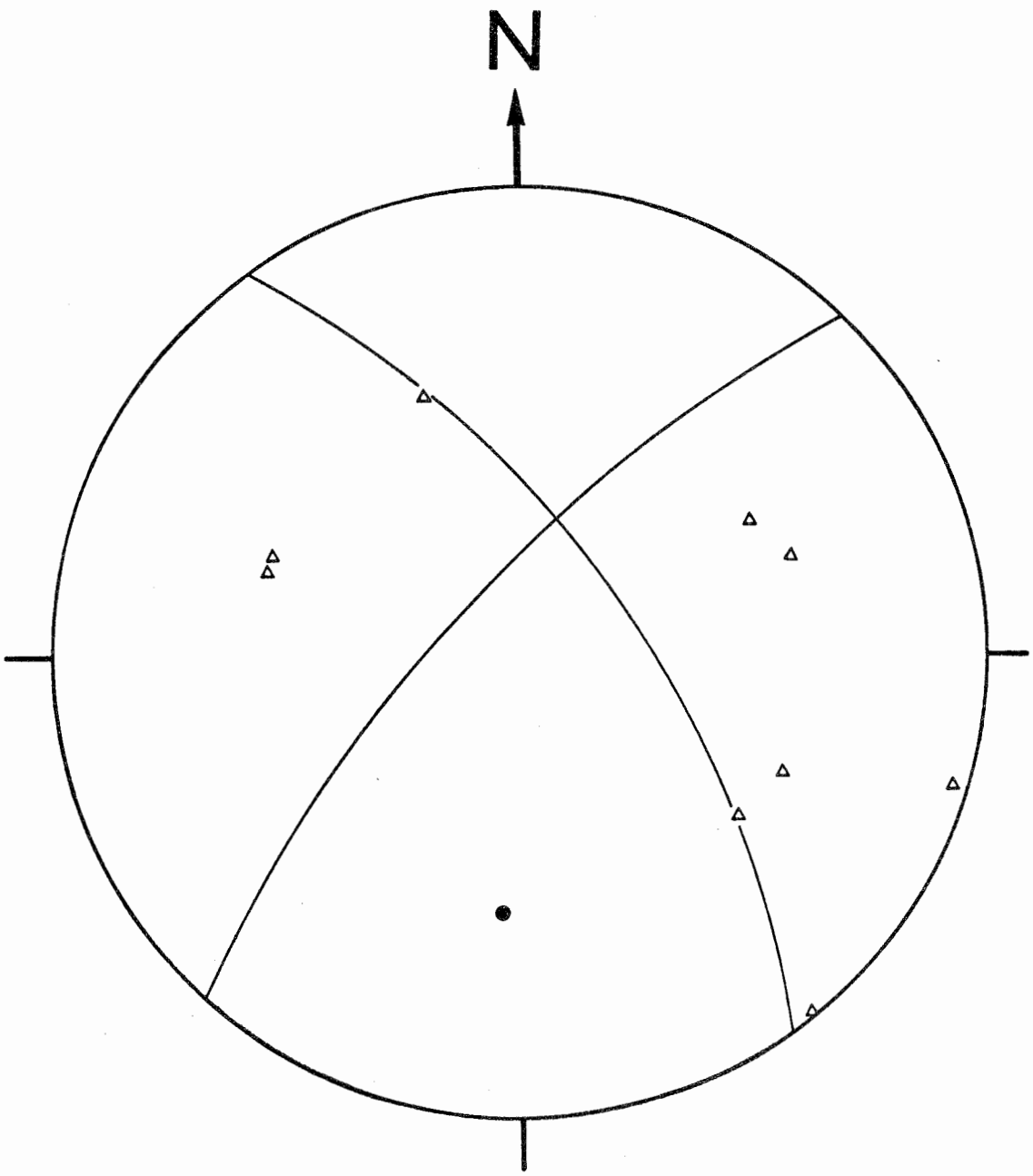

Fig. 1f

Fault-plane solution of the shock of September 12 at 08 09 00.

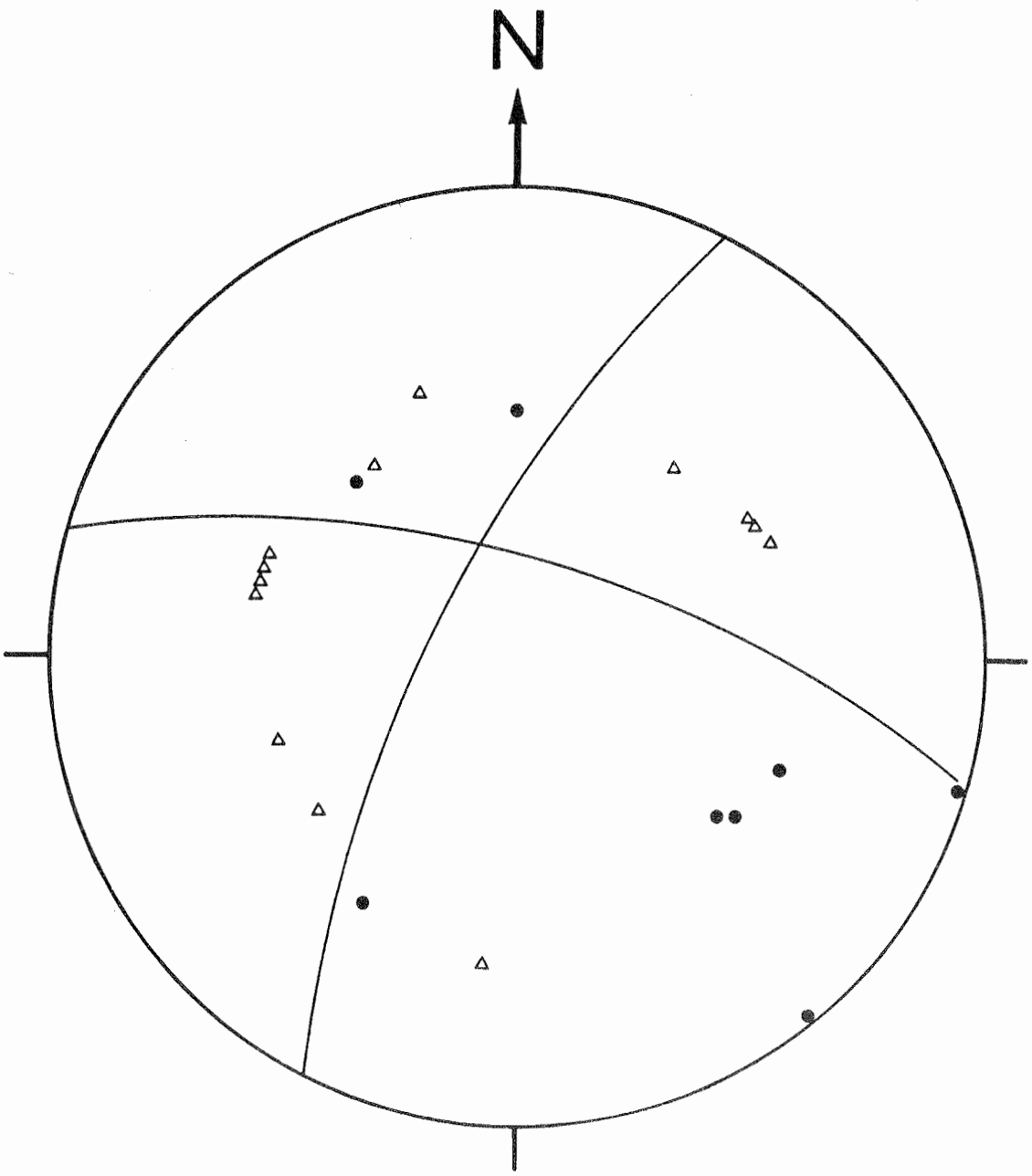

Fig. 1g

Fault-plane solution of the shock of September 15 at 03 15 17.0.

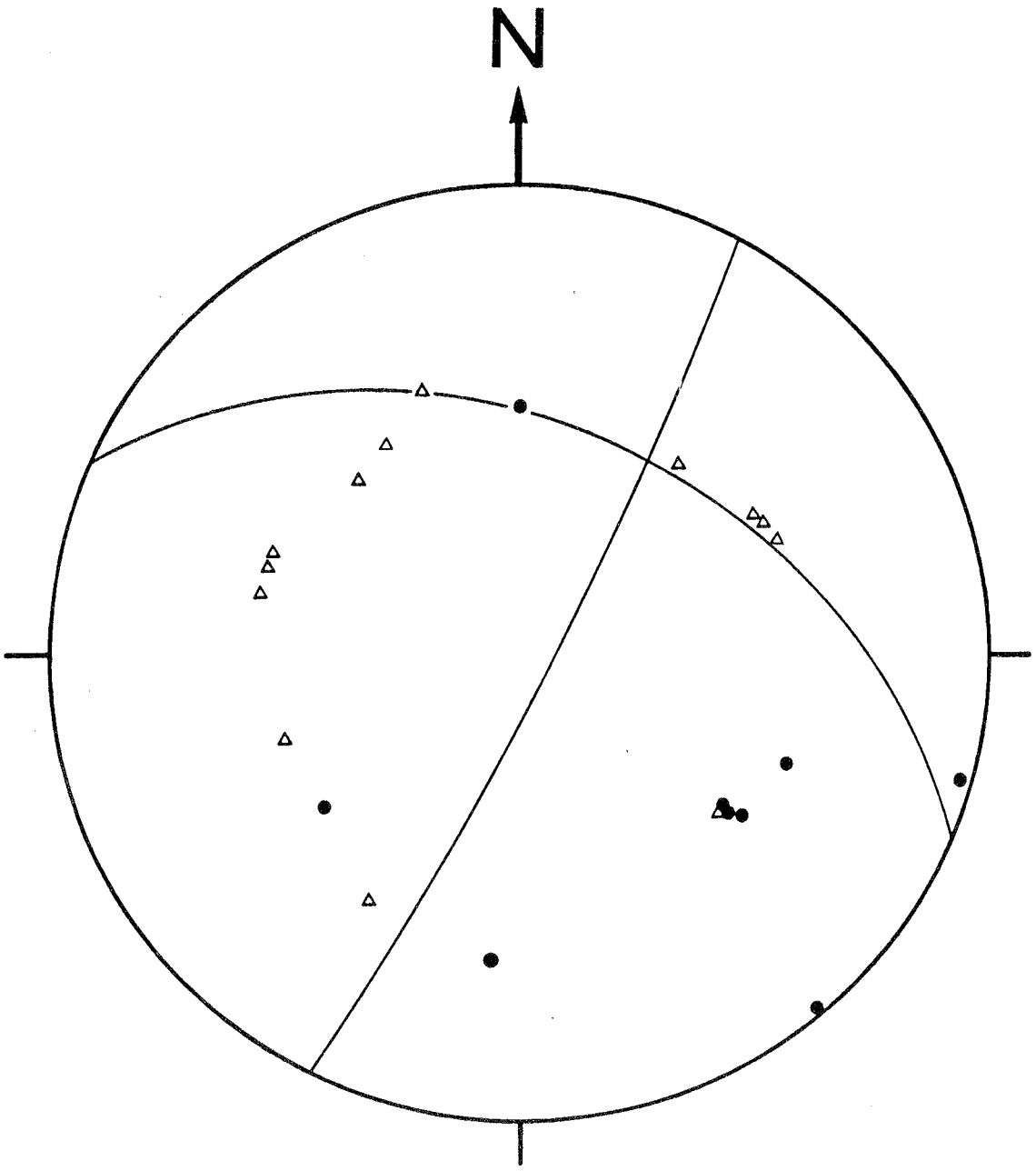

Fig. 1h

Fault-plane solution of the shock of September 15 at 09 21 16.6.

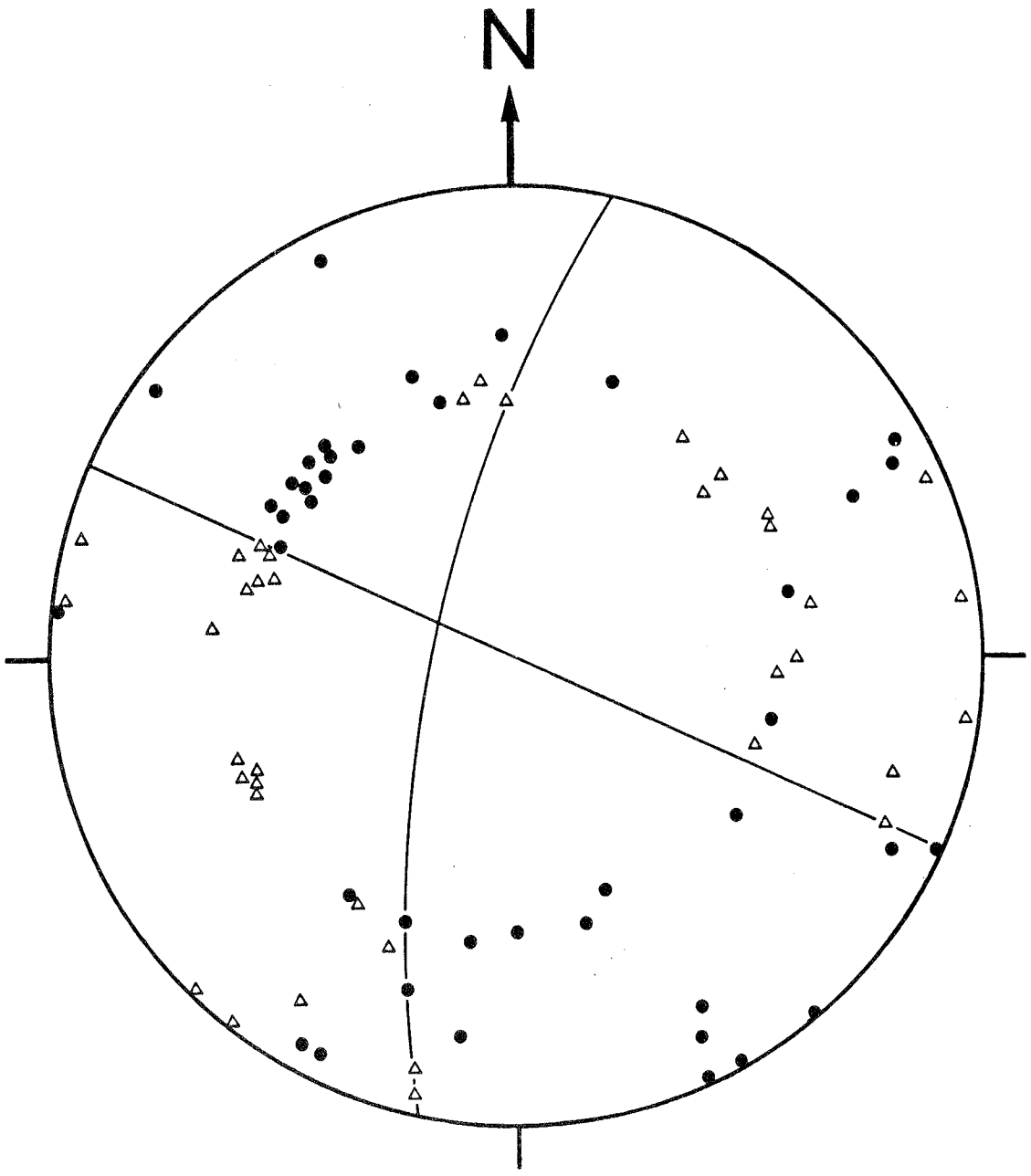

Fig. 2

Fault-plane solution of the 1928 and 1956 Tolmezzo earthquakes, the 1934 Carnia earthquake and the 1936 Cansiglio earthquake. Projection and symbols like in fig. 1.

Thus the state of stress in the Earth's crust in NE Italy can be properly considered Alpine in opposition to the Dinaric stress system which is the one displayed by the fault-plane solution of the Makarska 1962 earthquake (fig. 3) (Di Filippo and Peronaci, 1962b).

Post-Eocenic Rock Deformations.

Structural investigations have been carried out in the field NE and SE of Tarcento (fig. 4) where the belt of Eocenic flysch extending from the SE swings first to the north and then to the west becoming parallel to the Alpine trend.

The purpose of such investigation was to depict the chronological sequence of the deformational events related to the two trends.

Structural data have been grouped according to two separate areas; the one further to the SE in the zone of the Malina river exhibits a general trend of the rocks in a N-S direction and the other area towards the north around Mt. Bernadia displays an Alpine east-westerly trend.

In the Malina area (fig. 5) the axial surfaces of folds appear to be folded cylindrically about axes plunging 30° to the WNW while in the Bernadia area (fig. 6) the axes of the same cylindrically folded surfaces plunge 60° NW. Thus assuming that the axial surfaces are those of folds of the same generation it is clear that the deformational stage connected with the formation of the axial surfaces was followed by at least another deformation which folded the axial surfaces about two different axes or about a single axis which was later in its turn refolded.

According to the former hypothesis one has to assume that the axial surfaces had a different orientation in the Bernadia area and in the Malina area before refolding took place. The direction of maximum finite shortening that caused the folding of such surfaces being parallel to the pole to the plane defined by the axes of folding is thus plunging 25° to S6°E.

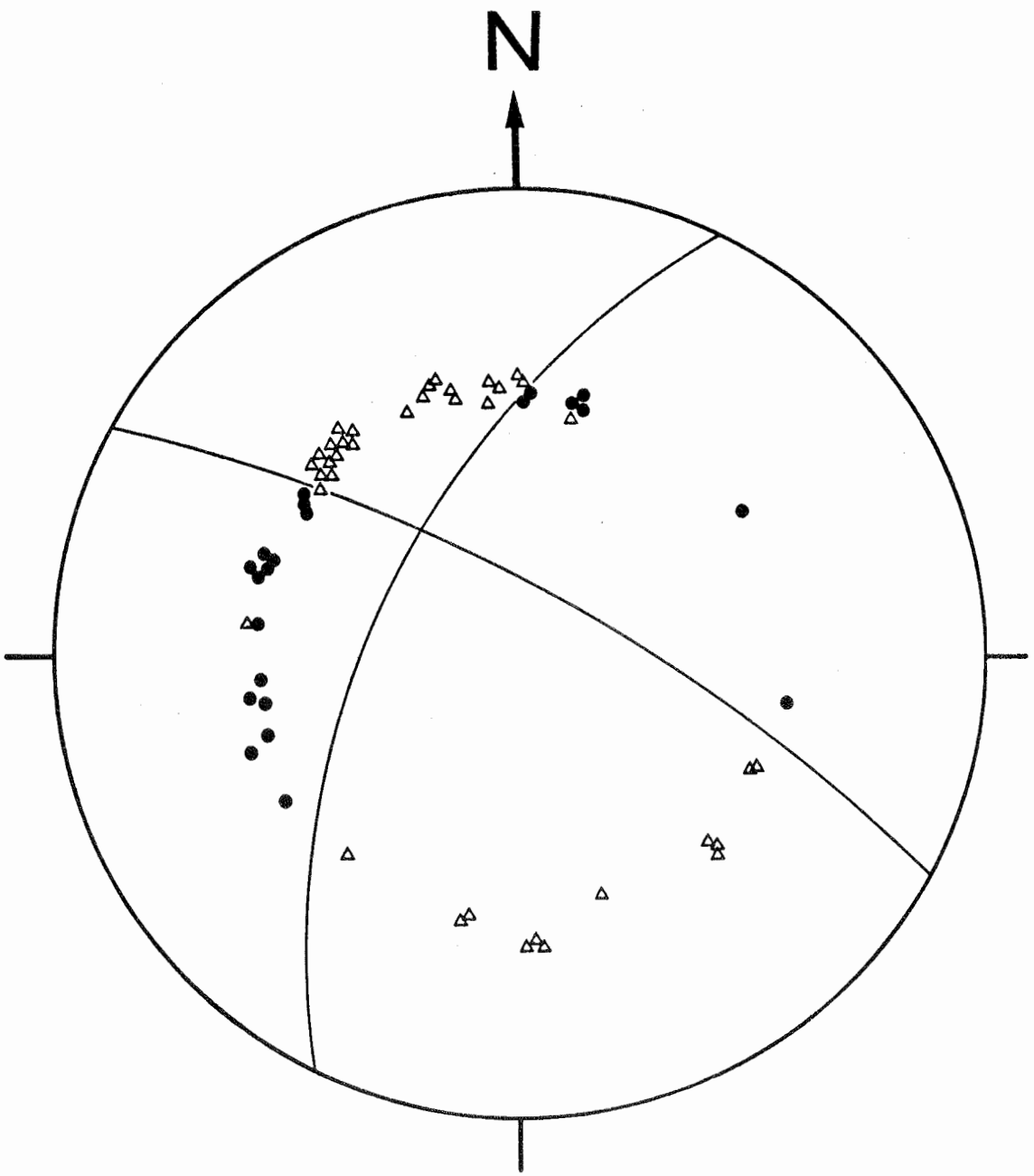

Fig. 3

Fault-plane solution of the 1962 Makarska earthquake; shocks of January 7, 11 and 21. Projection and symbols like in fig. 1.

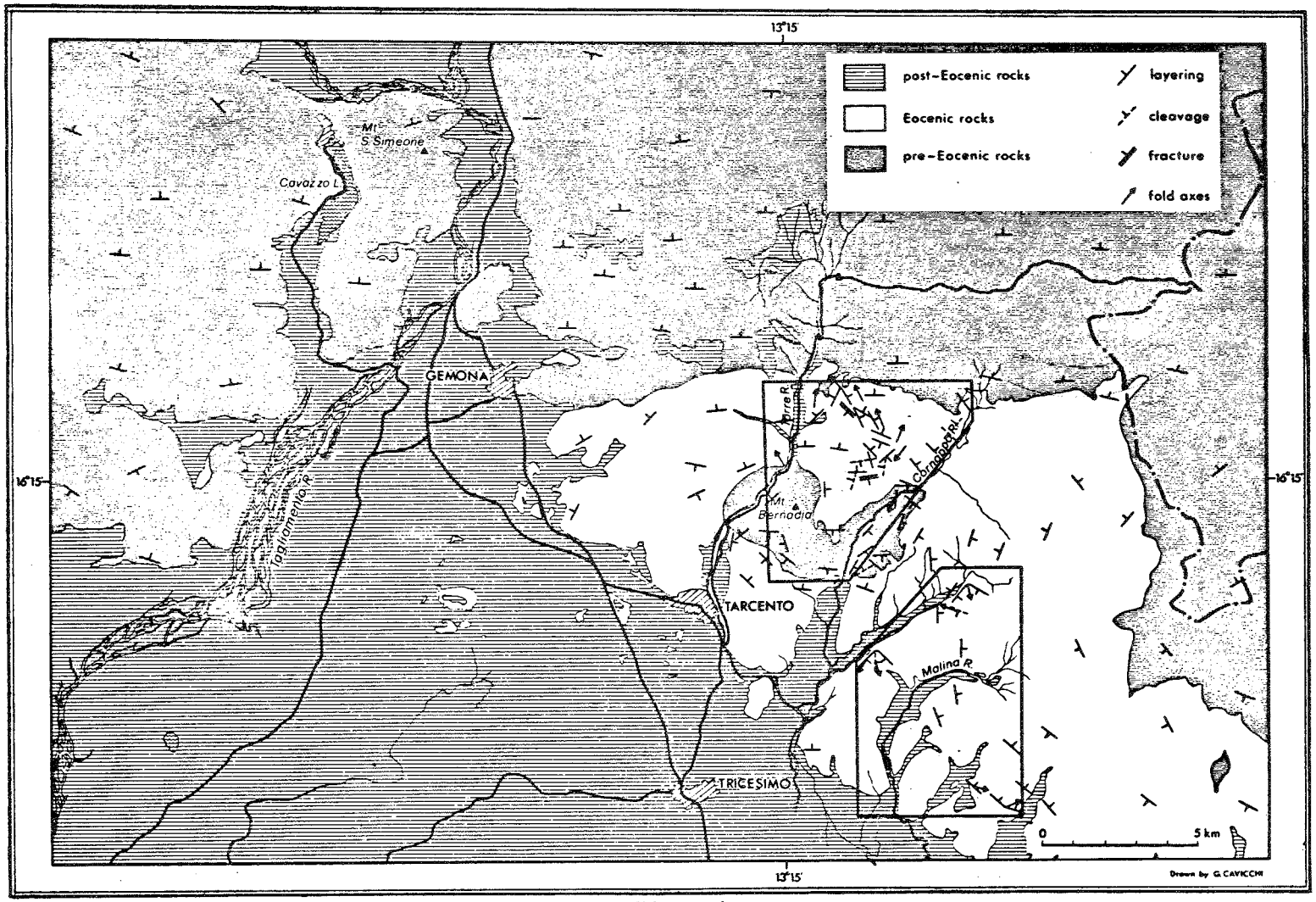

Fig. 4

Geological map of the piedmont area of eastern Friuli with the two areas chosen for structural investigation.

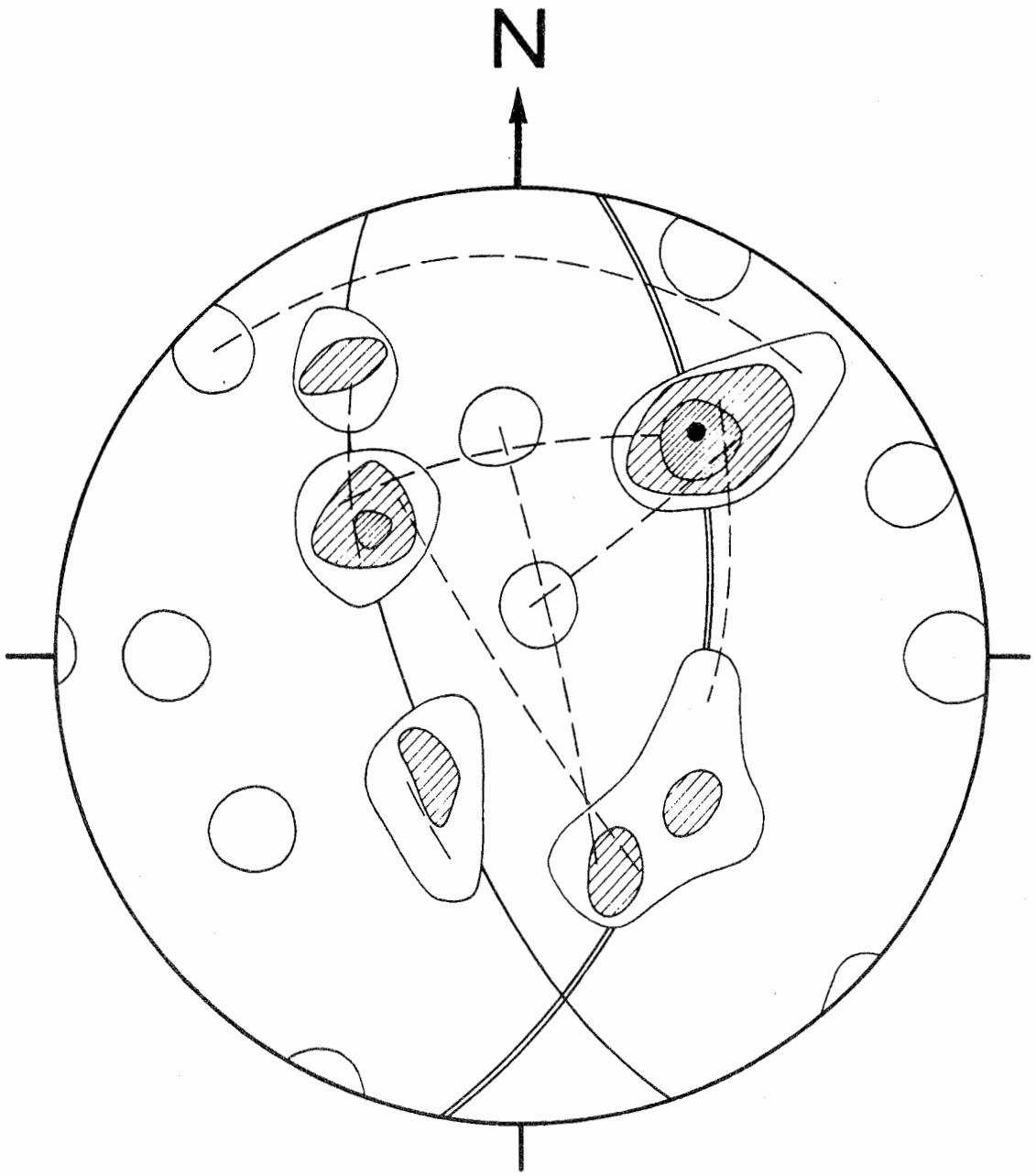

Fig. 5

Poles to planar structural elements of the rocks in the Malina area. Stereographic projection, equal-area net, lower hemisphere. Dotted lines: visible folded surfaces, assumed cylindrical; full line: compositional banding, maximum; double line: axial surfaces. 26 measurements. Contour intervals: 4%, 8%, 12% and 16%.

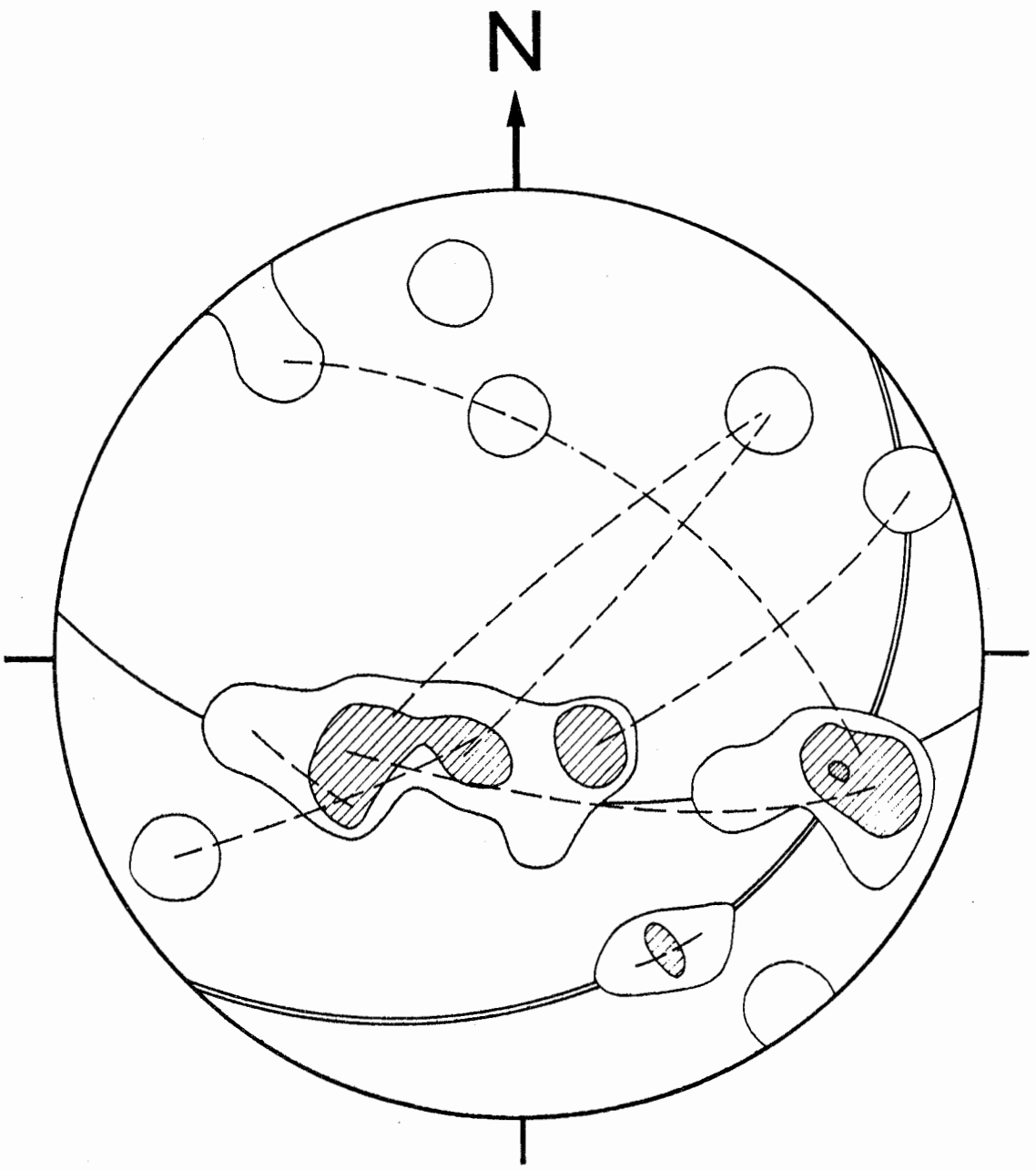

Fig. 6

Poles to planar structural elements of the rocks in the Bernadia area. Projection and symbols like in fig. 5. 23 measurements.

However since plane oriented at more than about 40° from the principal axes of shortening cannot be folded and bearing in this case the principal axis of shortening almost to the south, the pre-folding orientation of the axial surfaces could not have been an Alpine one. On the other hand if it had been a Dinaric orientation taken to strike roughly NW-SE then the pre-folding dip of the axial planes had to be 55°SW in the southern part of the area and vertical in its northern part.

The alternative hypothesis is that the axial surfaces were folded about axes with the same orientation across the whole area and that these axes were subsequently refolded. If so the axes of the refolded axial surfaces ought to lie on the same plane as the "a"-direction of maximum elongation connected with the folding of the same axes in the case of "similar" folding or o ught to lie on a conical surface about the "b"-axis of folding in the case of "concentric" folding. Hence either would the "a"-direction of the third deformation lie on the plane dipping 85° to N20°E or would the direction of the "b"-axis be unknown since the conical surface cannot be defined by two directions alone. Moreover in either instances the pre-folding orientation of the axial surfaces would be obviously unknown.

The poles to the compositional banding in the Malina area if projected on a stereographic net (fig. 5) make a girdle which trends NNW-SSE and intersects the girdles of the poles to the axial surfaces both in the Malina area and in the Bernadia area in the same direction along which the latter ones intersect.

In the Bernadia area instead the distribution of the poles to the compositional banding (fig. 6) is quite different. Their maximum concentration occurs at the intersection between the girdle that they make and that trends almost E-W and the girdle of the poles to the axial surfaces.

It can be assumed that the direction of maximum finite shortening related to the youngest stage of folding

is oriented parallel to the intersection between the girdles of the compositional banding and the axial surfaces of the folds of earlier generation. Hence one finds that the direction of maximum finite shortening dips shallowly to the south in the Malina area and equally shallowly to the ESE in the Bernadia area.

As discussed above such difference in orientation could be due to a still younger deformational stage or as suggested by field observations by an inhomogeneity of the deformation. Indeed in the Bernadia area the existence of an overthrust that has moved to the south along shallowly north-dipping planes has been proved (Martinis, 1966) while evidence of a comparable set-up is missing in the Malina area.

Therefore the different orientation of the principal axis of finite shortening in two areas has been ascribed to an inhomogeneity of the deformation.

Conclusions.

The orientation of the direction of maximum compressive stress related to the 1976 Friuli earthquake and in general to the earthquakes in the piedmont area of NE Italy dips shallowly to the south or SSE.

In the Malina area the principal axis of finite shortening of the youngest deformational stage displays the same orientation thus suggesting that there the strain has been irrotational. On the contrary in the Bernadia area one finds that the poles to the compositional banding are oriented in a plane subparallel to the plane of maximum shearing stress related to the May 6 shock thus suggesting that the deformation in the Bernadia area has been rotational. Obviously the main rotation ought to have occurred in a subvertical plane oriented N-S with either a component of heterogeneous simple shear in the planes of the poles to the compositional banding or more likely a shortening in the E-W direction. This additional part of the deformation yielded the reorientation of the plane of the poles to the axial surfaces in the Bernadia area about a north-

dipping axis and gave rise to the folds oriented parallel to the slip direction.

In conclusion it appears that since the Eocene the rocks in the piedmont area of eastern Friuli have been first deformed by a Dinaric stage and are presently further strained by an Alpine one.

Moreover the relationships in eastern Friuli suggest that conditions of true shear folding may exist at the borders between orogenic belts and stable areas.

References:

Finetti, I. and Morelli, C., 1972, Deep Seismic Refraction Exploration on Eastern Alps; Boll. Geofisica Teor. e Appl., 14, 53-4, 59-66.

Di Filippo, D. and Peronaci, F., 1962a, Terremoti di frattura e relazioni con la tettonica nelle Alpi orientali; Ann. Geofis., 15, 194-223.

Di Filippo, D. and Peronaci, F., 1962b, Contributo alla tettonica delle Alpi Dinariche; Ann. Geofis., 15, 379-97.

Martinis, B., 1966, Prove di ampi sovrascorrimenti nelle Prealpi friulane e venete; Ist. Geol., Univ. Milano, ser. G, 224, 31.

Müller, G., 1976, Fault-Plane Solution of the Earthquake in Northern Italy, 6 May 1976, and Implications for the Tectonics of the Eastern Alps; Geophysical Institute, University of Karlsruhe.

REVISED HYPOCENTERS AND MAGNITUDE DETERMINATIONS OF MAJOR FRIULI SHOCKS 1976

EUROPEAN MEDITERRANEAN SEISMOLOGICAL CENTRE
WORKING GROUP *)
ON THE FRIULI EARTHQUAKES

The aim of this study has been to obtain accurate source-parameters for 18 selected major Friuli-earthquakes, which occurred between May 6 and September 15, 1976. Observations from a maximum number of Eurpean seismic stations were used for this purpose, including mobile stations which were operated for some time in the epicentral area. All data were collected at the European-Mediterranean Seismological Centre (EMSC) in Strasbourg, and there also the final computations were carried out by the working group.

*) Members of the Working Group: R. Aric (Vienna), R. Console (Roma), H. Haessler (Strasbourg), B. Massinon (Paris), D. Mayer-Rosa (Zürich), St. Müller (Zürich), A. Peres, E. Peterschmitt, D. Rouland (Strasbourg), D. Seidl (Erlangen), E. Schmedes (München), G. Wittlinger (Strasbourg).

During the localization procedure the well recorded shock of May 11,1976, at 22:44 GMT was chosen as a "master event" for the determination of the travel-time delays at the various observation stations. For reference a flat-layer model with the following parameters has been introduced: V_p = 5.0 km/s to 1 km depth, 5.8 km/s to 2 km - , 6.0 km/s to 20 km - , 6.2 km/s to 43 km - , and 8.2 km/s below 43 km depth. The derived P_n - time delays with respect to this model were then applied for the relocalization of the other earthquakes in Friuli. Thereby only those stations are considered which recorded the master event and which show smaller systematic residuals than four times the RMS-value. Table I contains the result of these computations showing also, that relatively small computational errors could be achieved by this method. The computer-program HYPO 71 served for the calculations. The magnitudes listed in Table II were determined by the stations or institutions indicated.

Fig. 1 shows the epicentral map of the 18 earthquakes selected for this study. The dashed lines represent the isoseismals deduced from a macroseismic investigation. The event number of Table I is indicated. The depth of focus is written inside the circles. The size of the circles corresponds to the magnitude measured.

TABLE I : Revised determination of selected Friuli-earthquakes 1976

No	DATE	TIME H MN S	LAT N	LONG E	DEPTH Km	RMS s	ERH Km	ERZ Km	N	DM Km	GAP D^{o}
1	MAY 6	19 59 05.7	46.27	13.32	10	0.7	1.6	1.7	47	29	34
2	MAY 6	20 00 12.6	46.23	13.20	7	0.9	4.0	4.2	20	43	62
3	MAY 6	21 49 41.5	46.16	13.20	18	1.0	3.6	5.0	33	67	51
4	MAY 7	00 23 49.3	46.24	13.32	9	0.3	0.8	1.0	43	68	53
5	MAY 8	03 10 05.8	46.28	13.23	10	0.4	1.2	1.3	43	76	49
6	MAY 9	00 53 44.1	46.23	13.36	6	0.6	1.6	1.7	49	35	54
7	MAY 10	04 35 52.3	46.28	13.22	5	0.4	1.1	1.2	45	22	38
8	MAY 11	05 31 56.2	46.22	13.16	4	0.3	1.2	1.7	30	74	50
9	MAY 11	22 44 00.9	46.25	13.03	9	(0.2)	(0.5)	(0.4)	71	2	46
10	MAY 12	03 01 16.8	46.33	13.12	8	0.6	2.3	2.3	23	29	93
11	MAY 13	13 04 50.2	46.20	13.00	10	0.8	2.4	2.6	35	46	51
12	MAY 17	16 13 16.1	46.25	13.00	6	0.5	1.1	1.1	56	14	47
13	MAY 18	01 30 08.8	46.27	13.03	7	0.5	1.1	1.2	51	23	45
14	JUN 11	17 16 40.3	46.23	13.00	9	0.5	1.3	1.4	52	26	45
15	JUL 14	05 39 33.6	46.34	13.25	6	0.8	2.0	2.4	42	48	45
16	SEP 11	16 31 11.4	46.30	13.23	6	0.9	2.7	3.4	39	21	53
17	SEP 15	03 15 19.8	46.29	13.20	6	0.6	1.4	1.5	44	25	38
18	SEP 15	09 21 19.0	46.30	13.18	11	0.5	1.2	1.2	43	27	38

Explanations:
RMS = root mean square error of travel time residuals
ERH = horizontal error
ERZ = error in focal depth
N = number of stationsused
DM = distance to nearest station
GAP = angular sector lacking of stations

TABLE II : Magnitudes of selected Friuli-earthquakes 1976

No	DATE	TIME H MN S	MAGNITUDES RMP	TRI	LDG	STR	GRF	GS
1	MAY 6	19 59 05.7	4.5					4.5
2	MAY 6	20 00 12.6	6.2	6.5	6.5			6.0
3	MAY 6	21 49 41.5	3.9	3.9	3.8±0.2	4.1		4.0
4	MAY 7	00 23 49.3	4.9	4.6	5.5±0.4	4.9	5.3	4.7
5	MAY 8	03 10 05.8	4.5	4.1	3.9±0.3	3.5	4.4	
6	MAY 9	00 53 44.1	5.5		5.9±0.4	5.0	5.5	5.1
7	MAY 10	04 35 52.3	4.7	4.4	4.3±0.1	4.3	4.7	4.4
8	MAY 11	05 31 56.2	3.9	4.0	4.0±0.1	3.6	4.4	
9	MAY 11	22 44 00.9	5.3	4.8	5.9±0.5	5.0	5.5	5.2
10	MAY 12	03 01 16.8	3.6	3.6	3.6±0.2	3.	3.9	4.4
11	MAY 13	13 04 50.2	4.3	3.7	4.1±0.1	3.6	4.5	4.8
12	MAY 17	16 13 16.1	4.5	4.2	4.1±0.1	4.1	4.8	5.1
13	MAY 18	01 30 08.8	4.3	3.7	4.0±0.3	3.7	4.6	5.2
14	JUN 11	17 16 40.3	4.4	4.2	4.3±0.1	4.3	4.8	4.2
15	JUL 14	05 39 33.6	4.2	4.2	4.1±0.1	4.2	4.5	
16	SEP 11	16 31 11.4	5.5	5.1	5.7±0.4	5.1	5.5	5.2
17	SEP 15	03 15 19.8	6.1	5.9	5.7±0.3	5.9	6.2	5.7
18	SEP 15	09 21 19.0	6.0	6.1	6.2±0.2	6.3	6.6	5.4

Explanations: RMP = Roma, Monte Porzio
TRI = Trieste
LDG = Lab. de Géophysique, Paris
STR = Strasbourg
GRF = Gräfenberg
GS = U.S. Geological Survey

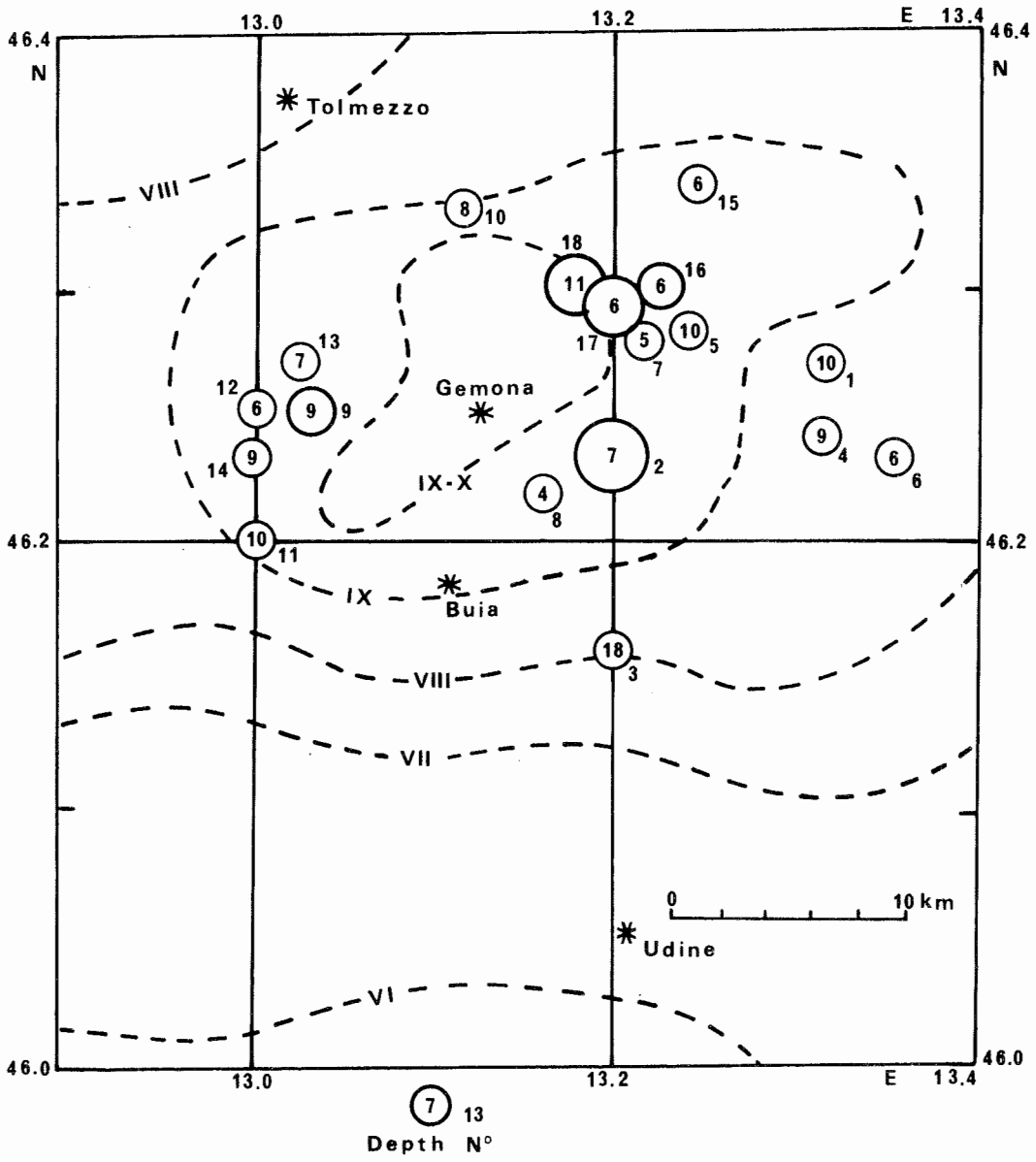

Fig.1: Epicenter-map of 18 selected Friuli-earthquakes between May 6 and Sep 15, 1976.
Dashed lines indicate isoseismals of a macroseismic investigation.

PRELIMINARY SPECTRAL ANALYSIS OF AFTERSHOCKS OF THE 1976 FRIULI EARTHQUAKES

BY

I. FINETTI* - U. FRINZI** - A. SCOTTI*

1. FOREWARD

This paper presents briefly the criteria followed during a preliminary spectral analysis applied to aftershock records taken at various sites in the Friuli seismic area since September 17, 1976. The purpose of this study is to find through the analysis of the dynamical characteristics of the events, the typical spectral responses of every examined site. Eventual correlation between stronger and

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weaker intensity earthquakes generated by the same seismic source were also seeked.

2. EXAMINED SITES

Even if the recording activity is still going on a preliminary analysis was made for the following localities: Gemona, Tolmezzo, Buia, Vito d'Asio. The geological stratigraphy of these sites are schematically the following:

a) Gemona
- alluvial cultivated ground: 2 m;
- gravel alluvions mixed with debris containing limestone elements, of a non-defined thickness (> 30 m);
- substratum of compact limestone at a non-defined depth.

b) Tolmezzo
- unconsolidated alluvium having a thickness of 2 m;
- alluvial gravel, occasionally cemented, having a variable thickness of 10 to 50 m;
- compact limestone at a depth exceeding 50 m.

c) Buia
- alluvial cultivated ground: 2 m;
- morain having a clay-muddish matrix with gravel and sand elements. The thickness has not been determined, but it is supposed to be relatively big.

d) Vito d'Asio
- alluvial cultivated ground: 2 m;

- compact limestone having a very big thickness.

3. FIELD EQUIPMENT AND EMPLOYED TECHNIQUES

The following equipment have been employed in recording the events:

a) vertical and horizontal moving coil velocity sensors made by GSC of the AS-10-1 type. The natural frequency of the sensor is 1 Hz. Such a sensor has been connected to a GMT preamplifier having a linearity characteristic between 1 and 80 Hz. The calibrating curve of the complete recording system has confirmed the value of the previously mentioned natural frequency and has given a total damping ratio $n = 0.48$; very near to the one called semi critical.

b) FM magnetic tape recorder of the type Brüel & Kjaer 7003.

c) FM portable P.I. (Precision Instrument) recorder of the type PI/6204.

Both the recorders were operating at their minimum speeds (1.5 "/sec for the Brüel & Kjaer and 0.375 "/sec for the Precision Instrument) in order to achieve their maximum autonomy.

4. RECORDED AND PROCESSED DATA

Table 1 shows the list of the most important recorded events in the period September 9 to October 27 in various sites of the damaged area of Friuli. In this period 54 tapes for the P.I. and 94 tapes for the B & K were recorded, for a total amount of respectively 1188 and 470 recording hours.

Due to the amount of experimental data and the short time at disposition to analyse them, only the most important events have been analyzed and therefore definitive conclusions cannot be presented here. The distribution of analyzed events is given on Tab. 2.

In this paper the used spectral analysis methodology is briefly presented and some preliminary results are discussed.

Some more representative aftershocks from the various recording sites, which were thought to be more significant, were visualized in the laboratory.

To make comparison with the main shock of May 6, was also analyzed the strong-motion accelerograms of Tolmezzo (Tab. 3).

5. PROCESSING EQUIPMENT AND SPECTRAL PROCEDURE

To do the spectral analysis of the recorded field data, the following equipment and techniques were employed.

a) A Kistler type 5211 preampliefier with a response linearity between DC and 10 kHz, coupled to a double wire Electrodynamics Corporation type 7/316 galvanometers, having

TAB. 1/1 - RECORDING SITE: GEMONA

LIST OF SPECTRALLY ANALIZED AFTERSHOCKS RECORDERD IN THE PERIOD SEPTEMBER 9 TO OCTOBER 27

EVENT N	D A T E			HOUR GMT	COMPONENT
	MONTH	DAY	YEAR		
1	09	17	76	11.58	H
2	09	17	76	12.44	H
3	09	17	76	14.31	H
4	09	17	76	15.08	H
5	09	17	76	16.35	H
6	09	17	76	17.02	H
7	09	17	76	18.25	H
8	09	17	76	18.26	H
9	09	17	76	18.27	H
10	09	17	76	18.44	H
11	09	17	76	12.44	V
12	09	17	76	12.53	V

TAB. 1/2 - RECORDING SITE: TOLMEZZO

LIST OF SPECTRALLY ANALIZED AFTERSHOCKS RECORDERD IN THE PERIOD SEPTEMBER 9 TO OCTOBER 27

EVENT N	D A T E			HOUR GMT	COMPONENT
	MONTH	DAY	YEAR		
13	09	24	76	16.12	H
14	09	25	76	12.32	H
15	09	25	76	13.37	H
16	09	25	76	14.34	H
17	09	25	76	20.06	H
18	10	16	76	13.26	H
19	09	22	76	15.24	V
20	09	24	76	16.12	V
21	10	17	76	21.19	V

TAB. 1/3 - RECORDING SITE: VITO D'ASIO

LIST OF SPECTRALLY ANALIZED AFTERSHOCKS RECORDED IN THE PERIOD SEPTEMBER 9 TO OCTOBER 27

EVENT N	D A T E			HOUR GMT	COMPONENT
	MONTH	DAY	YEAR		
22	10	16	76	04.57	V
23	10	17	76	13.26	V
24	10	17	76	16.23	V

TAB. 1/4 - RECORDING SITE: BUIA

LIST OF SPECTRALLY ANALIZED AFTERSHOCKS RECORDED IN THE PERIOD SEPTEMBER 9 TO OCTOBER 27

EVENT N	D A T E			HOUR GMT	COMPONENT
	MONTH	DAY	YEAR		
25	09	30	76	20.50	V
26	10	02	76	17.05	V
27	10	03	76	17.49	V

TAB. 2 - DISTRIBUTION OF ANALIZED EVENTS OF TAB. 1

RECORDING SITE	NUMBER OF EVENTS		
	COMPONENT		TOTAL
	H	V	
GEMONA	10	2	12
TOLMEZZO	6	3	9
VITO D'ASIO	-	3	3
BUIA	-	3	3

TAB. 3 - LIST OF STRONG MOTION SPECTRALLY ANALIZED ACCELEROGRAMS OF MAY 6 EARTHQUAKES (ENEL TOLMEZZO) FOR COMPARISON WITH AFTERSHOCKS

EVENT N	D A T E			HOUR GMT	COMP.
	MONTH	DAY	YEAR		
1	05	06	76	19.59.08	N-S
	05	06	76	19.59.08	E-W
	05	06	76	19.59.08	V
2	05	06	76	20.00.15	N-S
	05	06	76	20.00.15	E-W
	05	06	76	20.00.15	V

a response linearity range between 0 and 1200 Hz. The photographic recorder employed was the Consolidated Electrodynamics Corporation type 5/124 one with self-developing paper.

b) A Federal Instrument type UA-15A wave analyser in real time, equipped with an analog-to-digital converter coupled to two Hewlett Packard type 1201 & 1200 A memory oscillographs. These were necessary to visualise both the seismic event under analysis and the corresponding frequency spectral analysis. The frequency spectral analysis signal was also sent to a Hewlett Packard plotter.

The calibrating criteria for the spectral analysis in real time were chosen by limiting the input memory of an event to 25 sec with a band width of the filter equal to 0.04 Hz, which corresponds to a frequency range 0 ÷ 20 Hz. The complete calibrations of the apparatus was made using a Schenk vibrating table.

Due to the characteristics of the employed transducers, the records represent obviously the ground displacement velocities at the various measuring sites. The elaboration of the experimental data acquired with the help of the previously illustrated instruments, permits to compare the dynamical characteristics of earthquakes having a different intensity.

As this type of research needs a considerable amount of time to elaborate and analyse the results, the preliminary examination of the seismograms has been limited to the

spectral analysis and to the visualization on the plotter of the various frequencies of the quadratic components of the dispacements velocity, in order to determine the predominant motions. Subsequently these spectra were digitized to obtain the Fourier spectra of the accelerations. The shape of these spectra at the various measuring sites are represented as hystograms in the following tables:

- Gemona : tab. 1/1; Events 1 to 12
- Tolmezzo : tab. 1/2; Events 13 to 21
- Vito d'Asio: tab. 1/3; Events 22 to 24
- Buia : tab. 1/4; Events 25 to 27

The spectral hystograms of the May 6 Earthquake strong-motion accelerograms recorded at Tolmezzo are shown on Tab. 3/1 to 3/6.

6. PRELIMINARY CONCLUDING REMARKS

The spectral analysis above described, even if preliminary, allow to carry out some significant remarks:

a) Every examined site presents its typical and substantially persistent seismic response characterized by evidently predominant frequencies. These frequencies, very important from the point of view of the seismic engineering, are plotted on Fig.s 1,2,3 and 4, and in detail, on the hystograms previously mentioned.

In particular, the examined site of Gemona has a neattly

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 1

(H COMP.)

FREQUENCY	ACCELERATION	. . . . .
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.00085	
1.200	0.00173	
1.400	0.00616	-
1.600	0.00503	-
1.800	0.01244	-
2.000	0.00418	
2.200	0.01106	-
2.400	0.03167	---
2.600	0.02532	---
2.800	0.02991	---
3.000	0.03770	----
3.200	0.08668	---------
3.400	0.03204	---
3.600	0.01979	--
3.800	0.06924	-------
4.000	0.06126	------
4.200	0.12108	------------
4.400	0.04147	----
4.600	0.05231	-----
4.800	0.09155	----------
5.000	0.04618	-----
5.200	0.09934	----------
5.400	0.03393	----
5.600	0.12613	------------
5.800	0.09312	----------
6.000	0.12048	------------
6.200	0.09007	---------
6.400	0.01979	--
6.600	0.09331	----------
6.800	0.02105	--
7.000	0.04769	-----
7.200	0.09814	----------
7.400	0.06421	-------
7.600	0.04241	----
7.800	0.14213	--------------
8.000	0.14643	--------------
8.200	0.07728	--------
8.400	0.03129	---
8.600	0.16751	----------------
8.800	0.01093	-
9.000	0.25444	------------------------
9.200	0.19787	-------------------
9.400	0.19283	-------------------
9.600	0.06635	-------
9.800	0.39100	-------------------------------------
10.000	0.32358	-------------------------------
10.200	0.06981	-------
10.400	0.02265	--
10.600	0.32657	-------------------------------
10.800	0.16965	----------------
11.000	0.20546	-------------------
11.200	0.02092	--
11.400	0.15975	---------------
11.600	0.38265	------------------------------------
11.800	0.09557	----------
12.000	0.10468	----------
12.200	0.09199	----------
12.400	0.18548	------------------
12.600	0.22384	----------------------
12.800	0.42691	--
13.000	0.40841	---------------------------------------
13.200	0.51444	---
13.400	0.08357	---------
13.600	0.08482	---------
13.800	0.27313	----------------------------
14.000	0.05718	------
14.200	0.13383	------------
14.400	0.23810	------------------------
14.600	0.29814	------------------------------
14.800	0.02325	--
15.000	0.10766	----------
15.200	0.14231	--------------
15.400	0.00484	-
15.600	0.02450	---
15.800	0.00496	-
16.000	0.05495	------
16.200	0.04580	-----
16.400	0.11850	-----------
16.600	0.10367	----------
16.800	0.18887	------------------
17.000	0.13273	------------
17.200	0.08058	--------
17.400	0.09239	---------
17.600	0.05498	------
17.800	0.01112	-
18.000	0.03916	----

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 2

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.00063	
1.200	0.00188	
1.400	0.00264	
1.600	0.00856	-
1.800	0.00848	-
2.000	0.03760	----
2.200	0.00415	
2.400	0.03845	----
2.600	0.02614	---
2.800	0.03079	---
3.000	0.04555	-----
3.200	0.01910	--
3.400	0.02903	---
3.600	0.03167	---
3.800	0.01074	-
4.000	0.10556	----------
4.200	0.05796	------
4.400	0.07603	--------
4.600	0.01734	--
4.800	0.03651	----------
5.000	0.10160	----------
5.200	0.13886	----------
5.400	0.01998	--
5.600	0.12959	----------
5.800	0.04555	-----
6.000	0.19038	----------
6.200	0.06707	-------
6.400	0.25133	----------
6.600	0.14929	----------
6.800	0.04913	-----
7.000	0.18692	----------
7.200	0.37096	----------
7.400	0.05733	------
7.600	0.10983	----------
7.800	0.18143	----------
8.000	0.13898	----------
8.200	0.95316	----------
8.400	0.42223	----------
8.600	0.12818	----------
8.800	0.20499	----------
9.000	0.24033	----------
9.200	0.52603	----------
9.400	0.13880	----------
9.600	0.18206	----------
9.800	0.07923	--------
10.000	0.32657	----------
10.200	0.22431	----------
10.400	0.11435	----------
10.600	0.09990	----------
10.800	0.06786	-------
11.000	0.33901	----------
11.200	0.36615	----------
11.400	0.01775	--
11.600	0.29518	----------
11.800	0.19849	----------
12.000	0.13949	----------
12.200	0.01916	--
12.400	0.07342	--------
12.600	0.32594	----------
12.800	0.18353	----------
13.000	0.18378	----------
13.200	0.11197	----------
13.400	0.02947	---
13.600	0.20081	----------
13.800	0.29697	----------
14.000	0.14954	----------
14.200	0.23644	----------
14.400	0.12667	----------
14.600	0.04587	-----
14.800	0.01395	-
15.000	0.04681	-----
15.200	0.00949	-
15.400	0.00484	-
15.600	0.02435	---
15.800	0.02482	---
16.000	0.00503	-
16.200	0.01012	-
16.400	0.03607	----
16.600	0.02592	---
16.800	0.00525	-
17.000	0.01068	-
17.200	0.01081	-
17.400	0.01630	--
17.600	0.03848	----
17.800	0.04448	-----
18.000	0.01131	-

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 3

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.01175	-
1.400	0.00220	
1.600	0.02168	--
1.800	0.00267	
2.000	0.03999	----
2.200	0.03456	----
2.400	0.04976	-----
2.600	0.01021	-
2.800	0.00594	-
3.000	0.02827	---
3.200	0.01169	-
3.400	0.02177	--
3.600	0.02199	--
3.800	0.01046	-
4.000	0.00880	-
4.200	0.01319	-
4.400	0.00675	-
4.600	0.03676	----
4.800	0.00452	
5.000	0.00785	-
5.200	0.00817	-
5.400	0.01527	--
5.600	0.02287	--
5.800	0.02696	---
6.000	0.03522	----
6.200	0.00390	
6.400	0.01810	--
6.600	0.07556	--------
6.800	0.01473	--
7.000	0.04838	-----
7.200	0.02231	--
7.400	0.05504	------
7.600	0.09896	----------
7.800	0.05391	------
8.000	0.10424	----------
8.200	0.06698	-------
8.400	0.01304	-
8.600	0.11618	----------
8.800	0.10113	----------
9.000	0.05033	-----
9.200	0.01734	--
9.400	0.04725	-----
9.600	0.06937	-------
9.800	0.03695	----
10.000	0.07464	--------
10.200	0.04486	-----
10.400	0.08822	---------
10.600	0.07992	--------
10.800	0.11033	----------
11.000	0.08985	---------
11.200	0.05579	------
11.400	0.05372	------
11.600	0.01093	-
11.800	0.01112	-
12.000	0.03393	----
12.200	0.04562	-----
12.400	0.02727	---
12.600	0.01979	--
12.800	0.04825	-----
13.000	0.04053	----
13.200	0.02488	---
13.400	0.04210	----
13.600	0.02136	--
13.800	0.03013	---
14.000	0.09236	----------
14.200	0.05799	------
14.400	0.05840	------
14.600	0.01835	--
14.800	0.01847	--
15.000	0.01414	-
15.200	0.0	
15.400	0.0	
15.600	0.00490	-
15.800	0.00993	-
16.000	0.00500	-
16.200	0.0	
16.400	0.0	
16.600	0.01043	-
16.800	0.01056	-
17.000	0.00534	-
17.200	0.00537	-
17.400	0.00547	-
17.600	0.00550	-
17.800	0.0	
18.000	0.0	

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 4

(H COMP.)

FREQUENCY	ACCELERATION	. . . . .
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.0	
1.400	0.0	
1.600	0.0	
1.800	0.0	
2.000	0.0	
2.200	0.0	
2.400	0.0	
2.600	0.00082	
2.800	0.0	
3.000	0.0	
3.200	0.0	
3.400	0.0	
3.600	0.00113	
3.800	0.00478	-
4.000	0.00377	
4.200	0.00396	
4.400	0.0	
4.600	0.00289	
4.800	0.00148	
5.000	0.00628	-
5.200	0.00431	-
5.400	0.00170	
5.600	0.00864	-
5.800	0.00547	-
6.000	0.00927	-
6.200	0.00575	-
6.400	0.01005	-
6.600	0.01037	-
6.800	0.01709	--
7.000	0.01100	-
7.200	0.01357	-
7.400	0.04185	----
7.600	0.01885	--
7.800	0.01225	-
8.000	0.04524	-----
8.200	0.07634	--------
8.400	0.02903	---
8.600	0.04593	-----
8.800	0.07741	--------
9.000	0.03110	---
9.200	0.00578	-
9.400	0.05316	------
9.600	0.04775	-----
9.800	0.03047	---
10.000	0.09425	----------
10.200	0.07370	--------
10.400	0.07119	--------
10.600	0.04995	-----
10.800	0.04411	-----
11.000	0.11058	-----------
11.200	0.18648	------------------
11.400	0.12070	------------
11.600	0.01822	--
11.800	0.03707	----
12.000	0.09720	----------
12.200	0.15331	---------------
12.400	0.07728	--------
12.600	0.05890	------
12.800	0.04423	-----
13.000	0.02026	--
13.200	0.01244	-
13.400	0.02925	---
13.600	0.01282	-
13.800	0.03902	----
14.000	0.05240	-----
14.200	0.03559	----
14.400	0.01797	--
14.600	0.03211	---
14.800	0.06509	------
15.000	0.02809	---
15.200	0.01910	--
15.400	0.01451	--
15.600	0.00490	-
15.800	0.00993	-
16.000	0.00999	-
16.200	0.01527	--
16.400	0.02576	---
16.600	0.04665	-----
16.800	0.03148	---
17.000	0.04247	----
17.200	0.03223	---
17.400	0.02187	--
17.600	0.02765	---
17.800	0.01112	-
18.000	0.01125	-

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 5

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.0	
1.400	0.0	
1.600	0.00101	
1.800	0.00226	
2.000	0.00126	
2.200	0.00622	-
2.400	0.00075	
2.600	0.00785	-
2.800	0.0	
3.000	0.00754	-
3.200	0.00974	-
3.400	0.00641	-
3.600	0.00226	
3.800	0.01395	-
4.000	0.00613	-
4.200	0.00328	-
4.400	0.00270	
4.600	0.02312	--
4.800	0.01329	-
5.000	0.00942	-
5.200	0.02614	---
5.400	0.01696	--
5.600	0.01901	--
5.800	0.01822	--
6.000	0.02262	--
6.200	0.03449	----
6.400	0.02413	---
6.600	0.05635	-------
6.800	0.05982	------
7.000	0.08577	---------
7.200	0.04461	-----
7.400	0.01627	--
7.600	0.02388	---
7.800	0.22054	----------
8.000	0.19855	----------
8.200	0.11451	------ ------
8.400	0.10691	----------
8.600	0.16022	----------
8.800	0.09400	----------
9.000	0.02796	---
9.200	0.08671	---------
9.400	0.04725	-----
9.600	0.01791	--
9.800	0.01847	--
10.000	0.00622	-
10.200	0.02221	--
10.400	0.01960	--
10.600	0.01649	--
10.800	0.03361	----
11.000	0.08639	---------
11.200	0.02463	---
11.400	0.02507	---
11.600	0.03644	----
11.800	0.02595	---
12.000	0.01495	--
12.200	0.04191	----
12.400	0.03864	----
12.600	0.03534	----
12.800	0.00804	-
13.000	0.01634	--
13.200	0.02469	---
13.400	0.02947	---
13.600	0.02136	--
13.800	0.02168	--
14.000	0.02183	--
14.200	0.01338	-
14.400	0.00905	-
14.600	0.00459	
14.800	0.02325	--
15.000	0.02356	--
15.200	0.00949	-
15.400	0.00968	-
15.600	0.00487	-
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 6

(H COMP.)

FREQUENCY	ACCELERATION	. . . . .
0.200	0.0	
0.400	0.0	
0.600	0.00019	
0.800	0.00025	
1.000	0.00063	
1.200	0.00075	
1.400	0.00044	
1.600	0.00050	
1.800	0.00481	-
2.000	0.01134	-
2.200	0.00462	
2.400	0.02187	--
2.600	0.01634	--
2.800	0.00264	
3.000	0.01225	-
3.200	0.00603	-
3.400	0.01175	-
3.600	0.04976	-----
3.800	0.01162	-
4.000	0.01392	-
4.200	0.02318	--
4.400	0.00946	-
4.600	0.02545	---
4.800	0.00886	-
5.000	0.02042	--
5.200	0.04646	-----
5.400	0.00333	
5.600	0.03519	----
5.800	0.15306	----------
6.000	0.01319	-
6.200	0.03833	----
6.400	0.04423	-----
6.600	0.06220	-------
6.800	0.12840	----------
7.000	0.02818	---
7.200	0.00223	
7.400	0.04650	-----
7.600	0.10267	----------
7.800	0.07106	-------
8.000	0.05027	-----
8.200	0.18033	----------
8.400	0.37548	----------
8.600	0.14860	----------
8.800	0.20458	----------
9.000	0.02796	---
9.200	0.03145	---
9.400	0.03839	----
9.600	0.05671	------
9.800	0.24014	----------
10.000	0.15551	----------
10.200	0.03204	---
10.400	0.09802	----------
10.600	0.14985	----------
10.800	0.21715	----------
11.000	0.06849	-------
11.200	0.03519	----
11.400	0.03223	---
11.600	0.10477	----------
11.800	0.04448	-----
12.000	0.0	
12.200	0.06462	-------
12.400	0.15972	----------
12.600	0.04354	-----
12.800	0.05187	-----
13.000	0.12252	----------
13.200	0.10239	----------
13.400	0.04210	----
13.600	0.07263	--------
13.800	0.09899	----------
14.000	0.07424	--------
14.200	0.00892	-
14.400	0.01357	-
14.600	0.05045	-----
14.800	0.02790	---
15.000	0.06553	-------
15.200	0.00949	-
15.400	0.02419	---
15.600	0.07841	--------
15.800	0.09371	----------
16.000	0.04995	-----
16.200	0.02036	--
16.400	0.05152	-----
16.600	0.06739	-------
16.800	0.03673	----
17.000	0.02124	--
17.200	0.02686	---
17.400	0.01630	--
17.600	0.00553	-
17.800	0.01678	--
18.000	0.00565	-

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 7

(H COMP.)

FREQUENCY	ACCELERATION
0.200	0.0
0.400	0.0
0.600	0.0
0.800	0.0
1.000	0.0
1.200	0.00069
1.400	0.00440
1.600	0.00283
1.800	0.03365
2.000	0.00754
2.200	0.03233
2.400	0.02746
2.600	0.00550
2.800	0.02205
3.000	0.01414
3.200	0.02111
3.400	0.02488
3.600	0.02714
3.800	0.02209
4.000	0.03798
4.200	0.06861
4.400	0.04147
4.600	0.07351
4.800	0.01508
5.000	0.09739
5.200	0.04901
5.400	0.08991
5.600	0.15482
5.800	0.08954
6.000	0.06673
6.200	0.04869
6.400	0.15281
6.600	0.04084
6.800	0.08118
7.000	0.04618
7.200	0.13572
7.400	0.31878
7.600	0.25070
7.800	0.12252
8.000	0.09927
8.200	0.01803
8.400	0.26389
8.600	0.62753
8.800	0.04920
9.000	0.02827
9.200	0.12293
9.400	0.25101
9.600	0.25965
9.800	0.12494
10.000	0.16336
10.200	0.45057
10.400	0.18950
10.600	0.06597
10.800	0.19340
11.000	0.10367
11.200	0.27200
11.400	0.06035
11.600	0.08671
11.800	0.09924
12.000	0.14703
12.200	0.01916
12.400	0.26879
12.600	0.26521
12.800	0.17954
13.000	0.19604
13.200	0.08708
13.400	0.07998
13.600	0.08118
13.800	0.06937
14.000	0.07424
14.200	0.12403
14.400	0.06786
14.600	0.01376
14.800	0.05579
15.000	0.02340
15.200	0.02372
15.400	0.01451
15.600	0.00490
15.800	0.04964
16.000	0.09990
16.200	0.03563
16.400	0.07169
16.600	0.03110
16.800	0.01056
17.000	0.02655
17.200	0.00537
17.400	0.0
17.600	0.00550
17.800	0.02224
18.000	0.01131

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 8

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.00019	
0.800	0.00025	
1.000	0.00028	
1.200	0.00035	
1.400	0.00245	
1.600	0.00188	
1.800	0.01923	--
2.000	0.04964	-----
2.200	0.01106	-
2.400	0.06032	------
2.600	0.00393	
2.800	0.04411	-----
3.000	0.03735	----
3.200	0.03311	---
3.400	0.03418	----
3.600	0.01539	--
3.800	0.02626	---
4.000	0.02765	---
4.200	0.07389	--------
4.400	0.03918	----
4.600	0.07917	--------
4.800	0.06032	------
5.000	0.01728	--
5.200	0.01144	-
5.400	0.04750	-----
5.600	0.15032	----------
5.800	0.15221	----------
6.000	0.07785	--------
6.200	0.02683	---
6.400	0.06032	------
6.600	0.18787	----------
6.800	0.04210	----
7.000	0.12095	----------
7.200	0.02231	--
7.400	0.03211	---
7.600	0.08954	---------
7.800	0.15240	----------
8.000	0.19855	----------
8.200	0.18290	----------
8.400	0.15306	----------
8.600	0.20804	----------
8.800	0.20458	----------
9.000	0.05592	------
9.200	0.33238	----------
9.400	0.40753	----------
9.600	0.16415	----------
9.800	0.25293	----------
10.000	0.18350	----------
10.200	0.23199	----------
10.400	0.08070	---------
10.600	0.09657	----------
10.800	0.25884	----------
11.000	0.12670	----------
11.200	0.09067	----------
11.400	0.02507	---
11.600	0.10933	----------
11.800	0.57460	----------
12.000	0.59188	----------
12.200	0.38013	----------
12.400	0.15582	----------
12.600	0.03927	----
12.800	0.04423	-----
13.000	0.07295	--------
13.200	0.03732	----
13.400	0.04596	-----
13.600	0.13245	----------
13.800	0.04304	-----
14.000	0.12227	----------
14.200	0.07973	--------
14.400	0.02714	---
14.600	0.08200	---------
14.800	0.06465	-------
15.000	0.01414	-
15.200	0.02321	---
15.400	0.03365	----
15.600	0.00974	-
15.800	0.03475	----
16.000	0.04021	----
16.200	0.01527	--
16.400	0.02061	--
16.600	0.02073	--
16.800	0.02639	---
17.000	0.01602	--
17.200	0.03782	----
17.400	0.03826	----
17.600	0.01106	-
17.800	0.01118	-
18.000	0.01131	-

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 9

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.00031	
1.200	0.00035	
1.400	0.00082	
1.600	0.00094	
1.800	0.00170	
2.000	0.00063	
2.200	0.00346	
2.400	0.01131	-
2.600	0.00572	-
2.800	0.01018	-
3.000	0.00660	-
3.200	0.00201	
3.400	0.01389	-
3.600	0.00905	-
3.800	0.00716	-
4.000	0.00754	-
4.200	0.00386	
4.400	0.03456	----
4.600	0.01414	-
4.800	0.06183	------
5.000	0.05655	------
5.200	0.03845	----
5.400	0.02714	---
5.600	0.00864	-
5.800	0.02187	--
6.000	0.00377	
6.200	0.00584	-
6.400	0.04021	----
6.600	0.04288	----
6.800	0.03999	----
7.000	0.01951	--
7.200	0.01131	-
7.400	0.01605	--
7.600	0.06695	-------
7.800	0.02450	---
8.000	0.01257	-
8.200	0.14169	----------
8.400	0.17945	----------
8.600	0.04593	-----
8.800	0.14929	----------
9.000	0.12302	----------
9.200	0.05718	------
9.400	0.02953	---
9.600	0.14476	----------
9.800	0.08928	---------
10.000	0.06220	-------
10.200	0.14099	----------
10.400	0.08737	---------
10.600	0.08577	---------
10.800	0.05089	-----
11.000	0.05136	-----
11.200	0.01046	-
11.400	0.15400	----------
11.600	0.08671	---------
11.800	0.00368	
12.000	0.02639	---
12.200	0.04216	----
12.400	0.05796	------
12.600	0.00396	
12.800	0.02793	---
13.000	0.09802	----------
13.200	0.07408	--------
13.400	0.08419	---------
13.600	0.07210	--------
13.800	0.05595	------
14.000	0.02199	--
14.200	0.04873	-----
14.400	0.11310	----------
14.600	0.10022	----------
14.800	0.06004	------
15.000	0.01414	-
15.200	0.01898	--
15.400	0.03945	----
15.600	0.08765	---------
15.800	0.08878	---------
16.000	0.03996	----
16.200	0.03035	---
16.400	0.02560	---
16.600	0.01037	-
16.800	0.01049	-
17.000	0.0	
17.200	0.01081	-
17.400	0.00547	-
17.600	0.0	
17.800	0.00536	-
18.000	0.01131	-

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 10

(H COMP.)

FREQUENCY	ACCELERATION	. . . . .
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.00035	
1.400	0.00041	
1.600	0.00050	
1.800	0.00053	
2.000	0.00179	
2.200	0.00132	
2.400	0.00302	
2.600	0.00236	
2.800	0.00440	
3.000	0.00377	
3.200	0.00195	
3.400	0.00518	-
3.600	0.00330	
3.800	0.01511	--
4.000	0.00858	-
4.200	0.00644	-
4.400	0.00135	
4.600	0.01012	-
4.800	0.02714	---
5.000	0.01571	--
5.200	0.02243	--
5.400	0.03223	---
5.600	0.01583	--
5.800	0.01275	-
6.000	0.01885	--
6.200	0.03896	----
6.400	0.01731	--
6.600	0.05105	-----
6.800	0.03204	---
7.000	0.04335	-----
7.200	0.04071	----
7.400	0.12321	----------
7.600	0.09073	---------
7.800	0.20078	----------
8.000	0.12566	----------
8.200	0.10304	----------
8.400	0.05215	-----
8.600	0.02702	---
8.800	0.01659	--
9.000	0.04807	-----
9.200	0.10694	----------
9.400	0.13148	----------
9.600	0.06333	-------
9.800	0.09447	---------
10.000	0.04712	-----
10.200	0.02538	---
10.400	0.05825	------
10.600	0.11545	----------
10.800	0.01691	--
11.000	0.01392	-
11.200	0.01407	-
11.400	0.00716	-
11.600	0.03613	----
11.800	0.03156	---------
12.000	0.02639	---
12.200	0.03801	----
12.400	0.05843	------
12.600	0.10210	----------
12.800	0.16358	----------
13.000	0.07295	--------
13.200	0.01646	--
13.400	0.0	
13.600	0.01232	-
13.800	0.02152	--
14.000	0.00873	-
14.200	0.02677	---
14.400	0.01357	-
14.600	0.03139	---
14.800	0.00924	-
15.000	0.02356	--
15.200	0.04269	----
15.400	0.00481	-
15.600	0.01461	--
15.800	0.03971	----
16.000	0.01508	--
16.200	0.02529	---
16.400	0.04637	-----
16.600	0.02073	--
16.800	0.00525	-
17.000	0.00531	-
17.200	0.01081	-
17.400	0.02187	--
17.600	0.01659	--
17.800	0.02237	--
18.000	0.01125	-

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 11

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.00006	
0.400	0.00019	
0.600	0.00047	
0.800	0.00066	
1.000	0.00028	
1.200	0.0	
1.400	0.00880	-
1.600	0.02262	--
1.800	0.01188	-
2.000	0.02702	---
2.200	0.00990	-
2.400	0.01373	-
2.600	0.02777	---
2.800	0.02815	---
3.000	0.01640	--
3.200	0.01558	--
3.400	0.02488	---
3.600	0.02199	--
3.800	0.02388	---
4.000	0.06984	-------
4.200	0.14941	----------
4.400	0.19318	----------
4.600	0.03958	----
4.800	0.21715	----------
5.000	0.06927	-------
5.200	0.04084	----
5.400	0.11822	----------
5.600	0.00880	-
5.800	0.05014	-----
6.000	0.03707	----
6.200	0.03449	----
6.400	0.05630	------
6.600	0.03063	---
6.800	0.06104	------
7.000	0.03299	---
7.200	0.04907	-----
7.400	0.08256	----------
7.600	0.01649	--
7.800	0.05080	-----
8.000	0.04273	----
8.200	0.01272	-
8.400	0.10952	----------
8.600	0.07210	--------
8.800	0.10113	----------
9.000	0.01414	-
9.200	0.14580	----------
9.400	0.08181	----------
9.600	0.01508	--
9.800	0.04618	-----
10.000	0.00622	-
10.200	0.04125	----
10.400	0.05554	------
10.600	0.16493	----------
10.800	0.03361	----
11.000	0.00685	-
11.200	0.03519	----
11.400	0.06036	------
11.600	0.07288	--------
11.800	0.16682	----------
12.000	0.08599	----------
12.200	0.07665	--------
12.400	0.13634	----------
12.600	0.28667	----------
12.800	0.13964	----------
13.000	0.20420	----------
13.200	0.24693	----------
13.400	0.08357	----------
13.600	0.07210	--------
13.800	0.08671	----------
14.000	0.02183	--
14.200	0.03544	----
14.400	0.07691	--------
14.600	0.03189	---
14.800	0.12554	----------
15.000	0.05617	------
15.200	0.02388	---
15.400	0.02903	---
15.600	0.0	
15.800	0.0	
16.000	0.06993	-------
16.200	0.07125	-------
16.400	0.05667	------
16.600	0.05215	-----
16.800	0.17313	----------
17.000	0.01062	-
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.04524	-----

TAB. 1/1

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: GEMONA - EVENT N. 12

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.0	
1.400	0.0	
1.600	0.0	
1.800	0.0	
2.000	0.0	
2.200	0.0	
2.400	0.0	
2.600	0.0	
2.800	0.0	
3.000	0.0	
3.200	0.0	
3.400	0.0	
3.600	0.0	
3.800	0.0	
4.000	0.0	
4.200	0.0	
4.400	0.0	
4.600	0.0	
4.800	0.0	
5.000	0.0	
5.200	0.00490	-
5.400	0.00679	-
5.600	0.00704	-
5.800	0.0	
6.000	0.0	
6.200	0.0	
6.400	0.0	
6.600	0.0	
6.800	0.0	
7.000	0.0	
7.200	0.01593	--
7.400	0.01627	--
7.600	0.00471	
7.800	0.00490	-
8.000	0.02482	---
8.200	0.04326	-----
8.400	0.01304	-
8.600	0.00801	-
8.800	0.0	
9.000	0.01118	-
9.200	0.00289	
9.400	0.01169	-
9.600	0.03016	---
9.800	0.07923	--------
10.000	0.00933	-
10.200	0.00320	
10.400	0.00971	-
10.600	0.03299	---
10.800	0.00679	-
11.000	0.06220	-------
11.200	0.05231	------
11.400	0.00358	
11.600	0.01806	--
11.800	0.01854	--
12.000	0.03365	----
12.200	0.03041	---
12.400	0.05843	------
12.600	0.05542	------
12.800	0.00402	
13.000	0.01216	-
13.200	0.01244	-
13.400	0.03760	----
13.600	0.06836	-------
13.800	0.03013	---
14.000	0.0	
14.200	0.05353	------
14.400	0.13119	----------
14.600	0.10933	----------
14.800	0.06004	------
15.000	0.03277	---
15.200	0.01433	-
15.400	0.00968	-
15.600	0.0	
15.800	0.01489	--
16.000	0.03519	----
16.200	0.04046	----
16.400	0.01024	-
16.600	0.01043	-
16.800	0.01056	-
17.000	0.01593	--
17.200	0.01612	--
17.400	0.0	
17.600	0.00553	-
17.800	0.01678	--
18.000	0.02262	--

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 13

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.00006	
0.400	0.00009	
0.600	0.00019	
0.800	0.00226	
1.000	0.00534	-
1.200	0.01002	-
1.400	0.03870	----
1.600	0.07942	--------
1.800	0.01470	--
2.000	0.03833	----
2.200	0.01979	--
2.400	0.02262	--
2.600	0.07540	--------
2.800	0.04241	----
3.000	0.04995	-----
3.200	0.03720	----
3.400	0.01495	--
3.600	0.06048	------
3.800	0.09997	----------
4.000	0.03393	----
4.200	0.04892	-----
4.400	0.01351	-
4.600	0.01012	-
4.800	0.05278	------
5.000	0.12007	------------
5.200	0.03845	----
5.400	0.02545	---
5.600	0.06048	------
5.800	0.06377	-------
6.000	0.04078	----
6.200	0.03641	----
6.400	0.00396	
6.600	0.04976	-----
6.800	0.04273	----
7.000	0.00880	-
7.200	0.01357	-
7.400	0.01162	-
7.600	0.06447	-------
7.800	0.04411	-----
8.000	0.04716	-----
8.200	0.15268	----------
8.400	0.05542	------
8.600	0.00801	-
8.800	0.01640	--
9.000	0.04241	----
9.200	0.03179	---
9.400	0.04134	----
9.600	0.02985	---
9.800	0.04002	----
10.000	0.05220	------
10.200	0.03808	----
10.400	0.02912	---
10.600	0.01979	--
10.800	0.05429	------
11.000	0.01037	-
11.200	0.02111	--
11.400	0.02865	---
11.600	0.05419	------
11.800	0.00371	
12.000	0.02991	---
12.200	0.04181	----
12.400	0.03116	---
12.600	0.02771	---
12.800	0.01608	--
13.000	0.04963	-----
13.200	0.02881	---
13.400	0.02526	---
13.600	0.00855	-
13.800	0.04734	-----
14.000	0.00440	
14.200	0.02231	--
14.400	0.10405	----------
14.600	0.03211	---
14.800	0.02325	--
15.000	0.05184	-----
15.200	0.02388	---
15.400	0.07257	--------
15.600	0.02435	---
15.800	0.02466	---
16.000	0.00999	-
16.200	0.00509	-
16.400	0.0	
16.600	0.01043	-
16.800	0.01574	--
17.000	0.02670	---
17.200	0.01081	-
17.400	0.01087	-
17.600	0.01649	--
17.800	0.03355	----
18.000	0.04524	-----

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 14

(H COMP.)

FREQUENCY	ACCELERATION	. . . .
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.00377	
1.200	0.00173	
1.400	0.00660	-
1.600	0.01885	--
1.800	0.00374	
2.000	0.00377	
2.200	0.01847	--
2.400	0.03016	---
2.600	0.00408	
2.800	0.02545	---
3.000	0.03016	---
3.200	0.02011	--
3.400	0.08130	---------
3.600	0.03393	----
3.800	0.02388	---
4.000	0.12987	----------
4.200	0.05938	------
4.400	0.00691	-
4.600	0.01445	--
4.800	0.02413	---
5.000	0.03927	----
5.200	0.01602	--
5.400	0.05828	------
5.600	0.04574	-----
5.800	0.02004	--
6.000	0.01319	-
6.200	0.03449	----
6.400	0.03760	----
6.600	0.01037	-
6.800	0.03845	----
7.000	0.02199	--
7.200	0.02714	---
7.400	0.00465	
7.600	0.01433	--
7.800	0.11272	----------
8.000	0.02482	---
8.200	0.00763	-
8.400	0.00732	-
8.600	0.02937	---
8.800	0.01367	-
9.000	0.00559	-
9.200	0.00286	
9.400	0.00292	
9.600	0.02413	---
9.800	0.01212	-
10.000	0.02513	---
10.200	0.0	
10.400	0.00971	-
10.600	0.02309	--
10.800	0.01357	-
11.000	0.01037	-
11.200	0.02092	--
11.400	0.00358	
11.600	0.0	
11.800	0.00741	-
12.000	0.01122	-
12.200	0.01140	-
12.400	0.0	
12.600	0.00785	-
12.800	0.00402	
13.000	0.00405	
13.200	0.01659	--
13.400	0.00418	
13.600	0.00427	
13.800	0.00867	-
14.000	0.00873	-
14.200	0.00446	
14.400	0.00449	
14.600	0.00456	
14.800	0.0	
15.000	0.01414	-
15.200	0.00949	-
15.400	0.01935	--
15.600	0.00490	-
15.800	0.00493	-
16.000	0.00500	-
16.200	0.0	
16.400	0.00512	-
16.600	0.01037	-
16.800	0.00525	-
17.000	0.0	
17.200	0.00537	-
17.400	0.00547	-
17.600	0.0	
17.800	0.00559	-
18.000	0.00562	-

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 15

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.00009	
0.400	0.00063	
0.600	0.00016	
0.800	0.0	
1.000	0.00424	
1.200	0.02004	--
1.400	0.03063	---
1.600	0.04712	-----
1.800	0.12441	----------
2.000	0.02513	---
2.200	0.15834	----------
2.400	0.06409	-------
2.600	0.01552	--
2.800	0.06158	------
3.000	0.06974	-------
3.200	0.0	
3.400	0.01970	--
3.600	0.07587	--------
3.800	0.02388	---
4.000	0.12865	----------
4.200	0.09896	----------
4.400	0.11483	----------
4.600	0.04335	-----
4.800	0.08712	---------
5.000	0.03142	---
5.200	0.01470	--
5.400	0.07804	--------
5.600	0.0	
5.800	0.07471	--------
6.000	0.03958	----
6.200	0.02875	---
6.400	0.05344	------
6.600	0.02450	---
6.800	0.01923	--
7.000	0.03519	----
7.200	0.02007	--
7.400	0.03211	---
7.600	0.05253	------
7.800	0.01935	--
8.000	0.02513	---
8.200	0.02061	--
8.400	0.00261	
8.600	0.00267	
8.800	0.01913	--
9.000	0.01414	-
9.200	0.00578	-
9.400	0.01753	--
9.600	0.00298	
9.800	0.03387	----
10.000	0.08086	--------
10.200	0.01282	-
10.400	0.02265	--
10.600	0.08247	---------
10.800	0.04034	----
11.000	0.01370	-
11.200	0.03870	----
11.400	0.07100	--------
11.600	0.03644	----
11.800	0.03676	----
12.000	0.05608	------
12.200	0.04131	----
12.400	0.01948	--
12.600	0.00785	-
12.800	0.0	
13.000	0.03676	----
13.200	0.00823	-
13.400	0.03739	----
13.600	0.01709	--
13.800	0.03874	----
14.000	0.03493	----
14.200	0.01784	--
14.400	0.02262	--
14.600	0.00459	
14.800	0.00462	
15.000	0.01404	-
15.200	0.02388	---
15.400	0.00968	-
15.600	0.05356	------
15.800	0.02978	---
16.000	0.02498	---
16.200	0.01012	-
16.400	0.03091	---
16.600	0.02086	--
16.800	0.01056	-
17.000	0.03204	---
17.200	0.00540	-
17.400	0.02733	---
17.600	0.01659	--
17.800	0.02237	--
18.000	0.01131	-

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.00201	
1.000	0.00396	
1.200	0.01313	-
1.400	0.03035	---
1.600	0.02011	--
1.800	0.03365	----
2.000	0.01253	-
2.200	0.04354	-----
2.400	0.02790	---
2.600	0.05262	------
2.800	0.01696	--
3.000	0.02827	---
3.200	0.06636	-------
3.400	0.03836	----
3.600	0.04637	-----
3.800	0.05253	------
4.000	0.06911	-------
4.200	0.05152	-----
4.400	0.16886	----------
4.600	0.08482	---------
4.800	0.07383	--------
5.000	0.09896	----------
5.200	0.16182	----------
5.400	0.04496	-----
5.600	0.02111	--
5.800	0.07879	--------
6.000	0.05375	------
6.200	0.01533	--
6.400	0.05429	------
6.600	0.17417	----------
6.800	0.06409	-------
7.000	0.05853	------
7.200	0.07917	--------
7.400	0.03211	---
7.600	0.06597	-------
7.800	0.08225	---------
8.000	0.08042	--------
8.200	0.08759	---------
8.400	0.06070	------
8.600	0.02670	---
8.800	0.02733	---
9.000	0.05592	------
9.200	0.02312	--
9.400	0.01461	--
9.600	0.18397	----------
9.800	0.03079	---
10.000	0.11938	----------
10.200	0.07691	--------
10.400	0.03236	---
10.600	0.01649	--
10.800	0.04071	----
11.000	0.00691	-
11.200	0.02915	---
11.400	0.03940	----
11.600	0.04335	-----
11.800	0.09638	----------
12.000	0.02243	--
12.200	0.00767	-
12.400	0.00386	
12.600	0.01188	-
12.800	0.01206	-
13.000	0.03242	---
13.200	0.00823	-
13.400	0.02105	--
13.600	0.02564	---
13.800	0.01734	--
14.000	0.02620	---
14.200	0.03544	----
14.400	0.02246	--
14.600	0.0	
14.800	0.00924	-
15.000	0.02340	--
15.200	0.0	
15.400	0.05768	------
15.600	0.03836	----
15.800	0.02959	---
16.000	0.0	
16.200	0.02529	---
16.400	0.01024	-
16.600	0.0	
16.800	0.01583	--
17.000	0.01068	-
17.200	0.01081	-
17.400	0.02733	---
17.600	0.00550	-
17.800	0.02796	---
18.000	0.02827	---

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 16

(H COMP.)

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 17

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.00019	
0.600	0.00016	
0.800	0.00132	
1.000	0.01046	-
1.200	0.04527	-----
1.400	0.11435	----------
1.600	0.14137	----------
1.800	0.07050	-------
2.000	0.03760	----
2.200	0.06927	-------
2.400	0.09682	----------
2.600	0.00735	-
2.800	0.02121	--
3.000	0.06651	-------
3.200	0.08278	---------
3.400	0.08812	---------
3.600	0.09896	----------
3.800	0.02507	---
4.000	0.08209	---------
4.200	0.02705	---
4.400	0.03179	---
4.600	0.02023	--
4.800	0.01810	--
5.000	0.01539	--
5.200	0.01762	--
5.400	0.02664	---
5.600	0.00518	-
5.800	0.05466	------
6.000	0.03016	---
6.200	0.00779	-
6.400	0.00990	-
6.600	0.02859	---
6.800	0.01068	-
7.000	0.05498	------
7.200	0.01131	-
7.400	0.02325	--
7.600	0.00716	-
7.800	0.02177	--
8.000	0.03016	---
8.200	0.06183	------
8.400	0.05806	------
8.600	0.03811	-
8.800	0.00829	-
9.000	0.01937	--
9.200	0.00578	-
9.400	0.01753	--
9.600	0.00603	-
9.800	0.03695	----
10.000	0.00628	-
10.200	0.01904	--
10.400	0.00971	-
10.600	0.02639	---
10.800	0.00339	
11.000	0.01382	-
11.200	0.02092	--
11.400	0.04298	-----
11.600	0.02890	---
11.800	0.00368	
12.000	0.00374	
12.200	0.00383	
12.400	0.00773	-
12.600	0.00393	
12.800	0.00399	
13.000	0.00817	-
13.200	0.00829	-
13.400	0.00418	
13.600	0.01282	-
13.800	0.01301	-
14.000	0.00873	-
14.200	0.00446	
14.400	0.00905	-
14.600	0.0	
14.800	0.0	
15.000	0.00942	-
15.200	0.00949	-
15.400	0.00961	-
15.600	0.00490	-
15.800	0.00993	-
16.000	0.01508	--
16.200	0.0	
16.400	0.00515	-
16.600	0.01037	-
16.800	0.01056	-
17.000	0.00534	-
17.200	0.01074	-
17.400	0.00543	-
17.600	0.0	
17.800	0.0	
18.000	0.01131	-

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 18

(H COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.00057	
0.800	0.00201	
1.000	0.02290	--
1.200	0.01970	--
1.400	0.06126	------
1.600	0.08011	--------
1.800	0.06503	-------
2.000	0.10357	----------
2.200	0.05146	-----
2.400	0.03035	---
2.600	0.03456	----
2.800	0.04046	----
3.000	0.02073	--
3.200	0.00692	-
3.400	0.04769	-----
3.600	0.01018	-
3.800	0.05696	------
4.000	0.01235	-
4.200	0.01932	--
4.400	0.00270	
4.600	0.01838	--
4.800	0.00591	-
5.000	0.00628	-
5.200	0.00431	-
5.400	0.00679	-
5.600	0.01583	--
5.800	0.00182	
6.000	0.01885	--
6.200	0.00330	
6.400	0.00402	
6.600	0.00408	
6.800	0.00427	
7.000	0.00630	-
7.200	0.01115	-
7.400	0.01147	-
7.600	0.00942	-
7.800	0.00490	-
8.000	0.00231	
8.200	0.00515	-
8.400	0.00522	-
8.600	0.00270	
8.800	0.0	
9.000	0.00539	-
9.200	0.0	
9.400	0.00295	
9.600	0.00302	
9.800	0.00308	
10.000	0.00314	
10.200	0.00317	
10.400	0.00647	-
10.600	0.00330	
10.800	0.00336	
11.000	0.00342	
11.200	0.0	
11.400	0.00358	
11.600	0.00364	
11.800	0.0	
12.000	0.0	
12.200	0.0	
12.400	0.0	
12.600	0.0	
12.800	0.0	
13.000	0.0	
13.200	0.0	
13.400	0.0	
13.600	0.0	
13.800	0.0	
14.000	0.0	
14.200	0.0	
14.400	0.0	
14.600	0.0	
14.800	0.0	
15.000	0.0	
15.200	0.0	
15.400	0.0	
15.600	0.0	
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 19

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.00009	
0.400	0.0	
0.600	0.00113	
0.800	0.00251	
1.000	0.01602	--
1.200	0.01131	-
1.400	0.08985	---------
1.600	0.05042	-----
1.800	0.01602	--
2.000	0.01571	--
2.200	0.08432	---------
2.400	0.01131	-
2.600	0.02695	---
2.800	0.08432	---------
3.000	0.09425	----------
3.200	0.02011	--
3.400	0.10575	----------
3.600	0.01696	--
3.800	0.02029	--
4.000	0.07917	--------
4.200	0.04508	-----
4.400	0.01392	-
4.600	0.02601	---
4.800	0.03318	---
5.000	0.02199	--
5.200	0.03104	---
5.400	0.01998	--
5.600	0.01583	--
5.800	0.02915	---
6.000	0.01508	--
6.200	0.06707	-------
6.400	0.01810	--
6.600	0.01451	--
6.800	0.02136	--
7.000	0.04552	-----
7.200	0.00669	-
7.400	0.00930	-
7.600	0.03820	----
7.800	0.02205	--
8.000	0.03519	----
8.200	0.01288	-
8.400	0.02086	--
8.600	0.00267	
8.800	0.01106	-
9.000	0.01118	-
9.200	0.00286	
9.400	0.04675	-----
9.600	0.00302	
9.800	0.01539	--
10.000	0.01257	-
10.200	0.0	
10.400	0.01618	--
10.600	0.0	
10.800	0.01357	-
11.000	0.03801	----
11.200	0.01744	--
11.400	0.00716	-
11.600	0.01093	-
11.800	0.01112	-
12.000	0.01508	--
12.200	0.00383	
12.400	0.0	
12.600	0.00396	
12.800	0.00402	
13.000	0.00811	-
13.200	0.01244	-
13.400	0.00836	-
13.600	0.0	
13.800	0.00867	-
14.000	0.0	
14.200	0.02677	---
14.400	0.00898	-
14.600	0.00917	-
14.800	0.0	
15.000	0.0	
15.200	0.00949	-
15.400	0.0	
15.600	0.01470	--
15.800	0.00986	-
16.000	0.00503	-
16.200	0.0	
16.400	0.00512	-
16.600	0.01565	--
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.00547	-
17.600	0.0	
17.800	0.0	
18.000	0.0	

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 20

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.00050	
1.000	0.00126	
1.200	0.01018	-
1.400	0.01056	-
1.600	0.04172	----
1.800	0.03506	----
2.000	0.08168	---------
2.200	0.02281	--
2.400	0.01357	-
2.600	0.00471	
2.800	0.01696	--
3.000	0.07106	-------
3.200	0.01266	-
3.400	0.00726	-
3.600	0.02149	--
3.800	0.02865	---
4.000	0.02513	---
4.200	0.0	
4.400	0.01486	--
4.600	0.00283	
4.800	0.02865	---
5.000	0.01693	--
5.200	0.01307	-
5.400	0.00333	
5.600	0.02463	---
5.800	0.03644	----
6.000	0.00942	-
6.200	0.04791	-----
6.400	0.03563	----
6.600	0.01451	--
6.800	0.04273	----
7.000	0.01084	-
7.200	0.03346	----
7.400	0.07339	--------
7.600	0.00478	-
7.800	0.02450	---
8.000	0.03723	----
8.200	0.05089	-----
8.400	0.04172	----
8.600	0.02670	---
8.800	0.04920	-----
9.000	0.05938	------
9.200	0.0	
9.400	0.04030	----
9.600	0.01206	-
9.800	0.05542	------
10.000	0.07540	--------
10.200	0.03173	---
10.400	0.02589	---
10.600	0.01319	-
10.800	0.02017	--
11.000	0.03456	----
11.200	0.02815	---
11.400	0.06390	-------
11.600	0.05466	------
11.800	0.07414	--------
12.000	0.08294	---------
12.200	0.0	
12.400	0.05410	------
12.600	0.01979	--
12.800	0.03192	---
13.000	0.08916	---------
13.200	0.05321	------
13.400	0.04596	-----
13.600	0.05982	------
13.800	0.09971	----------
14.000	0.00873	-
14.200	0.00446	
14.400	0.08536	---------
14.600	0.06890	-------
14.800	0.07904	--------
15.000	0.08492	---------
15.200	0.02388	---
15.400	0.03387	----
15.600	0.07304	--------
15.800	0.00993	-
16.000	0.0	
16.200	0.01012	-
16.400	0.01546	--
16.600	0.04172	----
16.800	0.03167	---
17.000	0.01068	-
17.200	0.00540	-
17.400	0.01630	--
17.600	0.06597	-------
17.800	0.01668	--
18.000	0.05623	------

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.00019	
0.800	0.00101	
1.000	0.00311	
1.200	0.01092	-
1.400	0.00616	-
1.600	0.02875	---
1.800	0.09331	----------
2.000	0.11938	----------
2.200	0.04948	-----
2.400	0.03091	---
2.600	0.10619	----------
2.800	0.00880	-
3.000	0.04430	-----
3.200	0.05746	------
3.400	0.05554	------
3.600	0.02036	--
3.800	0.04656	-----
4.000	0.03063	---
4.200	0.01715	--
4.400	0.02837	---
4.600	0.03324	---
4.800	0.05278	------
5.000	0.01885	--
5.200	0.03525	----
5.400	0.05661	------
5.600	0.03974	----
5.800	0.03826	----
6.000	0.06117	------
6.200	0.02491	---
6.400	0.07323	--------
6.600	0.03063	---
6.800	0.02350	--
7.000	0.07257	--------
7.200	0.07807	--------
7.400	0.03487	----
7.600	0.03770	----
7.800	0.01935	--
8.000	0.07197	--------
8.200	0.04379	-----
8.400	0.02347	--
8.600	0.02937	---
8.800	0.03829	-
9.000	0.04241	----
9.200	0.01156	-
9.400	0.04134	----
9.600	0.02714	---
9.800	0.04876	-----
10.000	0.02799	---
10.200	0.01602	--
10.400	0.03559	----
10.600	0.01332	-
10.800	0.00672	-
11.000	0.02055	--
11.200	0.02441	---
11.400	0.01074	-
11.600	0.01806	--
11.800	0.01854	--
12.000	0.00377	
12.200	0.01533	--
12.400	0.01169	-
12.600	0.00792	-
12.800	0.00402	
13.000	0.00817	-
13.200	0.01659	--
13.400	0.00836	-
13.600	0.01709	--
13.800	0.00861	-
14.000	0.00437	
14.200	0.00446	
14.400	0.00452	
14.600	0.01835	--
14.800	0.00465	
15.000	0.00942	-
15.200	0.01433	--
15.400	0.00484	-
15.600	0.00490	-
15.800	0.00496	-
16.000	0.01508	--
16.200	0.01517	--
16.400	0.0	
16.600	0.01565	--
16.800	0.0	
17.000	0.00534	-
17.200	0.0	
17.400	0.00547	-
17.600	0.00553	-
17.800	0.01112	-
18.000	0.0	

TAB. 1/2

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: TOLMEZZO - EVENT N. 21

(V COMP.)

TAB. 1/3

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: VITO D'ASIO - EVENT N. 22

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.00035	
1.400	0.00176	
1.600	0.00330	
1.800	0.00509	-
2.000	0.01194	-
2.200	0.00660	-
2.400	0.00145	
2.600	0.00314	
2.800	0.03167	---
3.000	0.01367	-
3.200	0.06132	------
3.400	0.02073	--
3.600	0.02714	---
3.800	0.01671	--
4.000	0.01470	--
4.200	0.00902	-
4.400	0.01392	-
4.600	0.01272	-
4.800	0.00148	
5.000	0.01847	--
5.200	0.03594	----
5.400	0.03054	---
5.600	0.05702	------
5.800	0.01433	--
6.000	0.01885	--
6.200	0.01533	--
6.400	0.01206	-
6.600	0.00817	-
6.800	0.01052	-
7.000	0.00220	
7.200	0.00452	
7.400	0.01860	--
7.600	0.04477	-----
7.800	0.01225	-
8.000	0.02765	---
8.200	0.02036	--
8.400	0.01043	-
8.600	0.00270	
8.800	0.01367	-
9.000	0.01979	--
9.200	0.01734	--
9.400	0.00584	-
9.600	0.00603	-
9.800	0.01232	-
10.000	0.0	
10.200	0.00641	-
10.400	0.00327	
10.600	0.00990	-
10.800	0.0	
11.000	0.0	
11.200	0.00349	
11.400	0.00358	
11.600	0.00364	
11.800	0.00735	-
12.000	0.00374	
12.200	0.00383	
12.400	0.00390	
12.600	0.00396	
12.800	0.0	
13.000	0.0	
13.200	0.0	
13.400	0.0	
13.600	0.0	
13.800	0.0	
14.000	0.0	
14.200	0.0	
14.400	0.0	
14.600	0.0	
14.800	0.0	
15.000	0.0	
15.200	0.0	
15.400	0.0	
15.600	0.0	
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

FREQUENCY	ACCELERATION	. . . . .
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.00157	
1.200	0.00346	
1.400	0.00041	
1.600	0.01225	-
1.800	0.00679	-
2.000	0.02325	--
2.200	0.02111	--
2.400	0.00829	-
2.600	0.01806	--
2.800	0.01759	--
3.000	0.02733	---
3.200	0.02011	--
3.400	0.01659	--
3.600	0.03409	----
3.800	0.06161	------
4.000	0.03016	---
4.200	0.02111	--
4.400	0.00968	-
4.600	0.00424	
4.800	0.01508	--
5.000	0.01539	--
5.200	0.01634	--
5.400	0.00833	-
5.600	0.03870	----
5.800	0.03223	---
6.000	0.01483	--
6.200	0.01169	-
6.400	0.02212	--
6.600	0.01037	-
6.800	0.01068	-
7.000	0.01084	-
7.200	0.00679	-
7.400	0.00930	-
7.600	0.00471	
7.800	0.00490	-
8.000	0.00993	-
8.200	0.00254	
8.400	0.01304	-
8.600	0.00811	-
8.800	0.01093	-
9.000	0.00839	-
9.200	0.01144	-
9.400	0.00295	
9.600	0.00298	
9.800	0.0	
10.000	0.00628	-
10.200	0.0	
10.400	0.00327	
10.600	0.00333	
10.800	0.0	
11.000	0.00346	
11.200	0.00352	
11.400	0.0	
11.600	0.00364	
11.800	0.0	
12.000	0.0	
12.200	0.0	
12.400	0.0	
12.600	0.0	
12.800	0.0	
13.000	0.0	
13.200	0.0	
13.400	0.0	
13.600	0.0	
13.800	0.0	
14.000	0.0	
14.200	0.0	
14.400	0.0	
14.600	0.0	
14.800	0.0	
15.000	0.0	
15.200	0.0	
15.400	0.0	
15.600	0.0	
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

TAB. 1/3

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: VITO D'ASIO - EVENT N. 23

(V COMP.)

TAB. 1/3

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: VITO D'ASIO - EVENT N. 24

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.00063	
1.200	0.00151	
1.400	0.00123	
1.600	0.00613	-
1.800	0.01389	-
2.000	0.04596	-----
2.200	0.04147	----
2.400	0.01373	-
2.600	0.01307	-
2.800	0.01847	--
3.000	0.06469	-------
3.200	0.03016	---
3.400	0.04354	-----
3.600	0.10556	----------
3.800	0.01627	--
4.000	0.04656	-----
4.200	0.02705	---
4.400	0.02702	---
4.600	0.01838	--
4.800	0.04725	-----
5.000	0.06440	-------
5.200	0.03267	---
5.400	0.04496	-----
5.600	0.03870	----
5.800	0.01275	-
6.000	0.03016	---
6.200	0.00383	
6.400	0.01188	-
6.600	0.02903	---
6.800	0.03204	---
7.000	0.01759	--
7.200	0.00905	-
7.400	0.02293	--
7.600	0.00955	-
7.800	0.01225	-
8.000	0.01985	--
8.200	0.01288	-
8.400	0.05737	------
8.600	0.00534	-
8.800	0.00553	-
9.000	0.00559	-
9.200	0.01144	-
9.400	0.01772	--
9.600	0.01492	--
9.800	0.00308	
10.000	0.00314	
10.200	0.00952	-
10.400	0.00653	-
10.600	0.00330	
10.800	0.00679	-
11.000	0.00346	
11.200	0.00704	-
11.400	0.00358	
11.600	0.00723	-
11.800	0.00735	-
12.000	0.00374	
12.200	0.00380	
12.400	0.00390	
12.600	0.0	
12.800	0.0	
13.000	0.0	
13.200	0.0	
13.400	0.0	
13.600	0.0	
13.800	0.0	
14.000	0.0	
14.200	0.0	
14.400	0.0	
14.600	0.0	
14.800	0.0	
15.000	0.0	
15.200	0.0	
15.400	0.0	
15.600	0.0	
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

TAB. 1/4

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: BUIA - EVENT N. 25

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.0	
1.400	0.0	
1.600	0.0	
1.800	0.0	
2.000	0.0	
2.200	0.0	
2.400	0.0	
2.600	0.0	
2.800	0.0	
3.000	0.00188	
3.200	0.00487	-
3.400	0.00104	
3.600	0.0	
3.800	0.0	
4.000	0.0	
4.200	0.0	
4.400	0.0	
4.600	0.00145	
4.800	0.00302	
5.000	0.00157	
5.200	0.00160	
5.400	0.00339	
5.600	0.00173	
5.800	0.00182	
6.000	0.00556	-
6.200	0.05843	------
6.400	0.18407	----------
6.600	0.01659	--
6.800	0.00631	-
7.000	0.0	
7.200	0.00446	
7.400	0.00930	-
7.600	0.00236	
7.800	0.00242	
8.000	0.00496	-
8.200	0.0	
8.400	0.00792	-
8.600	0.00540	-
8.800	0.00820	-
9.000	0.00848	-
9.200	0.00289	
9.400	0.00886	-
9.600	0.01791	--
9.800	0.01539	--
10.000	0.00622	-
10.200	0.0	
10.400	0.00324	
10.600	0.0	
10.800	0.0	
11.000	0.0	
11.200	0.0	
11.400	0.0	
11.600	0.0	
11.800	0.0	
12.000	0.0	
12.200	0.0	
12.400	0.00390	
12.600	0.00396	
12.800	0.00798	-
13.000	0.01621	--
13.200	0.00823	-
13.400	0.0	
13.600	0.0	
13.800	0.0	
14.000	0.0	
14.200	0.0	
14.400	0.0	
14.600	0.0	
14.800	0.0	
15.000	0.0	
15.200	0.0	
15.400	0.0	
15.600	0.0	
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

TAB. 1/4

AFTERSHOCKS OF 1976 FRIULI EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: BUIA - EVENT N. 26

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.0	
1.400	0.0	
1.600	0.0	
1.800	0.0	
2.000	0.0	
2.200	0.0	
2.400	0.0	
2.600	0.00092	
2.800	0.00088	
3.000	0.00188	
3.200	0.00097	
3.400	0.00107	
3.600	0.00220	
3.800	0.00239	
4.000	0.01005	-
4.200	0.00644	-
4.400	0.00276	
4.600	0.00723	-
4.800	0.00754	-
5.000	0.00154	
5.200	0.00163	
5.400	0.00679	-
5.600	0.00518	-
5.800	0.00716	-
6.000	0.01319	-
6.200	0.01916	--
6.400	0.01188	-
6.600	0.01866	--
6.800	0.01709	--
7.000	0.02384	---
7.200	0.02941	---
7.400	0.03487	----
7.600	0.02388	---
7.800	0.02903	---
8.000	0.14577	----------
8.200	0.19836	----------
8.400	0.06597	-------
8.600	0.06484	-------
8.800	0.00553	-
9.000	0.00839	-
9.200	0.00572	-
9.400	0.00584	-
9.600	0.00302	
9.800	0.00616	-
10.000	0.00942	-
10.200	0.00641	-
10.400	0.00647	-
10.600	0.00990	-
10.800	0.01008	-
11.000	0.01027	-
11.200	0.00697	-
11.400	0.00710	-
11.600	0.00729	-
11.800	0.00368	
12.000	0.01131	-
12.200	0.02300	--
12.400	0.00779	-
12.600	0.01583	--
12.800	0.03619	----
13.000	0.00811	-
13.200	0.00823	-
13.400	0.00421	
13.600	0.00424	
13.800	0.0	
14.000	0.00440	
14.200	0.00443	
14.400	0.0	
14.600	0.0	
14.800	0.0	
15.000	0.0	
15.200	0.0	
15.400	0.0	
15.600	0.0	
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

TAB. 1/4

AFTERSHOCKS OF 1976 **FRIULI** EARTHQUAKES

SPECTRAL ANALYSIS

RECORDING SITE: BUIA - EVENT N. 27

(V COMP.)

FREQUENCY	ACCELERATION	
0.200	0.0	
0.400	0.0	
0.600	0.0	
0.800	0.0	
1.000	0.0	
1.200	0.0	
1.400	0.0	
1.600	0.0	
1.800	0.0	
2.000	0.0	
2.200	0.0	
2.400	0.0	
2.600	0.0	
2.800	0.0	
3.000	0.0	
3.200	0.0	
3.400	0.0	
3.600	0.0	
3.800	0.0	
4.000	0.0	
4.200	0.0	
4.400	0.0	
4.600	0.00141	
4.800	0.00452	
5.000	0.00157	
5.200	0.00653	-
5.400	0.00333	
5.600	0.00854	-
5.800	0.00895	-
6.000	0.01319	-
6.200	0.02143	--
6.400	0.04624	-----
6.600	0.03110	---
6.800	0.01894	--
7.000	0.03738	----
7.200	0.05799	------
7.400	0.03487	----
7.600	0.01885	--
7.800	0.05881	------
8.000	0.02482	---
8.200	0.09739	----------
8.400	0.05215	-----
8.600	0.12968	-------------
8.800	0.02733	---
9.000	0.14819	----------------
9.200	0.05781	------
9.400	0.03839	----
9.600	0.00597	-
9.800	0.00924	-
10.000	0.01571	--
10.200	0.01904	--
10.400	0.01618	--
10.600	0.00333	
10.800	0.00672	-
11.000	0.01037	-
11.200	0.00697	-
11.400	0.00716	-
11.600	0.0	
11.800	0.00371	
12.000	0.0	
12.200	0.0	
12.400	0.0	
12.600	0.0	
12.800	0.0	
13.000	0.00408	
13.200	0.00415	
13.400	0.00421	
13.600	0.00427	
13.800	0.0	
14.000	0.0	
14.200	0.0	
14.400	0.0	
14.600	0.0	
14.800	0.0	
15.000	0.0	
15.200	0.0	
15.400	0.0	
15.600	0.0	
15.800	0.0	
16.000	0.0	
16.200	0.0	
16.400	0.0	
16.600	0.0	
16.800	0.0	
17.000	0.0	
17.200	0.0	
17.400	0.0	
17.600	0.0	
17.800	0.0	
18.000	0.0	

| FREQUENCY | % G | . . .

FREQUENCY	% G	. . . . .
0.200	0.06	
0.400	0.19	-
0.600	0.13	-
0.800	0.05	
1.000	0.13	-
1.200	0.35	--
1.400	0.47	--
1.600	1.34	-------
1.800	2.51	------------
2.000	1.62	--------
2.200	0.95	-----
2.400	3.61	------------------
2.600	4.04	--------------------
2.800	3.27	---------- -----
3.000	2.91	--------------
3.200	2.68	-------------
3.400	3.82	---------------- ---
3.600	3.42	----------------
3.800	1.99	----------
4.000	1.72	--------
4.200	2.01	----------
4.400	1.51	--------
4.600	0.98	-----
4.800	1.06	-----
5.000	1.07	-----
5.200	0.71	---
5.400	0.18	-
5.600	0.58	---
5.800	0.31	-
6.000	0.36	--
6.200	0.44	--
6.400	0.05	
6.600	0.19	-
6.800	0.29	-
7.000	0.38	--
7.200	0.48	--
7.400	0.51	--
7.600	0.61	---
7.800	0.40	--
8.000	0.33	--
8.200	0.23	-
8.400	0.18	-
8.600	0.14	-
8.800	0.14	-
9.000	0.06	
9.200	0.07	
9.400	0.13	-
9.600	0.19	-
9.800	0.21	-
10.000	0.14	-
10.200	0.30	-
10.400	0.21	-
10.600	0.26	-
10.800	0.25	-
11.000	0.12	-
11.200	0.08	
11.400	0.06	
11.600	0.09	
11.800	0.06	
12.000	0.02	
12.200	0.08	
12.400	0.05	
12.600	0.11	-
12.800	0.10	
13.000	0.08	
13.200	0.08	
13.400	0.09	
13.600	0.05	
13.800	0.11	-
14.000	0.12	-
14.200	0.18	-
14.400	0.16	-
14.600	0.14	-
14.800	0.08	
15.000	0.06	
15.200	0.08	
15.400	0.08	
15.600	0.04	
15.800	0.02	
16.000	0.05	
16.200	0.05	
16.400	0.0	
16.600	0.01	
16.800	0.05	
17.000	0.02	
17.200	0.04	
17.400	0.09	
17.600	0.09	
17.800	0.07	
18.000	0.06	

TAB. 3 /2

FRIULI EARTHQUAKE - MAY 6 1976

SPECTRAL ANALYSIS OF ACCELEROGRAM

RECORDED AT TOLMEZZO (ENEL)

FORE SHOCK - HOUR 19.59.08 - E-W COMP.

FREQUENCY	% G	. . . . .
0.200	0.12	-
0.400	0.02	
0.600	0.12	-
0.800	0.10	
1.000	0.03	
1.200	0.05	
1.400	0.04	
1.600	0.07	
1.800	0.26	-
2.000	0.35	--
2.200	0.42	--
2.400	0.79	----
2.600	0.77	----
2.800	0.96	-----
3.000	0.33	--
3.200	0.20	-
3.400	0.33	--
3.600	0.46	--
3.800	0.40	--
4.000	0.39	--
4.200	0.42	--
4.400	0.53	---
4.600	0.53	---
4.800	0.60	---
5.000	0.72	---
5.200	0.82	----
5.400	0.59	---
5.600	0.66	---
5.800	0.59	---
6.000	0.45	--
6.200	0.21	-
6.400	0.19	-
6.600	0.19	-
6.800	0.23	-
7.000	0.16	-
7.200	0.17	-
7.400	0.08	
7.600	0.05	
7.800	0.09	
8.000	0.13	-
8.200	0.09	
8.400	0.07	
8.600	0.18	-
8.800	0.11	-
9.000	0.07	
9.200	0.07	
9.400	0.03	
9.600	0.07	
9.800	0.07	
10.000	0.07	
10.200	0.07	
10.400	0.12	-
10.600	0.06	
10.800	0.12	-
11.000	0.12	-
11.200	0.03	
11.400	0.07	
11.600	0.02	
11.800	0.06	
12.000	0.07	
12.200	0.0	
12.400	0.04	
12.600	0.06	
12.800	0.05	
13.000	0.02	
13.200	0.02	
13.400	0.08	
13.600	0.05	
13.800	0.03	
14.000	0.04	
14.200	0.02	
14.400	0.01	
14.600	0.03	
14.800	0.03	
15.000	0.04	
15.200	0.03	
15.400	0.06	
15.600	0.03	
15.800	0.01	
16.000	0.05	
16.200	0.04	
16.400	0.04	
16.600	0.02	
16.800	0.05	
17.000	0.03	
17.200	0.02	
17.400	0.03	
17.600	0.03	
17.800	0.02	
18.000	0.04	

TAB. 3 /3

FRIULI EARTHQUAKE - MAY 6 1976

SPECTRAL ANALYSIS OF ACCELEROGRAM

RECORDED AT TOLMEZZO (ENEL)

FORE SHOCK - HOUR 19.59.08 - V COMP.

FREQUENCY	% G	. . . . .
0.200	0.85	----
0.400	2.28	----------
0.600	3.93	----------
0.800	2.05	----------
1.000	1.92	---------
1.200	7.52	----------
1.400	7.38	----------
1.600	3.33	----------
1.800	4.91	----------
2.000	17.45	----------
2.200	0.23	-
2.400	8.03	----------
2.600	2.78	----------
2.800	6.14	----------
3.000	8.85	----------
3.200	2.37	----------
3.400	4.68	----------
3.600	10.63	----------
3.800	4.54	----------
4.000	5.54	----------
4.200	3.11	----------
4.400	3.79	----------
4.600	0.15	-
4.800	2.87	----------
5.000	3.87	----------
5.200	3.76	----------
5.400	4.11	----------
5.600	2.05	----------
5.800	3.11	----------
6.000	1.17	------
6.200	4.88	----------
6.400	0.95	-----
6.600	5.90	----------
6.800	2.95	----------
7.000	1.94	---------
7.200	3.32	----------
7.400	0.85	----
7.600	0.35	----
7.800	0.81	----
8.000	3.36	----------
8.200	2.28	----------
8.400	0.23	-
8.600	1.82	----------
8.800	1.06	-----
9.000	0.21	-
9.200	0.93	----
9.400	2.68	----------
9.600	1.33	------
9.800	0.70	---
10.000	0.39	--
10.200	1.65	--------
10.400	1.23	------
10.600	1.59	--------
10.800	1.63	--------
11.000	1.71	--------
11.200	0.53	---
11.400	0.51	--
11.600	1.64	--------
11.800	1.10	-----
12.000	0.80	----
12.200	0.87	----
12.400	0.45	--
12.600	0.06	
12.800	0.49	--
13.000	1.55	--------
13.200	0.59	---
13.400	0.33	--
13.600	1.07	-----
13.800	0.36	--
14.000	0.82	----
14.200	0.77	----
14.400	0.78	----
14.600	0.65	---
14.800	0.31	-
15.000	0.90	----
15.200	0.55	---
15.400	1.51	--------
15.600	0.48	--
15.800	0.49	--
16.000	0.22	-
16.200	0.49	--
16.400	0.31	-
16.600	0.37	--
16.800	0.40	--
17.000	0.44	--
17.200	0.48	--
17.400	0.11	-
17.600	0.13	-
17.800	0.42	--
18.000	0.37	--

TAB. 3 /4

FRIULI EARTHQUAKE - MAY 6 1976

SPECTRAL ANALYSIS OF ACCELEROGRAM

RECORDED AT TOLMEZZO (ENEL)

MAIN SHOCK - HOUR 20.00.15 - N-S COMP.

FREQUENCY	% G
0.200	2.16
0.400	0.82
0.600	1.27
0.800	5.25
1.000	4.15
1.200	6.34
1.400	14.48
1.600	20.76
1.800	5.08
2.000	17.19
2.200	6.26
2.400	5.59
2.600	7.53
2.800	14.79
3.000	5.50
3.200	1.69
3.400	3.99
3.600	5.81
3.800	4.56
4.000	2.45
4.200	1.41
4.400	2.51
4.600	3.03
4.800	5.96
5.000	1.67
5.200	0.39
5.400	3.60
5.600	4.32
5.800	4.12
6.000	2.47
6.200	2.94
6.400	2.99
6.600	3.67
6.800	1.12
7.000	2.63
7.200	3.19
7.400	1.26
7.600	0.46
7.800	1.96
8.000	1.17
8.200	0.46
8.400	1.43
8.600	1.66
8.800	1.81
9.000	1.01
9.200	0.36
9.400	0.73
9.600	0.33
9.800	0.68
10.000	1.48
10.200	1.18
10.400	0.95
10.600	0.21
10.800	0.79
11.000	0.19
11.200	1.33
11.400	1.45
11.600	0.78
11.800	0.74
12.000	0.25
12.200	0.14
12.400	0.68
12.600	0.55
12.800	0.45
13.000	0.83
13.200	0.28
13.400	0.22
13.600	0.40
13.800	0.49
14.000	0.32
14.200	0.69
14.400	1.13
14.600	0.86
14.800	0.76
15.000	0.29
15.200	0.37
15.400	0.44
15.600	0.20
15.800	0.21
16.000	0.26
16.200	0.11
16.400	0.58
16.600	0.30
16.800	0.25
17.000	0.29
17.200	0.55
17.400	0.16
17.600	0.29
17.800	0.55
18.000	0.08

TAB. 3 /5

FRIULI EARTHQUAKE - MAY 6 1976

SPECTRAL ANALYSIS OF ACCELEROGRAM

RECORDED AT TOLMEZZO (ENEL)

MAIN SHOCK - HOUR 20.00.15 - E-W COMP.

FREQUENCY	% G	. . . . .
0.200	1.12	-----
0.400	0.45	--
0.600	0.99	-----
0.800	0.43	--
1.000	1.01	-----
1.200	1.43	-------
1.400	1.74	--------
1.600	0.96	-----
1.800	1.37	-------
2.000	1.61	--------
2.200	0.49	--
2.400	0.93	----
2.600	2.31	----------
2.800	5.53	----------
3.000	5.33	----------
3.200	4.57	----------
3.400	3.16	----------
3.600	3.36	----------
3.800	0.88	----
4.000	5.11	----------
4.200	3.20	----------
4.400	2.93	----------
4.600	2.77	----------
4.800	1.27	------
5.000	5.21	----------
5.200	0.36	----
5.400	2.35	----------
5.600	5.66	----------
5.800	4.74	----------
6.000	5.43	----------
6.200	0.41	--
6.400	1.72	--------
6.600	3.49	----------
6.800	2.53	----------
7.000	3.42	----------
7.200	2.70	----------
7.400	2.52	----------
7.600	1.56	--------
7.800	1.50	-------
8.000	2.75	----------
8.200	1.83	---------
8.400	2.46	----------
8.600	3.10	----------
8.800	3.55	----------
9.000	1.36	-------
9.200	0.83	----
9.400	3.65	----------
9.600	1.76	--------
9.800	1.94	---------
10.000	2.66	----------
10.200	0.99	----
10.400	0.40	--
10.600	4.58	----------
10.800	1.98	----------
11.000	1.45	-------
11.200	3.35	----------
11.400	1.25	------
11.600	1.10	-----
11.800	2.55	----------
12.000	0.50	--
12.200	0.93	----
12.400	0.70	---
12.600	1.45	-------
12.800	3.33	----------
13.000	1.97	---------
13.200	1.98	----------
13.400	0.90	----
13.600	0.82	----
13.800	0.47	--
14.000	0.82	----
14.200	1.30	------
14.400	0.70	---
14.600	0.39	--
14.800	0.70	---
15.000	0.34	--
15.200	0.79	----
15.400	1.44	-------
15.600	1.03	-----
15.800	0.61	---
16.000	0.48	--
16.200	0.38	--
16.400	1.25	------
16.600	0.46	--
16.800	0.42	--
17.000	0.45	--
17.200	0.68	---
17.400	0.77	----
17.600	0.70	---
17.800	0.38	--
18.000	0.72	---

TAB. 3/6

FRIULI EARTHQUAKE - MAY 6 1976

SPECTRAL ANALYSIS OF ACCELEROGRAM

RECORDED AT TOLMEZZO (ENEL)

MAIN SHOCK - HOUR 20.00.15 - V COMP.

predominant velocity peak-frequency around the 8 Hz (Fig. 1). The site of Tolmezzo shows a more dispersed spectrum, with predominant frequencies ranging from 1 to 5 Hz (Fig. 2). Vito d'Asio site presents clear peak-frequencies at about 3.6 and 5.5 Hz. Buia site has its predominant frequencies from 6 to 9 Hz.
The spectral behaviours above indicated, are confirmed also by the spectral acceleration hystograms.

b) The spectral characteristics of the site is substantially not or scarcely influenced by the magnitude of the event (Fig. 5) nor by the hypocentral position of the recorded aftershocks.

This preliminary spectral study will be continued with analysis of the several most significant aftershocks recorded and of those expected for the future months.

For a valid correlation of the various exciting events having different magnitudes, all Fourier's and response spectra will be normalized.

FIG. 1 - RECORDING SITE: GEMONA

TYPICAL DIAGRAM OF SPECTRAL ANALYSIS OF SQUARE VELOCITY

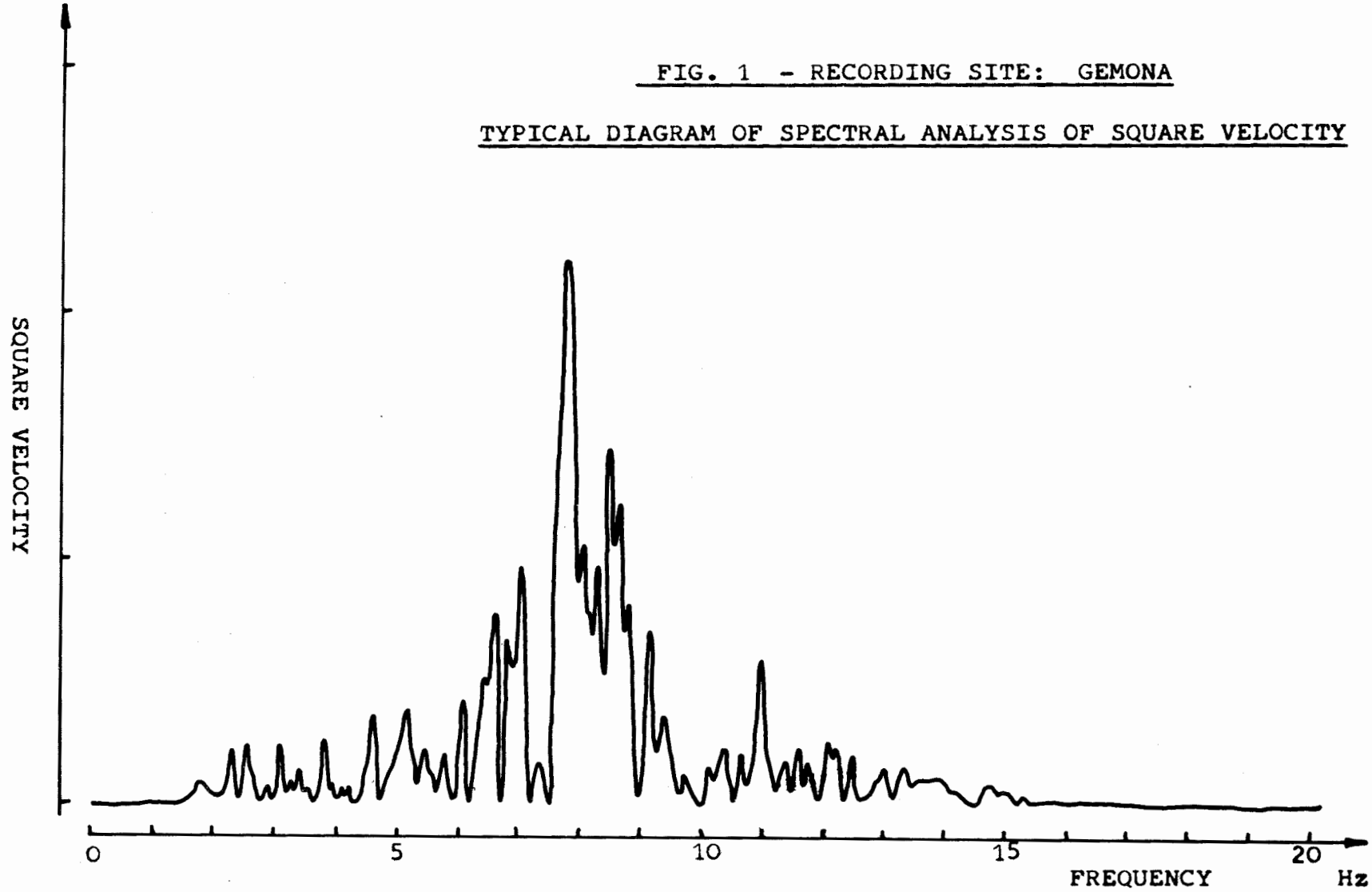


FIG. 2 - RECORDING SITE: TOLMEZZO

TYPICAL DIAGRAM OF SPECTRAL ANALYSIS OF SQUARE VELOCITY

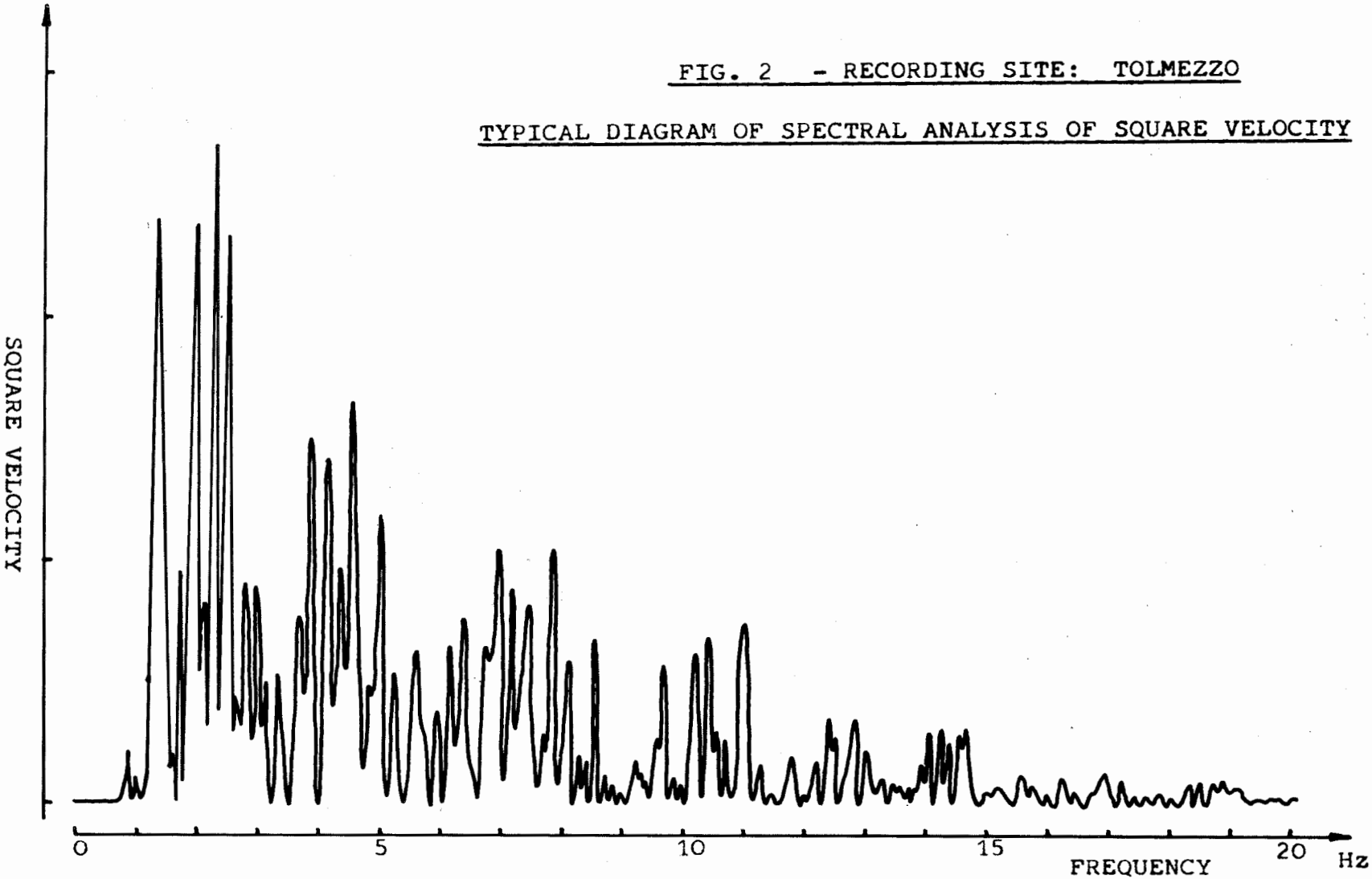


FIG. 3 - RECORDING SITE: VITO D'ASIO

TYPICAL DIAGRAM OF SPECTRAL ANALYSIS OF SQUARE VELOCITY

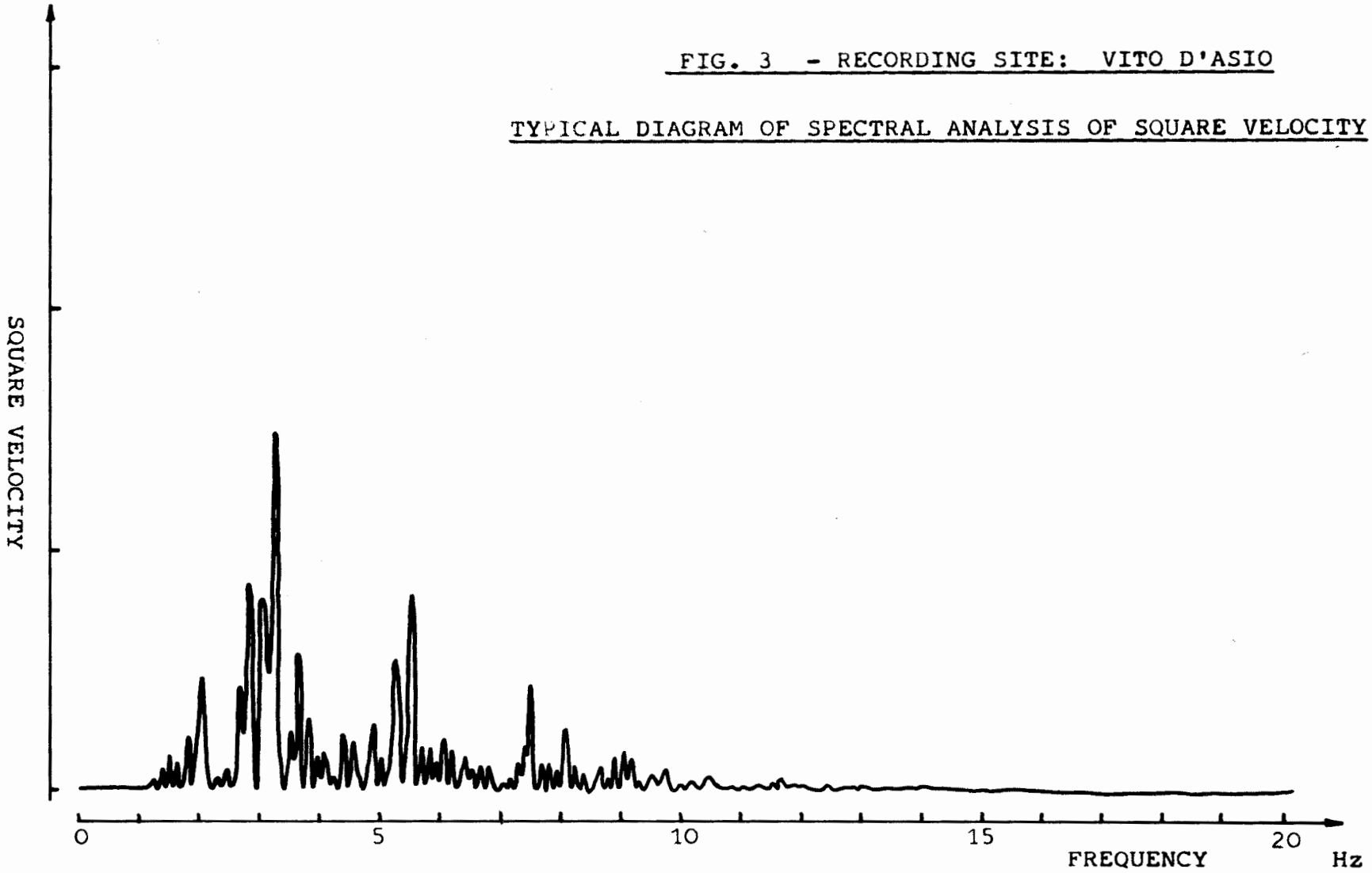
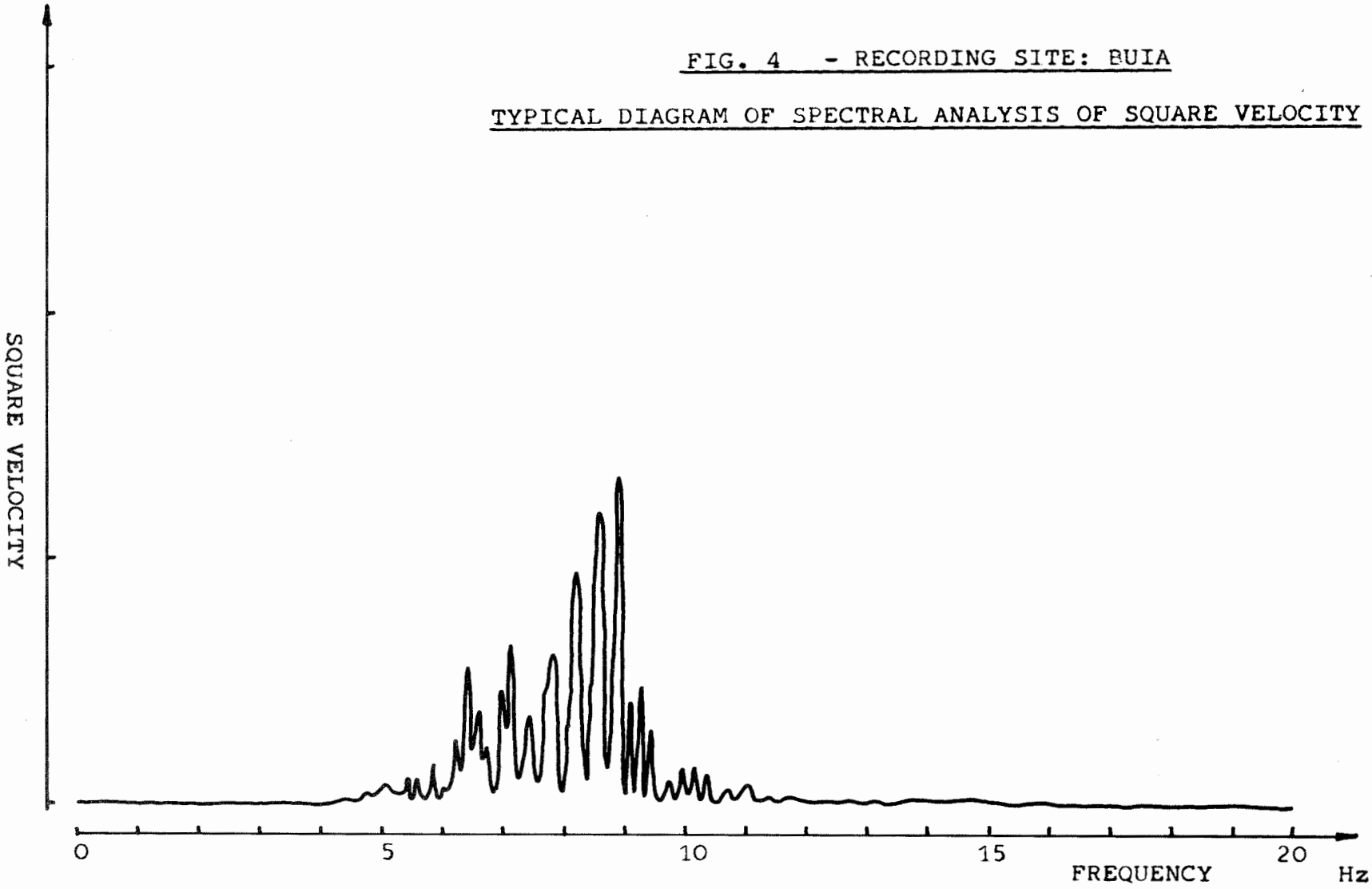


FIG. 4 - RECORDING SITE: BUIA

TYPICAL DIAGRAM OF SPECTRAL ANALYSIS OF SQUARE VELOCITY



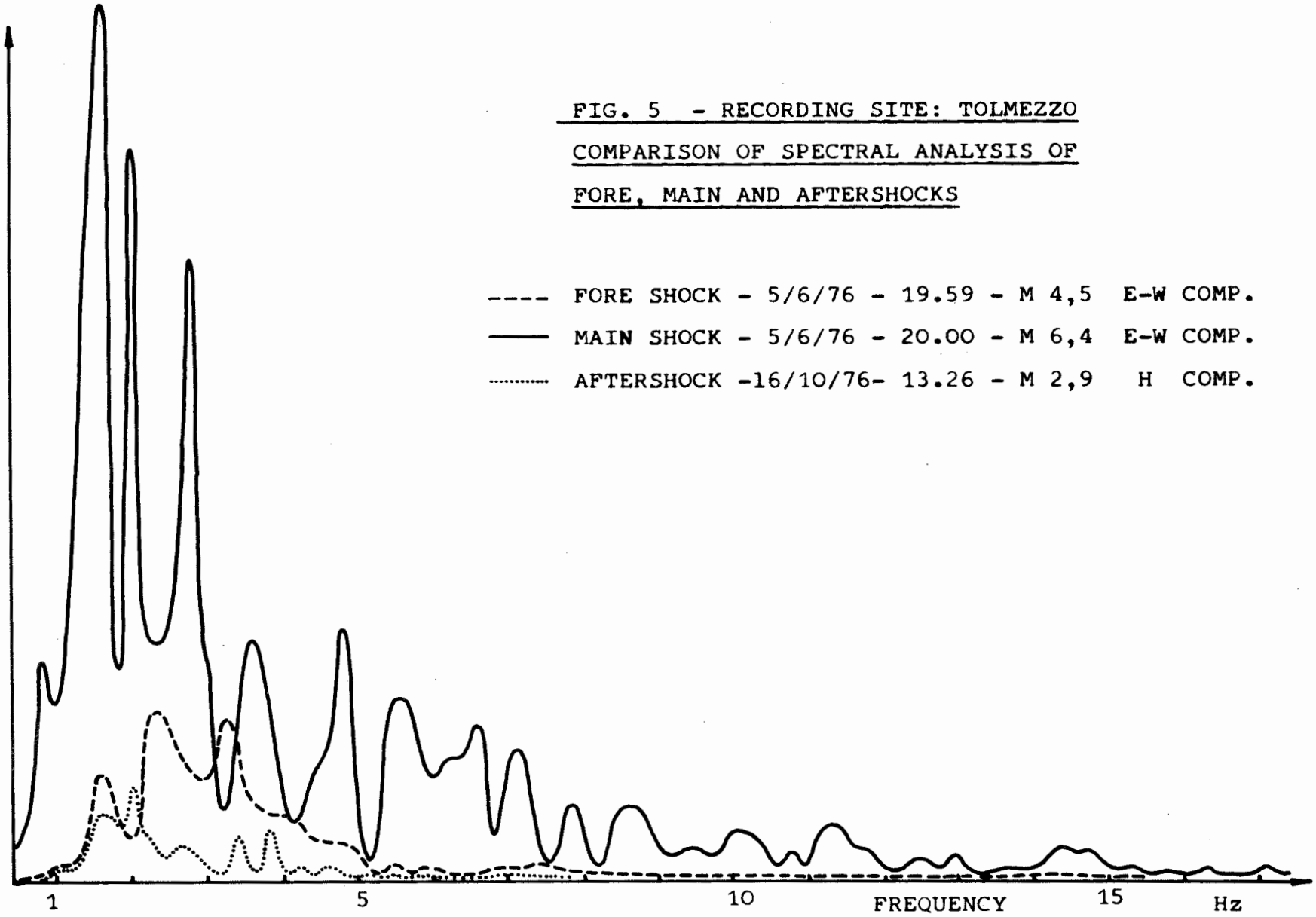


FIG. 5 - RECORDING SITE: TOLMEZZO
COMPARISON OF SPECTRAL ANALYSIS OF
FORE, MAIN AND AFTERSHOCKS

---- FORE SHOCK - 5/6/76 - 19.59 - M 4,5 E-W COMP.
—— MAIN SHOCK - 5/6/76 - 20.00 - M 6,4 E-W COMP.
..... AFTERSHOCK -16/10/76- 13.26 - M 2,9 H COMP.

REFERENCES

CASTELLANI A. (1968) - Sulla valutazione del rischio di danni sismici in mancanza di registrazioni di macrosismi. Istituto di Scienza e Tecnica delle Costruzioni del Politecnico di Milano, Pub. n° 448.

CASTELLANI A. (19) - Alcuni problemi di dinamica del suolo connessi con l'ingegneria. Istituto di Scienza e Tecnica delle Costruzioni del Politecnico di Milano.

ENEL (1976) - Terremoti del Friuli Maggio 1976 - Spettri di risposta I[a] parte. Enel Roma Ottobre.

KARNIK V. et al. (1976) - Proceedings of the Seminar on Seismic Zoning maps. Vol. I, Vol. II, UNESCO, Skopje.

PROZEN D. (1976) - Metode Seizmicze Mikroregionalizaciji. Beograd, 25÷27 Marz.

PETRINI V., CASTELLANI A. (1970) - Spettro di risposta di accelerogrammi di terremoti di debole e forte intensità. Istituto Lombardo di Scienze e Lettere (A). Vol. 104.

TIME SPACE EPICENTER AND HYPOCENTER DISTRIBUTION AND FOCAL MECHANISM OF 1976 FRIULI EARTHQUAKES

BY

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H.HAESSLER** - T.P.HOANG** -

D.SLEJKO* - C.WEILINGER**

S U M M A R Y

Precise epicenter locations made by a telemetric system during May and September Earthquakes in Friuli and some fault plane solutions have been correlated with seismic fractures identified by prospection in order to understand the focal mechanisms. The May earthquake corresponds to the activation of the Buia-Tricesimo thrust fault of the Dinaric system. The September shocks are interpreted as due to a movement of the successive block of Chiampon Mt. which thrusted the previous one of Buia as geodynamic reaction to the May 6 earthquake. It is to remark the high value of Vp to Vs ratio in the Friuli area (up to 1.9).

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** IPG - Institut de Physique du Globe - Strasbourg

O.G.S. - Osservatorio Geofisico Sperimentale - Trieste - Contrib. n. 258.
Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 21.

1.- INTRODUCTION

The correct understanding of natural phenomena frequently depends upon the kind of approach we use and upon the means we have. For what concerns the knowledge of the focal mechanism of the earthquakes occurred in Friuli from May 6 up to now we have used a combination of different approaches based mainly on accurate hypocenter determination and identification of the existing fracture which may be responsible of the occurred events.

The multichannel digital reflection seismic exploration of a critical area together with the knowledge of the surface geology allows to propose a convincible geodynamic outline of the seismic active area. The proper use of a telemetric seismographic system which can be readily installed and function automatically for a long period of time allows on the other hand to obtain a large quantity of seismological data. If these are readily digitalized and elaborated it becomes easy to follow the evolution of natural phenomena.

Another important condition is also the precision and the homogeneity of the seismological data determination. The compared analysis of tectonic and geological parameters, together with the time and space distribution of the hypocentres of the earthquakes will finally allow us to propose a focal mechanism both for the May 6 earthquake and for the strcng September shocks. The formulated hypothesis is confirmed by some clear fault plane solutions reconstructed. The numerous aftershocks recorded allow a reconstruction of several other fault plane solutions which probably do not refer to the general focal mechanism proposed but to some local aspect.

2.- TELESEISMIC SYSTEM AND BASIC DATA EMPLOYED

The telemetered network used is designed to record earthquakes in the vicinity of the epicentral region. The aim is to assume information on even small shocks preceeding or following major earthquakes. These small shocks, which remain undetected by distant stations, are of great importance in the understanding of the seismic phenomena.

The main advantages of this network are:

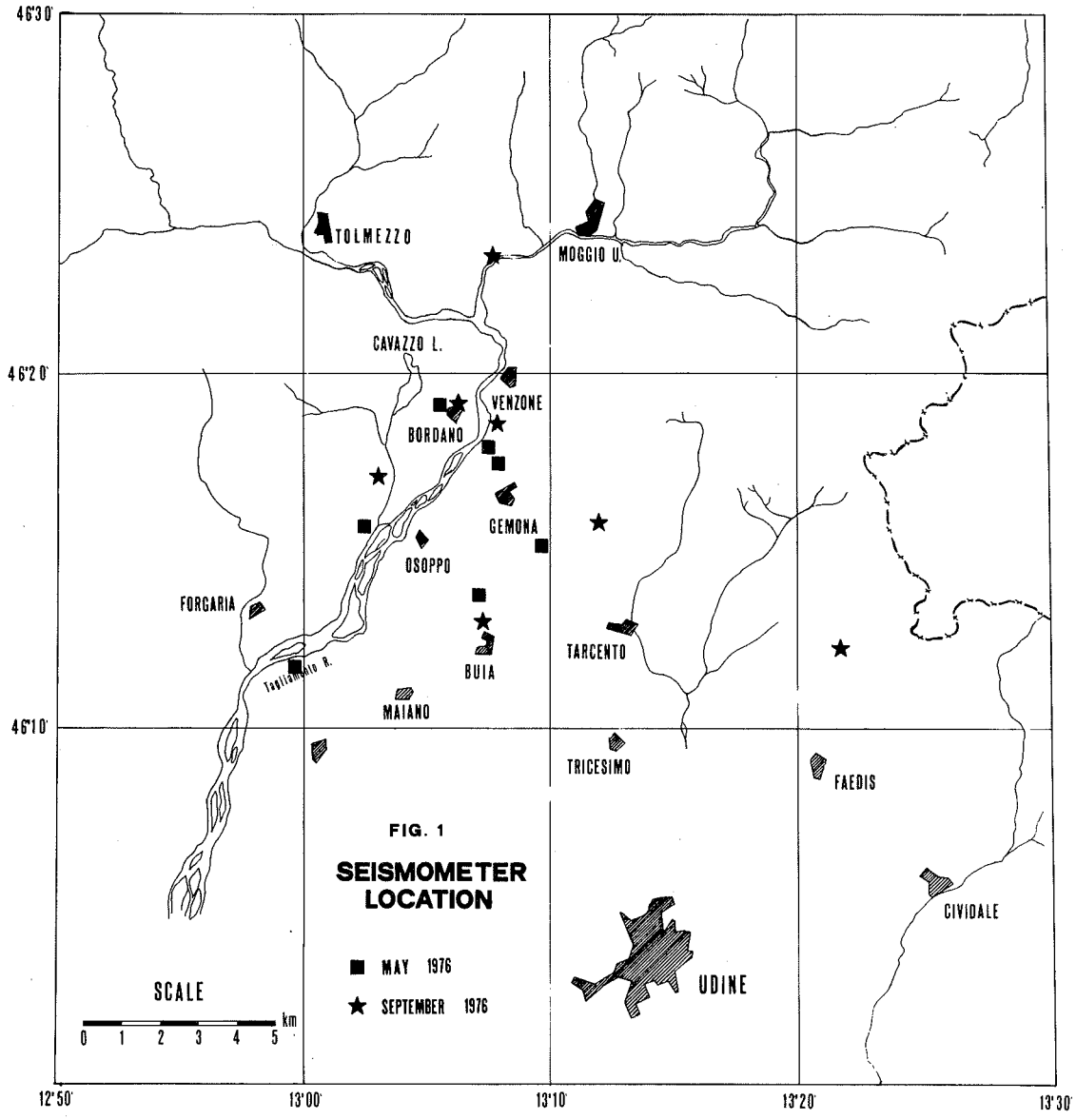
a) The small weight and ruggedness of the elements needed for the quick installation in order to record immediate aftershocks.

b) The quality of the obtained records allows an accurate hypocenter determination which is fundamental for several seismological investigations.

The signals of the seven vertical component seismometers are transmitted to a central recording station. In order to limit false alarms, the digital recording is made on the portable tape unit only when the preselected threshold is attained on at least three channels. All elements are alimented by batteries.

The network was operational in Friuli on May 10, 80 hours after the main shock. Having no information on the precise location of the main shock we installed the network centered on the zone of maximum damage (Fig. 1).

The range of the network towards East and West resulted not large enough. This is due to the difficulties of access in the surrounding mountains. The information furnished by the epicentral map obtained in May gave suggestions with regard to the new installation of the seismometers for the af


46°30'
46°20'
46°10'
12°50'
13°00'
13°10'
13°20'
13°30'
TOLMEZZO
MOGGIO U.
CAVAZZO L.
VENZONE
BORDANO
GEMONA
OSOPPO
FORGARIA
BUIA
TARCENTO
MAIANO
TRICESIMO
FAEDIS
CIVIDALE
UDINE
SCALE
0 1 2 3 4 5 km
FIG. 1
SEISMOMETER LOCATION
MAY 1976
SEPTEMBER 1976

tershock study of September. The precision of hypocenter determinations depends mainly on the seismometer array and not so much on magnitude. For shocks within the polygon of stations the accurracy of locations is of the order of ± 250m on all three coordinates. For shocks out of this polygon the error may increase to the order of 2 km. The seismicity map of September shows that it would be convenient to install one station on the NW, but this is not possible because of the high mountains which are unaccessible and prohibit the radio wave transmission. After the playback of field seismograms the differences in the P wave arrival time are calculated and these constitute the basic data for the hypocenter location. We employ the "Hypolar" (Eaton) program for the location using only P arrival times. Many determinations are then controlled by means of S arrival time.

3.- TIME SPACE EPICENTER DISTRIBUTION

The time-space epicentral distribution determined by OGS's Trieste station shows in May a concentration of shocks on an area around Gemona and E of the Tagliamento river. Successive aftershocks denote a tendency to a progressive migration northward with an extension to the W of the Tagliamento river, covering mostly the area N of the Gemona parallel. This aspect is punt in clear evidence by the teleseismic recording system. In fact all epicenters determined by the IPG's system soon after the main shock of May 6 (Fig. 2), lie on an ellipsoidal area of about 200 km^2 centered around Gemona. One of the most remarkable characteristic is the total absence of epicenters W of the Ta

gliamento river. Only on the western area some shocks occurred limited to a brief time and circumscripted to a very narrow space. Another remark is the elongation of the epicenter distribution in the E-W direction.

The epicenters recorded after the September earthquakes (Fig. 2) lie again on an ellipsoidal area which is located some 8km north of the first one. This area is larger than the May one (about 270 km^2) and more elongated in the E-W direction. Moreover the epicenters cover also zones W of the Tagliamento river, namely the area of Somplago, Bordano, up to Tolmezzo.

4.- TIME-SPACE HYPOCENTER DISTRIBUTION

The hypocenters of the recorded shocks have been projected on vertical planes having respectively E-W and N-S directions (Fig.s 3, 4). These sections show a distribution of the hypocenters between depths of 2.5 to 7 km, in May, with dispersed data down to 15 km and the maximum concentration of the energy around 4 km. In September the hypocenter depth has a range from 4.5 to 10 km with dispersed data down to 18 km, and the maximum concentration of energy at about 5.5 km. An interesting aspect of the September aftershocks is the fact that several hypocenters fit a northward dipping plane which is correlatable to a major fracture outcropping and known as the Periadriatic thrust-fault. These hypocenters have been carefully studied with sectional projections onto different N-S planes properly selected on different meridians. These specific projections (see fig.s 5, 6, 7, 8) show that the dipping pla

EPICENTER DISTRIBUTION

DETERMINED BY

IPG TELESEISMIC SYSTEM

PERIOD

MAY 10 TO 14

SEPTEMBER 30 TO OCTOBER 10

SCALE

0 1 2 3 4 5 10 Km

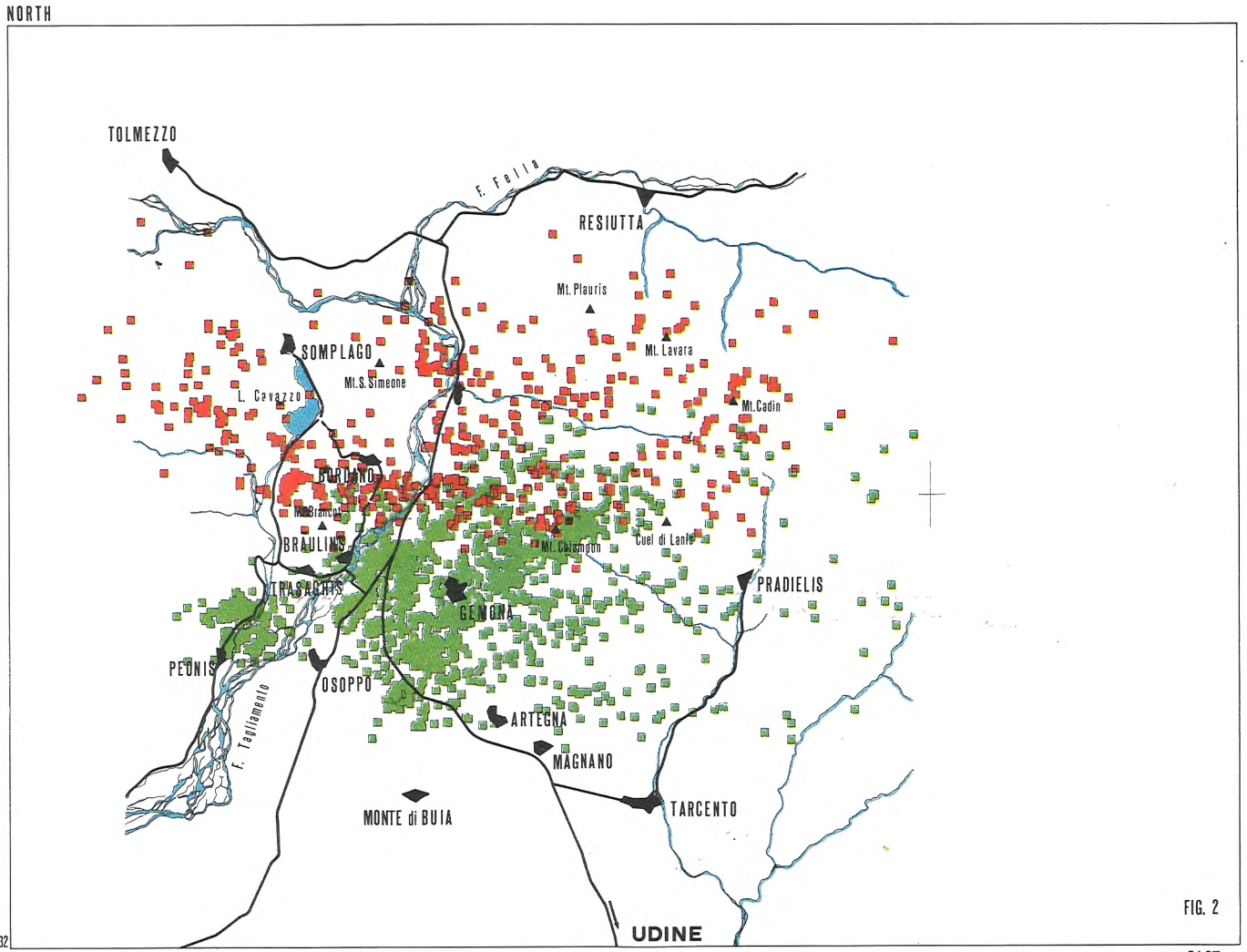
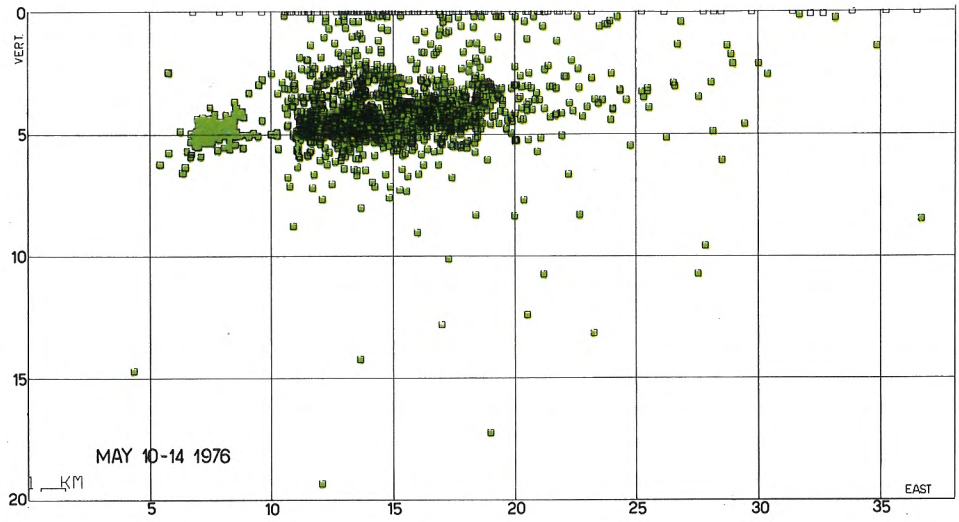


FIG. 2


VERT
0
5
10
15
20
MAY 10-14 1976
1 KM
5
10
15
20
25
30
35
EAST

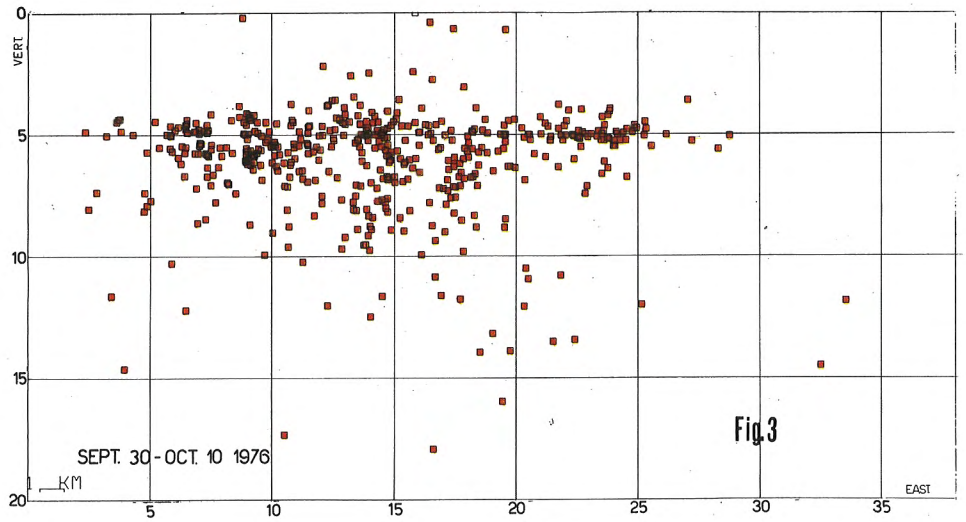
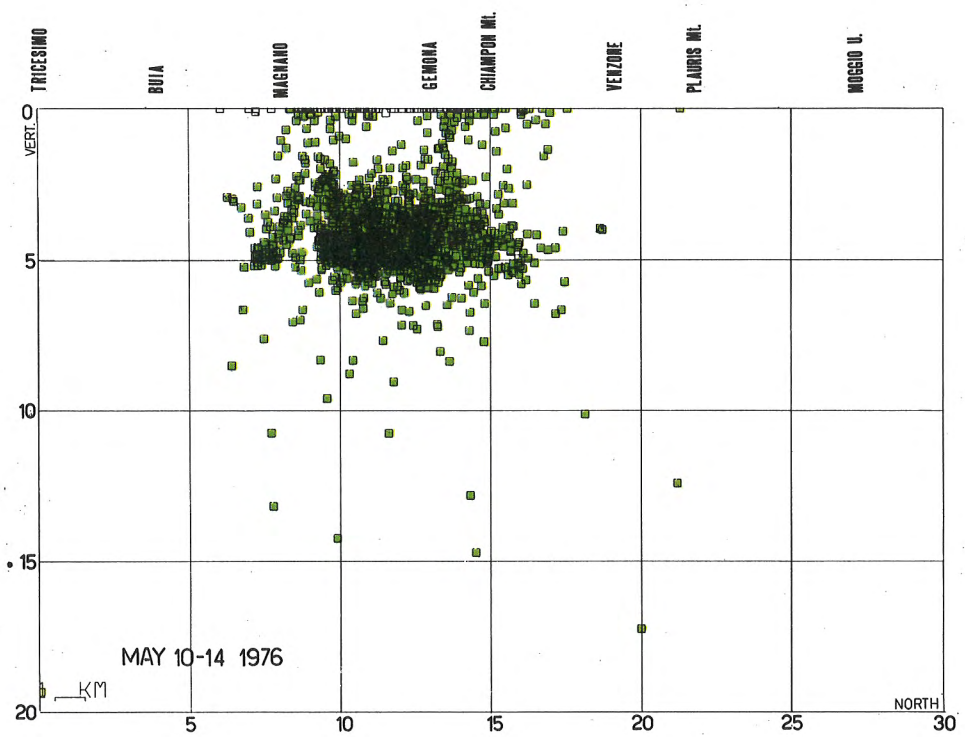

VERT
0
5
10
15
20
SEPT. 30 - OCT. 10 1976
1 KM
5
10
15
20
25
30
35
EAST

Fig.3


TRICESIMO
BUIA
MAGNANO
GEMONA
CHIAMPON MT.
VENZONE
PLAURIS MT.
MOGGIO U.
VERT.
0
5
10
15
20
MAY 10-14 1976
KM
5
10
15
20
25
30
NORTH

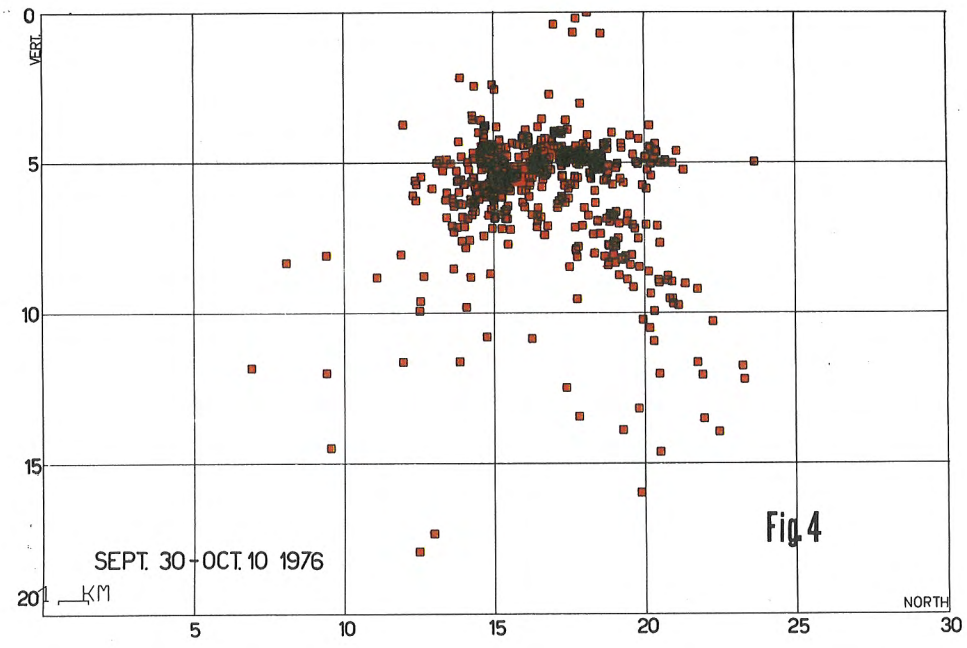

VERT.
0
5
10
15
20
SEPT. 30-OCT. 10 1976
KM
5
10
15
20
25
30
NORTH

Fig. 4

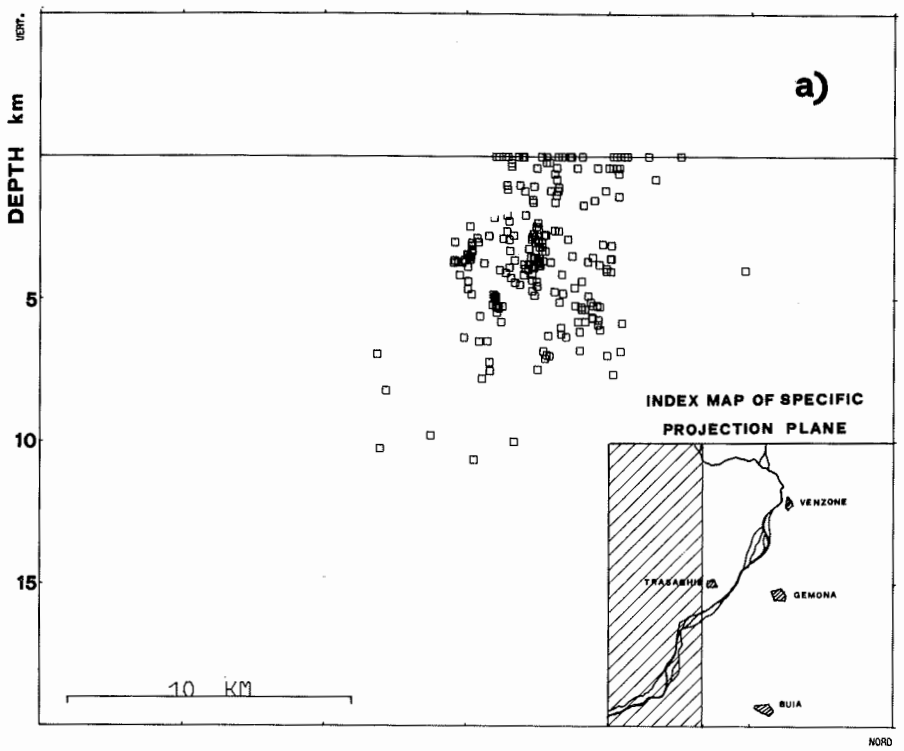

VERT.
DEPTH km
5
10
15
a)
INDEX MAP OF SPECIFIC
PROJECTION PLANE
VENZONE
TRASAGHIS
GEMONA
BUIA
NORD
10 KM
76 UDINE 30.09 /13.11 76

FIG. 5

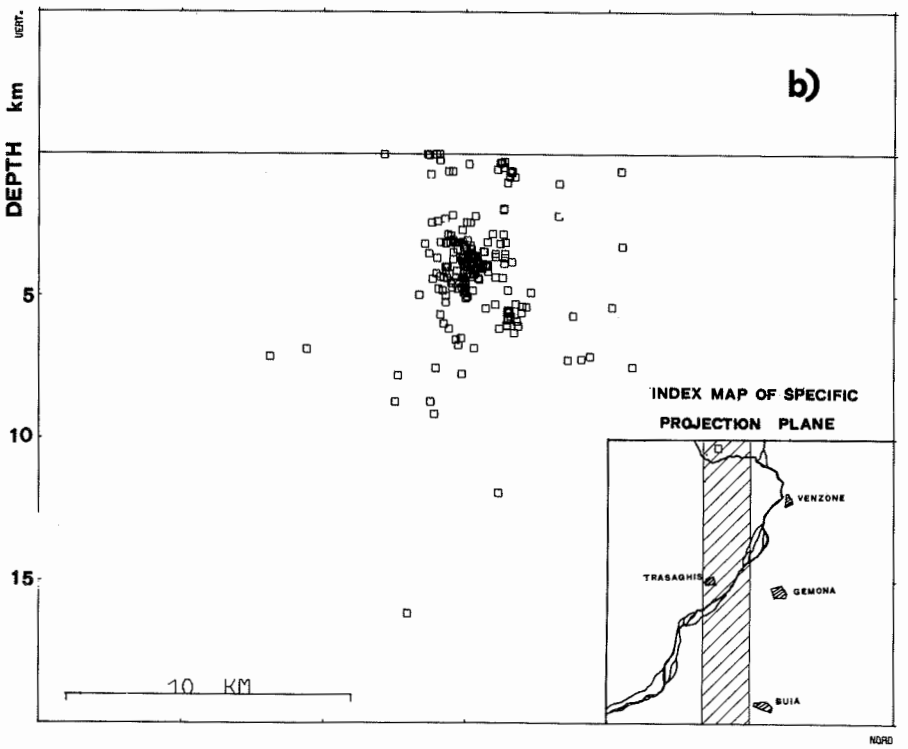
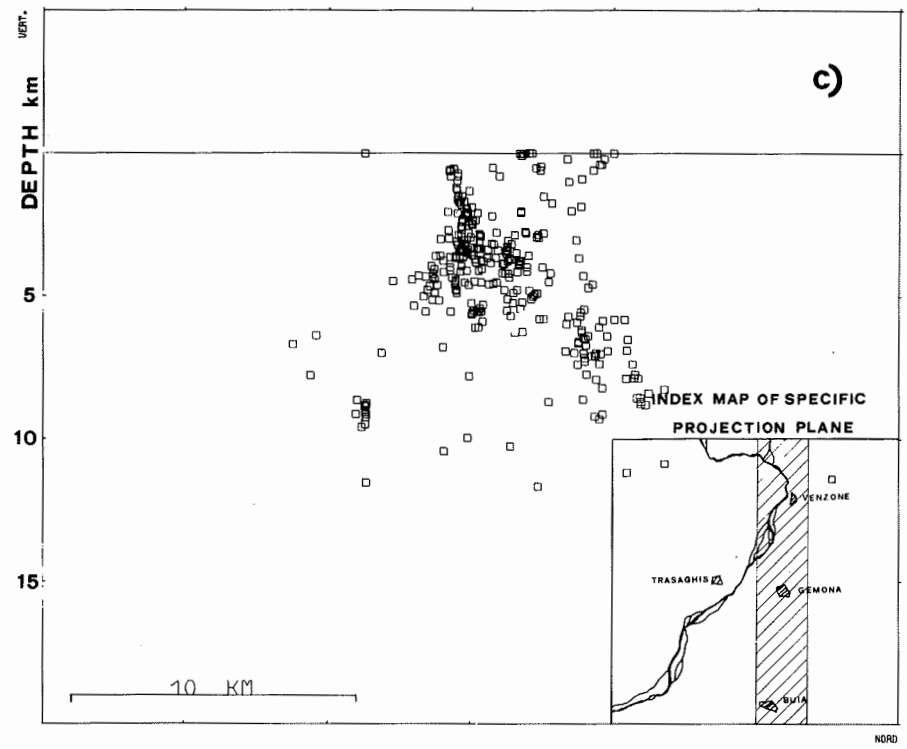
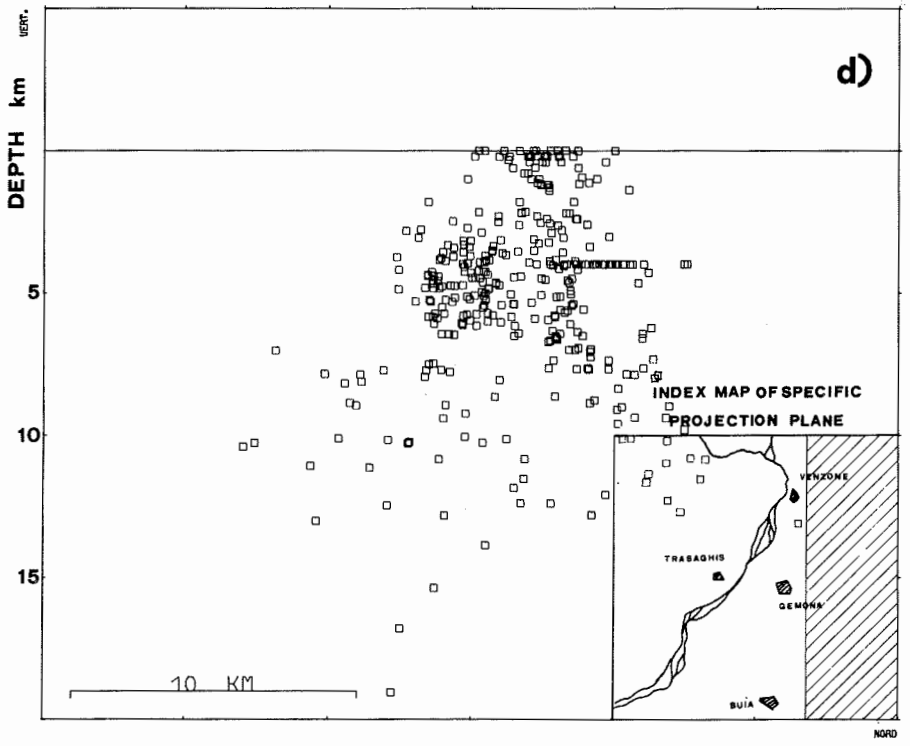

VERT.
DEPTH km
5
10
15
b)
INDEX MAP OF SPECIFIC
PROJECTION PLANE
VENZONE
TRASAGHIS
GEMONA
BUIA
NORD
10 KM
30.09 /13.11 76

FIG. 6



UDINE, 30.09 /13.11 76

FIG. 7



UDINE, 30.09 /13.11 76

FIG. 8

ne is limited to the area E of the Tagliamento river.

Another impressive observation is that in the area of the maximum concentration of May hypocenters no September shocks occur. This clearly shows that the focal position of September shocks is different from the May ones. The positions of the respective main shocks determined by the Trieste station lie in general in the middle of the epicenter area obtained by the teleseismic system. The only exception is the May 9 high magnitude aftershock which is at the eastern extremity of the epicenter area, but still inside the area. These close connections, in the authors's opinion confirm that the aftershocks activity area is directly related to the main shock one.

5.- TECTONIC SETTING AND FOCAL MECHANISMS

The basic geodynamical deformation of the Friuli mountaineous area is due to a remarkable compressional effect, consequent to the relative motion of European and Adriatic plates.

This compression folded, fractured and overthrusted blocks of rocks one imbricated over the other. In addition to the thrust-faults which are the largerly dominating tectonic elements of Friuli, it is possible to identify also some probable transcurrent fault systems lying along with Tagliamento valley from Forgaria up to Venzone-Somplago. This kind of faults seems to continue to the N from the Tolmezzo to the Paularo area.

Some thrust-faults are very active like the Buia-Tricesimo one and the Periadriatic thrust fault system,a little more to the N.Examining the fault-plane solution of some more clear

examples, the following results (Fig.s 9, 10):

a) Lago di Cavazzo area

Existence of only strike-slip fractures(September aftershocks);

b) Peonis area

Existence of overthrust and strike-slip fractures (May aftershocks);

c) Gemona area

Existence of overthrust having a slope of about 30° (May aftershocks);

d) Area East of Venzone

Existence of overthrust (September aftershocks).

Assembling onto the same N-S ideal cross-section the main existing fractures and the hypocenters (Fig. 10) a good correlation between fault-systems and seismic activity is shown. Such a correlation suggests the idea that the May 6 earthquake is connected to a thrust movement of the Buia-Tricesimo faults which have been identified by the seismic reflection exploration. These faults enter the area of maximum aftershocks activity at a depth of about 2.5 km and reach the higher density of hypocenters at about 4 to 5 km.All the May and part of June aftershocks are restricted to the area around these faults.At the end of June shocks begin to appear to the N of the previous area with a progressive increasing in their frequency.This activity is probably due to the fact that the May 6 earthquake produced a depression on the back side of the moved block.Such depression activated the successive thrust-block. In September this last block of Chiampon Mt. thrusted on the previous one producing the well known strong

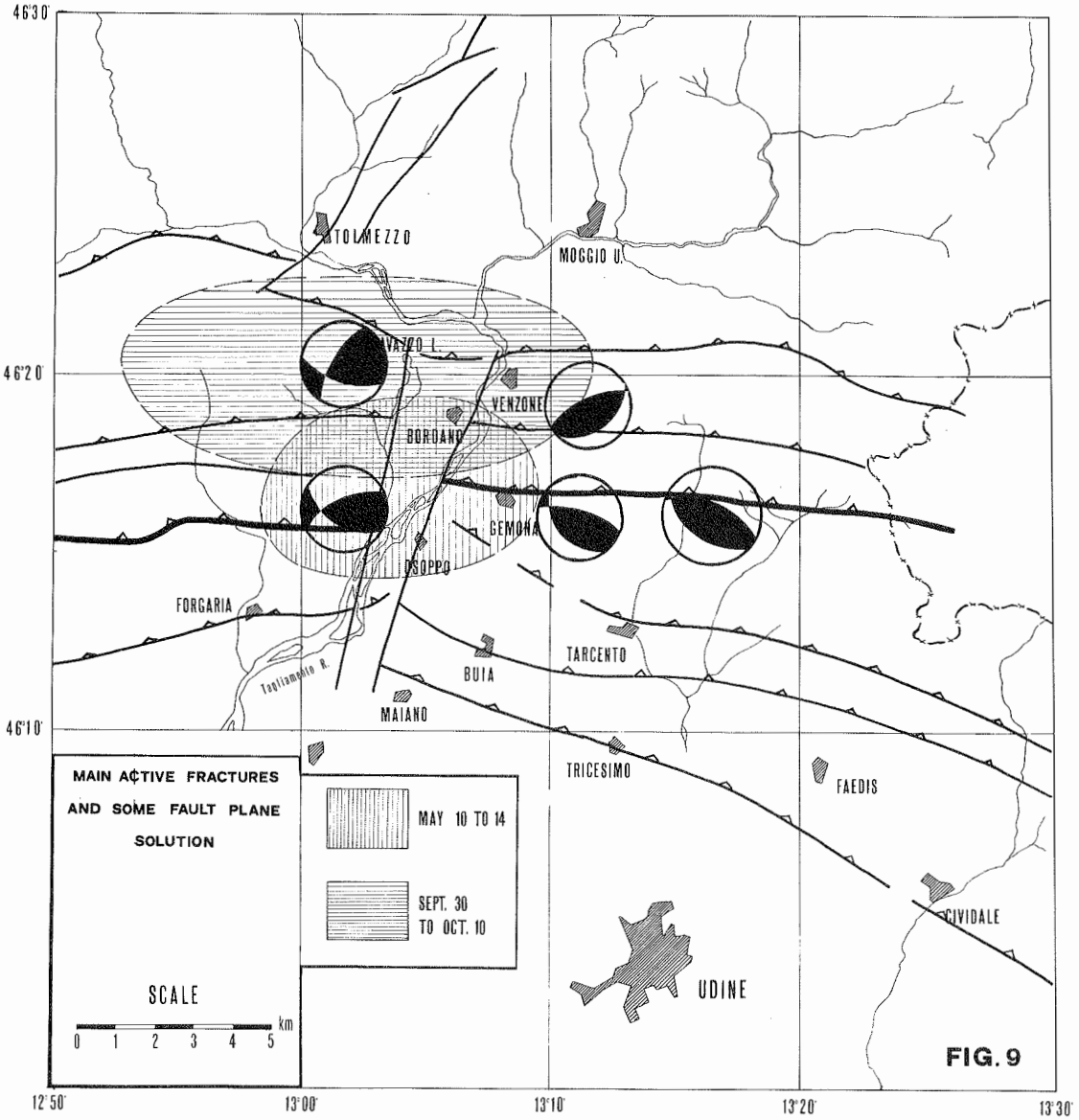

46°30'
46°20'
46°10'
12°50'
13°00'
13°10'
13°20'
13°30'
TOLMEZZO
MOGGIO U.
VAIZO L.
VENZONE
BORDANO
GEMONA
OSOPPO
FORGARIA
TARCENTO
BUIA
MAIANO
TRICESIMO
FAEDIS
CIVIDALE
UDINE
Tagliamento R.
MAIN ACTIVE FRACTURES AND SOME FAULT PLANE SOLUTION
MAY 10 TO 14
SEPT. 30 TO OCT. 10
SCALE
0 1 2 3 4 5 km

FIG. 9

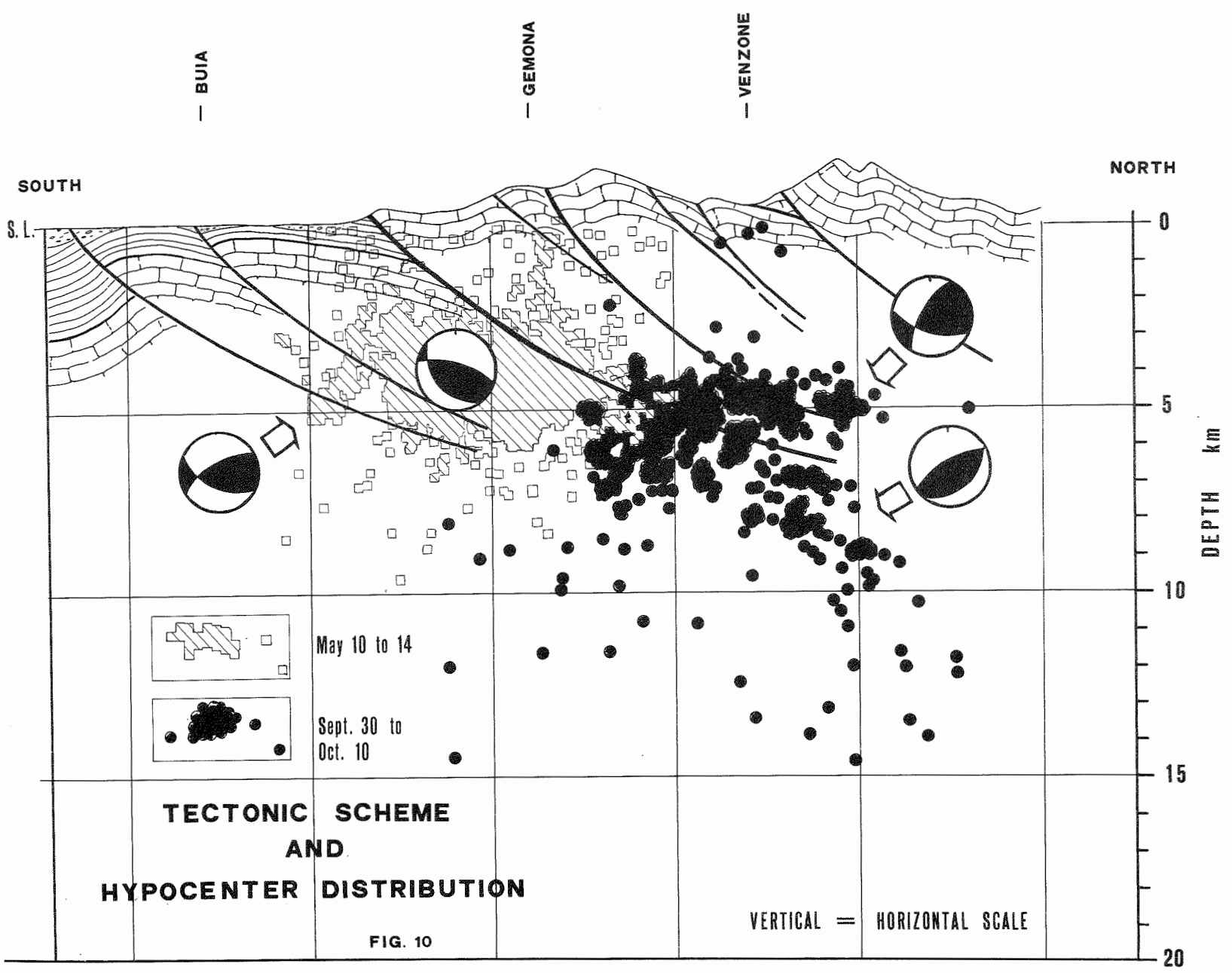

— BUIA
— GEMONA
— VENZONE
SOUTH
NORTH
S. L.
0
5
10
15
20
DEPTH km
May 10 to 14
Sept. 30 to
Oct. 10
TECTONIC SCHEME
AND
HYPOCENTER DISTRIBUTION
VERTICAL = HORIZONTAL SCALE

FIG. 10

earthquakes. So, these new high magnitude shocks, in the authors's opinion would represent a geodynamic reaction to the equilibrium perturbance produced by the southward movement of the Buia thrusted block.

6.- HIGH VALUE OF Vp TO Vs RATIO

In Fig. 11 the records of an aftershock are arranged like a Wadati diagram. Five records are used to reconstruct the diagram.

It is evident that a line with a normal slope corresponding to the value of Vp/Vs = 1.73 does not fit the S arrivals on several records. On the contrary a Vp to Vs ratio of 1.95 gives a line with a good fitness. In order to calculate a more precise value of the ratio Vp to Vs several hundred Wadati diagrams for the May and September aftershocks are plotted. A least square fitting gives values from 1.9 to 2.0. The mean value adopted is 1.94 (Fig. 12).

A similar high value of 1.90 is found by Gebrande (1976) for some aftershocks of the May 6 Friuli earthquake. The stations utilized by this author are at epicentral distance of about 40 km. Another control on these values is given by the OGS station of Trieste at an epicentral distance of 85 km. A mean value of 1.85 is found here. It seems that the value of the ratio Vp to Vs decreases with the epicentral distance. This fact may indicate that the anomaly is local.

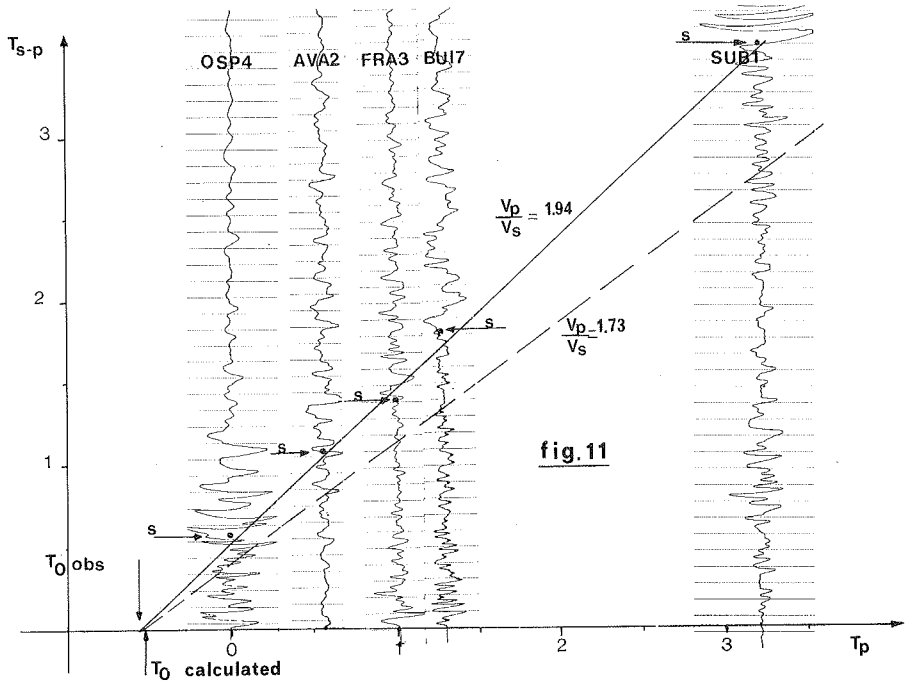
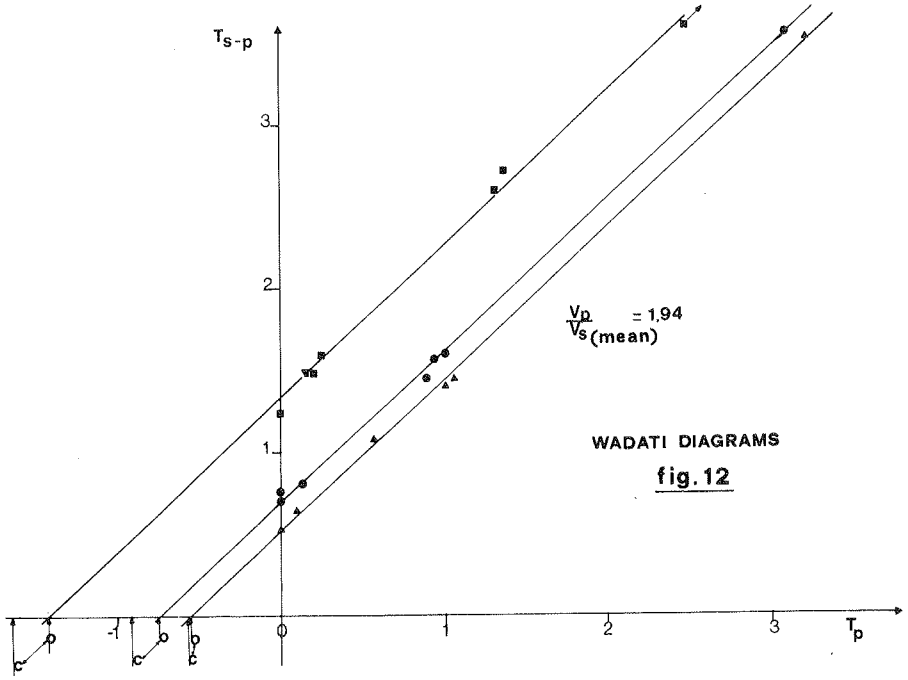


fig.11



WADATI DIAGRAMS

fig.12

FIGURES

Fig. 1 - Seismograph station location map.

Fig. 2 - Epicenter distribution determined by IPG's tele seismic system after each main shock respectively of May and September 1976.

Fig. 3 - Hypocentral position projected on a E-W vertical plane for May and September aftershocks.

Fig. 4 - Hypocentral position projected on a N-S vertical plane for May and September aftershocks.

Fig. 5 - Sectional projection of September hypocentral position projected on a vertical plane. Projection a).

Fig. 6 - Sectional projection of September hypocentral position projected on a vertical plane. Projection b).

Fig. 7 - Sectional projection of September hypocentral position projected on a vertical plane. Projection c).

Fig. 8 - Sectional projection of September hypocentral position projected on a vertical plane. Projection d).

Fig. 9 - Main active fractures and fault plane solutions of some particular source zones.

Fig. 10 - Tectonic scheme and hypocenter distribution along Buia-Venzone cross-section.

Fig. 11 - Seismogram correlation showing the V_p to V_s ratio anomaly.

Fig. 12 - Examples of Wadati diagrams.

REFERENCES

AMATO A., BARNABA P.F., FINETTI I., GROPPI G., MARTINIS B., MUZZIN A. (1976) - Geodynamic Outline and Seismicity of Friuli-Venezia Giulia Region. Proceeding of the meeting on Friuli Earthquake; 4-5 December 1976, Udine.

COLAUTTI D., FINETTI I., NIETO D., PUPIS C., SLEJKO D., SUHADOLC P. (1976) - Epicenter Distribution of Aftershocks of 1976 Friuli Earthquakes. Proceeding of the meeting on Friuli Earthquake; 4-5 December 1976, Udine.

GEBRANDE H., MILLER H., SCHMEDES E. (1976) - Digital Registration of Aftershocks of the Friuli Earthquake 1976.

HOANG-TRONG PHO, WITTLINGER G., HAESSLER H. (1976) - Enregistrement et distribution temporelle des repliques, 80 H après le sèisme destructeur du Frioul (Italie) du 6 mai 1976. C.R.Achd.Sc. Paris, t 283 (27 septembre 1976), Serie D-611.

Space and Time Distribution of 1976 Frioul Earthquakes

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00040 Monte Porzio (Roma)

Abstract. The seismic activity happened in Frioul during 1976 is studied by data coming from Italian and European networks and from local networks in cohoperation among I.N.G., E.N.E.L. and C.N.E.N. At first time distribution of aftershocks is examined. Then space distribution of the shocks is shown by a map and vertical representations at different azimuths. The third paragraph deals with M-log N plot, which in our case furnished a b-value of about 0.7. At last, application of Benioff's theory is tried, plotting the cumulated strain versus the logarithm of time.

Time distribution of aftershocks

Figure 7 gives a histogram where is plotted the number of shocks per day with magnitude greater than 2.5, since the main shock of May 6, 1976. It is easy to notice the strong seismic activity decreasing quite regularly till the beginning of September.

On September 11 and 15 the number of shocks per day was high again in connection with some new strong earthquakes.

In Fig. 2 we can see an enlargment of the first days after the main shock of May 6. The time interval in this plot is an hour. At last, in Fig. 3, there is the histogram of the period between September 11 and 17. As in this figure the time interval is also an hour, it is possible to resolve sharp increases on September 15.

Space distribution of aftershocks

Fig. 4 is a map of epicenters determined by two different methods. The first group was computed by the first arrival method for earthquakes having $M_L \geq 4.5$ (RMP). These epicenters are signed with black triangles on the map. Their hypocentral data are reported in Table 1.

The second group was computed by Sg-Pg method employing data from near stations only. The distance from the epicenters was not more than 100 km and several stations had been put in the epicentral zone during the seismic period (3). These epicenters are indicated by black dots on the map.

For the second group of events we drew a series of six vertical projections on planes at different angles with respect to the north. In the first projection (Fig. 5) the azimuth of the plane was zero. In the next one (Fig. 6)the azimuth was 30 degrees, and so on.

It is possible to see on the N-S and NNW-SSE projections a sort of aliqnement dipping about 30 degrees towards north. In the E-W and WSW-ENE projection there is no special distribution.

Log N versus M plot

Calling N(M) the number of shocks having magnitude $\geq$ M, generally a linear relation is accepted between log N(M) and M.

In Fig. 11 are shown three different kinds of such plots. By small triangles are plotted data concerning the period between May 6 and August 31. These points are fitted by the straight-line of equations

$$\log N = 4.528 - 0.763\ M_L$$

The small dots are referred to the period September 1 to September 30, and the equation is

$$\log N = 4.136 - 0.676\ M_L$$

By small squares we indicated the sum of the previous

groups. Their fitting equation is

$$\log N = 4.674 - 0.732\ M_L$$

Benjoff's theory

The series of 775 earthquakes having $M_L \geqslant 2.5$ was interpreted according the elastic rebound theory (1).

Figure 12 shows a classic Benioff's plot where in abscissa there is the logarithm of time computed since the main shock of May 6, in hours. In ordinate we reported strain obtained by the sum of square root of the energy for the single events. Energy was computed by the Gutenberg-Richter formula (2)

$$\text{Log } E = 11.8 + 1.5\ M$$

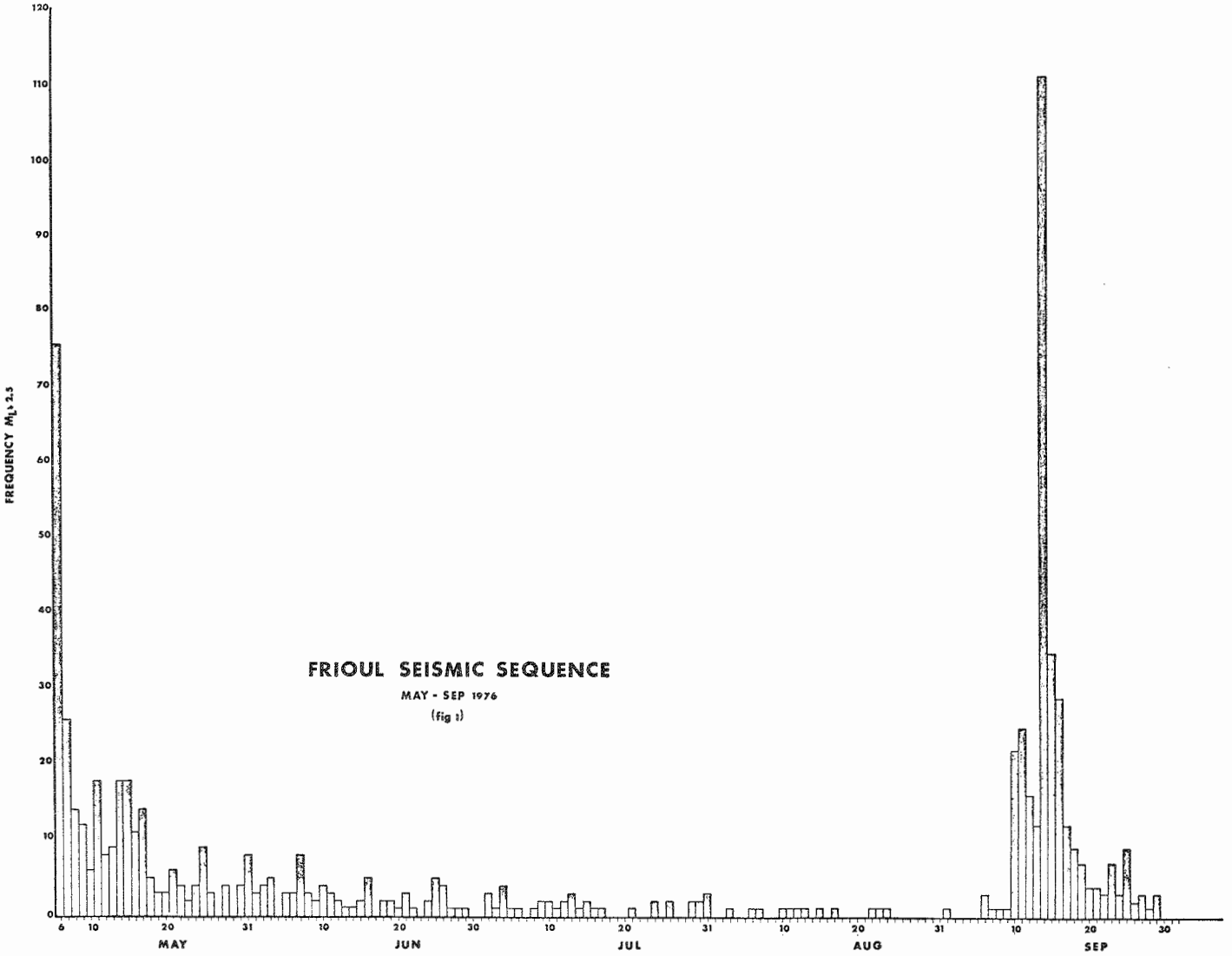
In this plot we can see a first phase in which strain changes in a linear way versus the logarithm of time. In a second phase, beginning with the shock of May 9, about 52 hours after the main shock, the slope is greater than in the first phase.

A sharp change in the slope is found finally at the beginning of September. At it seems to us that a new phenomenon is starting at this point, we drew a new plot (Fig. 13) computing time since September 11, in which strain variation is again linear versus the logatithm of time.

TAB. 1

LOCALIZZAZIONE DEGLI IPOCENTRI DI M_L 4,5 (RMP)

N	DATA	H	M	S	φ_N	λ_E	h	M_L
1	6.V	19	59	04	46,259 ± 0,018	13,286 ± 0,024	24	4,5
2	6.V	20	00	12	46,149 ± 0,050	13,108 ± 0,064	26	6,2
3	7.V	00	23	49	46,239 ± 0,029	13,358 ± 0,037	30	4,9
4	9.V	00	53	43	46,273 ± 0,026	13,389 ± 0,033	19	5,5
5	10.V	04	35	51	46,274 ± 0,028	13,166 ± 0,037	9	4,7
6	11.V	22	43	59	46,270 ± 0,023	13,019 ± 0,030	18	5,3
7	17.V	16	13	15	46,284 ± 0,028	12,988 ± 0,037	15	4,7
8	8.VI	12	14	37	46,387 ± 0,053	13,344 ± 0,081	29	4,7
9	9.VI	18	48	15	46,353 ± 0,060	13,072 ± 0,107	15	4,5
10	11.VI	17	16	39	46,270 ± 0,042	12,975 ± 0,071	17	4,6
11	17.VI	14	28	48	46,175 ± 0,042	12,919 ± 0,067	18	4,6
12	26.VI	11	13	47	46,227 ± 0,061	13,196 ± 0,085	17	4,5
13	14.VII	05	39	33	46,195 ± 0,085	13,107 ± 0,145	19	4,7
14	11.IX	16	31	05	46,256 ± 0,031	13,128 ± 0,051	0	5,5
15	11.IX	16	34	58	46,359 ± 0,040	13,275 ± 0,061	0	5,9
16	12.IX	19	53	27	46,270 ± 0,039	13,157 ± 0,055	15	4,8
17	13.IX	18	54	45	46,243 ± 0,032	13,136 ± 0,048	16	4,6
18	15.IX	03	15	18	46,260 ± 0,023	13,206 ± 0,034	17	6,1
19	15.IX	04	38	52	46,302 ± 0,029	13,185 ± 0,045	17	5,0
20	15.IX	04	58	41	46,354 ± 0,024	13,203 ± 0,037	12	4,7
21	15.IX	09	21	17	46,322 ± 0,017	13,165 ± 0,025	20	6,0
22	15.IX	11	11	10	46,266 ± 0,032	13,221 ± 0,046	19	5,0
23	15.IX	19	31	11	46,204 ± 0,036	13,201 ± 0,055	26	4,6


FRIOUL SEISMIC SEQUENCE
MAY - SEP 1976
(fig 1)
FREQUENCY $M_L \geq 2.5$
0
10
20
30
40
50
60
70
80
90
100
110
120
6
10
20
31
10
20
30
10
20
31
10
20
31
10
20
30
MAY
JUN
JUL
AUG
SEP

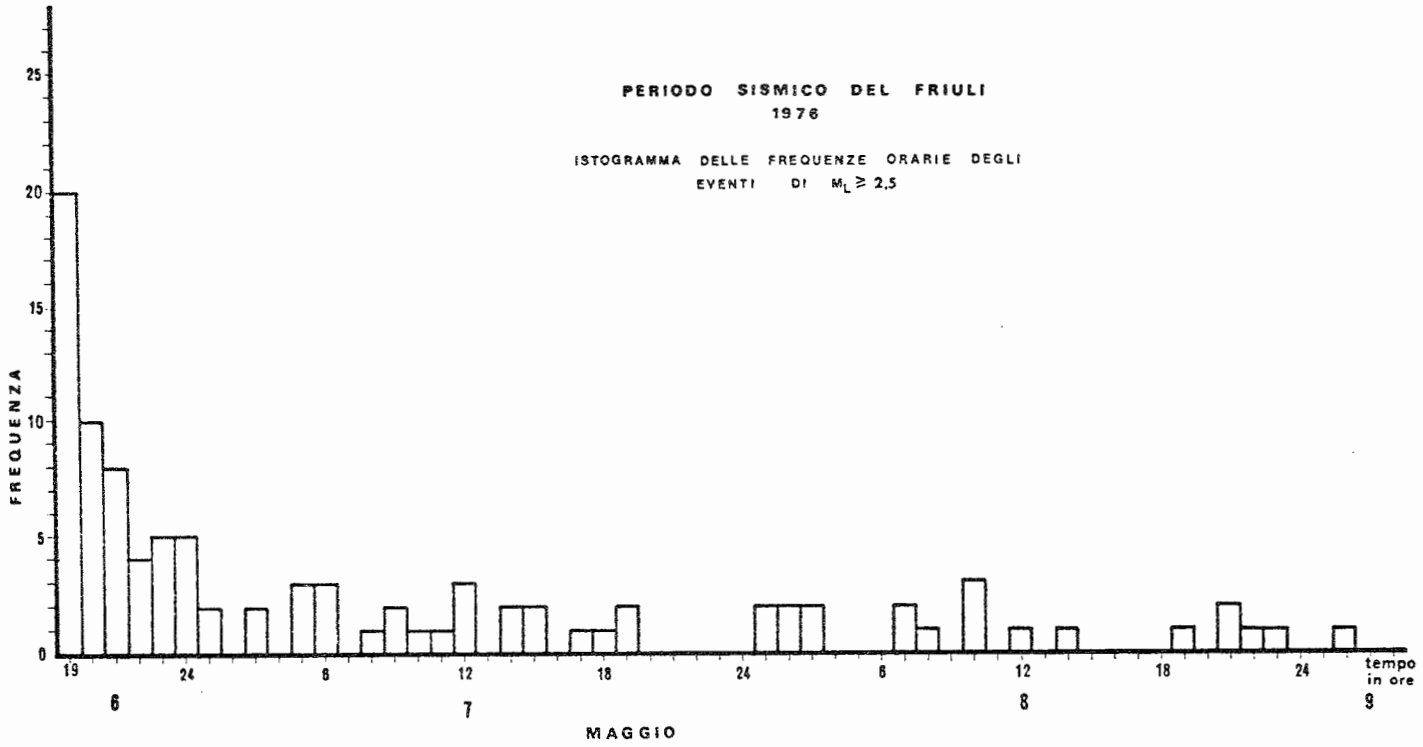
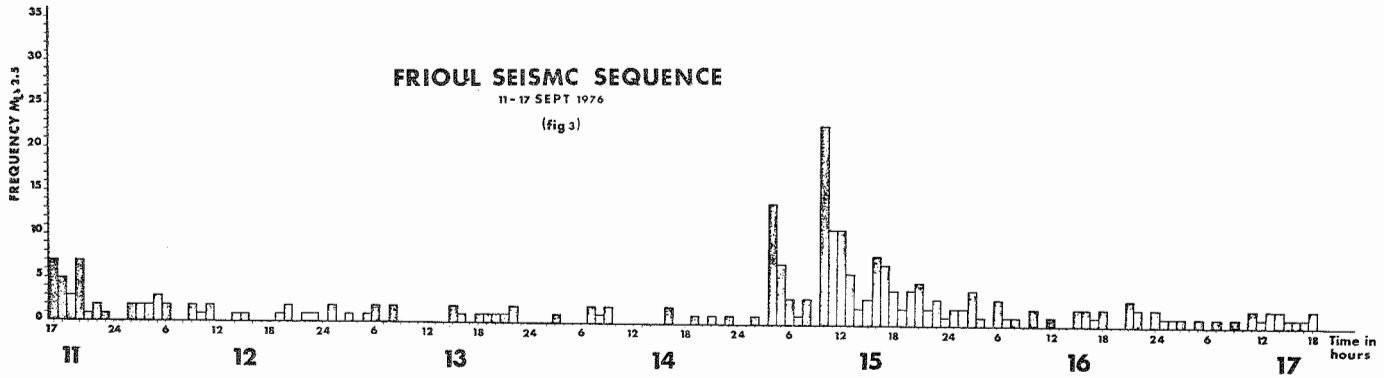

PERIODO SISMICO DEL FRIULI
1976
ISTOGRAMMA DELLE FREQUENZE ORARIE DEGLI EVENTI DI $M_L \geq 2,5$
FREQUENZA
25
20
15
10
5
0
19
24
6
12
18
24
6
12
18
24
tempo in ore
6
7
8
9
MAGGIO

fig 2


FRIOUL SEISMC SEQUENCE
11-17 SEPT 1976
(fig 3)
FREQUENCY $M_L \geq 3.5$
0
5
10
15
20
25
30
35
17
24
6
12
18
24
6
12
18
24
6
12
18
24
6
12
18
24
6
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6
12
18
24
6
12
18
11
12
13
14
15
16
17
Time in hours

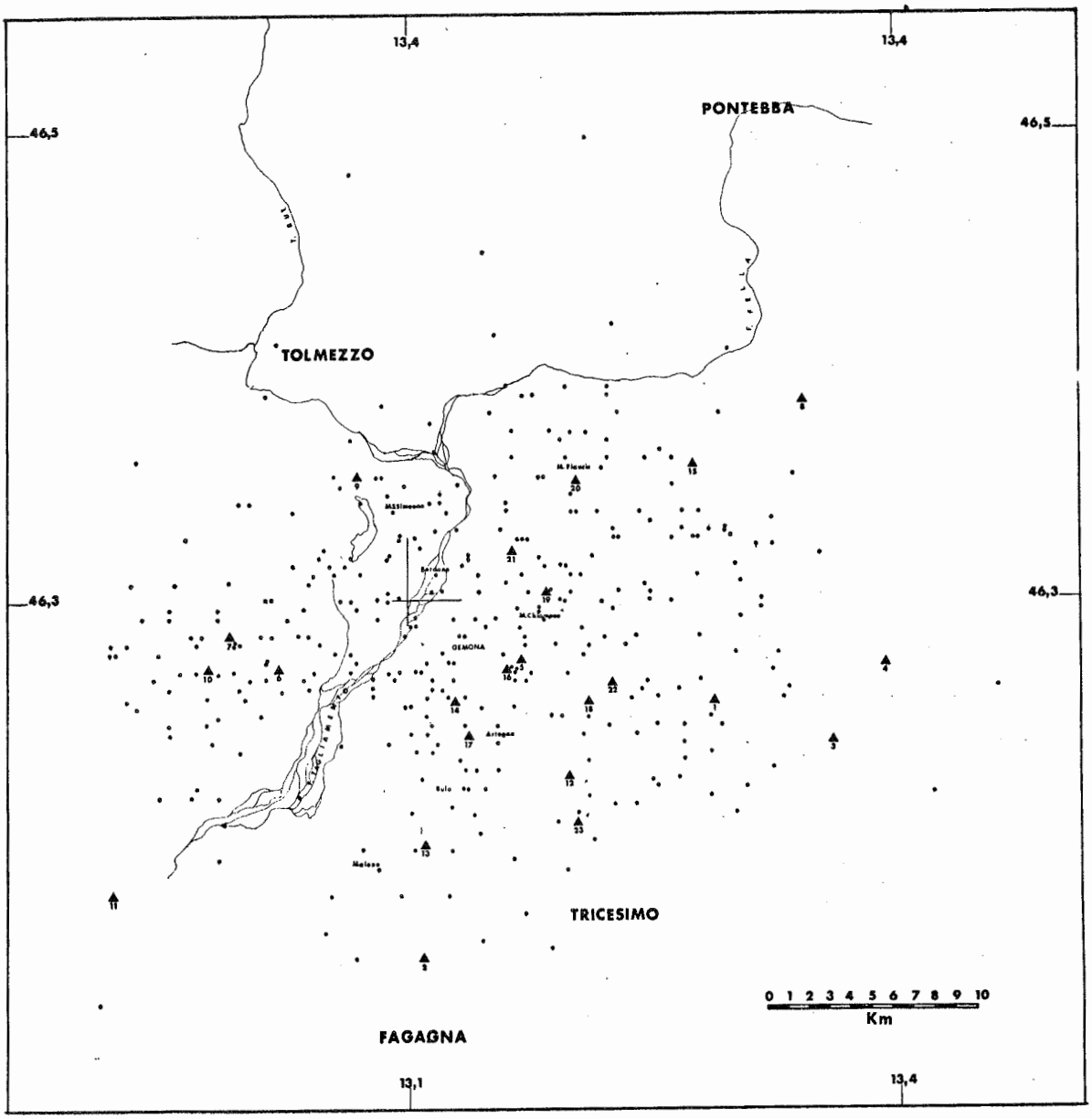
13,4
13,4
PONTEBBA
46,5
46,5
TOLMEZZO
46,3
46,3
GEMONA
TRICESIMO
FAGAGNA
13,1
13,4
0 1 2 3 4 5 6 7 8 9 10
Km

fig 4

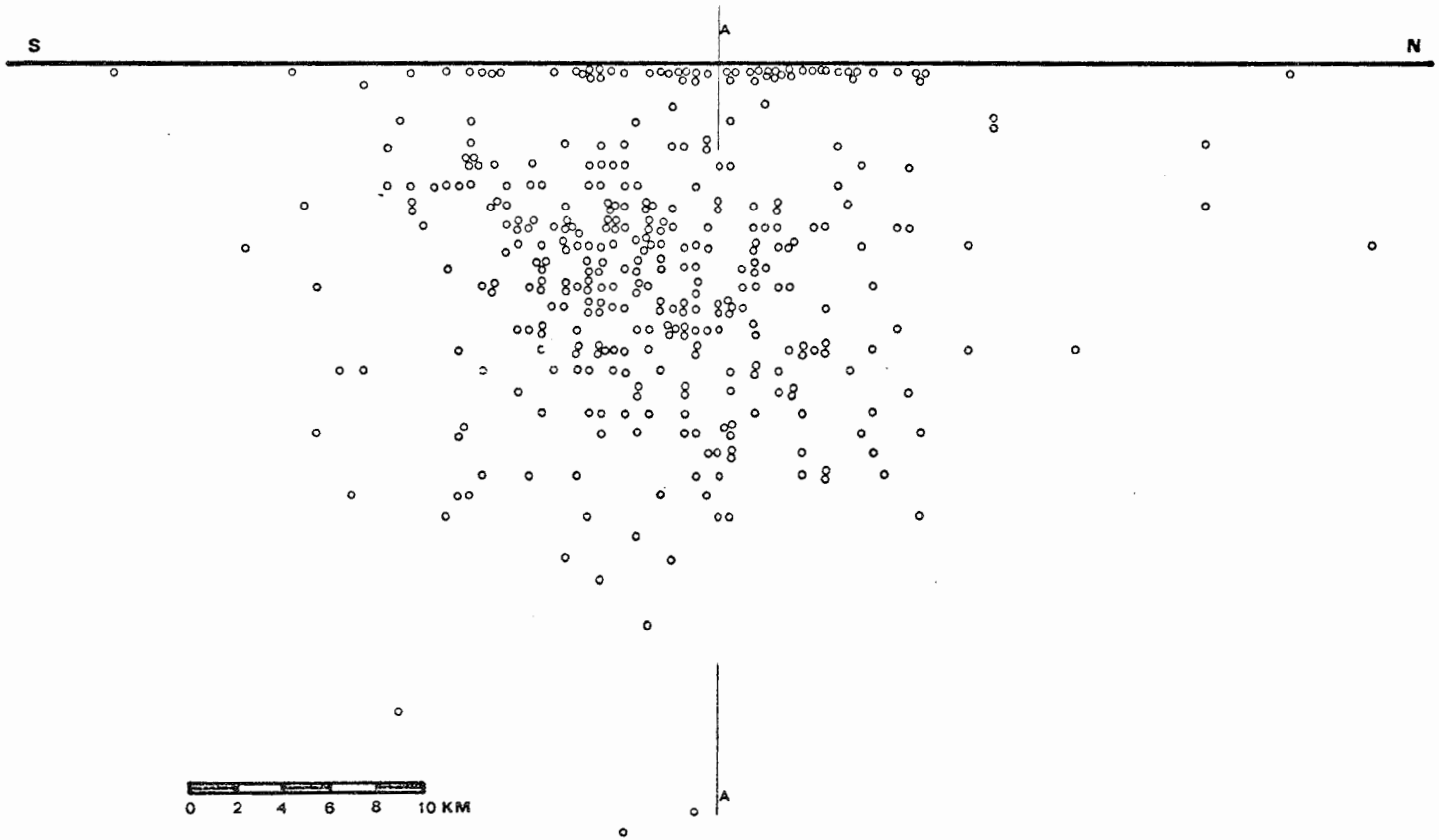

fig 5

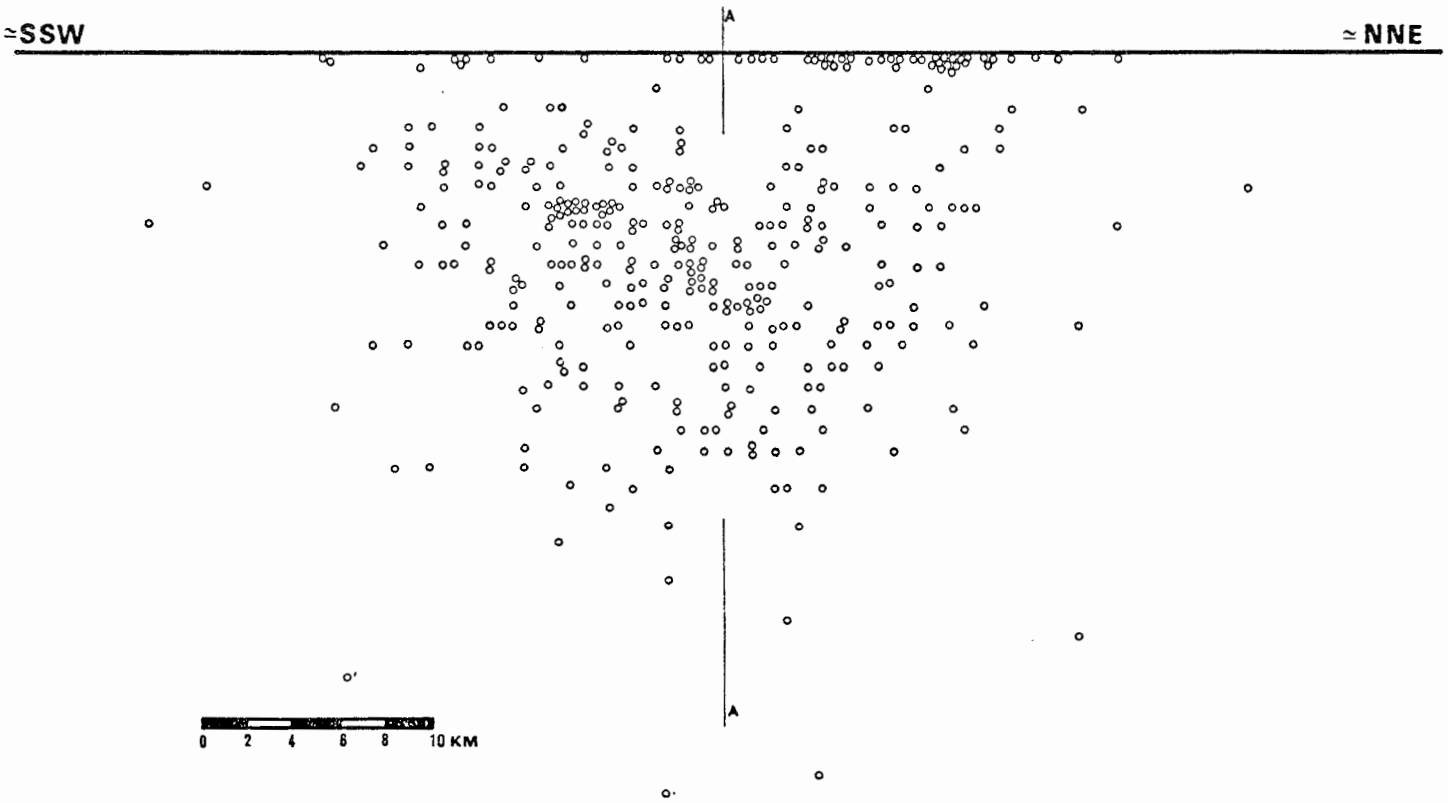

fig 6

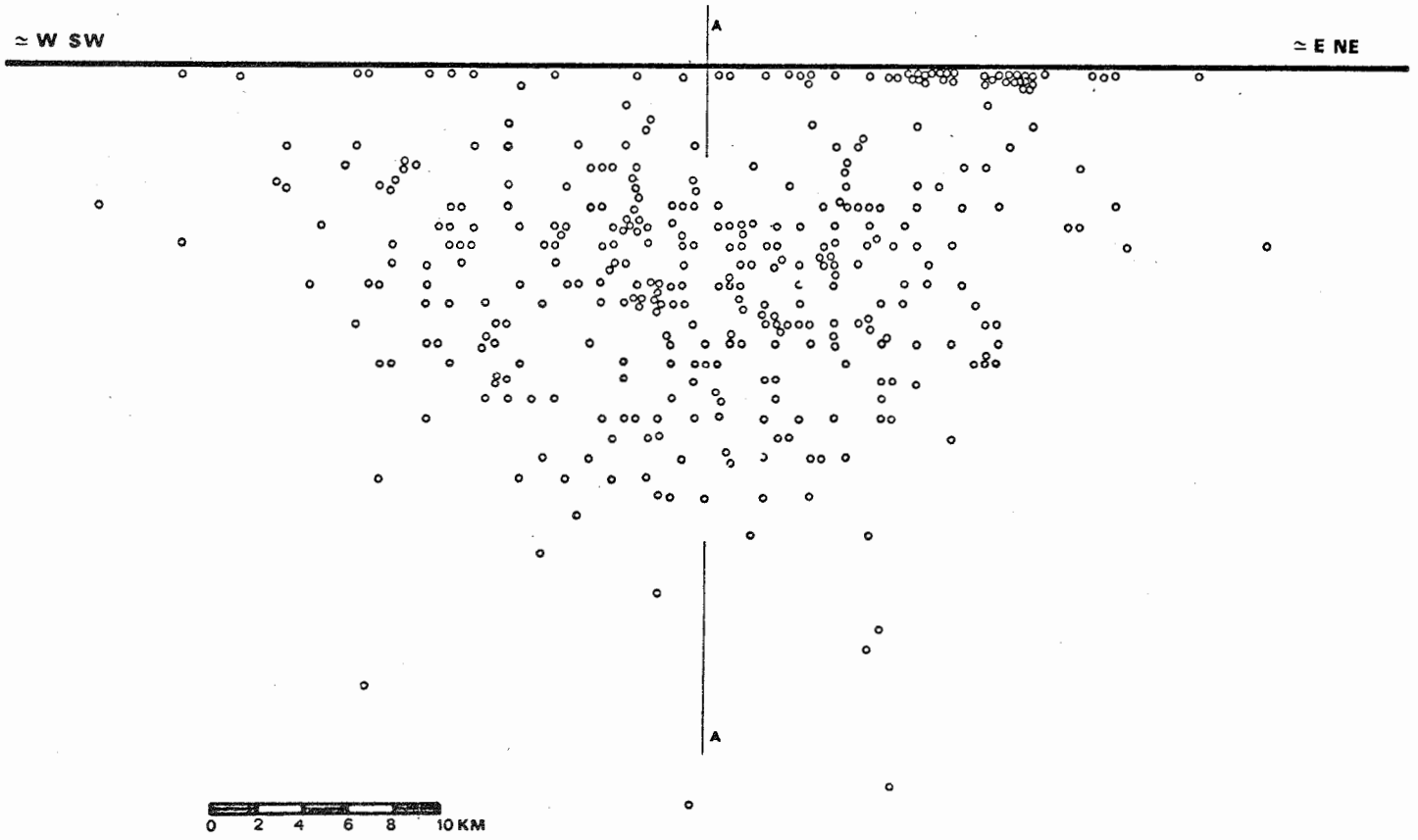

fig 7

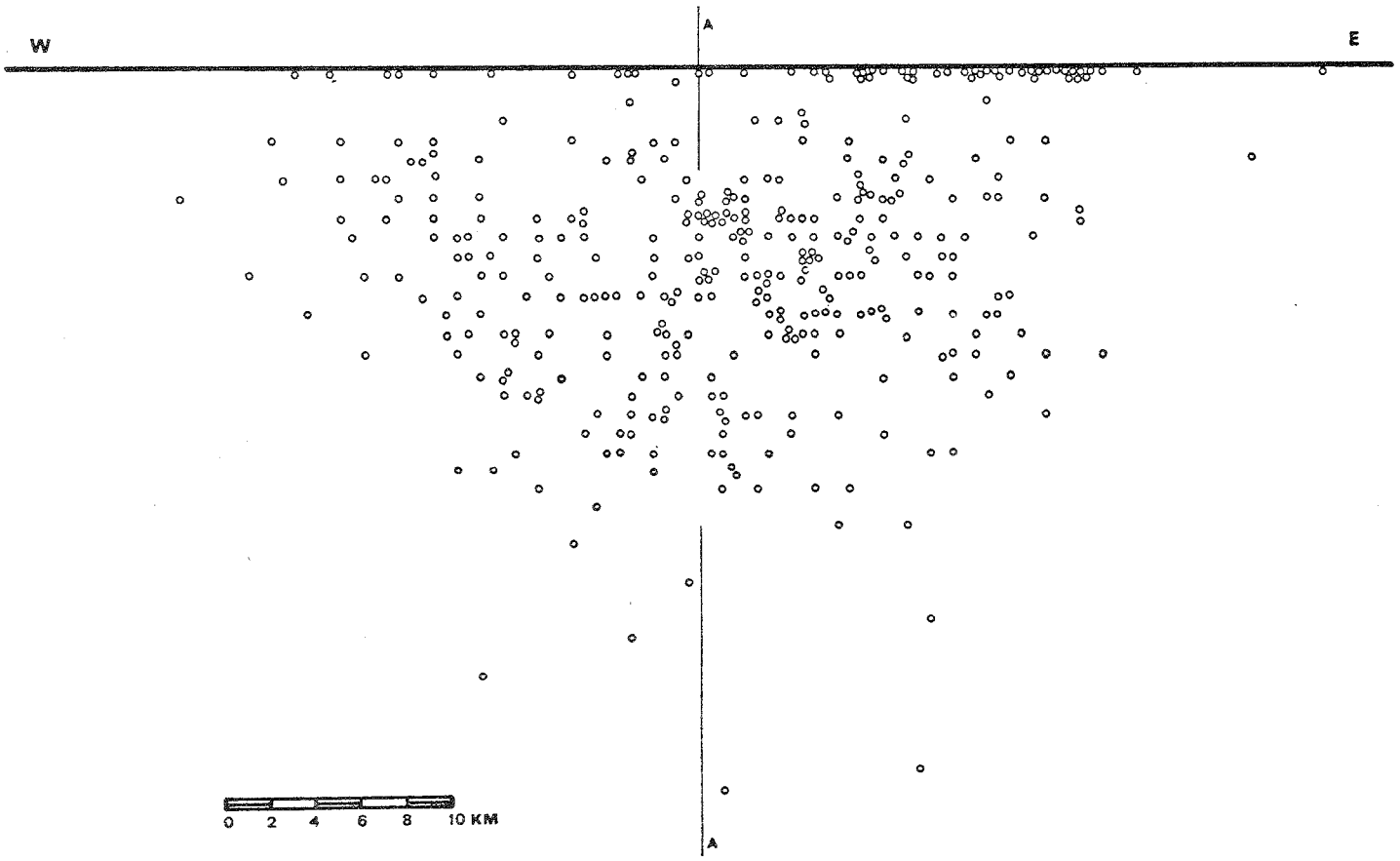

fig 8

fig 9

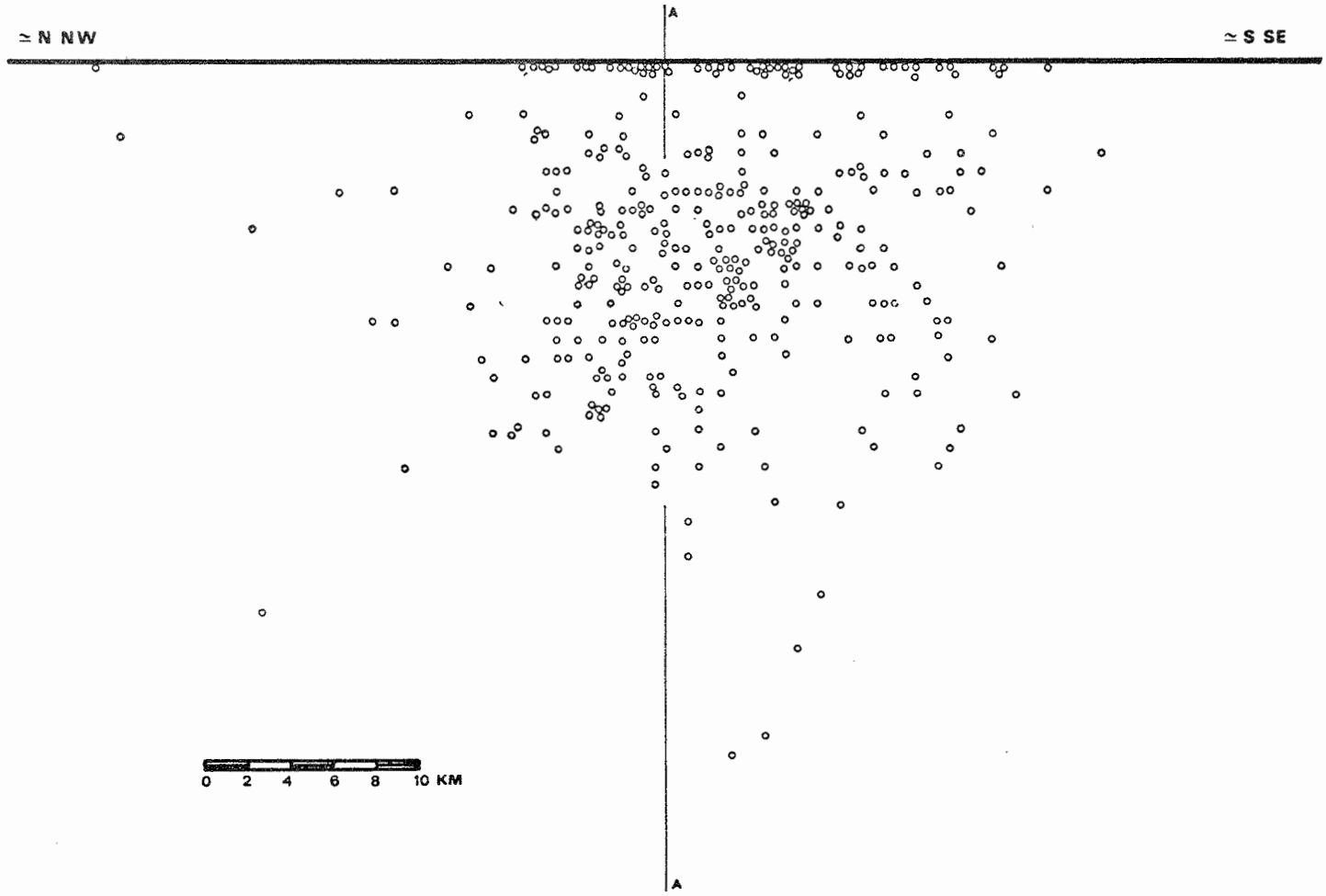

fig 10

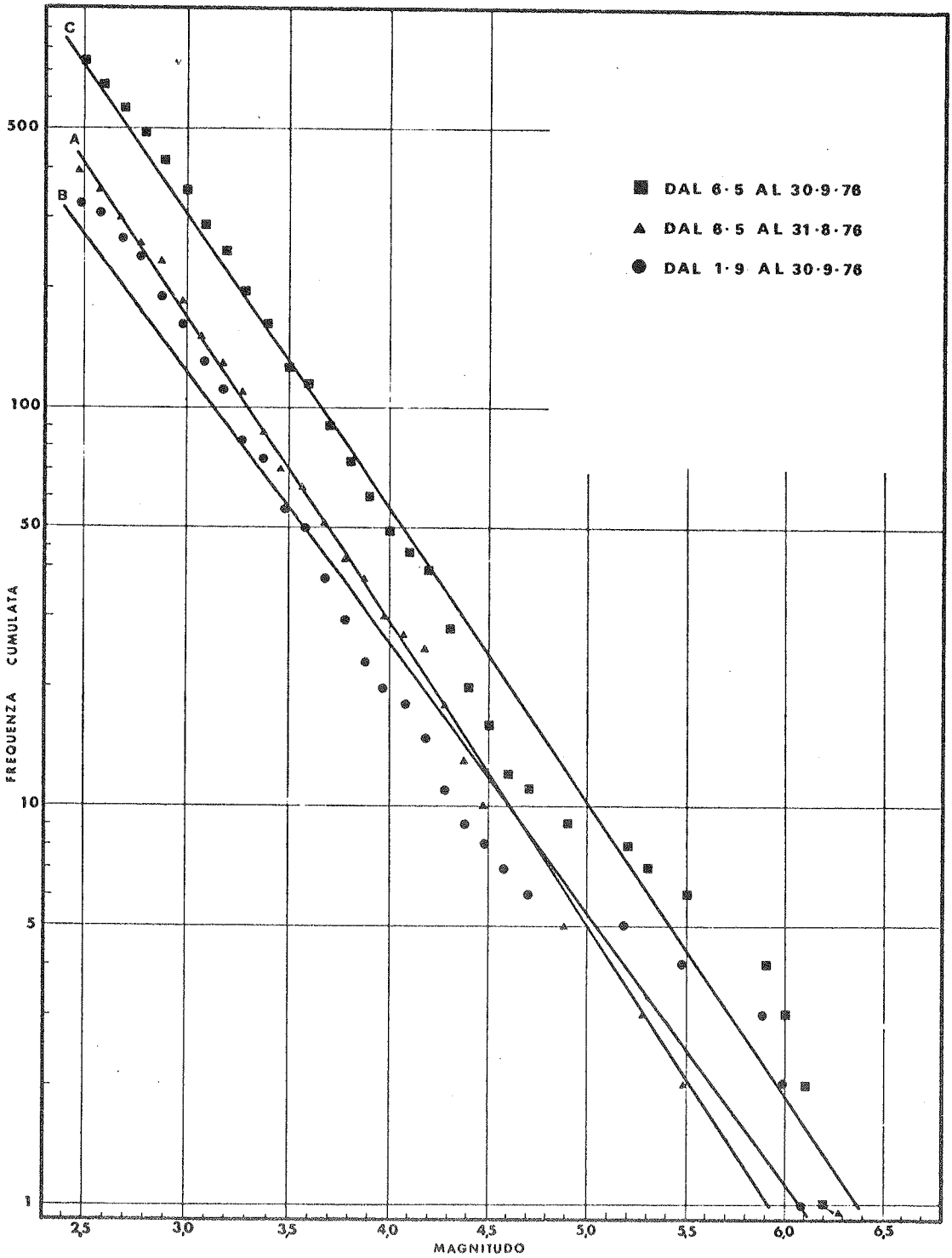
C
A
B
500
100
50
10
5
1
FREQUENZA CUMULATA
DAL 6·5 AL 30·9·76
DAL 6·5 AL 31·8·76
DAL 1·9 AL 30·9·76
2,5
3,0
3,5
4,0
4,5
5,0
5,5
6,0
6,5
MAGNITUDO

fig 11

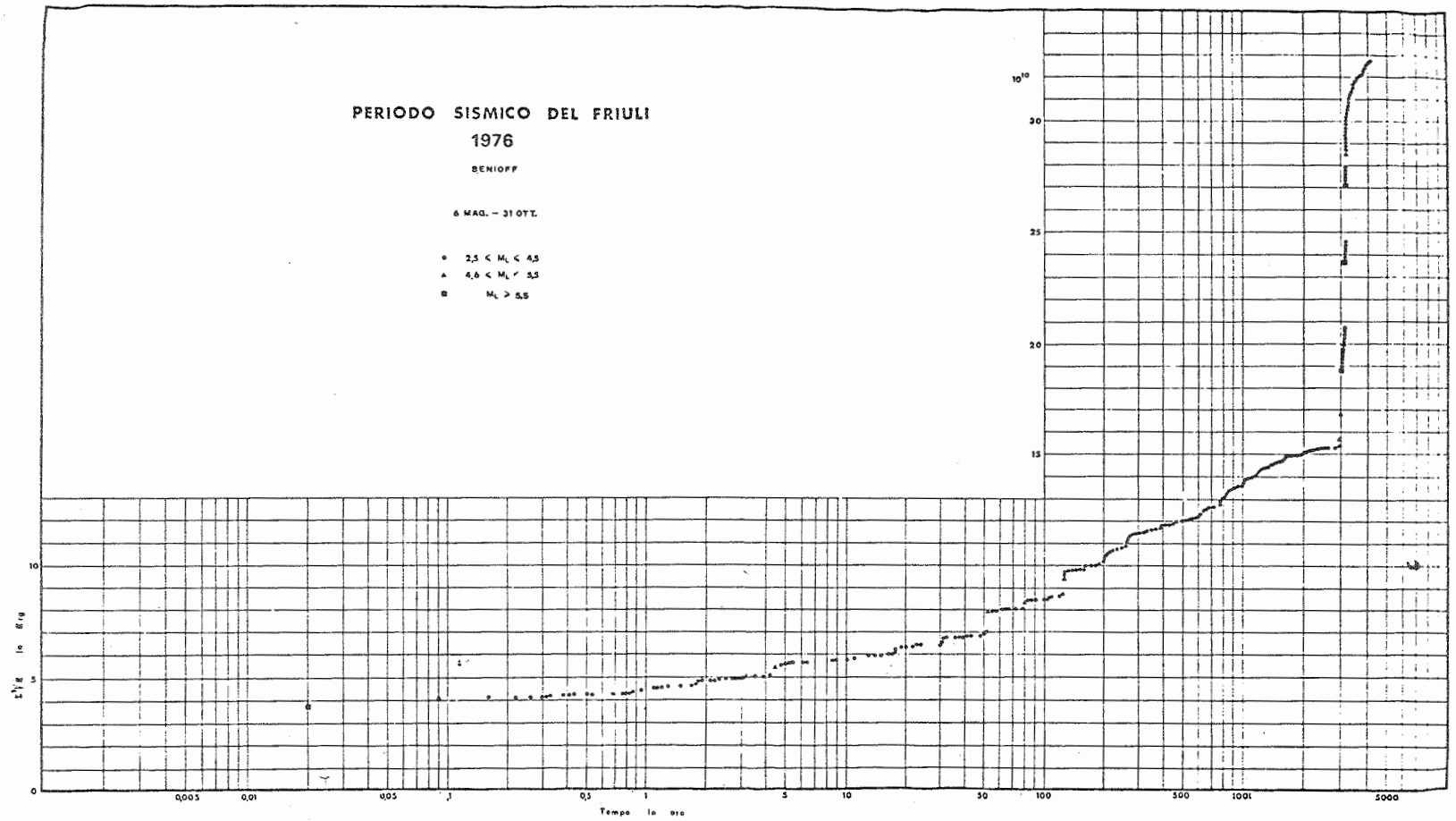
PERIODO SISMICO DEL FRIULI
1976
BENIOFF
6 MAG. – 31 OTT.
2,5 ≤ ML ≤ 4,5
4,6 ≤ ML ≤ 5,5
ML ≥ 5,5
10^10
30
25
20
15
10
5
0
0,005
0,01
0,05
0,1
0,5
1
5
10
50
100
500
1001
5000
Tempo in ore

fig 12

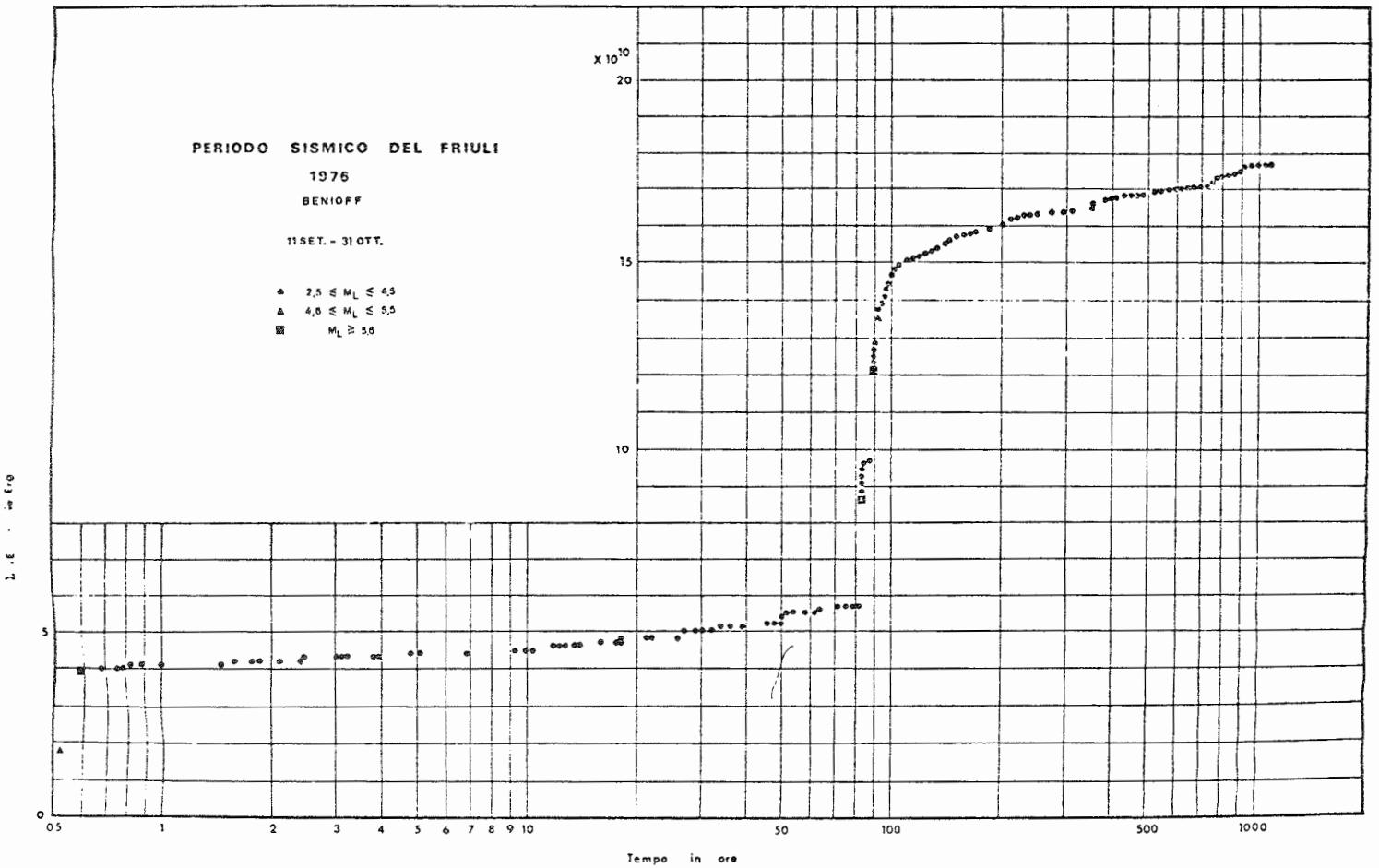
PERIODO SISMICO DEL FRIULI
1976
BENIOFF
11 SET. - 31 OTT.
2,5 ≤ ML ≤ 4,5
4,6 ≤ ML ≤ 5,5
ML ≥ 5,6
x 10^10
20
15
10
5
0
0.5
1
2
3
4
5
6
7
8
9
10
50
100
500
1000
Tempo in ore

fig 13

References

(1) Benioff H. Earthquakes and rock creep.
Bull. Seism. Soc. of. Am.
Vol. XLI, 1951

(2) Gutenberg B.- Richter C.F.
Earthquake magnitude, intensity, energy and acceleration.
Bull. Seism. Soc. Amer.
Vol. XLVI, 1956

(3) Istituto Nazionale di Geofisica
Supplemento al bollettino sismico definitivo.
Maggio, Giugno 1976 - Roma

An Attempt of Focal Depth Determinations for Friuli Aftershocks by Means of Later Arrivals Using Realistic Models of Crustal Structure.

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Accurate hypocenter determinations are of greatest importance for the geodynamic interpretation of seismicity. Up to now large discrepancies still exist between results of different groups working on Friulian earthquakes. It seems therefore worthwhile to make use of all kinds of relevant observations including later arrivals.

It is well known, that focal depth determinations obtained from the evaluation of first onsets are reliable only, if observations at stations close to the epicenter are incorporated. This is due to the fact that travel times of the direct wave to distant stations are nearly independent of focal depth. If observations at nearby stations are not available, the evaluation of specific later arrivals at distant

stations offers an alternative possibility of focal depth determination. As a first step we tried to identify such later arrivals on recordings of our stations in the Eastern Alps for some particular aftershocks, whose focal depths could be determined as reported by Schmedes, Miller and Gebrande[1]. If such arrivals can be clearly identified at distant stations they may also be used for focal depth determinations independent of nearby stations.

Starting with events localised with our stations Malemaseria, Nassfeld and Arnoldstein (see figure 3 in paper 1) we searched for two types of later arrivals, which are indi-

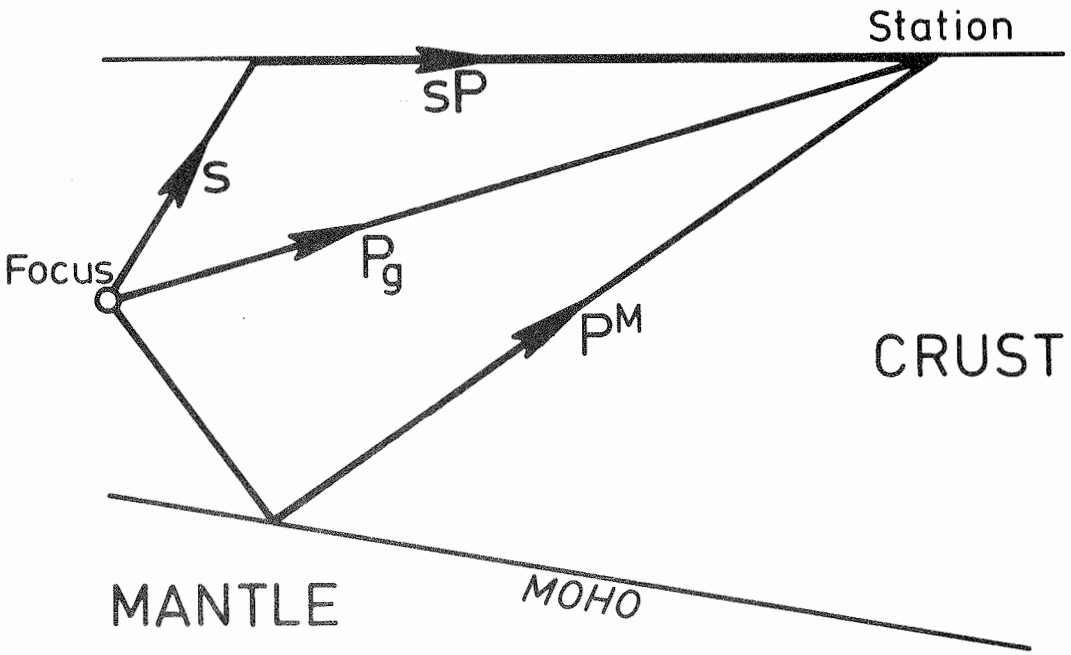

Fig. 1: Schematic ray path of the direct wave (P_g) and the two types of later arrivals (sP and P^M) used in the present study.

cated in figure 1. Apart from the direct wave P_g from the focus to the station two other ray paths are shown schematically. The upper one is the ray path of the sP-wave, which travels up to the surface as a shear wave and is there converted into a longitudinal wave. The lower one, the P^M-wave, is reflected at the crust-mantle boundary, which in this simplified model is a plane dipping from the epicentral area towards the stations in the North. The time differences between the later arrivals and the P_g arrival - contrarily to the P_g arrival time alone - depend strongly on the focal depth.

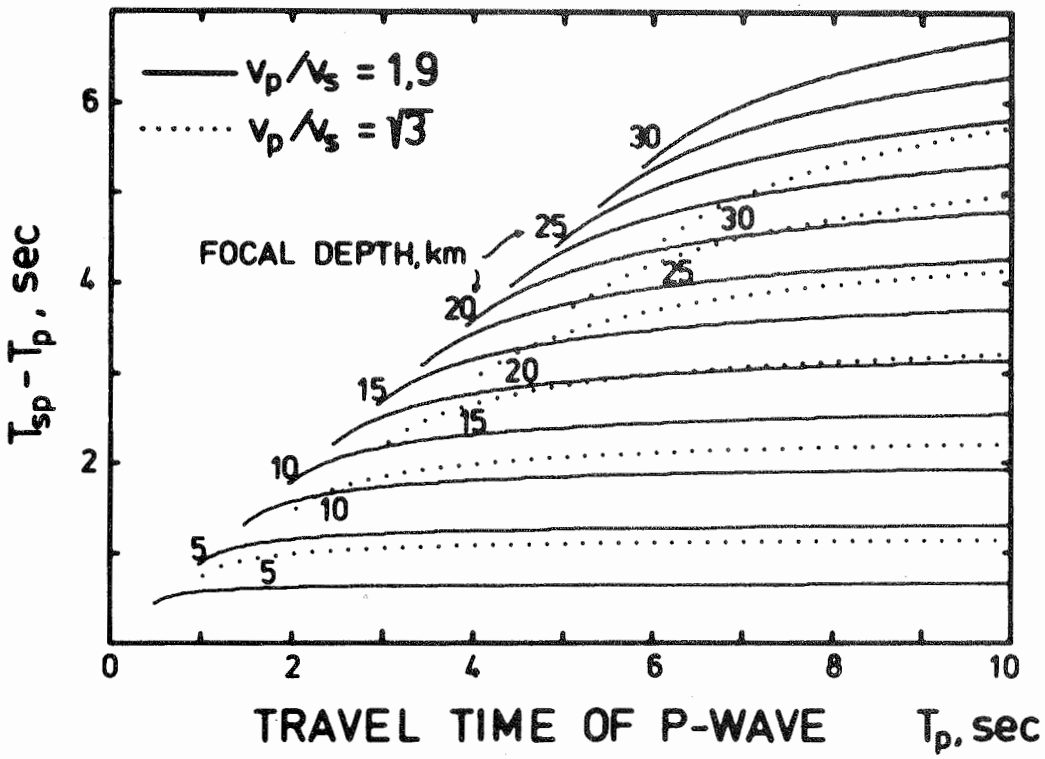

Fig. 2: sP-P_g times plotted against P_g travel times with focal depths as parameters. Solid and dotted lines are calculated for a v_p/v_s-ratio of 1.9 and $\sqrt{3}$, respectively.

At first we would like to discuss the time differences between the sP and the P_g arrivals, which are to be expected for different depths and distances. Figure 2 shows two families of curves, each curve corresponding to an individual focal depth. sP-P_g times are plotted over P_g travel times. Depending on focal depth the converted sP wave may only be observed from a certain critical distance onwards. Solid lines are calculated for a v_p/v_s-ratio of 1.9, which we found to be valid in the epicentral area of Friuli (Gebrande, Miller and Schmedes[2]), and dotted lines correspond to a standard value of $\sqrt{3}$, which apparently holds outside of Friuli.

On the seismograms several onsets are observed between s and p arrivals and the question arises, whether some of these may be interpreted as sP waves. This possibility has been checked for a number of events with known focal depth, two of which are reproduced in figure 3. The curves plotted within the record sections give the expected arrival times of the sP wave, if the calculated focal depth were correct. In both record sections some onsets may be seen near to the predicted arrival times, but there is no convincing evidence that this are indeed sP arrivals. The same holds for the other events we have studied. At the present stage of the study our first conclusion therefore must be a negative one: it seems neither possible to confirm calculated focal depth by sP arrivals nor to calculate them from sP-P_g times only. This conclusion needs not to be definite. We feel that an improvement may be reached

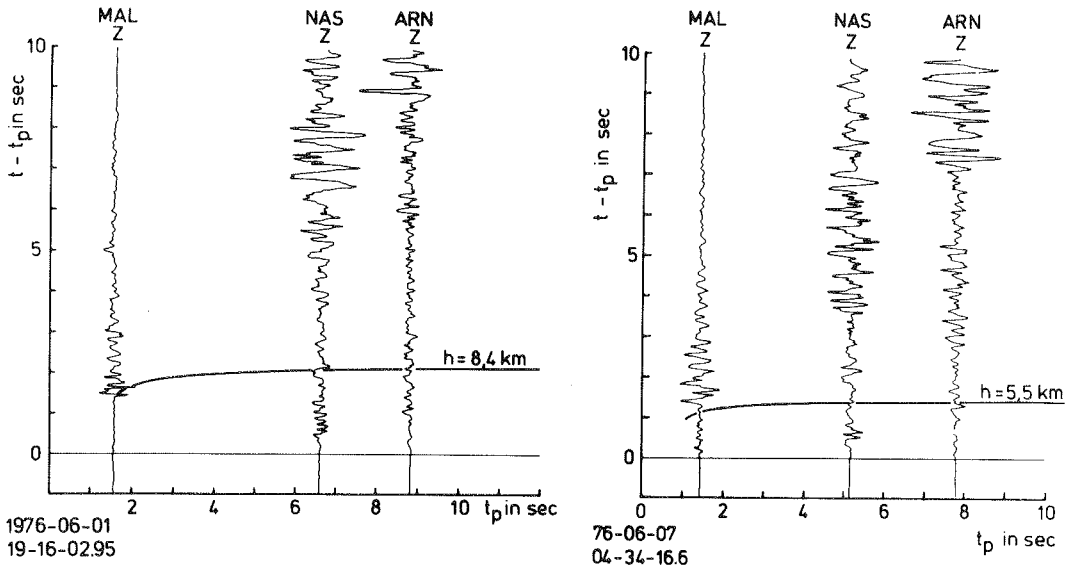

Fig. 3: Seismogram sections with calculated sP-P_g times for two aftershocks with focal depth of 8.4 and 5.5 km.

by denser observations enabling phase correlations and by application of digital filter techniques, especially polarizing filters.

One may wonder why in spite of strong shear wave radiation only poor sP arrivals can be observed. An explanation may be found in the rough topography between the epicentral area and our stations. Since the wavelength of the topography is of the same order of magnitude as the seismic wavelength a homogeneous sP wave front cannot be generated and therefore the corresponding onsets are not well correlated. This would not be the case for a flat surface and hence similar observations towards the South may be more successful.

The second approach would be, as was indicated in figure

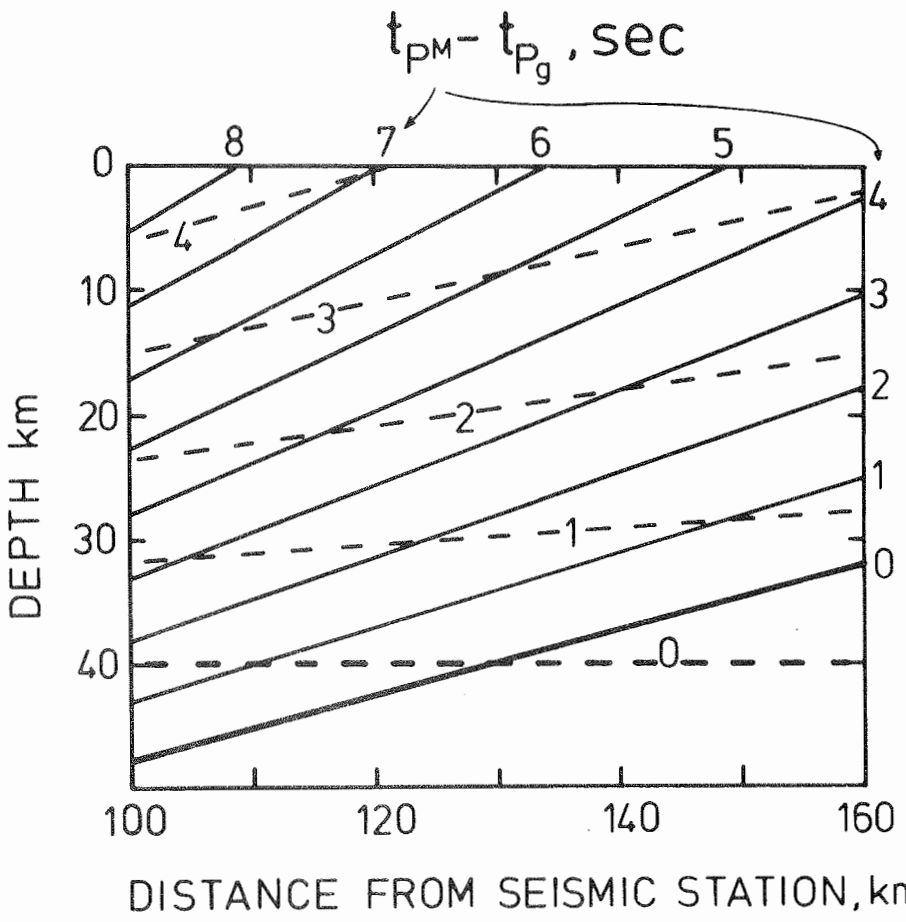

Fig. 4: Lines of equal P^M-P_g time differences. Hypocenters on the same curve give the same P^M-P_g time difference at a station in a distance indicated by the abscissa. Solid lines are calculated for an inclined and broken lines for a horizontal Moho.

1, to use the time differences between the P^M and the P_g phases. Figure 4 shows these time differences as parameters of two sets of curves in a focal depth - distance section. Solid lines are calculated for a Moho, which is dipping with 15 degree towards the station and broken lines correspond to a horizontal Moho. A mean crustal p-wave velocity of 6.0 km/s has been assumed for the calculations. Hypocenters on anyone

of these lines give the same P^M-P_g time at a station in a distance indicated on the abscissa. For a focus on the Moho direct and reflected wave are identical. The curve with the parameter 0 therefore represents the Moho directly in the two cases. As there is a significant difference between the inclined and horizontal case with regard to the P^M-P_g times, it is obvious that detailed knowledge of the morphology of the Moho is required in the area under study, when this approach is used.

Such information is now available due to a recent reinterpretation of the Eschenlohe-SE refraction profile (Miller, Gebrande, Schmedes[3]), which has been observed by our insti-

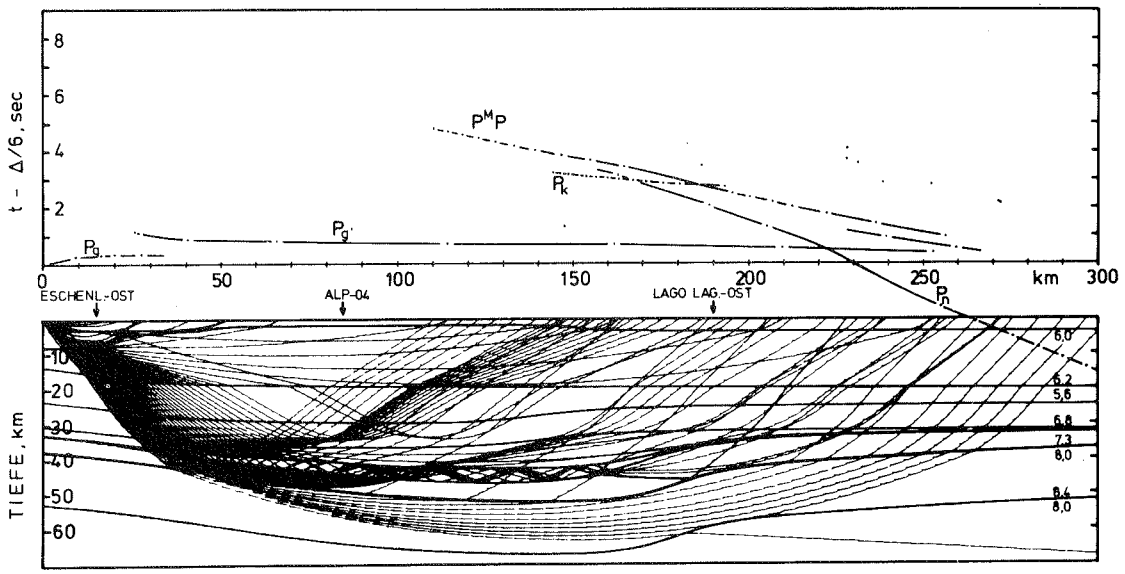

Fig. 5: Crustal structure along the Eschenlohe-SE profile with calculated ray paths and traveltime curves after Miller, Gebrande, Schmedes[3]. Crustal structure is defined by velocity isolines; numbers indicate p-wave velocities in km/s.

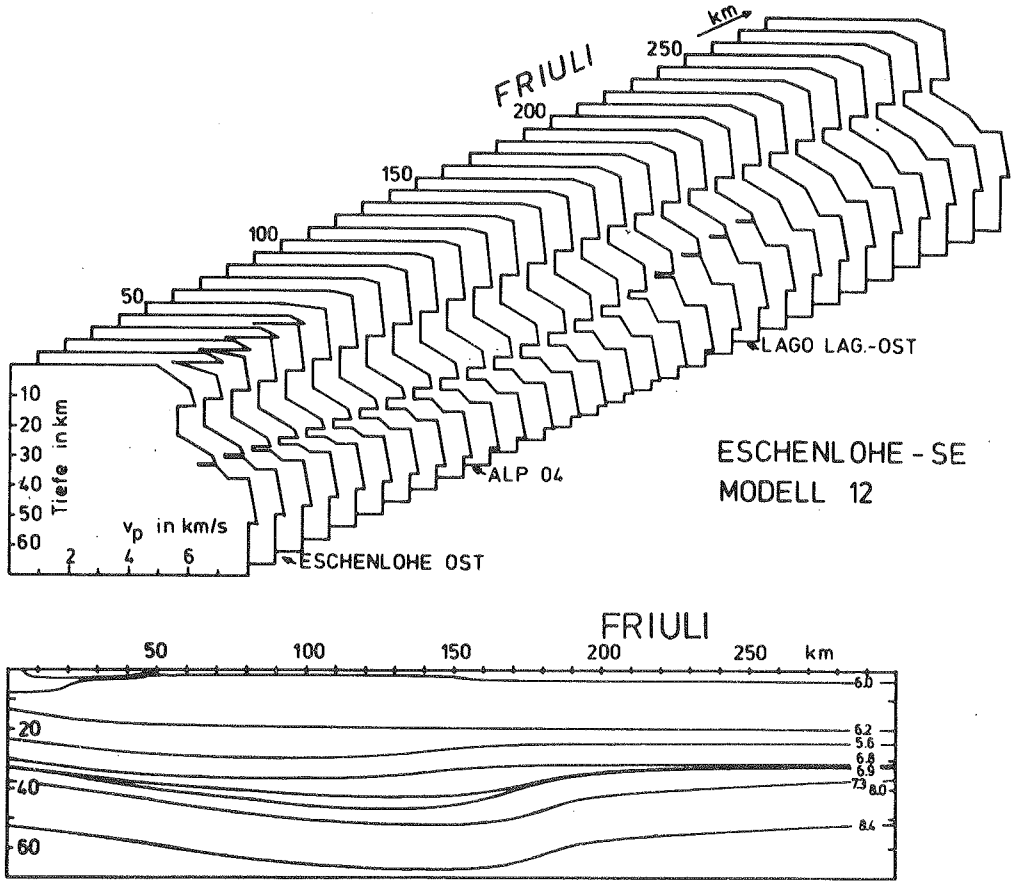

Fig. 6: Crustal structure along the Eschenlohe-SE profile. Top part: perspective view of velocity-depth-functions. Bottom part: isoline-representation of velocity structure.

tute some years ago and which passes right through the region of Friuli. The reinterpretation was done by a ray-tracing method (Gebrande[4]) including new informations from the Alpine Longitudinal Profile and additional data from older profiles like Eschenlohe-E and Lago Lagorai-E.

Figure 5 shows ray paths and traveltime curves for our latest model, which once more is represented in figure 6. With this model, which could still be improved by additional

refraction seismic investigations, especially in the south-eastern part, travel times for given hypocenters have been calculated in the reverse direction and have been compared

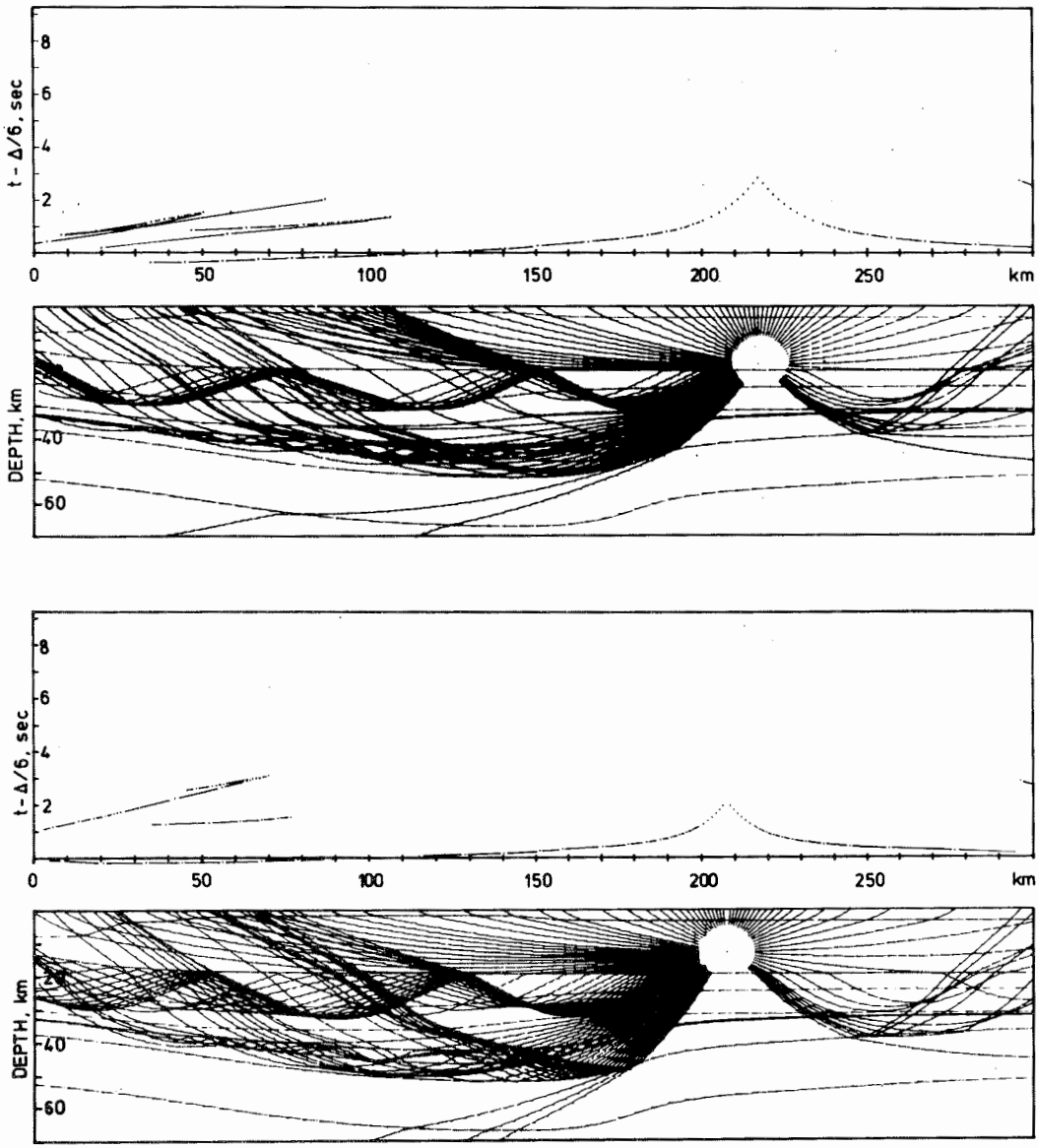

Fig. 7: Ray paths and traveltime curves calculated with the crustal model of fig. 6 for two different Friulian after-shocks. Upper part: focal depth is 18 km; lower part: focal depth is 12 km.

with observed travel times of aftershocks at our stations in the Eastern Alps near to the profile. The upper part of fig. 7 shows ray paths and travel times for a hypocenter at 18 km depth. Like in fig. 5 three different traveltime branches may be seen, corresponding to the direct wave P_g, a reflection from the middle crust P_k and the reflection from the Moho P^M. It may be noticed that with this focal depth the P^M-P_g time is relatively small. For this event no clear P^M onsets could be detected on recorded seismograms at the predicted arrival times.

Similar calculations are presented in the lower part of fig. 7 for an aftershock with 12 km focal depth. In this case P^M-P_g times and critical distance are significantly larger. This tendency continues with decreasing focal depth.

Figure 8 shows results of calculations performed for an aftershock close to Gemona (λ=13° 12' E, φ = 46° 18' N, 3.6.76 19-35-54,3 UT) with focal depth 6 km in comparison with observations. There seems to be satisfactory agreement between calculated and observed travel times, which in this case confirms the focal depth of this particular event as well as our crustal model, which had been derived from independent data. Up to now we have not yet been able to apply this method to extensive sets of data, but from our present results it seems that generally better agreement between observations and calculations is obtained for smaller than for larger focal depths. The main difficulty in applying this method is the

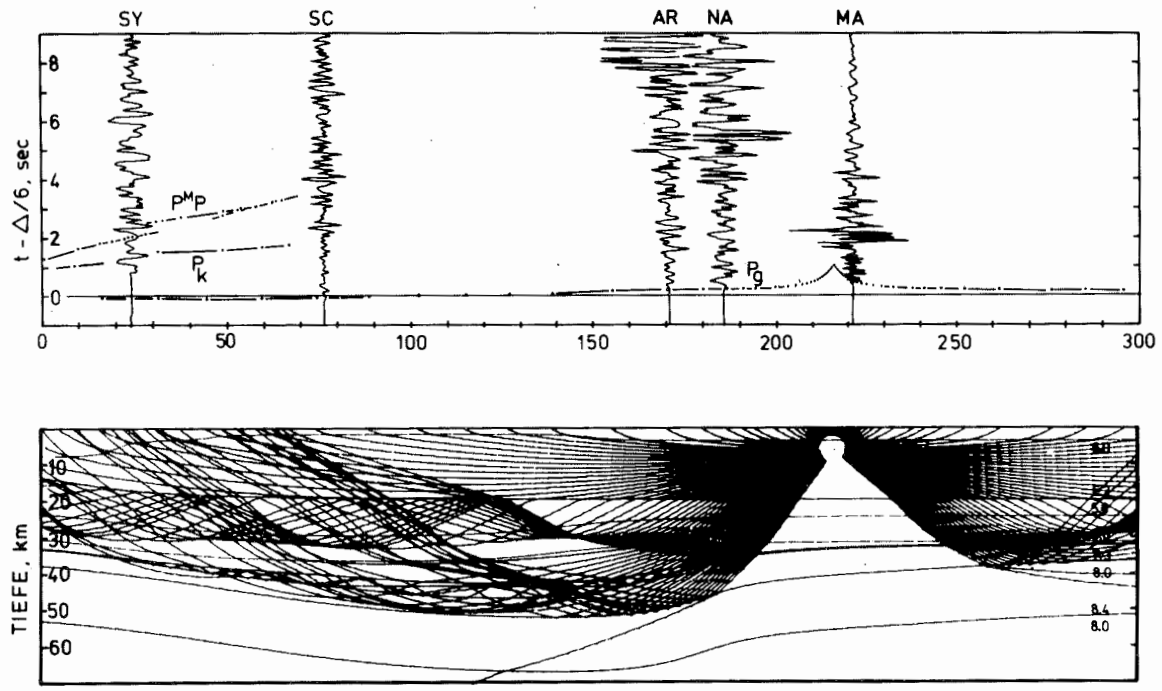

Fig. 8: Ray paths and travel times calculated for the crustal model of fig. 6 and an aftrshock near Gemona with a focal depth of 6 km. Calculated travel times are compared with observed seismograms

correct identification of the P^M onsets at single stations. Denser observations enabling phase correlations would relieve these difficulties.

References

1. Schmedes, E., H. Miller and H. Gebrande, v_p/v_s Ratio and Implications for Hypocenter Determinations of Aftershocks of the Friuli Earthquake, May 6th, 1976, this volume

2. Gebrande, H., H. Miller and E. Schmedes, Digital Registrations of Aftershocks of the Friuli Earthquake 1976, Proc.15th

Gen. Ass. Europ. Seis. Comm. Krakow, Sept. 1976, in press.
3. Miller, H., H. Gebrande und E. Schmedes, Ein verbessertes Strukturmodell für die Ostalpen, abgeleitet aus refraktionsseismischen Daten unter Berücksichtigung des Alpen-Längsprofils, Geol. Rundsch., 66, in press, 1977.
4. Gebrande, H., A Seismic Ray-Tracing Method for Two-Dimensional Inhomogeneous Media, in Explosion Seismology in Central Europe, P. Giese, C. Prodehl and A. Stein, Eds., Springer, Berlin, 1976.

REPORT ON THE HYDRO-GEOLOGICAL SURVEY CARRIED OUT BY THE GOVERNMENT SPECIAL DELEGATION FOR FRIULI

Enrico GIORGETTI
Seismic Service of the Ministry of Public Works
Government Special Delegation for Friuli
Udine

The Government Administration has been seriously engaged in the construction of buildings made necessary by the recent earthquakes in Friuli. This activity is being carried out by the Government Special Delegation set up by employees of the Ministry of Public Works, of the Department of Interior, of the Fire Corps and the Army. The Delegation has organized on the territory particularly qualified checkings which are still going on. Such a survey was accomplished to obtain the minimum requirements for territorial planning, necessary also in situations of extreme emergency, as at present the construction of prefabricated buildings.

The greatest effort was dedicated to the geological survey of the areas chosen for temporary settlements. In addition, the Health Chief Institute has recently provided for the checking of the hygienical-sanitary conditions of water conduits and sewage systems.

When the second emergency plan started, after the seis-

mic shocks of September 1976, the territorial survey accomplished by the Region Friuli-Venezia Giulia after the May earthquake proved to be important in order to face the new tasks with adequate methods. In view of this the Seismic Service of the Ministry of Public Works, having already cooperated with the Region during the previous events, immediately offered their assistance to the Governmental Delegate. At the same time the National Association of Geologists had made public opinion and the bodies entrusted with reconstruction sensitive to the importance of territorial surveys. Bearing in mind this importance, the Delegate set up - within the Department for Prefabricated Buildings formed by qualified technicians of the Civil Engineers Office, Fire Corps and Army units under the management of the Regional Hydro-geological Superintendent of Public Works - a Hydro-geological Service having to check the suitability of the areas chosen for the prefabricated buildings.

At the head of this Service there is a geologist of the Ministry of Public Works assisted by:

- two engineers who have to keep the contacts with the Communes to study the problems conncected with buildings and infrastructures and to fill in summary reports;
- a geologist who has to carry out field surveys and draw up the conclusions, and
- a geologist encharged with the serious problems of earth slides on roads and settlements.

The first part of the survey was dedicated to the collection of cartographic material for which more time than planned was needed, owing to the fact that many Communes, due to political-administrative reasons, were able to supply information on their requirements only after a rather long period. Therefore, some delay occurred in the action

of the Service.

The geological field survey was entrusted , with as far as possible time-predetermined assignements, to indipendent geologists selected by the Coordinating Centre in Udine. To speed up the field survey as much as possible, and to file immediately the essential geological and statistical data, a card for each individual area was prepared.

The first part of the card includes geographical and urban items on the area. The second part refers to plane areas and contains information on the morphology, lithology, geotechnique, geohydrology, climatology, slope geostatics and stability conditions of the surveyed area. The third part considers the sloping areas including morphology, lithology, tectonics, geotechnique, geohydrology, climatology and geostatics. The fourth part deals with works necessary for proper arrangement of the settlement areas by evaluating possible risks, a judgment on the infrastructures, suggestions, recommendations and various arrangements, and, finally, the conclusions on the suitability of the areas.

Cards were replaced by a simple descriptive report in atypical cases.

For each Commune a report on the geological suitability based on the survey cards with field checkings and air-photographs in case of more complex conditions was prepared in the subsequent phase by the Hydro-geological Service. The evaluation was then transmitted to the competent office of the Department of Public Works.

According to the almost final results, which are being now completed, only a very small part of the surveyed areas is not suitable. Many of these areas have requirements such as: to place the prefabricated buildings on pilasters besides on a gravel layer in order to avoid the moisture of the soil and maintain the natural profile of the ground;

to construct or ameliorate mainly unimportant works in protecting from water damage; to prohibit considerable excavations; to observe proper safety distancies from escarpment edges, mountain sides, watercourses, gas and electric lines; to provide for sewage systems and prohibit wood cutting, etc.

Considering a Region like Friuli, which had endured two earthquakes on a surface of 3,610 sq. km with 20,600 houses damaged (9,300 during the first and 10,300 during the second earthquake) and 80,000 homeless persons (respectively 35,000 and 45,000), it can be affirmed that the commitments are both very urgent and exacting.

The emergency programme, drawn up during this second phase by the Government Delegation, covers about 55% of the prefabricated buildings required after the two earthquakes. In order to study the settlement areas, the Hydro-geological Service employed 22 geologists for 45 days (including one of the Service), totalling almost 100 working days. Thus, about 2,500 settlement areas with over 11,000 homes were studied. Only 30% of these areas will form rather large settlements, while the others refer to one family-homes and scattered houses.

The first practical result of this activity shows that the present cost of these geological studies amounts to less than Lit. 1,000 per home with an average of Lit. 6,000 per each settlement area.

However, such low costs and short terms can be possible only when well coordinated volunteer professionals, full of good will, as necessary in similar situations striking the national community, are available.

In the end, it must be said that this subject has to be examined in detail by Ministries and local Administrations. Bearing this in mind, it is important to exploit from now on the results obtained by the

geologists who humbly struggled in Friuli, village after village, being able to report sufficiently to assure the Friuli people the home and the tranquillity so much longed for.

It will be also necessary to set down a method for the work carried out with equal efforts by engineers, technicians, architects, urbanists, sociologists and medical staff during the months which were so difficult and important for the reconstruction in the Region. Only by summarizing all the professional experiences made studying the needs of the people, it will be possible to create the lines necessary for territorial planning in emergency situations.

The idea and necessity of science at the exclusive service of the community is also being strengthened through humble experiences like these.

AN EXAMPLE OF MICROSEISMIC ZONING IN THE MADONNA DI BUIA AREA

F. GIORGETTI

UNIVERSITY OF TRIESTE

SUMMARY

An example of seismic microzoning has been performed in the Madonna di Buia area (Udine). The Medvedev method (1960) has been applied using geophysical methods (geoelectrical vertical soundings and refraction seismic profiles) in order to obtain the required parameters. The water bed level has been measured in several bore holes existing in the investigated area.

The results are in good agreement with the macroseismic map of the area obtained using the seismic intensity scale version MSK (1964).

O.G.S. - Osservatorio Geofisico Sperimentale - Trieste - Contrib. n. 259.
Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 22.

AN EXAMPLE OF MICROSEISMIC ZONING IN THE MADONNA DI BUIA AREA

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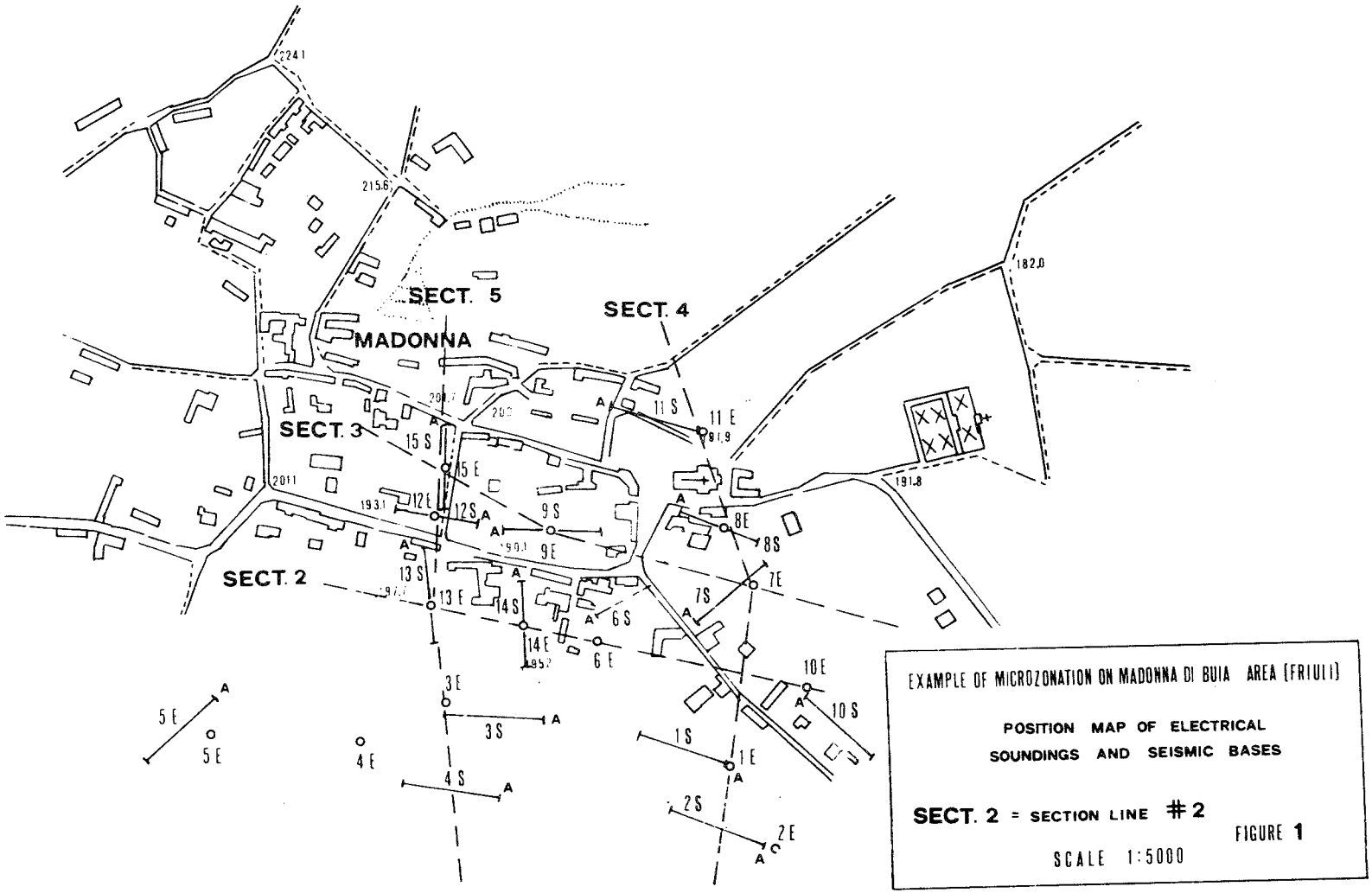
UNIVERSITY OF TRIESTE

Numerous studies in different fields of research have been carried on during these last months. Their common purpose is to obtain a better understanding of the most important parameters which are known to be useful and necessary to rebuild the Friuli region destroyed during the May 6 earthquake.

In this paper I would like to present the results of an example of seismic microzoning performed in the Madonna di Buia area. The main purpose of this study is to give an example of the application of Medvedev's method (1960) in Italy and to verify it results. The data have been obtained using very simple geophysical techniques which proved to be also inexpensive.

The May 6 earthquake corroborated the already universal


SECT. 5
SECT. 4
MADONNA
SECT. 3
SECT. 2
215.6
224.1
182.0
191.8
11 S
11 E
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15 E
12 E
12 S
9 S
9 E
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14 S
14 E
6 S
6 E
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7 S
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4 S
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EXAMPLE OF MICROZONATION ON MADONNA DI BUIA AREA (FRIULI)
POSITION MAP OF ELECTRICAL SOUNDINGS AND SEISMIC BASES
SECT. 2 = SECTION LINE # 2
FIGURE 1
SCALE 1:5000

ly accepted theory, according to which the increase in seismic intensity, keeping all other parameters unchanged, depends mainly on local stratigraphic conditions.

The macroseismic survey carried on immediately after May 6 in Madonna di Buia has allowed to estimate the effects of the earthquake in an area in which big discontinuities exist. The substratum of this area consists of eocene flish-like marly calcareous rock. This substratum is covered with an incoherent layer consisting of moraine mixed with alluvio nal material or sometime just alluvium. The thickness of this loose material exceeds 15 m, with the exception of the North-West area.

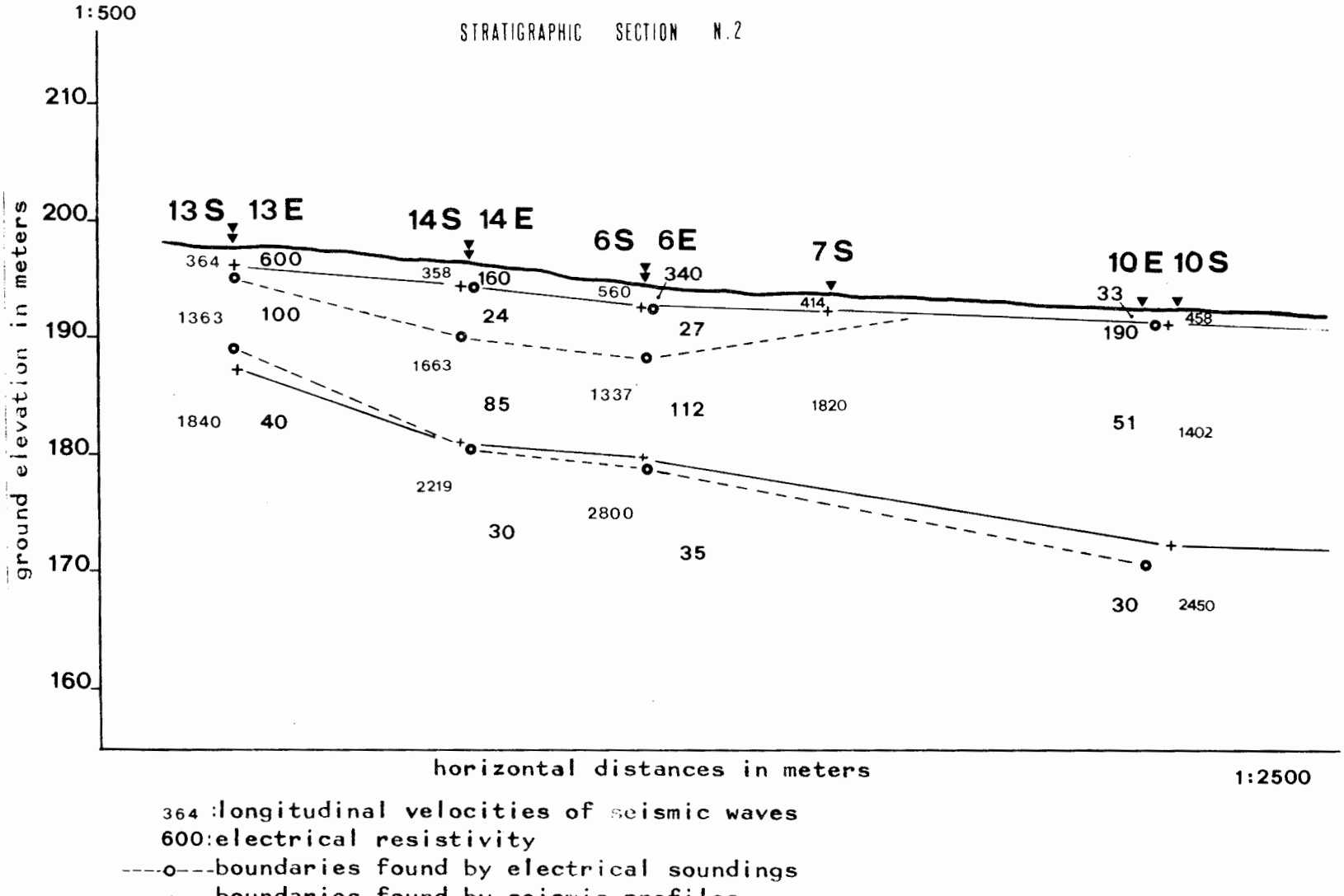
The method followed during the investigation of the Bu ia area has been selected due to the following:

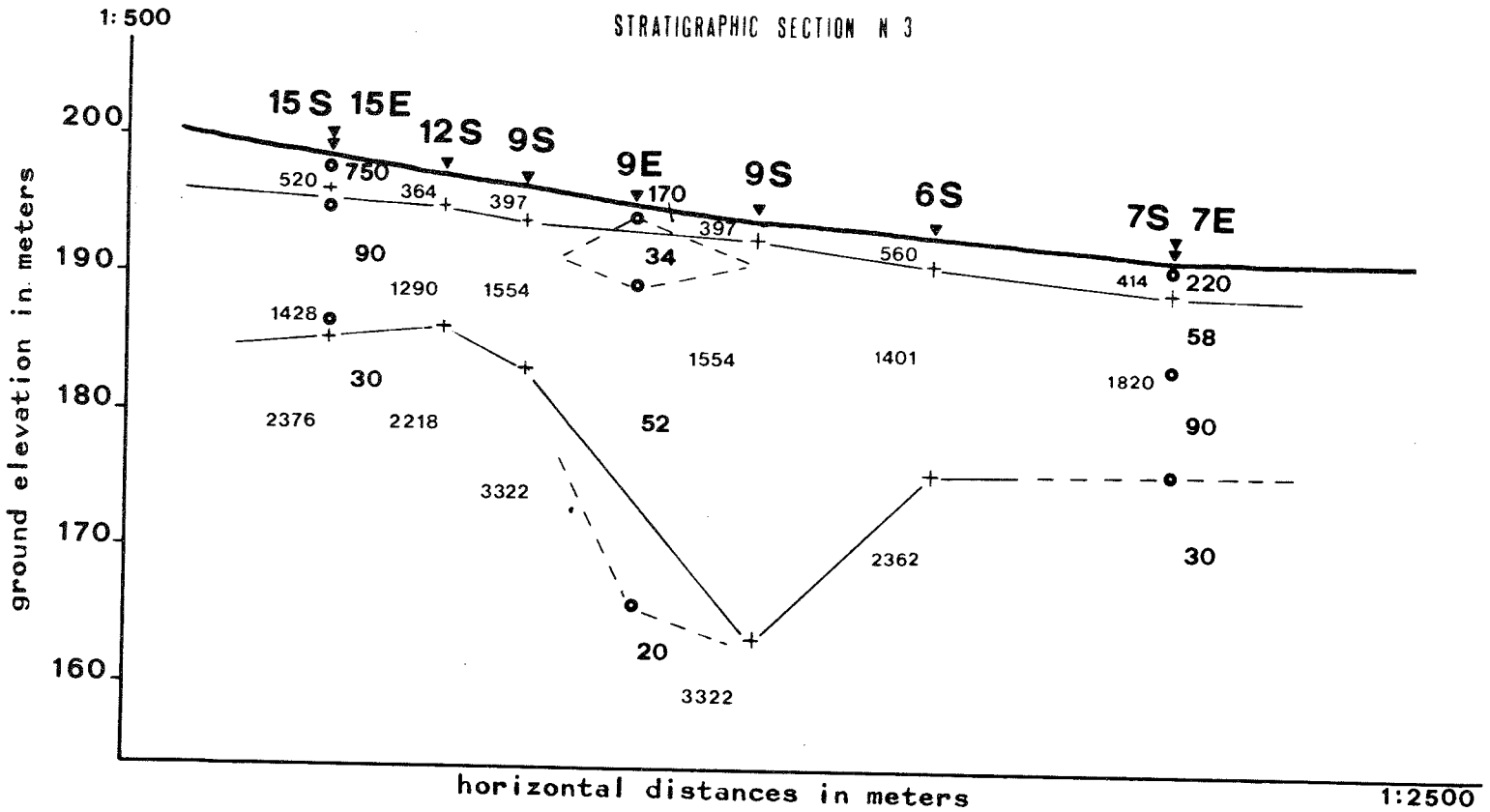
1) it can be easily applied to the geomorphological conditions of the ground;
2) it is simple to carry out;
3) it can be generalized to every type of ground.

Let us denote by V_i, V_j the propagation velocities of longitudinal seismic waves in two different types of ground, by q_i and q_j their corresponding densities, by h the depth of the eventual ground-water level and by b a coefficient depending on the type of ground.

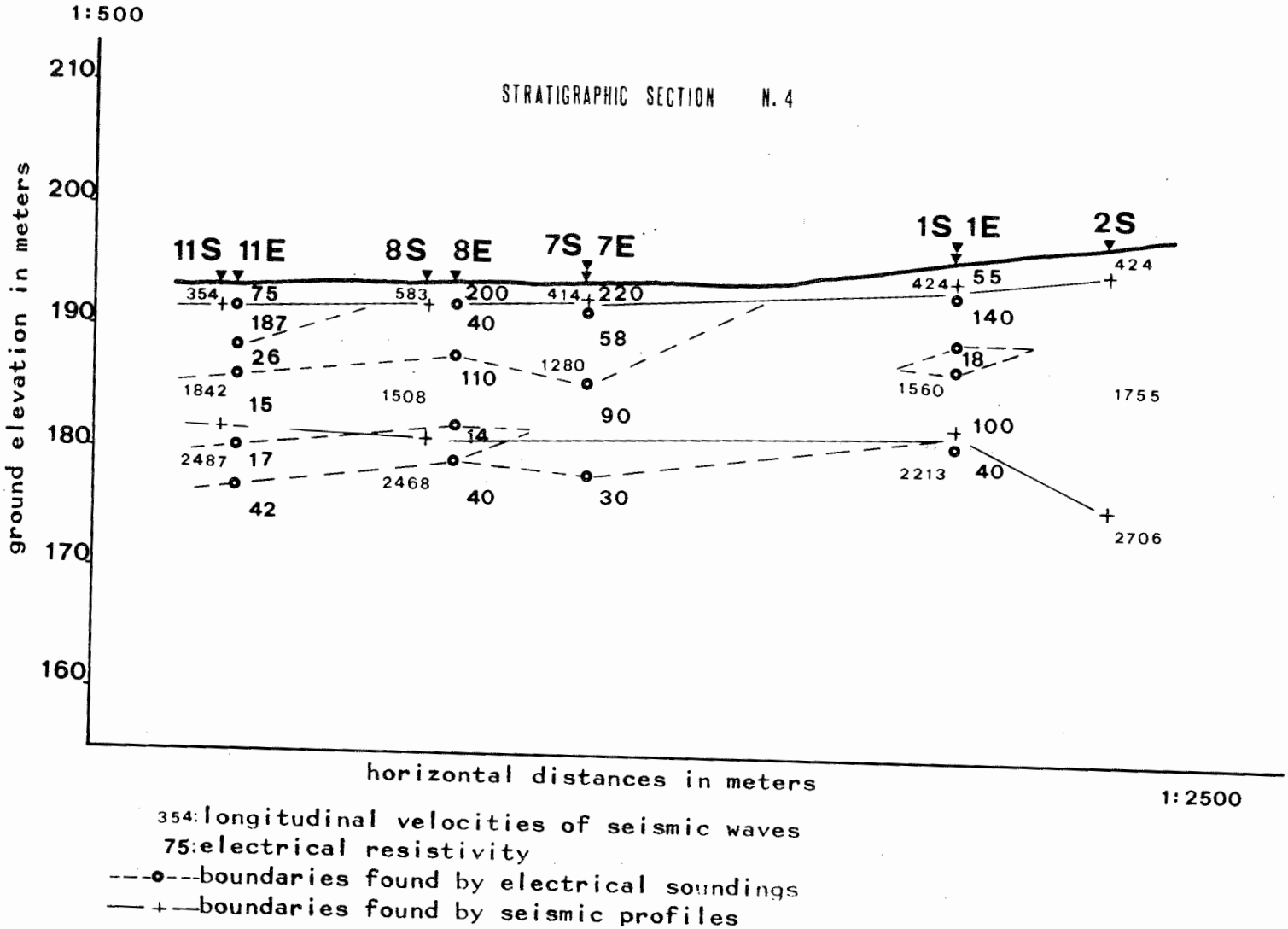
$$\Delta I = 1.67 \left[\log (V_i\, q_i) - \log (V_j\, q_j) \right] + be^{-0.04\, h^2} \quad (1)$$

15 electrical vertical soundings and 15 refraction seismic bases have been done in Madonna di Buia (see Position map, Figure n° 1).


1:500
STRATIGRAPHIC SECTION N.2
210
200
190
180
170
160
ground elevation in meters
13 S 13 E
14 S 14 E
6S 6E
7S
10 E 10 S
364
600
1363
100
1840
40
358
160
24
1663
85
2219
30
560
340
27
1337
112
2800
35
414
1820
33
190
458
51
1402
30
2450
horizontal distances in meters
1:2500
364 :longitudinal velocities of seismic waves
600:electrical resistivity
----o---boundaries found by electrical soundings
——+——boundaries found by seismic profiles



520: longitudinal velocities of seismic waves
750: electrical resistivity
---o---boundaries found by electrical soundings
——+——boundaries found by seismic profiles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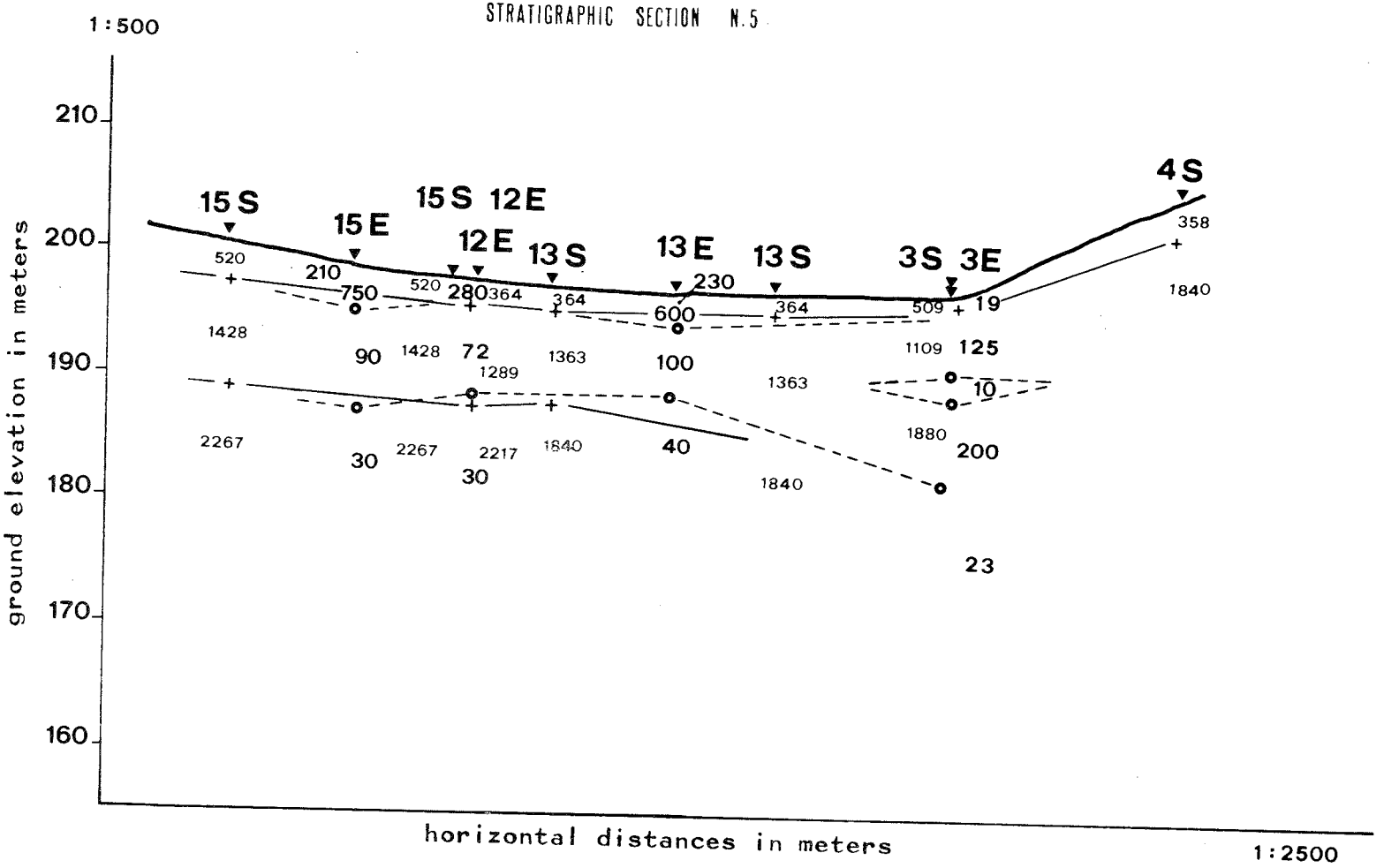
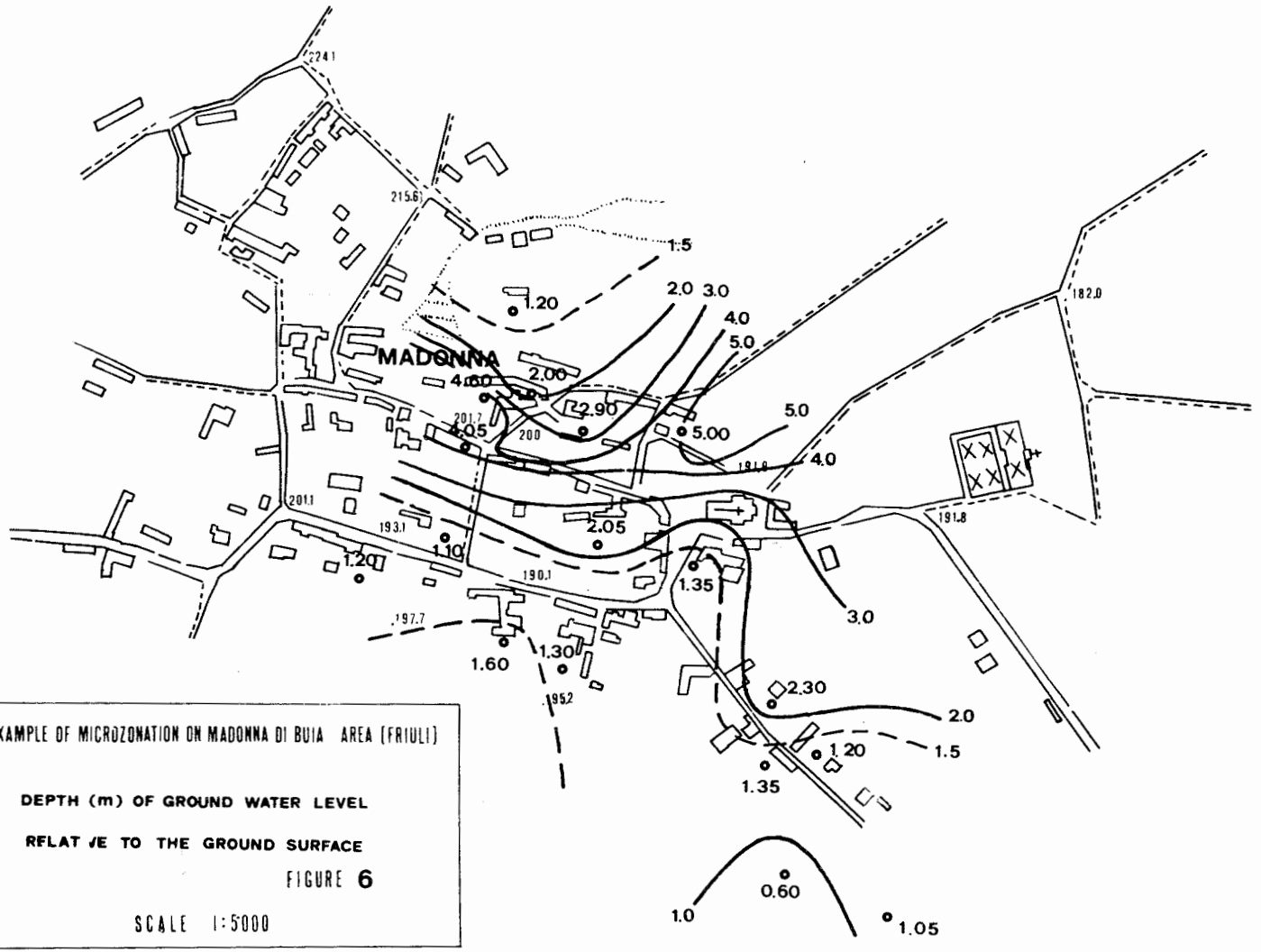
STRATIGRAPHIC SECTION N. 4
ground elevation in meters
210
200
190
180
170
160
11S 11E
8S 8E
7S 7E
1S 1E
2S
354
75
187
26
1842
15
2487
17
42
583
200
40
1508
110
14
2468
40
414
220
58
1280
90
30
424
55
140
18
1560
100
2213
40
424
1755
2706
horizontal distances in meters
1:2500
354: longitudinal velocities of seismic waves
75: electrical resistivity
---o---boundaries found by electrical soundings
—+—boundaries found by seismic profiles



520: longitudinal velocities of seismic waves
210: electrical resistivity
---o--- boundaries found by electrical soundings
—+— boundaries found by seismic profiles



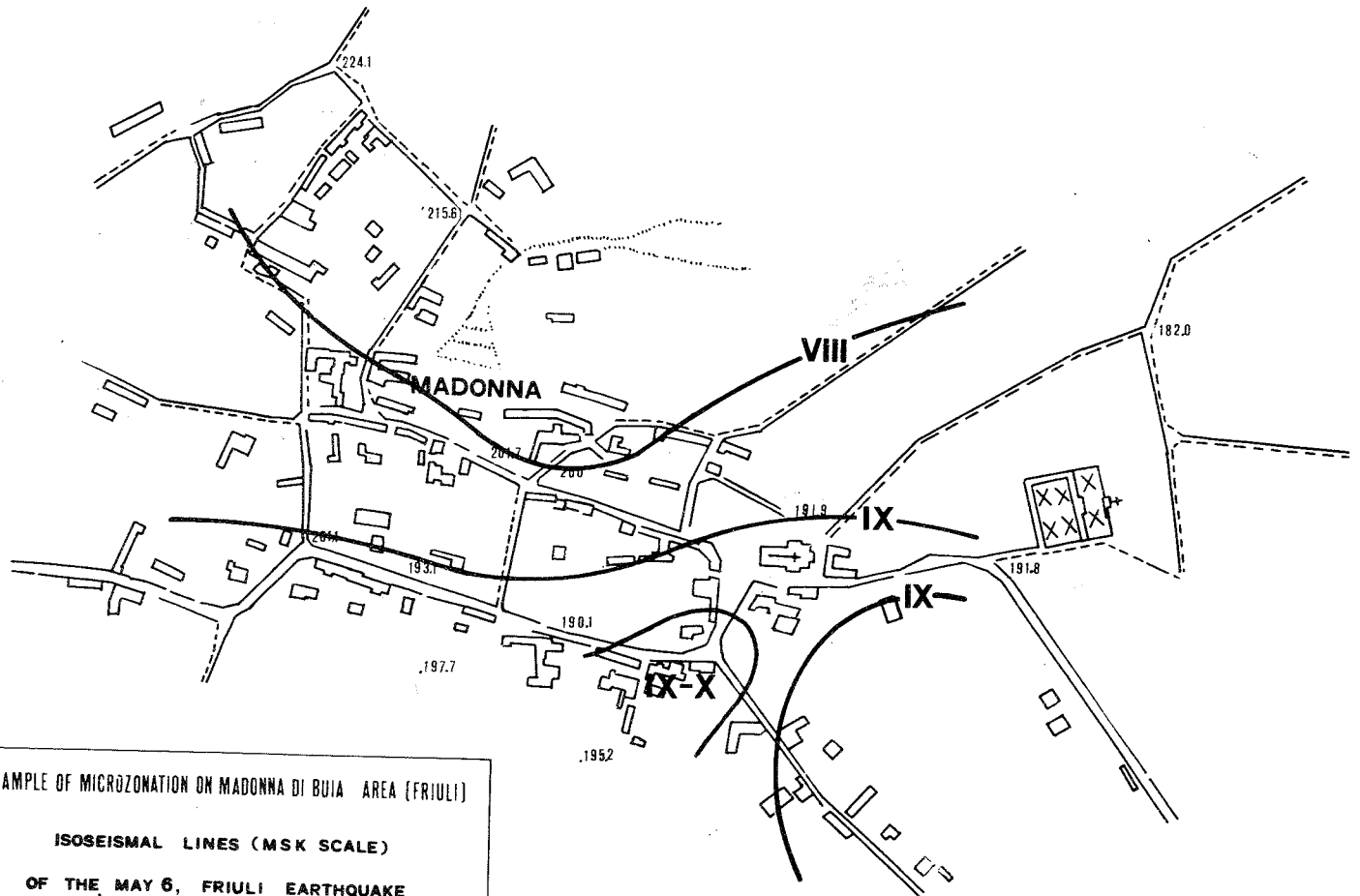
EXAMPLE OF MICROZONATION ON MADONNA DI BUIA AREA (FRIULI)

DEPTH (m) OF GROUND WATER LEVEL

RELATIVE TO THE GROUND SURFACE

FIGURE 6

SCALE 1:5000



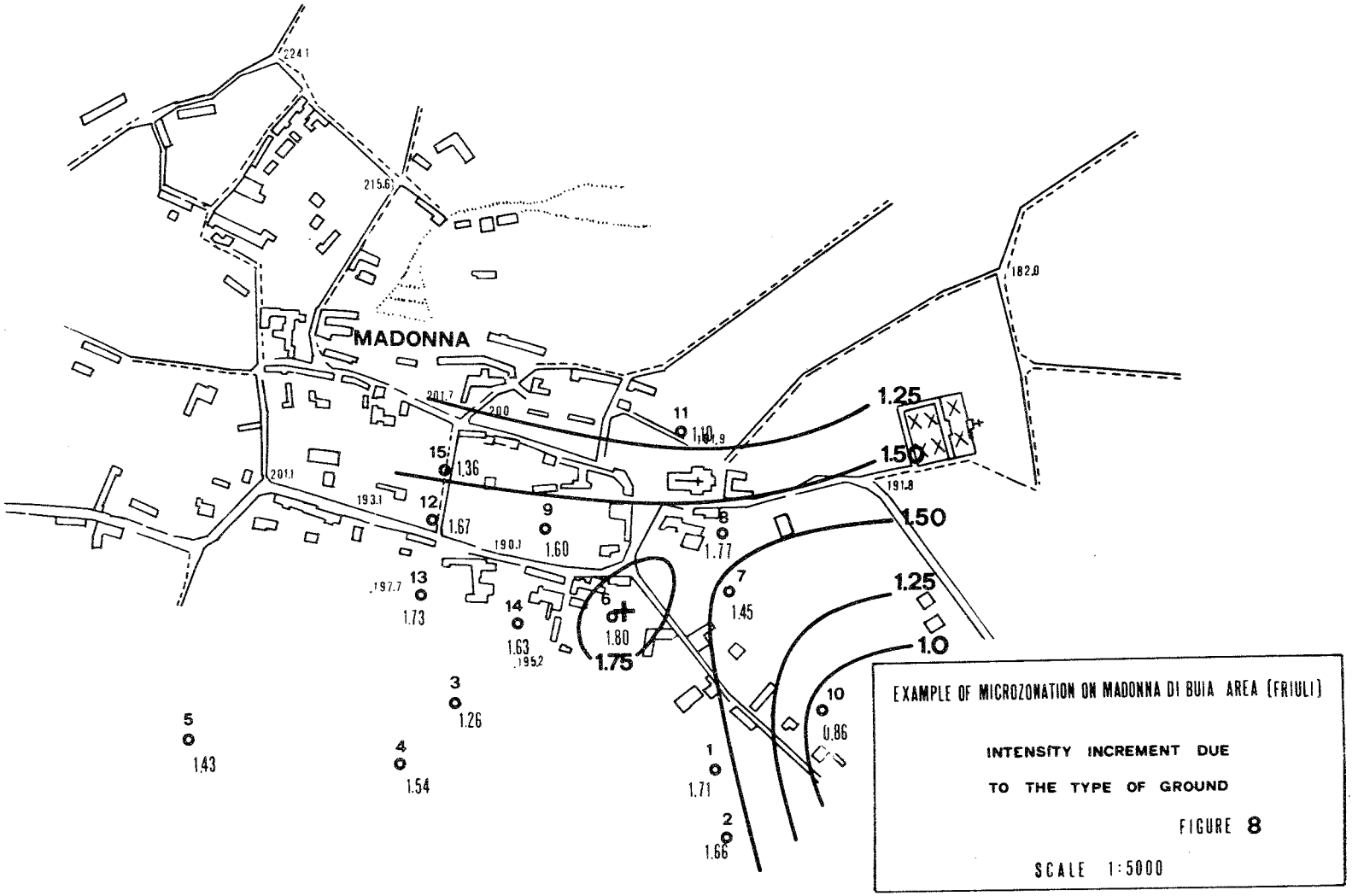
EXAMPLE OF MICROZONATION ON MADONNA DI BUIA AREA (FRIULI)

ISOSEISMAL LINES (MSK SCALE)

OF THE MAY 6, FRIULI EARTHQUAKE

FIGURE 7

SCALE 1:5000


MADONNA
224.1
215.6
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201.7
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197.7
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1.25
1.50
1.50
1.25
1.0
1.75
1.10
1.36
1.67
1.60
1.77
1.45
1.80
1.63
1.73
1.26
1.43
1.54
1.71
1.66
0.86
EXAMPLE OF MICROZONATION ON MADONNA DI BUIA AREA (FRIULI)
INTENSITY INCREMENT DUE
TO THE TYPE OF GROUND
FIGURE 8
SCALE 1:5000

The analysis of the geophysical results and especially the compared analysis of the data has led to obtain some stratigraphic sections, the values of the longitudinal velocities in the various formations and the fundamental data about the lithological composition of the ground (see Figures 2, 3, 4, 5 which contain also the values of the velocities and ground resistivities). The densities have been indirectly determined by analysing the values of resistivity and comparing the results obtained in adjacent and wellknown similar areas.

The depth of the water bed level (see Figure 6) has been determined testing 17 wells in the area under investigation.

The macroseismic survey has been accomplished using the MSK (Medvedev, Sponheuer, Karnik) scale (1964). The results are presented in Figure 7, which is a part of the technical map of the F.V.G. region in scale 1:5.000.

At every measuring point the values of intensity increments are calculated for 20 meters of material and referred to sound flish-like rock. The results are drawn on a map and contoured on Figure 8.

Comparing the intensity increment map with the map of the damages due to the earthquake, one can clearly convince himself of the validity of the described method.

References

Medvedev S.V., 1960: The forecast of seismic effects on constructions; Proc. of second world confer. on earthq. eng., Japan.

ISOSEISMAL MAP OF THE MAY 6, 1976 FRIULI EARTHQUAKE

BY

F.GIORGETTI

UNIVERSITY OF TRIESTE

S U M M A R Y

The isoseismal map showing the effects of the May 6, 1976 Friuli earthquake has been constructed using primarily macroseismic observations made in the epicentral region. Some supplementary informations have been provided by the regional authorities and some were found in local newspapers. The macroseismic intensities have been determined on the basis of the MSK (1964) scale.

1.- INTRODUCTION

This isoseismal map has been constructed taking into account different sources.

The Department of Public Works of the Friuli-Venezia Giulia Region has kindly permitted us to consult his files repor

O.G.S. - Osservatorio Geofisico Sperimentale - Trieste - Contrib. n. 260.
Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 23.

ting the damages due to the earthquake in all the townships of Friuli.

As regards the right side of the map (areas not in Italy) we would like to take this opportunity to thank prof. B. Ribarič of the Astronomical Geophysical Observatory - Ljubljana, for letting us have the isoseismal map of the S.R. of Slovenija that he and prof. B. Sikosek of the Seismological Institute - Belgrade, constructed. We would also like to thank prof. H. Reuter of the Zentralanstalt für Metereologie und Geodynamik - Wien for sending us the isoseismal map of Austria. All the macroseismic intensities have been determined on the basis of the M.S.K. (1964) scale.

2. MACROSEISMIC DATA

A week after the May 6 earthquake occured, 9 teams were sent in the epicentral area to analyse and record the damages caused by the earthquake. Figure 2 shows the points of observation of these teams. (see Enclosure 5)

Subsequently about 40.000 cards carrying information on the earthquake damages were analysed.

These cards have been compiled by special Damage Survey Commissions of the Department of Public Works of the Friuli-Venezia Giulia Region.

Each card contains the description of the works to be done on a single building in order to repair it. Taking into account the number of damaged buildings in a single locality, the type of damage and the type of building, we assigned to the locality a given M S K intensity grade. The correlation

between the data found in the cards and the M S K scale has been improved in the following way.

We compared the results obtained from the cards with the correct ones obtained by our teams of observation. This was possible to do in some localities in wich both kinds of information were available. We then assumed the relation to be valid in the whole region.

The first isoseismal lines surrounding the epicentral area and those to the South and East are quite rigorous. This is due to the great number of observation points and to the contribution of the isoseismal map of the S.R. of Slovenija.

The isoseismal lines to the West of the epicentral area are more approximate. This is due to the lack of observation points, as in that part of the region there is a scarcely populated mountainous area. The intensities were therefore sometimes assigned on the basis of the effects the earthquake produced on the nature.

3. THE ISOSEISMAL MAP

On the isoseismal map (see Enclosure 5) the lines contour the areas where different intensities occured. The isoseismal line of the I_n intensity was drawn in such a way to enclose all the intensities higher or equal to I_n.

The innermost epicentral line contours the area of assigned intensity X. Each following line contours an area in which the intensity is smaller by half a degree. The outermost line represents the limit up to which an intensity VI was felt.

A separate map on a smaller scale was used to compute areas of Vth and IVth intensity grades.

The meisoseismal area is the one contoured by the isoseismal line relative to the IX degree of intensity. In this area several smaller ones have emerged in which the intensity was definitely X. It was however troublesome to group and contour these islands . It was therefore decided to contour with an intensity X isoseismic line only the triangle encompassing the localities of Gemona,Trasaghis and Osoppo.Some other islands of X intensity degree were in this way left out (e.g. a part of Venzone area).

The main feature of the map is obviously the high gradient of intensity in the South direction. To reach the isoseismal line limiting the seven intensity grade we need to travel only 16.4 km from the meisoseismal area to the South, whereas the distance amounts to 48 km if we go to the North, 55 km if we go to the SW and 69 if we go to the SE. If the intensity attenuation towards the South had been the same as the one towards the North, a quite greater portion of Friuli would have been greatly damaged, including the heavily populated area around Udine.

The slow attenuation of the intensity towards the East may be due to the tectonic feature, as the main overthrusting is in that direction. The slow attenutaion towards the SW is probabily due also to the inhomogeneous type of ground of the Pordenone area. In the following table the sizes (in km^2) of the areas in which the respective intensity was felt are shown.

Intensity	Area
X	34 km^2
IX	262 "
VIII-IX	608 "
VIII	1,658 "
VII-VIII	3,173 "
VII	6,624 "
VI- VII	13,760 "
VI	26,152 "
V	69,500 "
IV	410,000 "

4. INTENSITY ATTENUATION AS A FUNCTION OF DISTANCE

Following Sponheuer's method (1960) we tried to fit the experimental points (see Figure 3) denoting the mean attenuation of intensity using the Kővesligethy formula

$$I_o - I = 3 \log \frac{d}{h} + 1.3 \alpha (d - h) \qquad (1)$$

where:

I_o = epicentral intensity

I = intensity at a distance r

$d^2 = r^2 + h^2$ = hypocentral distance

r = epicentral distance

h = depth of focus

α = attenuation coefficient

The experimental points were determined on the basis of the isoseismal map of the May 6, Friuli earthquake (see Enclo

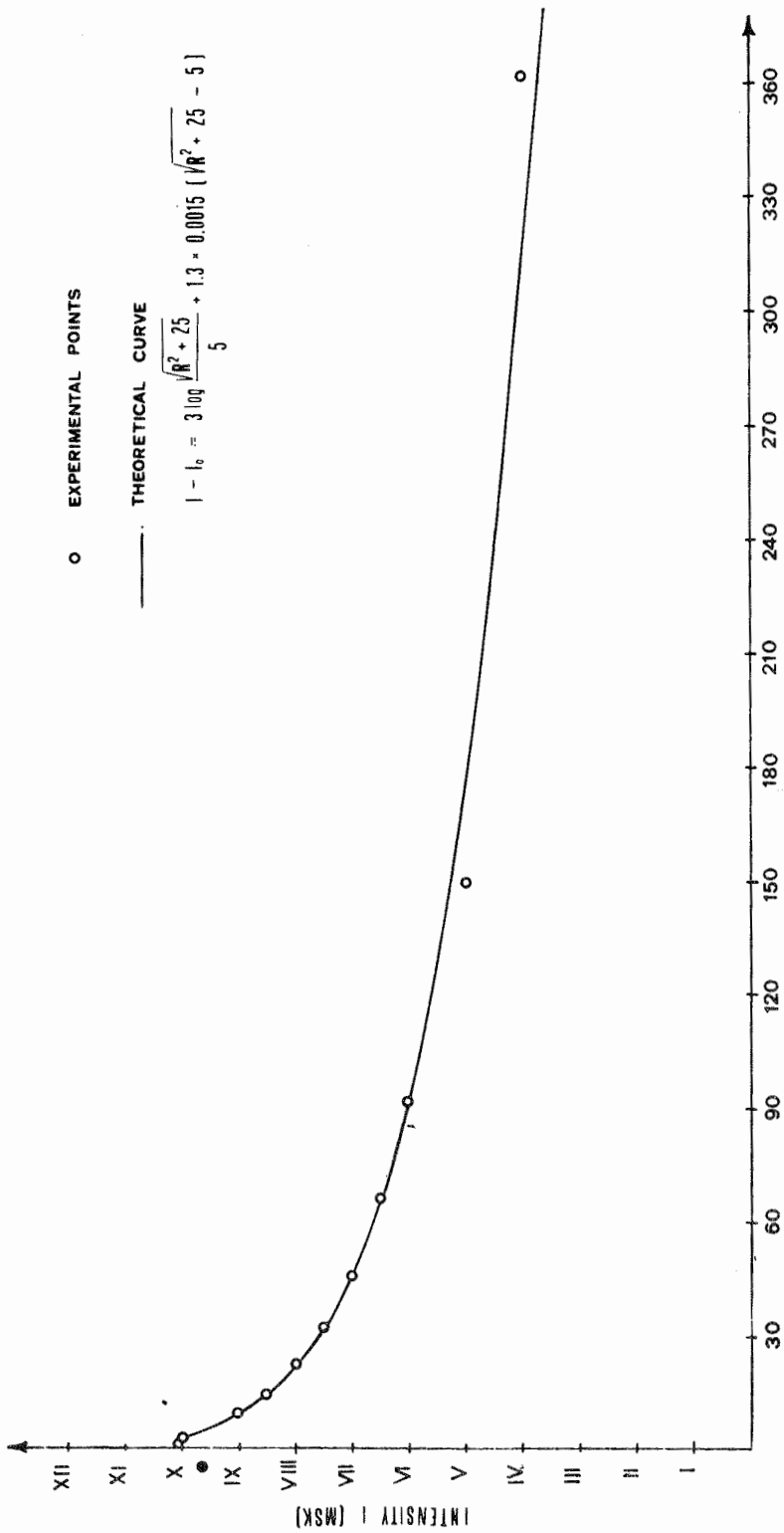
EXPERIMENTAL POINTS
THEORETICAL CURVE
$I - I_0 = 3 \log \frac{\sqrt{R^2 + 25}}{5} + 1.3 \times 0.0015 \left(\sqrt{R^2 + 25} - 5 \right)$
INTENSITY I (MSK)
XII
XI
X
IX
VIII
VII
VI
V
IV
III
II
I
30
60
90
120
150
180
210
240
270
300
330
360
RADIUS R (KM)

Fig. 3

sure 5). The best fit to the experimental points is given by the following values of focal depth and attenuation coefficient:

$h = 5$ km

$\alpha = 0.0015$

In the following table the experimental values and those determined using Kövesligethy formula with $h=5$km, $\alpha=0.0015$ are given. The differences between the experimental and theoretical values are also shown.

The fit is very good to distances up to 100 km from the meisoseismal area. The error becomes a little bigger if we consider the isoseismal lines corresponding to the 5^{th} and 4^{th} intensity grade. This is probably due to the fact that the determination of these isoseismal lines is more troublesome and therefore more approximate.

Table

r (km)	(I_o-I) exp.	(I_o-I) theor.	Δ
9	1.0	.95	.05
15	1.5	1.52	- .02
22	2.0	1.99	.01
32	2.5	2.48	.02
45	3.0	2.95	.05
90	4.0	3.93	.07
150	5.0	4.71	.29
360	6.0	6.26	- .26

5. ACKNOWLEDGMENTS

The Author is deeply indebited to dr. Suhadolc and Mr. G. Calzi for their vary valuable cooperation.

6. REFERENCES

SPONHEUER W., 1960:"METHODEN ZUR HERDTIEFEN-BESTIMMUNG IN DER MAKROSEISMIK" Geoph., C 88, Akad. Verlag, Berlin.

MACROSEISMIC INVESTIGATIONS AND MAPS FOR THE FRIULI EARTHQUAKE, MAY 6, 1976

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Abstract

A computerized method of handling macroseismic data in general is introduced. Isoseismal maps, derived from macroseismic observations in the epicentral area, as well as in Switzerland, allow the estimation of focal depth to $h = 8$ km . Attenuation factors, according to the Kövesligethy-law, are compared for several large earthquakes in the Alps.

1. Macroseismic data processing

Macroseismic data is a very special kind of geophysical data. It is not measured by any instrument, it is just felt and reported by people. Therefore a single message is influenced by the reporting person and the particular circumstances, under which this person witnessed the earthquake. Even if the earthquake caused damage to buildings, there are a lot of uncertainties in the estimation of the intensity. All these problems are well known and should not be discussed here in detail. But however, macro-

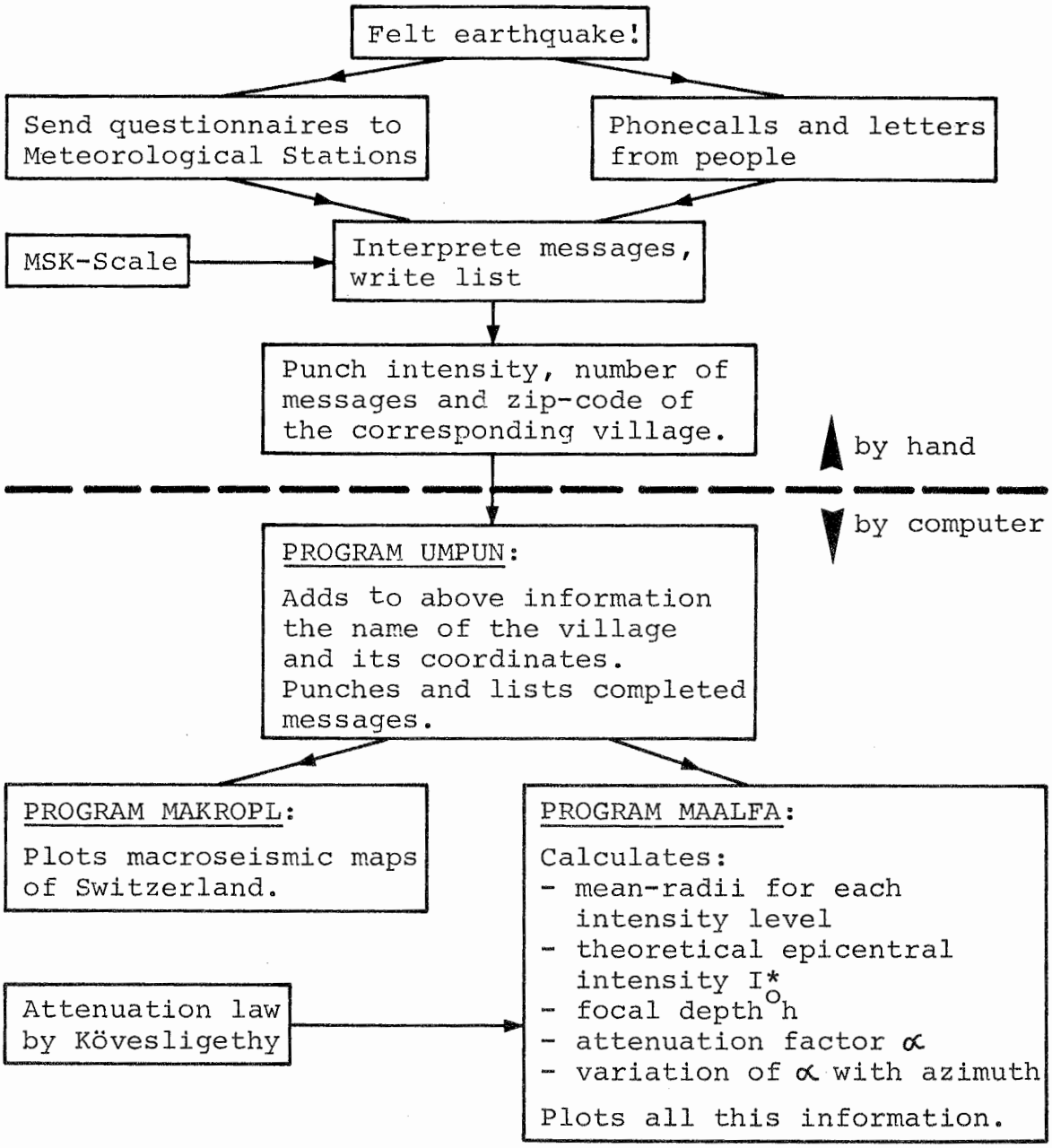

Table 1 : Processing of macroseismic data

seismic data is still of great importance, especially for seismic risk analysis, because intensity says more about the ground shaking and its integral effect on artifical buildings, than the instrumentally measured magnitude.

For that reason we developped a method to handle data as far as possible by the computer. Human interpretation was excluded, whenever possible. Table 1 shows how it works:

As soon as an earthquake was felt, questionnaires are sent to about 350 meteorological Stations, uniformly distributed over whole Switzerland. The operators of these stations are used to observe natural phenomena and therefore report much more objectively than most other people. These values allow to eliminate extreme observations from other people (especially from old, frightened ladies). All messages are interpreted according to the MSK-scale (Medvedev et al., 1964), put together for each village and punched on cards (only intensity, number of messages and zip-code). All the rest of the procedure is done by three computer programs:

a) Program UMPUN adds to the punched information the name of the village and its coordinates. It punches this completed messages and prints a complete list in decreasing order of intensities. The punch is the input for the other two programs.

b) Program MAKROPL plots macroseismic maps of Switzerland. Instead of the normally used symbols it plots numbers, indicating directly the intensity. These maps are important for determination of the macroseismic epicenter.

c) Program MAALFA does the main work. Instead of drawing isoseismals by hand, it computes the mean radii for each intensity-level. This radius is associated with an intensity, 0.5 intensity-units higher than the isoseismal-level used in Sponheuer's method (Sponheuer, 1960). An attenuation curve of the form

$$I = I_0^* - 3 \log \left(\frac{1}{h}\sqrt{h^2+s^2}\right) - 1.3\,\alpha\,\left(\sqrt{h^2-s^2} - h\right),$$

where I : intensity at distance s from epicenter (MSK)

I_o^* : theoretical epicentral intensity (calculated) (MSK)

h : focal depth (km)

s : distance from epicenter (km)

α : attenuation factor

proposed by Kövesligethy (Sponheuer, 1960), fitted to the observational data by using a least square method. This fit delivers the three parameters I_o^*, h and α. For larger earthquakes with sufficient data in all directions, the variation of α with the azimuth is calculated.

This way of handling macroseismic data is very time saving and objective as far as possible and gives results consistent with those calculated from microseismic data as shown for the Friuli earthquake of May 6, 1976.

2. Intensity attenuation for the Friuli earthquake, May 6, 1976.

2.1. The data

The mean radii s for the intensity-levels IX, VIII and VII were calculated from the equal area circles of isoseismals. The isoseismals were obtained by a group of Swiss engineers, who made reconnaissance of the damage in the epicentral area (Glauser et.al., 1976). The subsequent radii for the intensity levels VI and V were estimated from reports and local newspapers of the areas envolved. Thereby only the sector towards Switzerland was taken into consideration. In Switzerland the earthquake was felt with a maximum intensity of IV in the eastern part of the country, up to the distance of 430 km from the epicenter. A macroseismic map of the epicentral area as well as of Switzerland was published by Mayer-Rosa et.al., 1976.

2.2. The results

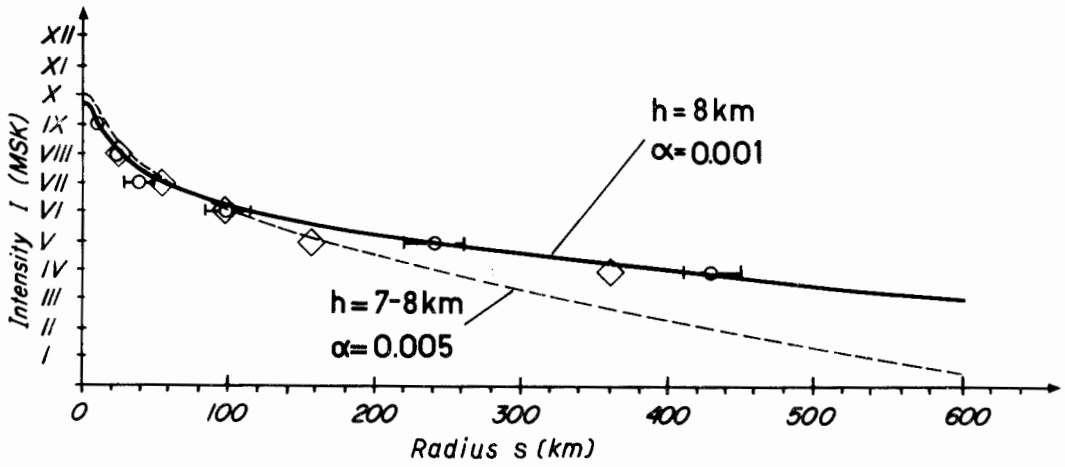

Figure 1 : Attenuation curves for the Friuli earthquake May 6, 1976

Figur 1 shows the attenuation curve (solid line, data points = circles) calculated as described in chapter 1. The horizontal bars indicate the range of uncertainty. This curve indicates a focal depth of 8 km with an attenuation factor of 0.001. As will be shown in chapter 3, attenuation factors of about 0.001 also explain macroseismic maps obtained from earthquakes in the Suthern Swiss Alps. The focal depth of 8 km coincides very well with the instrumentally determined depth of focus (CSEM-working group, 1976) of about 7-8 km.

The dashed line in figure 1 (data points = quadrilaterals) shows the attenuation curve based on a collection of macroseismic observations from Czechoslovakia, Austria, Federal German Republic, France, Poland, Switzerland and Yugoslavia (Karnik et.al., 1976). This curve was correlated to a focal depth of 7-8 km and an attenuation factor of 0.005. The higher

attenuation factor is obviously the result of not taking in consideration the data point for I = 4 (s = 360 km).

3. Comparision of attenuation factors

The attenuation factor α of the Friuli main shock is compared with the α-values of 4 large and well documented earthquakes in the Southern Swiss Alps.

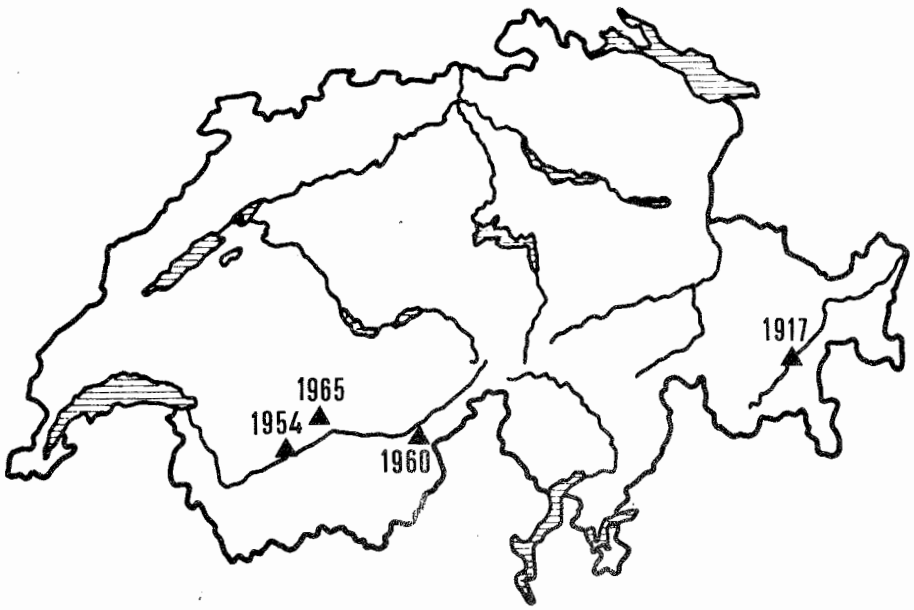

Figure 2 : Location of the 4 earthquakes

Figure 2 shows a map of Switzerland and the location of these 4 earthquakes, indicated by triangles. The numbers indicate the year of occurence. The largest shock, that caused considerable damage to buildings in the epicentral area (City of Brig, Canton Valais) occured in march 24, 1960.
Figure 3 shows the calculated attenuation curves for these 4 events. In two cases an attenuation factor of 0.001 (1954 and 1965) and in the two other cases of 0.005 (1917 and 1960) was found (see Table 2).

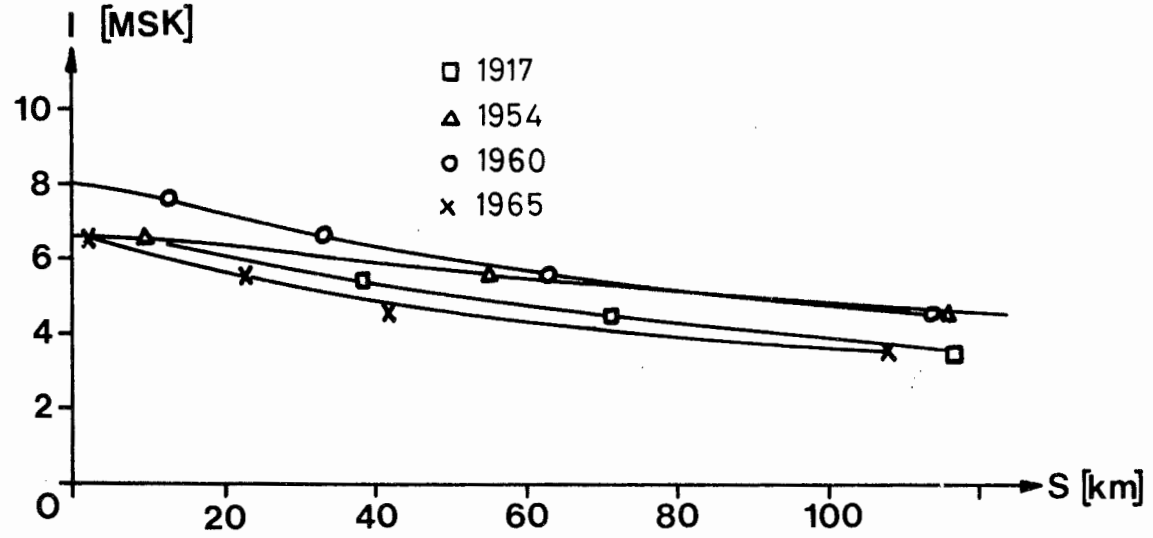

Figure 3 : Calculated attenuation curves

DATE	GMT	I_o^*	h [km]	α
1917 dec 9	21:41	6.7	18	0.005
1954 may 19	9:35	6.5	30	0.001
1960 mar 23	23:09	7.9	14	0.005
1965 oct 24	12:16	6.5	12	0.001

Table 2 : Parameters of the 4 attenuation curves plotted in figure 3

References

1. CSEM-working-group, Revised parameters for Friuli earthquakes 1976, Proc. Udine 1976, Meeting on Friuli earthquake, 1976.

2. Glauser, E. et.al., Das Erdbeben im Friaul vom 6. Mai 1976, Beanspruchung und Beschädigung von Bauwerken, Schweiz. Bauzeitung, 38, 555-573, 1976.

3. Karnik, V. et.al., Macroseismic effects of the Friuli earthquake of May 6, 1976 in Austria, Czechoslovakia, F.G.R., France, Poland, Switzerland and Yugoslavia, Proc. Udine 1976, Meeting on the Friuli-earthquake, 1976.

4. Mayer-Rosa, D. et.al., Investigations of intensities, aftershock-statistics and the focal mechanisme of the Friuli earthquake May 6, 1976, Pure Appl. Geophys., 6 (in press), 1976.

5. Sponheuer, W., Methoden zur Herdtiefenbestimmung in der Makroseismik, Freiberger Forschungshefte C88, Akademie Verlag Berlin, 1960.

Contribution No. 170, Institute of Geophysics, Swiss Federal Institute of Technology, Zurich

TOPOGRAPHICAL EFFECT ON THE DISTRIBUTION OF EARTHQUAKE DAMAGE

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University of Tokyo
Yayoi 1-1-1, Bunkyo, Tokyo, Japan

In this earthquake, many buildings made of stone or brick without reinforcing were damaged severely and the reason of such a weekness against earthquake could be explained by such a brittleness in their materials.

Among these brittle buildings, the author could recognize the difference of severeness of their damages corresponding to their location from macroscopical view points.

Relative to the location of severe damages, the following two points will be accepted ;

1. Damaged towns are located in the vicinity of rocky and hard hill or mountain, and are located on the comparatively soft surface deposit.
   Venzone, Gemona, and Osoppo could be pointed out as examples.
2. Severe damages happened to the buildings at the top of hills or at the top of cliffs.
   Castello of Gemona and many churches are pointed out as examples.

The author made simulation through Finite Element Method in order to explain the above mentioned phynomena.

Fig.1 indicates the mesh model for the cross section of Gemona town.

Boundary conditions are of free in both sides and of fixed type at the basement of the ground. Input earthquake is a strong motion seismograph recorded at Tolmezzo during this earthquake.

In our simulation, the velocity of S wave in hard mountains is adopted 500m/s and that in soft deposits 100m/s. An actual velocity of S wave in rock is considered to be much more, however, the adopted velocity is limited as above by the stability condition of FEM computation.

Fig.2 shows the maximum ground acceleration on the ground surface of Osoppo due to the horizontal input earthquake.

From this figure, ground acceleration in the region of approximately 300 m from the rocky hill much severer than in other region, and especially, we have to recognize that strong vertical components of acceleration are generated in the above mentioned region, even though the input earthquake of this simulation is of only the horizontal component.

Stone or brick buildings are considered to resist against earthquake mainly by means of its friction which is produced by their dead weights, however, vertical components of ground acceleration decrease their dead weight and friction as a result.

The author considers that this generated vertical ground motion and amplified horizontal acceleration made a big role in severe damages in vicinity of rocky hills.

Fig.3 shows almost the same max. acceleration distribution of Gemona town, and in this case we can find the severe horizontal and vertical acceleration on the slope deposit on which the severest damaged part of Gemona is located.

MOTOHIKO HAKUNO

Concluding Remarks

The author made clear that a topographical effect on the acceleration on the ground surface, and on the damages of towns is not small, so we have to take in to account of this effect at the time of Microzonation.

The author wishes to give his sincere thanks to Prof. Grandori in Milano Politechnic,Mr. Corvo in Udine city and his colleagues for their heartful conveniences given at damage survey.

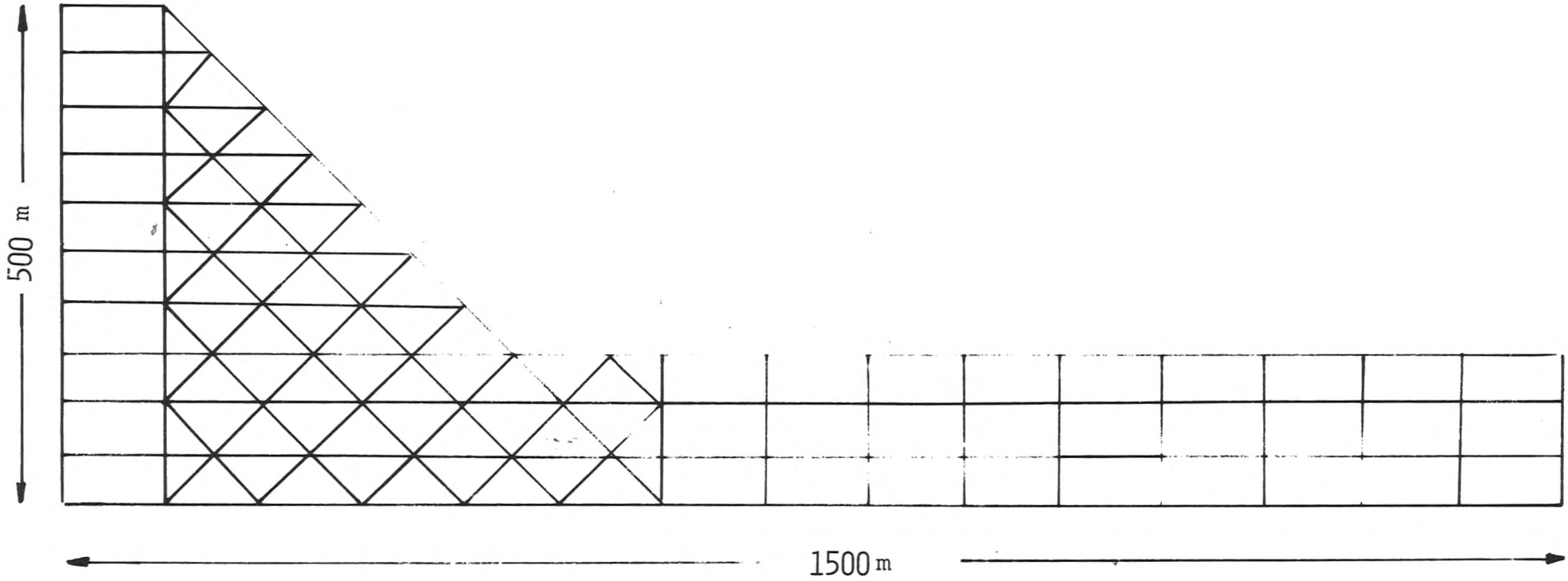

Fig. 1

Mesh Division for FEM Simulation at the Town of Osoppo.

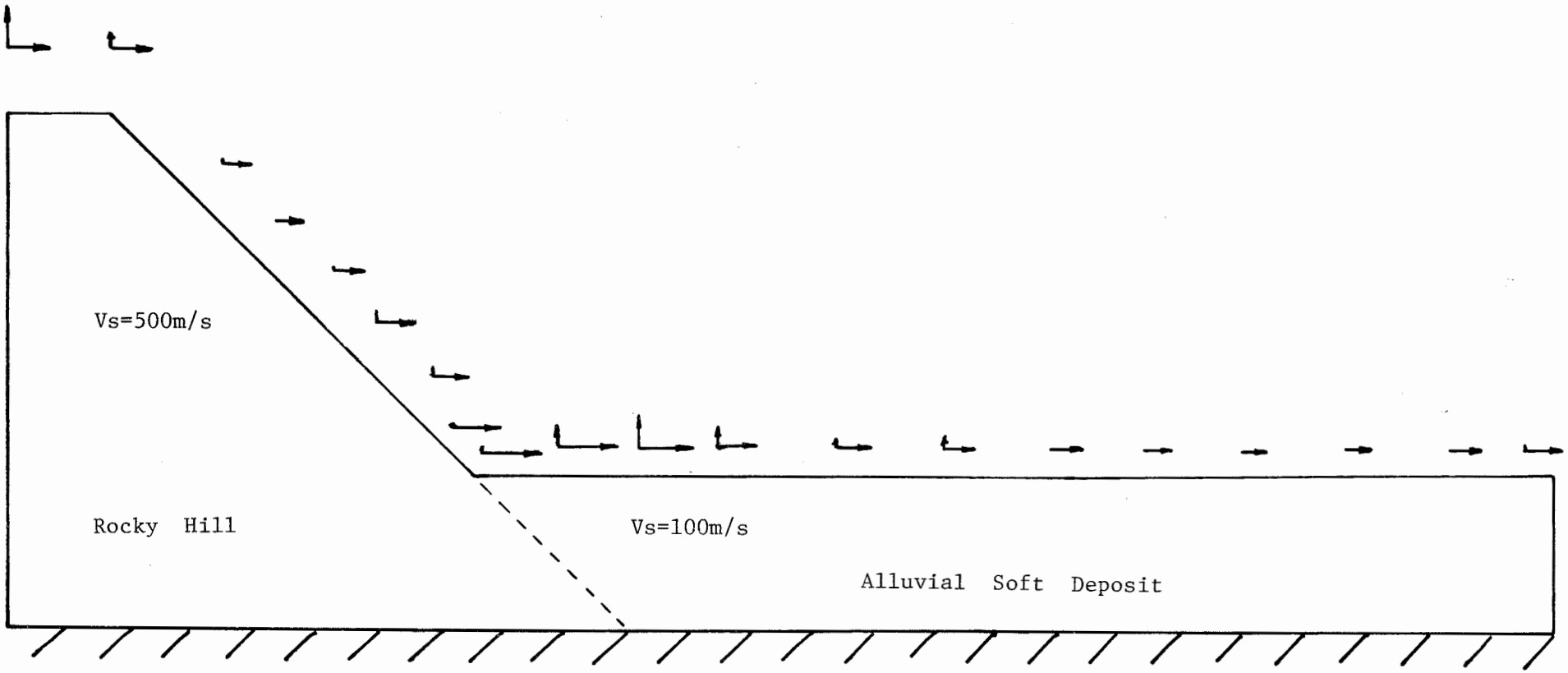

Fig. 2

Distribution of Maximum Acceleration on the Ground of Osoppo.

Input Earthquake : Strong Motion Record at Tolmezzo.

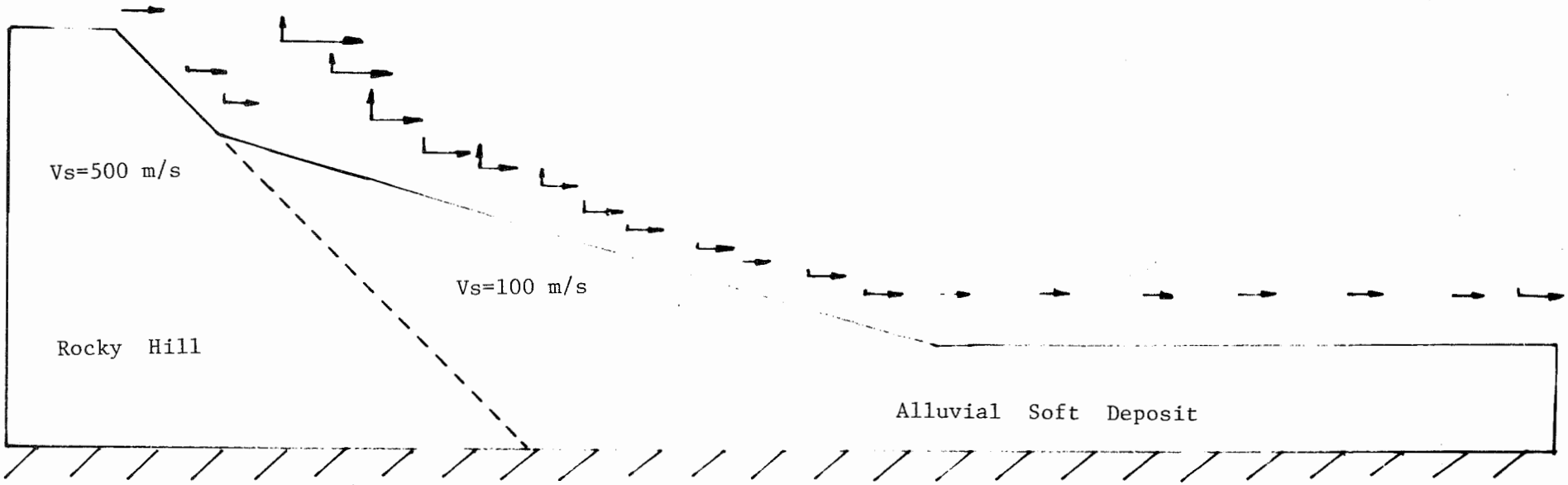

Fig. 3

Distribution of Maximum Acceleration on the Ground of Gemona.

Input Earthquake : Strong Motion Record at Tolmezzo.

MACROSEISMIC EFFECTS OF THE FRIULI EARTHQUAKE OF MAY 6, 1976 IN AUSTRIA, CZECHOSLOVAKIA, F.G.R., FRANCE, POLAND AND YUGOSLAVIA

BY

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S U M M A R Y

The macroseismic field of the earthquake of May 6, 1976 shows the typical irregular extension towards the North observed for all shocks in the Eastern Alps. The map is not complete because the macroseismic information from Italy and G.D.R. has not yet been made available.

INTRODUCTION

This paper originated on the initiative of the seismologists from Czechoslovakia who invited the seismologists from other countries to combine individual portions of the macroseismic field into one isoseismal map. The result is shown in Fig. 1, the map has a preliminary character and needs completion by data from Italy and G.D.R. +).

MACROSEISMIC SURVEY IN CZECHOSLOVAKIA

For a systematic collection of macroseismic observations the territory of Bohemia and Moravia was divided into unit areas of 10 km x 10 km and macroseismic questionnaires were distributed to at least one locality within each area. 2841 reports from 566 localities on the territory of Bohemia and Moravia were collected, 2588 reports from 459 localities being positive. In Slovakia the investigated earthquake was observed only in two localities - Bratislava and Kúty.

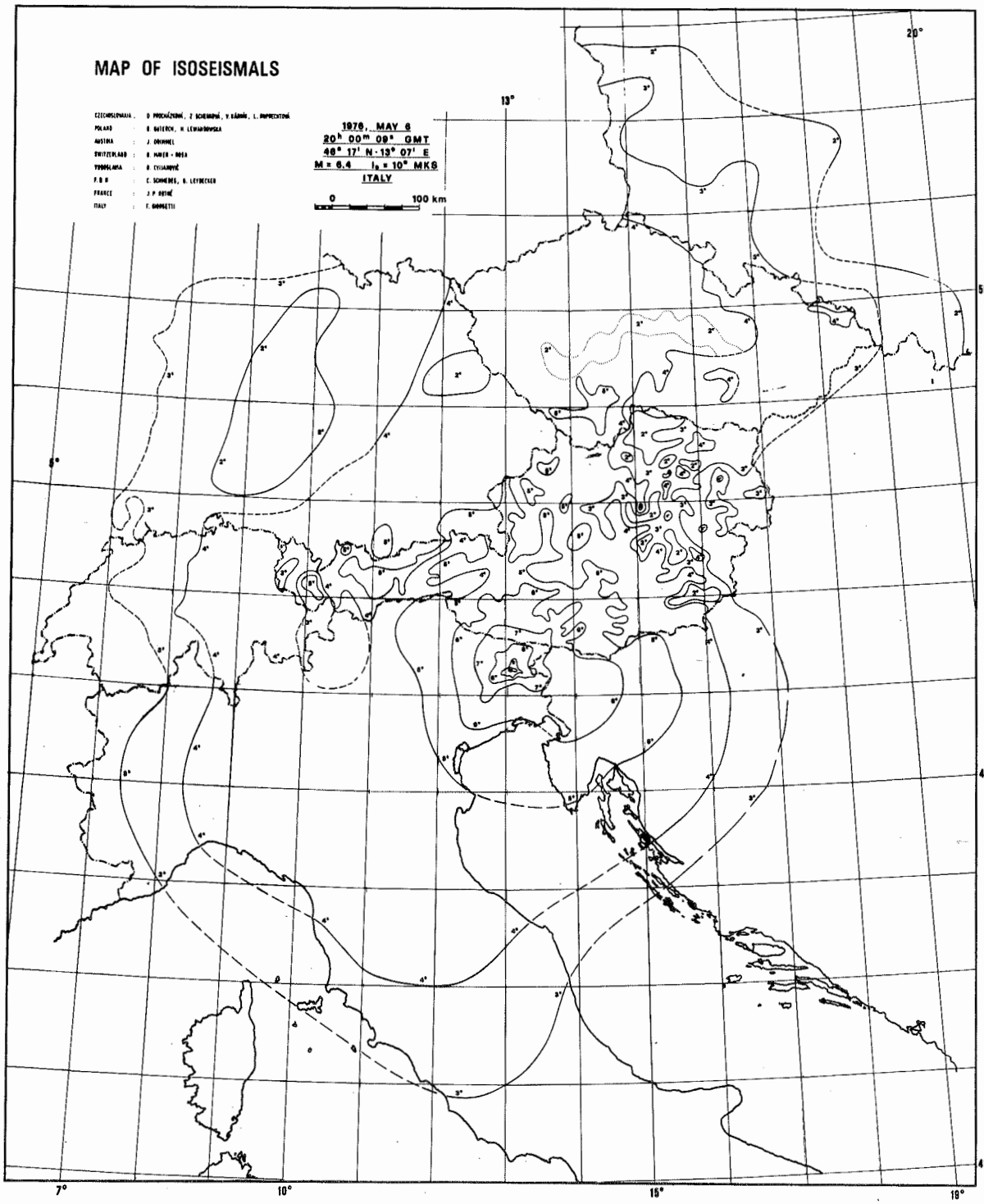
The observed effects were classified according to the macroseismic scale MSK-64 with the accuracy of $\pm$ 0.5^{c}. The

+) Note added in proof : Isoseismal map for Italy which has been just provided by Dr.F.Giorgetti will be added to our map.

observations from the 5th and higher floors were reduced by an empirical correction -0.5° which may be too small for the tenth and higher floors. The localities for which tree or more reports were available were represented by a statistical mode representing a typical value of intensity with the largest frequency. For two observations the arithmetical mean was used.

The representative values of intensity were drawn on a map to the scale of 1 : 1 million. The Bohemian Massif is covered densily by the observations and differs from the Carpathian region where macroseismic phenomena are very scarce probably because of strong damping towards NE and E. This pattern is typical for the macroseismic fields of all earthquakes originating in the Eastern Alps.

The regional deviations connected with the geological structure of the Bohemian Massif are oriented particularly in zones of SW-NE direction and partly also of NW-SE direction. The observations are concentrated in the regions of deep fault structures (mainly crossing faults) which were regererated in the neotectonic era. There sedimentary complexes originated as a consequence of subsidence e.g. in the South-Bohemian Basin (see the isoseismal 5°, Fig. 1), then the Krušné Hory Basin, the Ostrava Basin and the North Bohemian Cretaceous. The existence of a quiet zone oriented nearly W-E should be noted; it separates South and Central Bohemia (see Fig. 1). A relatively low density of observations exists in the region of the Moravian Block which appears as a stable formation in this case. The influence of local ground conditions was well manifested on the territory of Prague, a detailed isoseismal map under preparation. The main problem is the evaluation of the behaviour of tall buildings (10 and more floors) which oscillated strongly.


MAP OF ISOSEISMALS
CZECHOSLOVAKIA : D. PROCHÁZKOVÁ, Z. SCHENKOVÁ, V. KÁRNÍK, I. MRLINA
POLAND : B. GUTENBERG, H. LEWANDOWSKA
AUSTRIA : J. DRIMMEL
SWITZERLAND : B. MAYER - ROSA
YUGOSLAVIA : D. CVIJANOVIĆ
F.R.G. : C. SCHNEIDER, G. LEYDECKER
FRANCE : J.P. ROTHÉ
ITALY : F. BARBETTI
1976, MAY 6
20h 00m 09s GMT
46° 17' N - 13° 07' E
M = 6.4 I0 = 10° MKS
ITALY
0 100 km
20°
13°
50°
6°
45°
41°
7°
10°
15°
19°

MACROSEISMIC SURVEY IN AUSTRIA

The Austrian macroseismic map of the Friuli earthquake is based upon about 1600 well distributed reports. Many of these observations are collective reports from local police and other authorities and are therefore reliable. The determination of the earthquake intensity was evaluated by means of the MSK-64 scale.

The map of isoseismals (original scale 1 : 500 000) shows very clearly the anisotropic radiation and propagation of seismic energy from the hypocentre near Gemona towards the North and Nortwest : in the Northeastern and Eastern parts of Austria limited areas with intensities below 4° MSK-64 or even with negative reports are frequent, however, throughout the rest of Austria there are mostly high intensities, reflecting in many cases the complicated geological conditions of the Alpine area.

The Friuli earthquake reached the southern border of Austria with an intensity of 7.5° and caused generally slight to moderate damage in wide parts of Carinthia (Kärnten) and East Tyrol (Osttirol); the most serious damage to buildings occurred in the valley of the river Gail. The irregular area of earthquake intensity at least 6° MSK-64 has an area of about 5350 km^2 in Austria; in this value about 800 km^2 correspond to intensities between 7 and 7.5° . In epicentral distances of more than about 200 km there were strong teleseismic effects (resonances of multi-story buildings susceptible to relatively long period oscillations, of factory chimneys, of lustres. Stopping of pendulum clocks was caused by the maximum phase with a duration of 20 to 40 seconds and a dominant period of about 1 to 1.5 seconds. A clear classification by the macroseismic scale was not feasible in each case, because, for instance in Vienna, there were many negative reports from a very limited area as well as informations about frigh-

tened persons, somewhere even leaving the buildings.

MACROSEISMIC SURVEY IN THE FEDERAL GERMAN REPUBLIC

On the basis of macroseismic observations in about 60 localities in F.G.R. the map of isoseismals for this territory was constructed (original scale 1 : 1 million). The investigated area was shaken with intensities up 2^{o} to 5^{o}. The intensity 5^{o} was observed in two areas in the Southern part of F.G.R. on the boundary with Austria. The course of isoseismals on this frontier agrees with the isoseismals on the territory of Austria. The South-Eastern part of the investigated territory was shaken with the intensity 4^{o}. In Figure 1 two regions in which the macroseismic intensity was smaller than 3^{o} are marked. It is noteworthy that the macroseismic field reached the towns North of Hannover.

MACROSEISMIC SURVEY IN FRANCE

The French portion of the macroseismic map (original scale 1 : 320 000) was constructed on the basis of macroseismic observations in the regions Haut-Rhin, Bas-Rhin, Vosges, Meurthe-et-Moselle and Moselle. The observed intensities range from 2^{o} to 5^{o}; in most cases the intensity 3^{o} appears, therefore, the corresponding isoseismal is marked in Figure 1. The shock was strongly felt in the Rhin Graben where sedimentary complexes reaches to several thousand meters and was not practically macroseismically felt in the crystalline area of Vosges and in the great part of the plateau Lorrain. The real boundary of compact macroseismic field corresponds almost exactly to the line marking the epicentral distance 500 km. The macroseismic observations in larger distances, for example in towns Epinal, Nancy etc. are sporadic.

MACROSEISMIC SURVEY IN POLAND

Map of isoseismals on the territory of Poland was constructed on the basis of macroseismic observations in about 100 localities in South-Western Poland (the fore-Sudetic monocline). The intensities range from 2^{o} to 4^{o}. In greater towns, for example in Warsaw, Lodz, Torun single observations in higher floors of prefabricated buildings were reported. In Figure 1 the isoseismals of degree 3^{o} and 2^{o} are marked.

MACROSEISMIC SURVEY IN SWITZERLAND

The map of macroseismic observations in Switzerland is based on the direct investigation of about 200 rain-measuring stations belonging to the meteorological agency. They are distributed equally all over the country. A special form was distributed to all persons in charge of the stations. Intensities derivered from these questionnaires are defined according to the MSK-64 scale. The maximum felt intensity in Switzerland for the investigated shock is 4^{o} in the Eastern part of the country. It is remarkable, that this earthquake was not felt in the Western part of the country, i.e. in the Cantons of Valais and Vaud. For the territory of Switzerland the isoseismals 4^{o} and 3^{o} were constructed. Their course fits well the corresponding isoseismals on the frontiers with F.G.R. and France.

MACROSEISMIC SURVEY IN YUGOSLAVIA

The investigated shock was macroseismically felt on the North-Eastern part of Yugoslavia. The degrees from 2^{o} to 8^{o} were observed. The corresponding isoseismals are marked in Figure 1. The isoseismals of degrees 7, 4 and 3 agree well with the isoseismals in Austria. The isoseismals of degree 6

and 5 extend farther to the East in Yugoslavia than in Austria and Hungary; a certain shift is observed.

CONCLUSIONS

The isoseismal map for the territory of Austria, Czechoslovakia, F.G.R., France, Poland, Switzerland and Yugoslavia at the scale 1 : 1 million in Figure 1 demonstrates well the known extension of the macroseismic field in the N and NW directions to large epicentral distances and on the other hand a quick damping of the macroseismic phenomena to the East. This phenomenon is typical for all East-Alpine earthquakes. The regional deviations connected with the geological structure appear throughout the whole investigated area.

Using average radii of isoseismals (r_8 = 25 km, r_7 = 55 km, r_6 = 100 km, r_5 = 160 km, $r_4 \geq$ 350 km, $r_3 \approx$ 550-600 km) and the Kövesligethy formula (Fig. 2 : Intensity atteunation with epicentral distance) the depth of focus h = 7 - 8 km and the atteunation α = 0.005 were estimated.

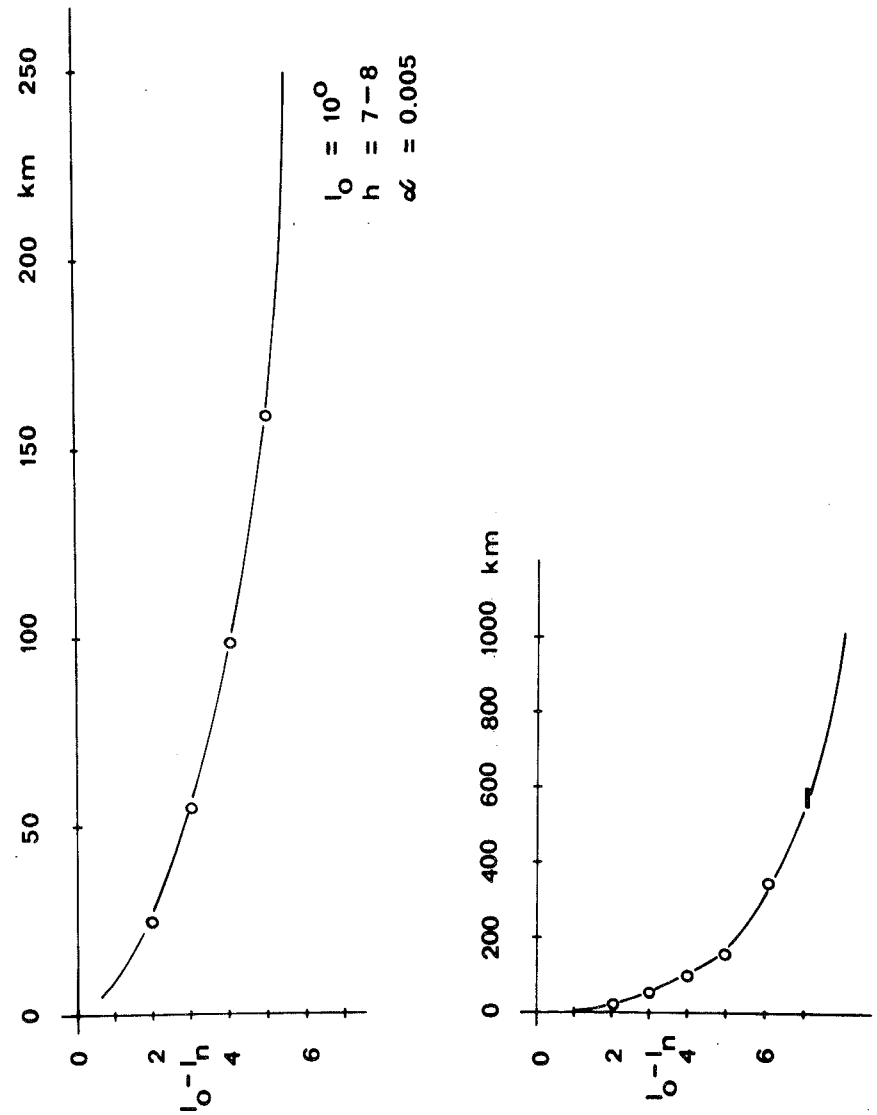

0
50
100
150
200 km 250
0
2
4
6
$I_o - I_n$
$I_o = 10^o$
h = 7–8
α = 0.005
0
200
400
600
800
1000 km
0
2
4
6
$I_o - I_n$

Fig. 2

RESEARCH ON THE RELATIONSHIPS BETWEEN SURFACE GEOLOGY AND SEISMICALLY ACTIVE TECTONIC STRUCTURES

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Comitato Nazionale Energia Nucleare
Centro Studi Nucleari Casaccia
ROMA - Italia

The knowledge of the relationships between surface geology and seismically active tectonic structures is a fundamental step for evaluating the potential seismic level, or in other words, for evaluating the seismic forces at the ground surface.

Having this purpose in mind, researches along several directions have been performed in the NE part of Italy after the May 6th earthquake in Friuli.

We report here some considerations about the relationships among the paleogeography, tectonics, historical seismicity and Bouguer's anomalies of the area.

Our past experience, based on field observations and analysis of historical seismicity data, is indicating that the boundaries of fault basins can be delimited by still active tectonic features.

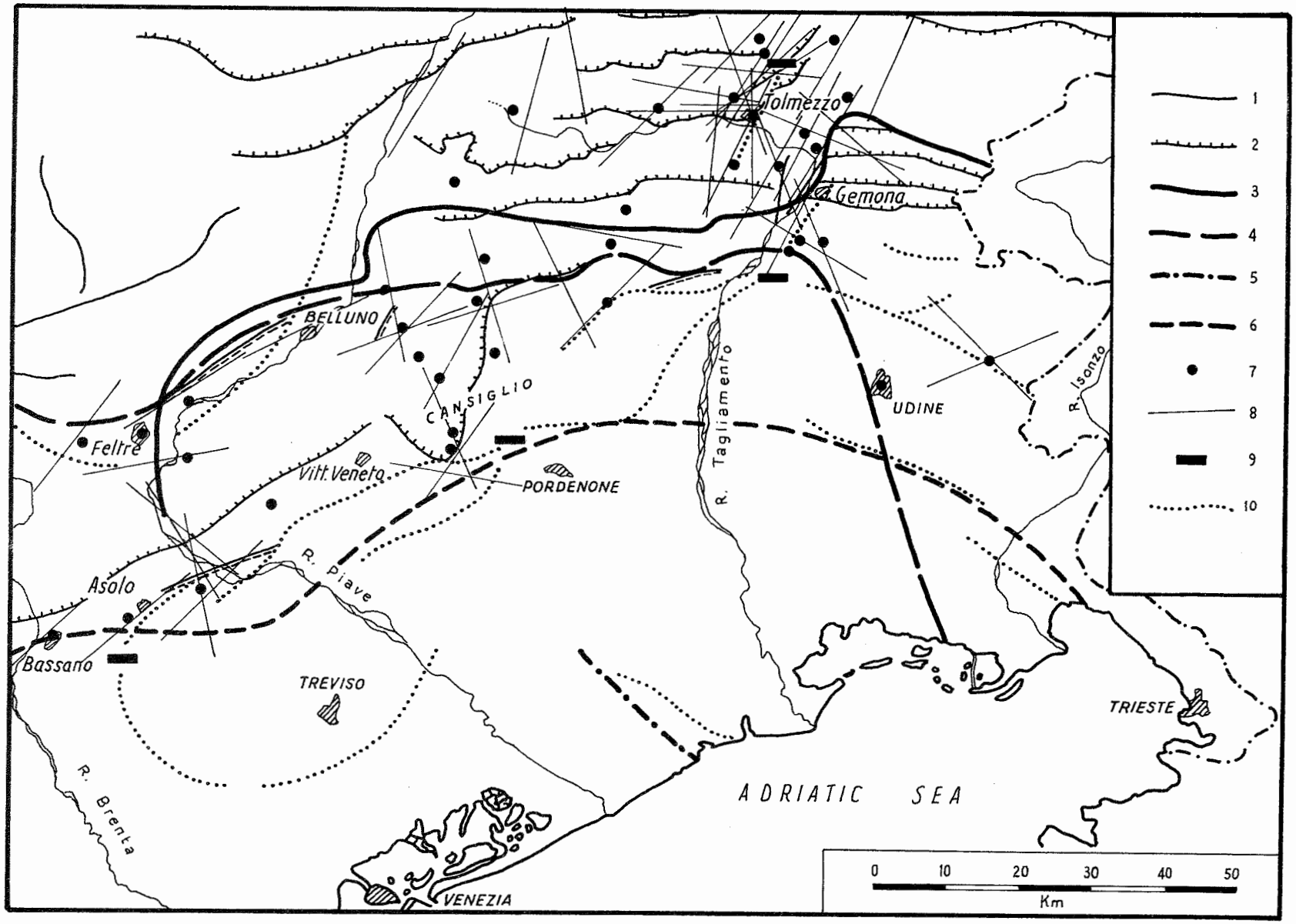
Tolmezzo
Gemona
BELLUNO
CANSIGLIO
R. Tagliamento
UDINE
R. Isonzo
Feltre
Vitt. Veneto
PORDENONE
Asolo
R. Piave
Bassano
TREVISO
TRIESTE
R. Brenta
ADRIATIC SEA
VENEZIA
1
2
3
4
5
6
7
8
9
10
0 10 20 30 40 50
Km

Fig. 1

With the aim to check once again the validity of this convinction the paleography reconstruction of the sedimentary basins developed East of the tectonic structure Schio-Vicenza during the Upper Cretaceous-Eocene, the Miocene, the Lower Pliocene and the Lower Quaternary have been drawn (Fig. 1).

On the same figure the main tectonic structures described in geological bibliography, the macroseismic epicenters with depths greater than 5 km, the directions of major propagation of seismic waves have been superimposed.

Looking from West to East to the boundary of the Upper Cretaceous-Eocene basin (flysch), we can observe that the South part of the boundary, along the Piave river (where it is overlain by younger deposits) is passing through a seismic area and it is roughly identifiable with some directions of major propagation of seismic waves. Therefore probably deep tectonic structures capable of generating earthquakes correspond to the South extension of the boundary of the above mentioned basin.

Fig. 1 - Relationships among paleogeography, tectonics, historical seismicity and Bouguer's anomalies of Friuli area (1:normal and transcurrent faults; 2: reverse faults and overthrusts; 3: boundary of the Upper Cretaceous-Eocene basin; 4: boundary of the Miocene basin; 5: boundary of the Lower Pliocene basin; 6: boundary of the Lower Quaternary basin; 7; macroseismic epicenters with depths greater than 5 km; 8: directions of major propagation of seismic waves; 9: minima of Bouguer's anomalies; 10: "valleys" of the Bouguer's isoanomalous curves).

Similar considerations are valid for that part of the boundary that follows the Tagliamento river almost parallel to the faults located along Cavazzo lake and Tagliamento valleys.

As far as the Miocene basin (molasse) is concerned, its boundary between Brenta and Tagliamento rivers, is more or less oriented according to the directions of major propagation of seismic waves and of important tectonic structures.

Again we can argue that probably deep seismically active tectonic structures are located beneath this part of Miocene basin boundary.

The boundary of the Lower Pliocene sedimentary basin can be only partially followed; nevertheless we can observe that:

- the basin is limited by a normal fault cutting the underlain cretaceous limestones;
- tectonic structures, directions of major propagation of seismic waves and macroseismic epicenters have the same trend of the NNW extention (Cansiglio zone) of the boundary of the basin.

Examining the boundary of the Lower Quaternary sedimentary basin we can observe that:

- the important seismic centres of Asolo and of Cansiglio area are located near the boundary of the basin;
- almost all the macroseismic activity is located North of the boundary of the basin;
- the part of boundary passing South of Udine, in the area of Pozzuolo del Friuli, follows an active fault.

The main features concerning the Bouguer's anomalies can be summarized as follows:

- It seems to exist a connection between seismic activity and the areas

where the Bouguer's anomalies are minima: the seismic areas of Asolo, Cansiglio, Gemona and Tolmezzoare located near the zones where the Bouguer's anomalies reach their minima.

- A considerable portion of the boundaries of the sedimentary basins, particularly that of Lower Quaternary, can be identified with the "valleys" of the Bouguer's isoanomalous curves; the extension of the boundary of the Miocene basin East of Tagliamento river shows the same direction of a "valley" of Bouguer's isoanomalous curves and of a major propagation direction of seismic waves.
- The directions of major propagation of seismic waves often seem to be associable to such "valleys" (see the areas of Asolo, Belluno, Gemona, Tolmezzo, etc.).
- Also tectonic structures located or not at the border of sedimentary basins (fold of Belluno-Feltre; reverse fault of Bassano del Grappa-Vittorio Veneto; faults systems of But-Chiarzot, North of Tolmezzo, and of Tagliamento and Cavazzo valleys; Pozzuolo del Friuli active fault) seem to be associable to "valleys" of Bouguer's isoanomalous curves.

It seems to us premature to attempt to give an interpretation of physical basis of the correlation among Bouguer 's anomalies, macroseismic activity, boundaries of sedimentary basins and tectonic structures.

Only an extensive study of all the data that we are still gathering and elaborating will throw some further light on it.

RESPONSE SPECTRA ANALYSIS FOR DIFFERENT SITES IN FRIULI

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V.PETRINI[OO] R.RAMPOLDI[O]

It is well known that the Fourier spectrum shape of an earthquake, if we don't take into account the recording instrumentation characteristics, is a function of three factors, that is:

I) the focal parameters (magnitude, and so on);
2) the distance between the hypocentre and the recording station, and the characteristics of the medium;
3) the local geological conditions.

Now, our principal goal is to determine how and how much local geological conditions affect the characteristics of the Fourier spectra, and therefore of the response spectra too, of Friuli earthquakes.

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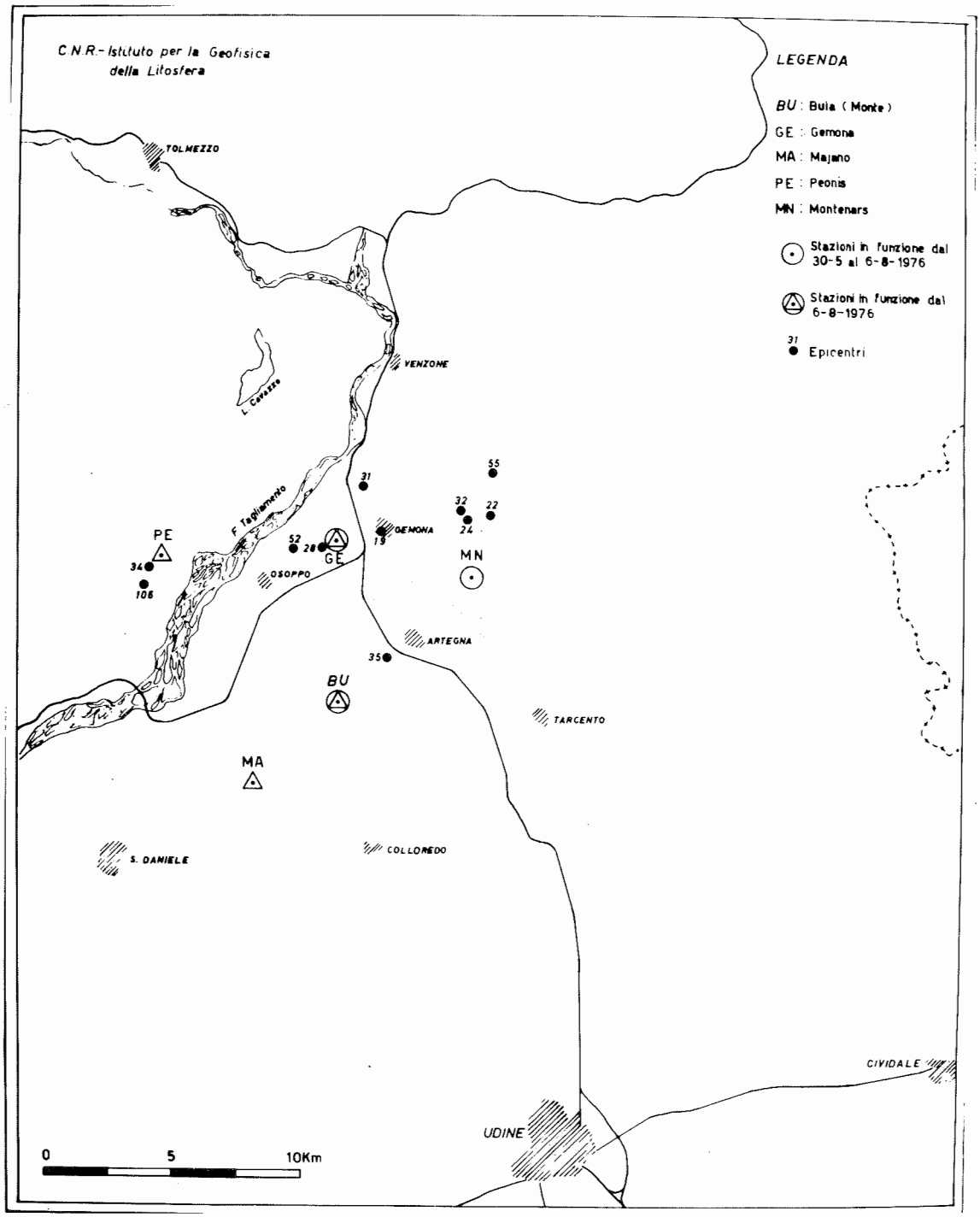

Fig.I - Semplified map of Friuli shaked area, showing stations position and some epicentres

This could allow us to:

a) define the variations of the shaking characteristics for the same earthquake at different sites, and/or for different shocks at the same place, both for intensity and frequency distribution, for anti-seismic engineering purposes;

b) establish some quantitative relations between small and larger earthquakes;

c) attempt for a reconstruction of the characteristics of the May 6 event in different places.

In practice, we want to know which is the influence of the three factors above mentioned. This can be done, at the moment, in a statistical way only, that is knowing and treating a great quantity of both geological and seismological primary data.

In order to get the necessary primary seismological data, we first installed a network of three stations (BU, GE and MN in Fig.I) in three different local geological conditions, that is:

BU : at the top of a hill, sandy flysch made; three component central station;

GE : in the alluvial plane of the Tagliamento river; in this position the alluvium is some 200 m. thick and the depth of the water table is some few meters (Martinis, personal communication); vertical component only;

MN : few meters of morenic material, lying above calcareous flisch; vertical component only.

Short period seismometers are employed.

All the informations are recorded on a multichannel magnetic tape recorder placed at BU central station; MN and GE are radio-linked to BU. Radio signals for timing are ensured by a D.C.F. receiver. The replay is

done on a high speed Siemens jet-pen.
The whole sistem is linear, within 3dB, between 0.9 and 23 Hz.
This network was in function from May 30, to August 6.

In a second time we changed and improved it: instead of MN, we installed two new stations (PE and MA in Fig.I) with horizontal components. An horizontal component was added to GE station.
The local geological condition for the two new stations is:
MA : silty morenic material about 30 m thick;
PE : compact carbonatic rocks.
This network is still recording.

In spite of the numerous, obvious, difficulties which contrasted the data collecting, a number of significant shocks was recorded up to now. Unfortunately we had no time enough to study them in a complete way.

That is why what we are presenting now is essentially a methodology and just some applications.
General results will be presented and discussed in a future work.

Particular attention is paid for the data qualification. Only those events which are significant in all the stations are considered.
The recording quality must be good, too.

The epicentres of the considered shocks are computed; we used a geometrical model based on the first arrival time to the stations. In Fig.I one can see the epicentres of some shocks from the period May 30-June I2; of course we need an accurate hypocentral position; therefore we must know the velocity function in the area.

Signals from analog magnetic tapes are converted into digital; the digitizing procedure is automatically performed by a computer: the sampling interval is constant and equal to 0.02 seconds.

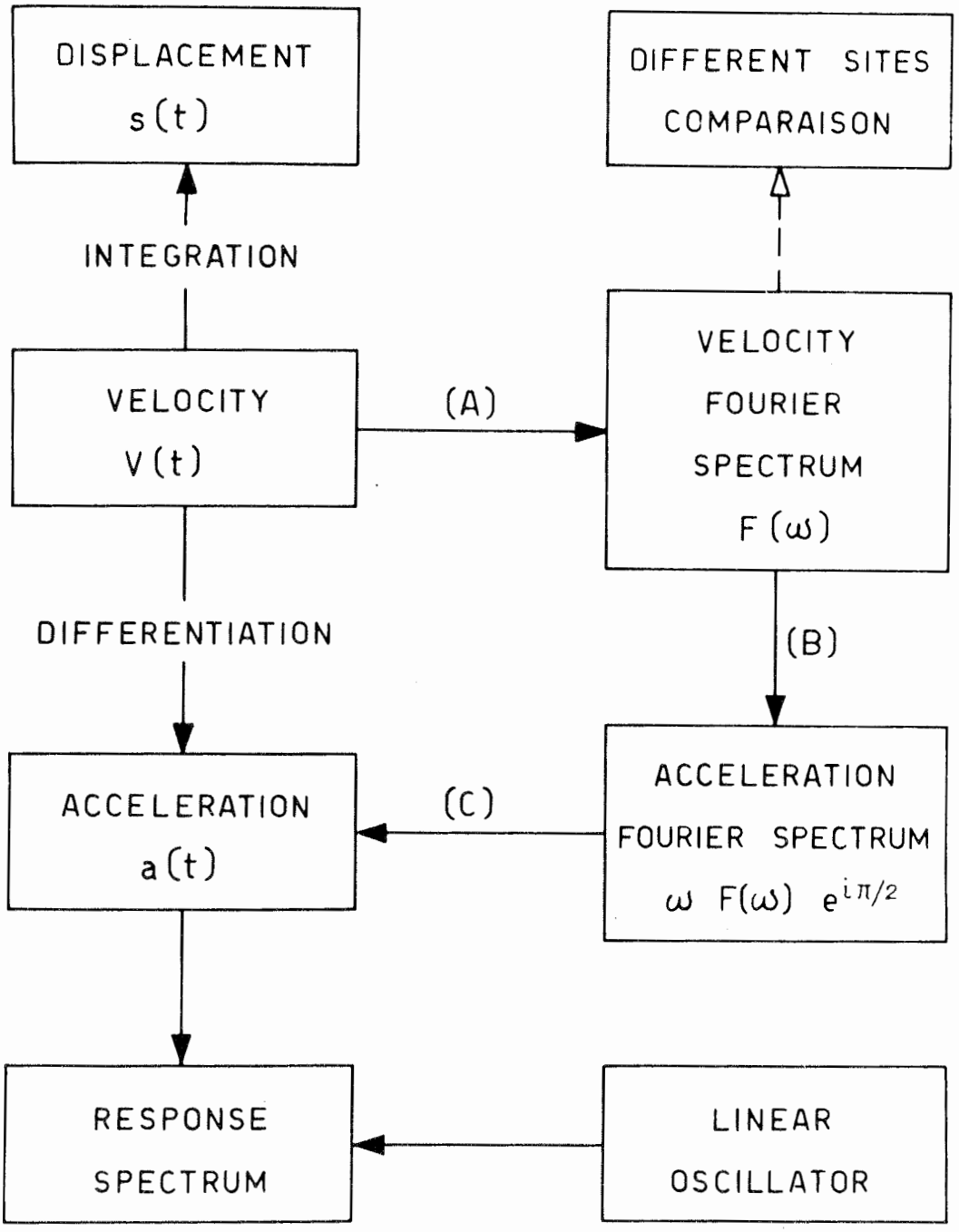

Fig.2 - Scheme of the procedure to obtain Fourier and response spectra starting from the velocity of the ground motion

The digitized data are treated as follow:

I) preliminary adjustement of the base line and plotting of the data in order to check the accuracy of the digitizing procedure is performed;

2) a precision adjustement with linear regression method is performed;

3) maximum velocity and maximum displacement of the ground are computed, in order to give some initial seismological data directly useful to the seismic engineering;

4) the velocity Fourier spectrum is computed.

Following the requests coming from the engineers to reconstruct the characteristics of the May 6 event in different Friuli places, for istance to obtain some response spectra, we tried to check if velocity records

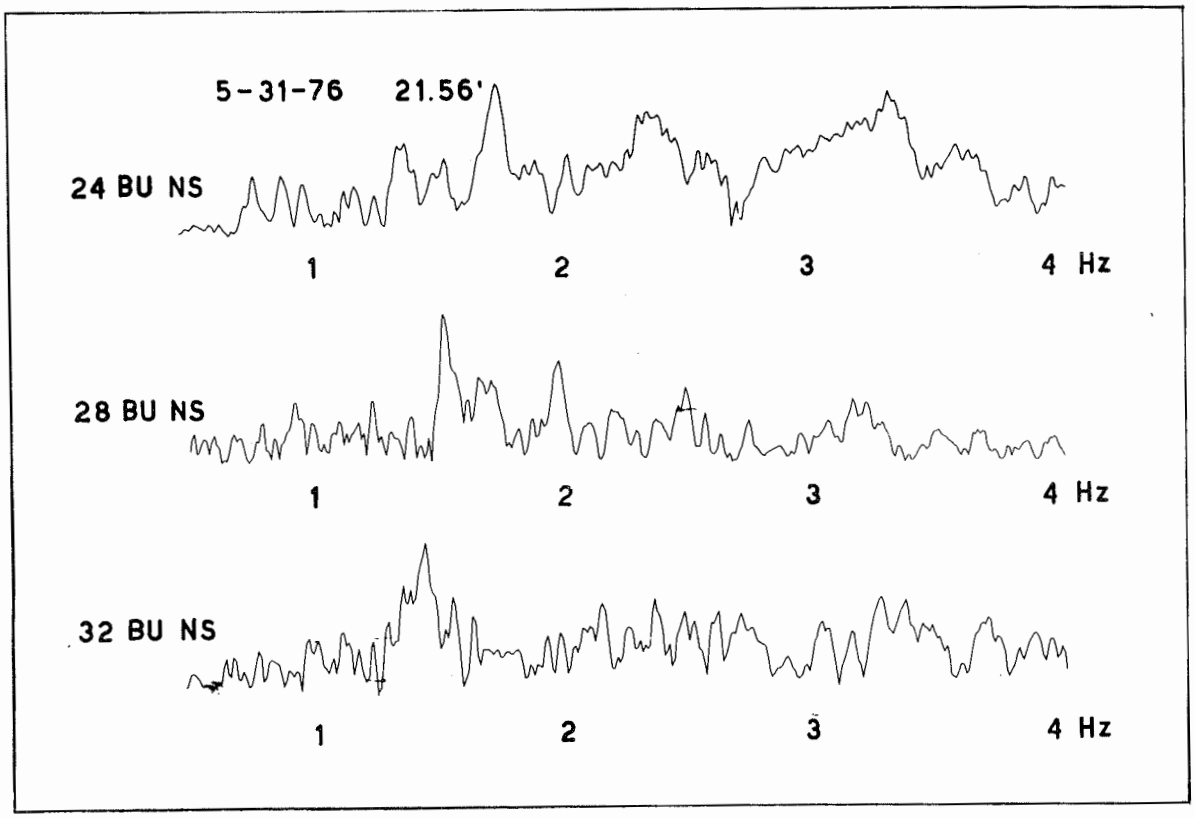

Fig.3 - Velocity amplitude Fourier spectra of different shocks recorded at the same site

of a large number of relatively small events can help us to answer the question.

The adopted procedure is illustrated in the scheme of Fig.2.

The initial data are expressed in terms of velocity of ground motion. Having a numerical, not analitical, velocity function, its transformation in terms of displacement or acceleration function, implies a numerical integration or differentation rispectively.

The differentation procedure gives not completely reliable results; therefore we prefer to transform velocity into velocity Fourier spectrum (A); then into acceleration Fourier spectrum (B); and finally back into acceleration (C). Applying a linear ascillator, as well known, we obtain the response spectrum.

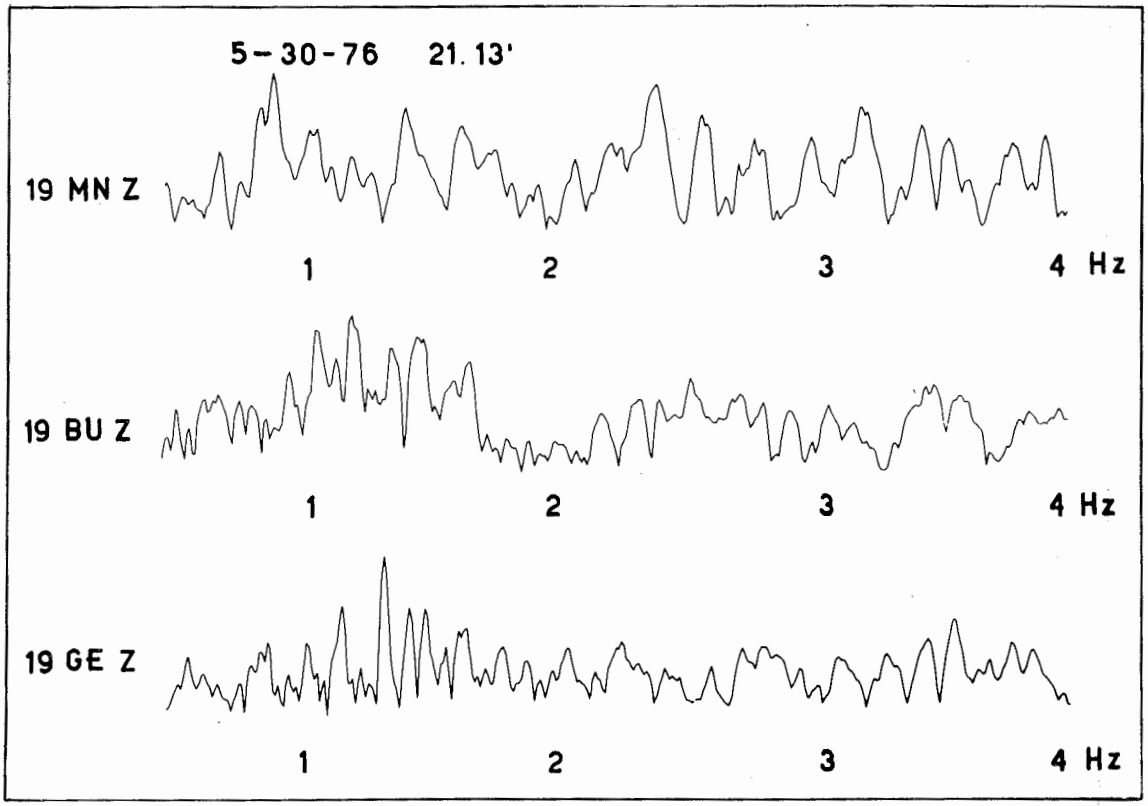

Fig.4 - Velocity amplitude Fourier spectra of the 2I^{h}I3' May 30 shock

The passage described as (A) is not only a phase of the complete procedure, but also allow us to get input data for different sites comparison.

This procedure needs some checks.

The most important one is, as already told, to check the influence of these factors:

- focal parameters;
- distance between hypocenter and recording station and characteristics of the medium;
- local geological conditions;
- instrumentation characteristics;

on the Fourier spectra in the range of frequencies more useful to the engineers, that is the range of the low-seismic frequencies (in the field of short period, of course).

In order to make out these checks we must compute and examine a lot of Fourier spectra for different shocks recorded at different places. That is what we are doing at this moment and will be completed in a next future.

Up to now,special attention was paid to the range 0.5 ÷ 4 Hz, as requested by the engineers.

In Fig.3 we can observe the velocity amplitude Fourier spectra of three different shocks as recorded at the BU N-S component.

We can see a predominant frequency (about I.5 Hz); only in one case different peaks are present too.

In Fig.4 and 5 we can observe the velocity amplitude Fourier spectra of a single shock as recorded in three different stations.

These are only some examples of shocks examined until now. In any case the number of events considered allow us to have only a negative

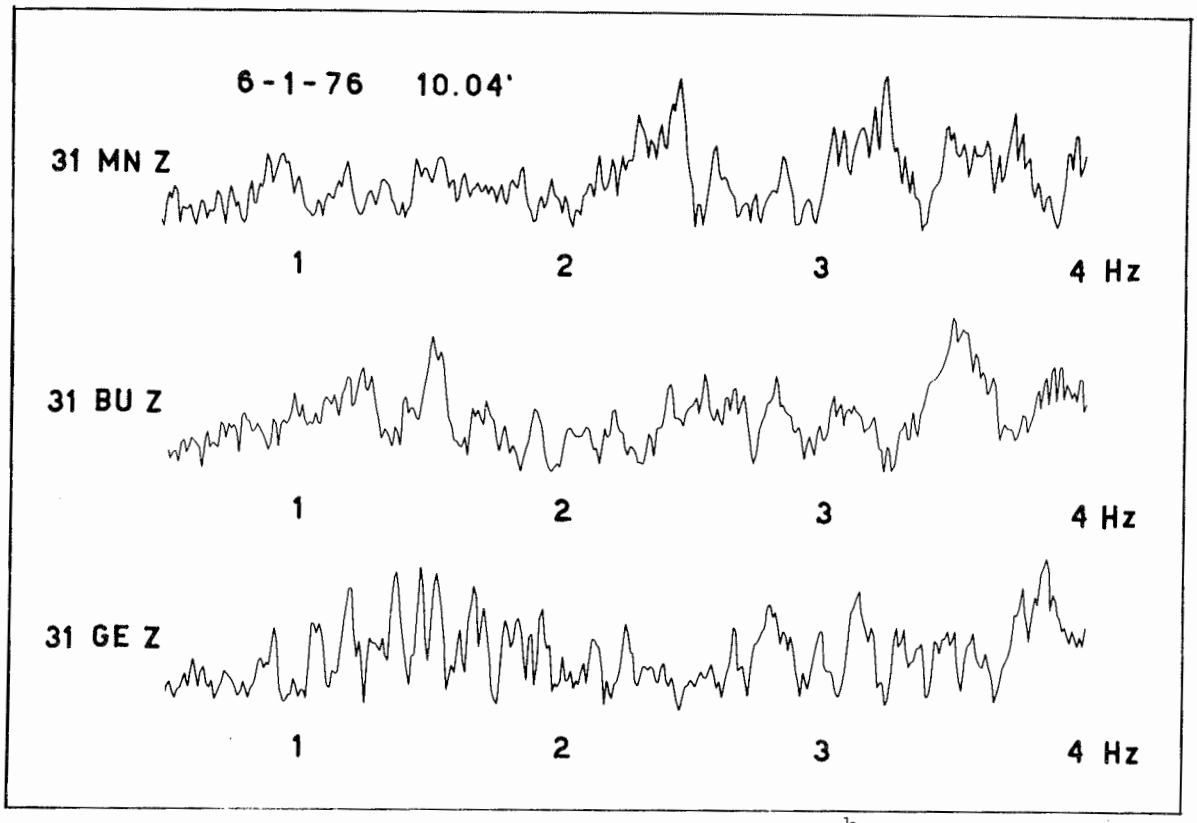

Fig.5 - Velocity amplitude Fourier spectra of the $10^{h}04'$ June I shock

conclusion; that is a larger number of events must be treated in order to give some quantitative evaluation of the parameters above mentioned.

RIASSUNTO

Viene presentata una metodologia per il calcolo di spettri di risposta, a partire da registrazioni sismologiche in termini di velocità di spostamento del suolo. Il metodo viene sperimentato su eventi registrati in diverse località del Friuli. Sono presentati alcunw risultati iniziali.

SUMMARY

A methodology ofr response spectra analysis is presented, referring to seismographic recordings in terms of velocity of ground motion.

The methodology is applied to some events recorded in different Friuli localities.Some initial results are presented.

REFERENCES

Ayers, R.L. and Bollinger, G.A., A study of microseismic and macroseismic ground motions in Virginia, Pageoph., II3, I975

Bath, M., Spectral analysis in geophysics, Elsevier, I974

Bendat, J.S. and Piersol, G.A., Random data: analysis and measurement procedures, Wiley-Interscience, I97I

Brady, A.G., Studies of response to earthquake ground motion, Thesis, California Institute, Pasadena, I966

Espinosa, A.F., Ground amplification study at two sites near Bakersfield, California Earthquake Notes, Vol.XI, N.3, I969

Grandori, G., Introduzione alla ingegneria sismica, Tamburini, I970

Newmark, N.M. and Rosenblueth, E., Fundamentals of earthquake engineering, Prentice-Hall, I97I

Wiegel, R.L., Earthquake engineering, Prentice-Hall, I970

THE FRIULI EARTHQUAKE OF MAY 6, 1976:GEOLOGY

Edited by:

Bruno Martinis

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1 - FOREWORD

The present report gives a brief account of the investigation carried out by the geological work-group of the National Research Council (C.N.R.) as a part of the research project indicated as "Geodinamics".

Essentially, the main objectives of the group were to obtain information about the geology of the area primarily involved in the earthquake of May 6, 1976 through an appropriate field survey and to make an inventory of landslides caused by the earthquake as well as a study of unstable slopes.

Unfortunately, the achievement of this latter part of the program was delayed by the occurrence of the new seismic event of September 15 which caused an even greater

Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 25.

number of disruptions than that of May 6. Therefore operations are still under way at this date.

The geological survey was directed mainly toward the study of the surficial deposits, since these are most often the site of urban and industrial installations.

In addition to their areal distribution, the study included the grain size and the thickness of these deposits and the water table depth, all these being important factors in the determination of the risk involved in the event of seismic disturbances

The survey also traced the evidence of neo-tectonis, that is of those features testifying the latest tectonic history which conditioned today's displacements of the ground.

Likewise, the survey allowed to locate geomorphological processes that are active today, such as forming alluvial fans and talus cones, steep slopes under rapid erosion, areas subject to flooding, etc.

Such a knowledge may be useful in the evaluation of the "geological risk", this being always closely related with the above mentioned processes.

The cartography used in the field survey consisted of maps on the scale 1:25.000 and, sometimes, 1:10.000 and of aerial photographs taken both before and after the earthquake of May 6.

The study included also geophysical investigations (a refraction seismic survey and an electric survey) which were made with the purpose of obtaining more accurate data about

the litological characteristics and subsurface thickness of the surficial deposits.

The survey was carried out by 35 participants from different C.N.R. organisms and university institutes with the cooperation also of a team from GEOTECNECO, a company of the ENI group.

The scale 1:25.000 was then reduced to 1:50.000 in order to provide a practical document for reference.

It is felt that the obtained results may provide useful information, even more so as the published geological cartography of the region so far dates back to nearly 50 years ago (1925). Moreover, it is now out of print and not easily available.

The documents provided hereby, especially the maps in the scale 1:25.000, may also become an instrument for further applied research, such as, for instance, the laying out of preliminary designs in the field of land planning.

We are grateful for help and cooperation to dr.Querini, Regional chief, Assessorato dell'Agricoltura delle Foreste e dell'Economia Montana.

GEOLOGIC SETTING

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Introduction. Friuli region is located in the eastern part of the Southern Calcareous Alps. The boundary with the Austrides coincides with the Gail line towards the north, whereas a transitional zone characterizes the boundary with the Dinarides s.s. towards the east. The following structural units can be distinguished from the north to the south: 1) the Carnic Range stricking east-west and delimited by the Gail and Fella Sava lines; 2) the Tolmezzo Alps comprised between the Carnic Range to the north, the Tagliamento Valley towards the south and the Fella Valley towards the east; 3) the Julian Alps delimited by the Fella-Sava line and the Resia Valley; 4) the Carnic Prealps delimited northwards and eastwards by the Tagliamento river and facing the Friuli Plain; 5) the Julian Prealps eastwards of the Carnic Prealps; 6) finally the Gorizia-Trieste Karst

in south-east part of the region.

Stratigraphy. The outcropping formations range in age from the Silurian to the Miocene. Most of them indicate marine and/or transitional environment.
Paleozoic units, up to 4000 m tick, form the Carnic Range: they are carbonatic (Devonian reef limestones), terrigenous (Hochwipfel Formation, Val Gardena Sandstones) and evaporitic (Bellerophon limestone p.p.). The Triassic succession, up to 5000 m tick in the western part of the area, includes two terrigenous units (Werfen Formation and Raibl Group) and some carbonatic complexes including the Serla Dolomite and Haupt Dolomite. They form nearly all the Friuli Alps while in the Prealps Late Triassic (Norian and Rhaetian) tidal flats prevail. Giurassic and Cretaceous formations have a thickness up to 1000 m; they are entirely carbonatic except a cretaceous flysch outcropping in the Natisone and Venzonassa Valley.
A neritic facies supports the existence of a ridge in the Carnic Prealps during Giurassic and Cretaceous times; this facies passes to a pelagic one to the west (Belluno Trough), to the north (Carnic Plateau) and to the east (Julian Trough). The basinal physiography is characterized by seamounts plateaus and slopes, probably fault slopes.
During the Tertiary era, sedimentation is exclusively terrigenous with flysch facies in the Paleocene-Eocene and molasse facies in the Oligo-Miocene. The flysch, up to 2000m thick, outcrops along nearly all the southern side of the Prealps, while the molasse, wich has a thickness in excess

Regional structures, created during meso and neo-alpine orogeny, are presently accounted either to gravity flow due to the uplift of the Alps or subduction and collision between "adriatic-plate" and the European continent.

greenish sandstones and siltstones, often interbedded with light or dark massive, at time oolitic limestones (500-700 m) (Campill Member).

3) Lusnizza Formation°° (lower Anisian): incoherent to massive thinly bedded dolomites (50-350 m).

4) Serla Dolomite*(lower-middle Anisian): light, mostly massive dolomitic limestones (150-300 m).

5)××Nodular well bedded limestones and red siltstones (Bivera Formation);grey often laminated marly silthstones; green or grey, more or less tuffitic interbedded sandstones, breccias, siltstones and derty limestones (Buchenstein formation). These lithostratigraphic units of upper Anisian to middle Ladinian age one of ten found in wedges involves in overthrust movements and therefore their original thicknessen cannot be well assessed.

6)°°°Dark well bedded cherty limestones (30-40 m) (middle? - upper? - Ladinian)

7) Schlern Dolomite*(upper Ladinian - Carnian p.p.): light, massive or thichly layered limestones, at places dolomitic limestones (500-800 m)

8) Raibl group (Carnian):a)°°° dark bedded limestones (100 m); b)××greenish more or less tuffitic sandstones and marls (10-30 m);c)°°° black platy limestones (150-300 m);d)°°°dark,well bedded limestones and marls (100-200m);e)×××coarse and fine grained sandstones variously interbedded with siltstones, marls and limestones (100 -200 m);f)°°° bedded dolomites and dolomitic limestones (20-50 m);g)××× redgreen and grey siltstones, slates and sandstones interbedded with massive

with intraclasts and Crinoids (800 m).
14) Ellipsactinic Limestones * (Tithonian-lowermost Cretaceous?): light grey massive biorudites (about 400 m).
15) Rosso Ammonitico°°°(Malm): deep red nodular calcilutites and calcarenites with Crinoids (0 to 120 m).
16) Soccher Limestones°°°(Malm to middle-upper Cretaceous): variegated,platy cherty calcilutites (a few tems m, locally up to 150-200 m).
17 Limestones with Nerinee and Caprinids°°°(lower and middle Cretaceous): white or light grey calcilutites, mostly in beds under 1 m thich (near Peonis and M.Ciaurlec) (over 400m).
18) Calcreous marly Flysch**(lower and middle Cretaceous): cherty calcirudites, calcarenites and calcirudites with interbedded brown marls, in beds from 60 m and 6-7 m thich (M.S.Simeone).
19) "Calcari a Rudiste * (upper Cretaceous): light grey, massive, rarely well bedded bioclastic limestones and biorudites (about 350 m). At Bernadia the formation in 600 m thich and its age ranges from the Tithonian and the Turonian).
20) Scaglia Rossa**: a) reddish interbedded cherty clayey limestones and marls (northern sector of the Julian Prealps) (150-200 m);***b) darke red or greenish marls and slates (southern Prealps) (0-40 m).
21) Flysch Friulano *** a) Stregna Flysch and Pulfero Flysch (Paleocene p.p. lower Eocene?): interbedded sandstones, marls, conglomerates, calcareous fine breccias and calcarenites. b) Cormons Flysch*** (lower and middle Eocene) interbedded marls and grated sandstones in beds meter 1 m thich, with less frequent interbedded fine breccias

*** Flysch and flysch-like rocks

** "carbonatic Flysch"

++ molasses

+ Oligocene conglomerate

+++ Tortonian conglomerate

= Pontian conglomerate

variously from the upper Permian to the middle Oligocene. The age of the overthrust features of the Carnic and Julien Prealps can well be established to the late Neogene, since formations of Messinian age are involved. However the Sauris overthrust older, of Eocenic age.

The main overthrust units of the Tolmezzo Alps and Carnic Prealps, from north to south, are:

1 - The Sauris overthrust. It carries upper Permian terrains over Carnic formations. Toward the East, near Zuglio, it splits into two units, the southern being located just north of Tolmezzo

2 - The upper Tagliamento - M.S.Simeone overthrust. It is mostly made of "Dolomia principale" formation. The trust surfaces changes its attitude from suborizzontal in the western Carnic Prealps (upper Val Cimoliana) to dips of 60°-70° at its eastern end (M.Festa).

3 - The Duranno - Alto Meduna - Avasinis overthrust. The lithologic and structural characteristics of the unit are similar to those of the overthrust 2.

4 - Periadriatic overthtrust. It carried the "Dolomia Pricipale" formation over Cretaceous and Tertiary terrains

5 - The Arzino averthrust. The thrusted sequence covers a flexure, locally grading to a fault-folden feature, with vergence to the south, over which a syncline with Messinian are followed by an anticline with Serravallian core are learning.

In the Julian Alps and Prealps, from North to South, the main features are:

1 - The Valle di Resia line: a medium - to low dipping fault with vergence to the North carrying the uppermost beds of the Carnian stage over the Dolomia Principale formation

reactivated during a subsequent phase by strike slip movements. This fault system also originated fosther displacements of the E-W overthrust features.

3 - NW-SE and NNW-SSE subvertical faults often marked by slightly cataclasized belts, thickly and regularly effect the whole area. The displacements are small, mainly horizontal and at time oblique. In some cases the displacements of a few hundred m have been measured. A set of faults of this system runs from Gemona of the middle T. But across Amaro and Imponzo. Another set is aliqued between the area W of Gemona and Tolmezzo across Cavazzo. This fault system cuts all the previous ones.

4 - N-S faults. These are vertical, neatly cut faults, especially developed South of Tolmezzo between the meridian of Spilimbergo and that of Venzone. The relationship with the other systems vary from area to area. The main observed set lies between Somplago and Trasaghis, where two sets of steps of N-S faults originate the tectonic depression (sift) of the lake of Cavazzo.

Evidence for neotectonic activity. The observations for detecting the most recent tectonic features were based on the mutual relationships of displacements between the facture systems described above as well as by a survey of facture system found in recent terrains where some compaction was attained (e.g. the "Conglomerato di Ceslans" formation probably of early Quaternary age and the younger, although pre-Wurmian, periglacial breccias of Pusea.

At a first analysis (see fig.) a principal facture planes

SURFICIAL DEPOSITS IN THE VALLEY AREAS

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The field geological survey (1), mostly in the scale 1: 10.000, provided information about the different kinds and the main characteristics of surficial deposits.

In addition to the geographical distribution and areal extent of such deposits, their degree of cementation and grain size were studied with special attention, these being important factors in the stability of slopes and trasmission of seismic waves.

The different units were classified according to their depositional facies as alluvial, lacustrine, slope and glacier deposits.

(1) The survey was carried out by members of the "Gruppo di studio delle Università Emiliane per la Morfologia" and by other students from the Universities of Milano, Padova and Trieste.

maps are dated to the latest glacial epoch.

Loose alluvial deposits consisting of well-to poorly sorted gravel with sand and large boulders were located along the sides and on the alluvial plain of the largest water courses. Locally, such deposits form a series of terraces, such as those to be seen in the Resia valley and in the valley of the Cornappo stream. From the section of wells drilled in the Resia valley the thickness of these deposits appeared to be over 20 m. The largest areal extent of loose alluvial deposits is found in the valley plains of the Tagliamento and Fella rivers. A seismic section across the Fella river, near Resiutta, shows an interval of alluvial deposits with a minimum thickness of 14 m approximately.

At the debouch of torrents into the main valleys, there are extensive alluvial cones with steep slopes, some of which are still in the process of building up.

The investigated area, especially in the tract between the Cavazzo lake and the Villa village, has several morphological basins filled with mud and peat deposits, which from the results of some holes drilled in those basins appeared to have a thickness ranging from 15 to 40 m.

Among sediments deposited under the control of gravity with the concurrent action of water and snow, the most important from the view point of this study are scree breccias, some of which formed the body of several landslides caused by the earthquake, such as those fallen above Braulins and the landslide of Portis, all of which consisted of cemented limestone and dolomite rock fragments.

THE TAGLIAMENTO MORAINIC AMPHITHEATRE (TMA)

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A rapid and essentially practical examination has been made of the Tagliamento Morainic Amphitheatre (TMA). Field work was based on an earlier lithological and morphological analysis of air photos by G.Gasperi and R.Gelmini. This ensured rapid and exact delimitation of the various units. A geomorphological and structural check of the map was carried out with the aid of small-scale air photos by G. Govi. Previous studies of the TMA were made many years ago. Their results can be seen in Sheet 25 - Udine (1925) of the Geological Map of Italy, and its accompanying notes (1920).

The TMA consists of a series of concentric and very symmetrical semi-circles. This symmetry is broken by a set of small circles at Urbignacco, these are near the left-hand inside edge of the amphitheatre. Several groups of

description of the geological situation is virtually impossible. A set of typical profiles found in such an amphitheatre is included in diagrammatic form with the explanatory notes in Italian, to make the map more useful to local bodies.

The TMA bears many signs of tectonic deformation. These are now being studied and a report will by presented at the Xth INQUA Conference (Birmingham, August 1977). The entire structure appears to be locally displaced in a series of raised (Susans, Maiano, Buia, etc.) and depressed (Ledra, Cormor, etc. valleys) blocks, mostly along N40E-S40W and N40W-S40E lines, as in the case of the substratum Horsts and Grabens; these, however, underwent further development and are attenuated in the Quaternary cover.

In addition to these major features, a whole series of minor disturbances have been noted: faults of uncertain orientation, with vertical displacement of the circles at the Tricesimo level; minor faults, also vertical, displacing the morainic deposits near Zeglianutto, Bronzacco, etc.

morainic amphitheatre and on the northern of Spilimbergo.

The lacustrine deposits, which we found particularly between Maiano and S.Daniele of Friuli, have a thickness which can reach 20-30 meters, are mostly formed by muds and, is a much smaller quantity, by peats.

In the area between the Torre stream and the Tagliamento river, on the south of the morainic amphitheatre and between Maiano and S.Daniele of Friuli, the gravels are covered by a thin brown soil, on irregular basis with cuneiform and deep composition of up to a meter in depth which can be defined as Orgeln.

In the remaining areas the alluvial deposits are almost without any soil. Regarding the thickness of the alluvial loose deposits, they reach a depth of 70-90 meters in the Osoppo plain, between Maiano and S.Daniele of Friuli, while in the plain to the south of the morainic amphitheatre they can exceed a hundred meters, with the exception of the area of Udine, where conglomeratic layers have been found in the wells of water even up to 20-30 meters from the surface.

The alluvial deposits formed by the greater flows of water are often cut in many terraces which reach number 6 near Pinzano, on the right of the right of the Tagliamento river and to the south of Meduno.

The valley of the small Corno stream to the south of S.Daniele of Friuli is also large, deep and terraced in spite of its dimension. It seems likely that this valley was formed by a river whose dimensions were as large as

GROUND WATER

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The area found South of the mountain zones of Friuli and to the East of the Tagliamento River can be divided into three different areas from the hydrogeological view point; the Osoppo Plain, the Terminal Moraines Area and the Northern Friuli Plain.

In the Osoppo Plain, mainly formed of highly permeable alluvial gravels, there is a single phreatic stratum to the depth of a few meters, with principal groundwater flows from North to South and a water table gradient of a few meters for thousand. Phreatic water comes from seepage from the Tagliamento and the other rivers that flow from eastern mountain areas in their alluvial cones (Vegliato R., Storto E. etc.). A subsurface rock barrier, but more especially the presence of moraine deposits, stop the free

sense. The mechanism which brings the water to the surface is analogous to that which causes springs in the Osoppo Plain. The reason why water cannot flow freely from the Northern Friuli Plain southwards is due to the presence of impermeable deposits,silty-sands, found to the South. A good part of the phreatic water of the Northern Friuli Plain comes from river bed seepage (F.Tagliamento, T.Torre etc.).

To the West of the Tagliamento there is a single phreatic stratum which has analagous characteristics to those found in the Northern Friuli Plain to the East of the river. However in this area, given the lack of moraine, the sudden change in gradient of the water table takes place at the contact zone between mountain and plain; this is geographically more to the North and higher than the contact zone between moraine and plain. This causes the water to reach greater depths and in fact just a few kilometers from the mountains towards the plain, water is found at 150-200 m below the surface.

The tests carried out at the food of Mount Faeit (near Artegna and Magnano in Riviera), allowed the determination of the velocity of propagation of longitudinal elastic waves in the marly-arenaceous flysch (Eocene). This for mation has a velocity ranging between 2300 and 5300 m/s, with average values between 2500 and 3500 m/s. The value of 5300 m corresponds to a calcareous rock located near Borgo Urana.

The tests near Venzone showed that the longitudinal elastic waves in the limestones or in the mesozoic dolomites have a velocity of approximately 3000 m/s. Where rock types are fractured and/or weathered, the values drop to 2400 m/s.

As far as the loose deposits are concerned, the velocity in the moraines varies according to grain size and compaction up to a maximum of approx. 2000 m/s, and in clay from 1600 to 1800 m/s. The top soil has a low velocity (350 m/s). The thickness of these deposits in generally 2 to 4 m, and locally reaches 8 to 10 m (Cavazzo Carnico, Magnano in Riviera).

Results of the seismic survey showed that even using light equipement, the various bedrock formations can be distinguished according to velocity of longitudinal elastic waves. By grouping the formations having similar velocity ranges, a thematic base map can be obtained. This map is useful for a preliminary evaluation of one of the parameters (elastic wave velocity) necessary for a correct land management involving antiseismic buildings.

autumn 1975 and April 1976.

The photointerpretative investigations were integrated by field investigations on the larger and more significant landslides, particularly on those reactivated by the september shocks.

For some slopes, which were more ruined than others, detailed longitudinal profiles along the trajectory of the falling rock were carried out by aerophotogrammetric restitution and on the profiles the bouncing or rolling of the single blocks movements were indicated.

The examined area surrounds the seismic epicenter and covers completely the I.G.M. 1/25.000 scale sheets for Tolmezzo, Moggio Udinese, Gemona del Friuli, Trasaghis and partially the sheets for Majano and Buia.

The study considered not only the mapping of the rock fallings but also their distribution analysis with reference to the local lithologic, tectonic and topomorphic characteristics of the slopes.

After examining the collected data, we can make following considerations:

- The earthquake with reference to the landslides, effected all the rock units of the examined area, from the Upper Trias to the early Quaternary (dolomites, limestones, marls, sandstones, conglomerates, breccias). It is not possible to indicate a clear and direct connection between the rock-falling density and the litology, given that some lithofacies (dolomites and limestones) are more widely represented than others and that their distribution is not homogeneous

- In the structural setting, the strata inclination toward free face had not great importance in producing landslides, as the slides along bedding planes are rare. The bed arrangement had an indirect importance, as it controlled the relief "energy" and therefore the slope steepness.

In conclusion it is possible to state with considerable confidence that firstly: if we take units at the same distance from the epicentral seismic zone, the slopes which are more ruined are those characterized both by lithological non-homogeneity and tectonic complexity; and secondly,given the first point in these units, the seismic shaking produced the greatest effects on steeper sloper and frequently in preference on their higher section.

The cracks located during the field survey are ranged in several directions in which different trends may be recognised but the main ones appear to be NW-SE and E-W, that is to say parallel to the prevailing structural trends of the region. The cracks opened in unconsolidated surface deposits, such as scree and alluvial deposits and pontic and quaternary conglomerates.

Cracking of scree deposits, for instance is represented on the southern slope of Mt. Quarnan by long cracks running for tens and sometimes hundreds of meters with an E-W trend almost parallel to ground level contours.

Similar features are presented by cracks located south of Mt. Cuar, which are just mentioned here, since they have been lately described in detail by Bosi, Camponeschi and Giglio.

Cracking of alluvial deposits is evident in many places: in the plain extending to the north of the Susans hill (Majano), consisting of mud deposits, in the terraced alluvial gravel of Ragogna, in the mixed lacustrine and fluvial deposits on the western shore of the Ragogna lake, etc.

In the first mentioned site, north of the Susan hill, the cracks show a WNW-ESE trend which conforms with the northern slope of the relief and with faulting located in this area. The cracks at Ragogna have two main trends, NNW-SSE and WSW-ENE, apparently in conformity the steep scarps bordering the alluvial terraces of S.Pietro and Borgo di Mezzo.

Two cavities of the ground bordered by circular cracks

height up to 2 m

Actually no evidence of this could be traced on the field, yet some indications suggest that in the past the lake waters could have extended a 28 m inland beyond the present shore line. It should be noted, however, that the field survey was carried out in July and September of 1976, after a period of exceedingly dry weater which may have affected the lake wather level.

As to the cracks located in quaternary and pontic conglomerates, some of them are clearly controlled by gravity and slope conditions as, for instance, the deep cracks at the Osoppo fortress which trend N-S, or parallel to the mountain slope. Such a kind of fractures is found also in pontic conglomerates on the Monte di Ragogna. An example is offered by the cracks located on the top of the hill in the floor of the open space surrounding the hotel which is being built at the end of the road. The ENE-WSW direction of these cracks is parallel to the strike of the outcropping rock beds.

Cracking of pontic sedimentary formations was found also on the hill where the castle of Ragogna is located. Here two different systems of cracks may be recognised; the main one trends NE-SW, parallel to the strike of rock beds and is mainly controlled by gravity and slope conditions. The second system ranging E-W irrespective of slope conditions is seen to outcrop not far south of the castle.

The cracks penetrated through the 20 cm thick layer of surface deposits into the underlying conglomerates for

A similar occurrence was recorded at Gemona, near the cart-road that runs along the irrigation ditch SSE of Cañciane. Though most of the original features have been canceled by wheel tracks left by the passage of carts after May 6, three small sand mounds were still evident on July 12 along the central axis of the road and therefore roughly in a N-S direction, over a lenght of about 1,35 m. They are 7 to 9 cm deep and 20 to 35 cm across, with the major axis directed N-S as their aligment.

Sparsely distributed sand mounds without any apparent directional arrangement were recorded in the vicinity of the above mentioned locations and in the plain of Lessi. According to local sources, the emission of sand was accompanied here by hot water. At Gemona, west of the above mentioned cart road this phenomenon is visible on a sand covered area stretching across the road. Within a shallow depression of the floor, there are 4 small cone-shaped mounds. Each mound has a central elliptic cavity 12 to 18 cm deep. Their axis range from 37 to 45 cm for the minor axis and from 46 to 55 for the maximum axis.

A study has been undertaken on the correlation of these sands and of those found near Majano with the sub-surface sedimentary formations.

The emission of water and sand from the ground is reported by prof. Stefanini of the Trieste University, to have occurred not only in the above mentioned places but also in the alluvial plain of Avasinis, near the Molino Maserèt (Trasighis), in the neighbourhood of Tomba (Rivoli di Osoppo) and north of Mels.

Simplified geological map of Friuli Venezia-Giulia region
Udine
Gorizia
Trieste
Grado
Lignano
Latisana
Palmanova
Cividale
Tarcento
Gemona
Tolmezzo
Maniago
Spilimbergo
Sacile
Pordenone
Vittorio Veneto
Conegliano
Vivaro
Sequals
Travesio
Meduno
Forgaria
Osoppo
Buia
Mereto di Tomba
Codroipo
Tricesimo
Pozzuolo del Friuli
Buttrio
Rivignano
Portogruaro
S. Vito al Tagliamento
S. Giorgio di Nogaro
Monfalcone
Duino
Aurisina
Opicina
F. Tagliamento
F. Piave
Fig. 2

CONSIGLIO NAZIONALE DELLE RICERCHE
COMITATO PER LE SCIENZE GEOLOGICHE E MINERARIE
Progetto finalizzato "GEODINAMICA"

Fig. 3

GEOLOGICAL MAP OF THE FRIULI AREA PRIMARLY INVOLVED IN THE EARTHQUAKE OF MAY 6th, 1976

Edited by B. Martinis

Geology by: U. Bonazzi, G. Cadel, F. Carraro, A. Carton, P. Casati, A. Cavallin, R. Costacurta, L. Dall'Arche, A. Della Libera, F. Ferrari, A. Fileccia, F. Frascari, G. Gasperi, R. Gelmini, A. Girardi, P. Grandesso, R. Iacuzzi, U. Manfredini, F. Mantovani, G. Marchetti, B. Martinis, F. Massari, G. Orombelli, M. Panizza, G. Papani, F. Petrucci, G. Rodolfi, S. Tagliavini, C. Tellini, V. Toniello, F. Vaia, L. Vernia, D. Visonà, A. Zanferrari, L. Zarotti, R. Zottel.

L E G E N D

SURFICIAL DEPOSITS

Fluvial deposits and landforms
- Mud
- Sand
- Gravel
- Peat
- Strongly cemented conglomerate
- Weakly cemented conglomerate
- Weakly cemented conglomerate in lenses
- Active alluvial fan
- Inactive alluvial fan

Glacial deposits
- Ablatio till
- Lodgment till
- Erratic boulders

Inactive
- Muddy-sandy colluvium
- Scree
- Landslide debris
- Large boulders due to rockfall
- Landslide block
- Strongly cemented breccia
- Weakly cemented breccia
- Cavernous breccia
- Talus cone

Active
- Muddy-sandy colluvium
- Scree
- Landslide debris
- Large boulders due to rockfall
- Talus cone

Caused by the earthquake of may 6, 1976
- Scree
- Landslide debris
- Large boulders due to rockfall
- Talus cone

Slope deposits and landforms

Lacustrine deposits
- Mud
- Sand
- Gravel
- Peat
- Travertine

BEDROCK

Carbonate rocks
- Massive and/or thick bedded (i.e. Haupt Dolomite)
- Thin bedded (i.e. Soccher Fm.)
- Cavernous (i.e. Bellerophon Limestone)
- Cataclastic

Gypsum

Terrigenous rocks
- Pelitic-arenaceous sequence and flysch a.s. (i.e. Raibl Group, Cormòns Flysch)
- Calcareous flysch (i.e. Pulfero Flysch)
- Molasse
- Conglomerates
- Weakly cemented sandstone and conglomerate

- Contact
- Contact, approximately located
- Strike and dip of beds: 0°-10° | 11°-45° | 46°-75° | 76°-90°
- Strike and dip of overturn beds: 0°-45° | 46°-90°
- Contorted beds
- Overthrust
- Fault
- Buried fault
- Supposed fault
- Fracture
- Buried fracture
- Supposed fracture
- Ground crack
- Karst
- Flood plain

Scala 1:50000

Fig. 4

EXAMPLE OF THE GEOLOGICAL MAP: MT.S.SIMEONE-MT.BRANCOT AREA

EXPLANATION

SURFICIAL DEPOSITS

FLUVIAL DEPOSITS
1) Gravel
2) Strongly cemented conglomerate

LACUSTRINE DEPOSITS
3) Mud
4) Peat

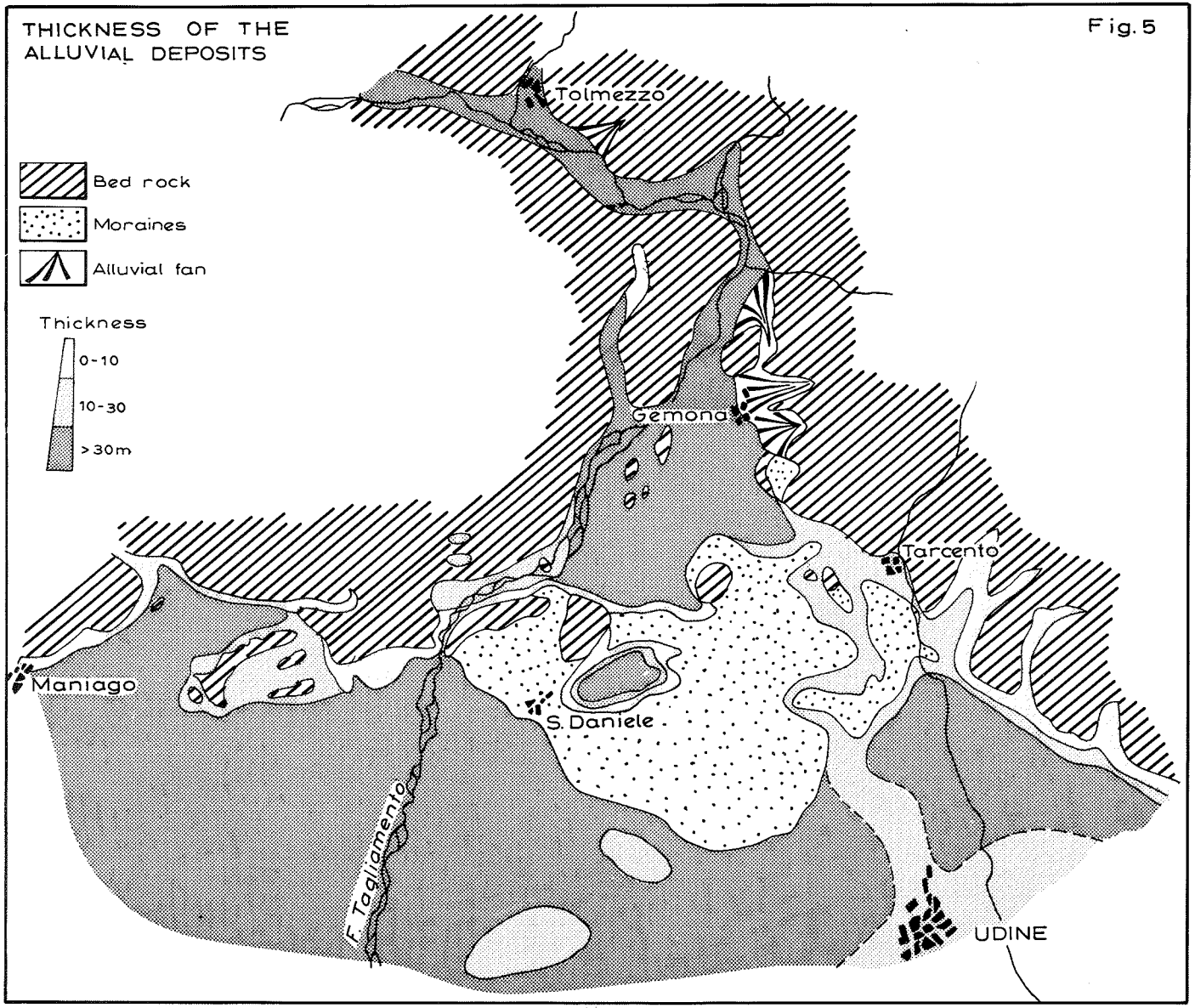
SLOPE DEPOSITS AND LANDFORMS
Inactive:
5) Scree
6) Large boulders due to rockfall
7) Strongly cemented breccias
8) Talus cone

Active:
9) Scree
10) Large boulders due to rockfall
11) Talus cone

CAUSED BY THE EARTHQUAKE OF MAY 6, 1976
12) Scree
13) Landslides debris
14) Large boulders due to rockfall

BEDROCK
15) Massive and/or thick bedded carbonate rocks
16) Thin bedded carbonate rocks
17) Pelitic-arenaceous sequence and Flysch s.s.
18) Molasse

19) Strike and dip of beds
20) " " " " overturn beds
21) Overthrust
22) Fault
23) Supposed fault
24) Flood plain.


THICKNESS OF THE ALLUVIAL DEPOSITS
Fig. 5
Bed rock
Moraines
Alluvial fan
Thickness
0-10
10-30
>30m
Tolmezzo
Gemona
Tarcento
Maniago
S. Daniele
F. Tagliamento
UDINE

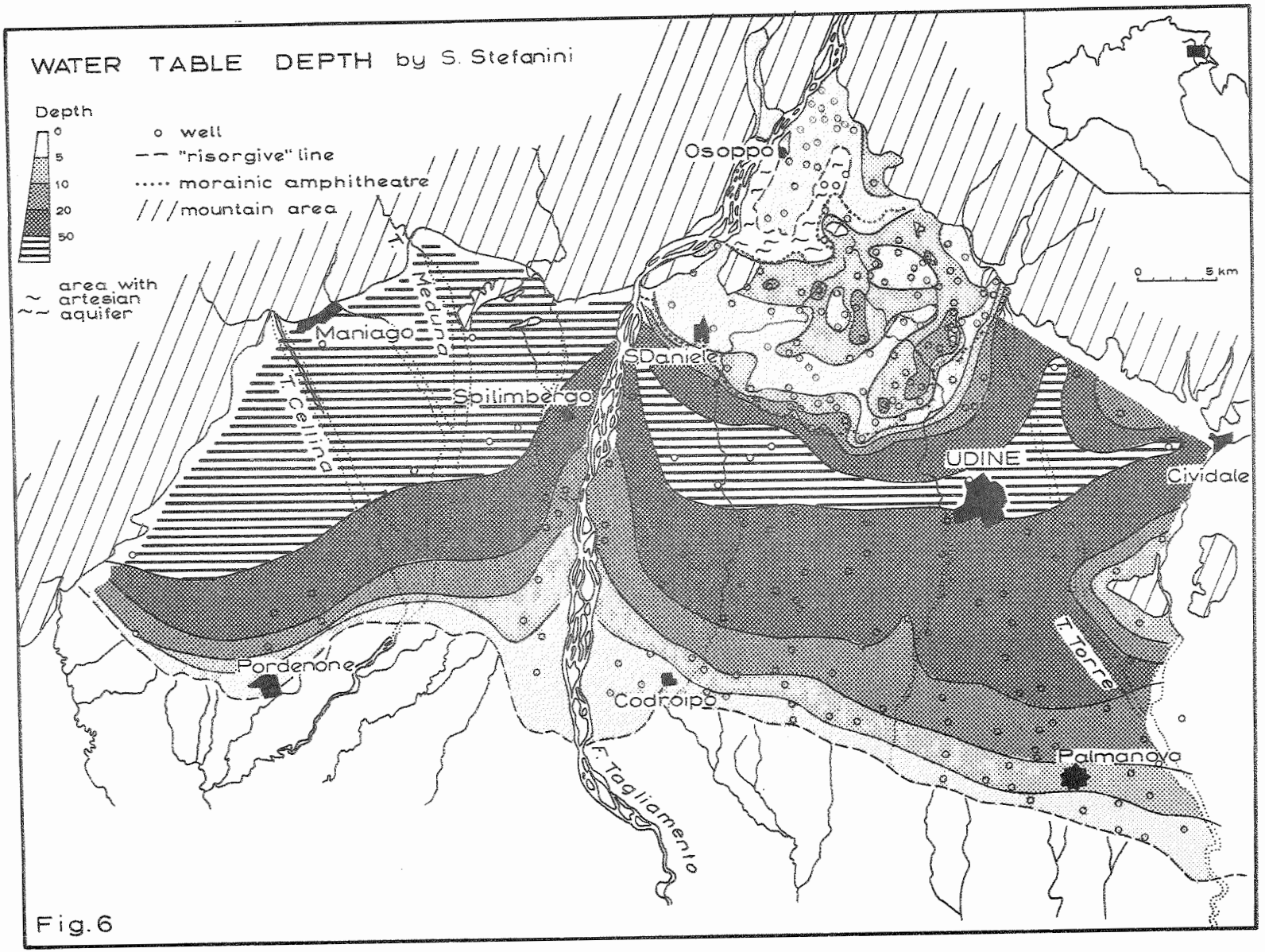
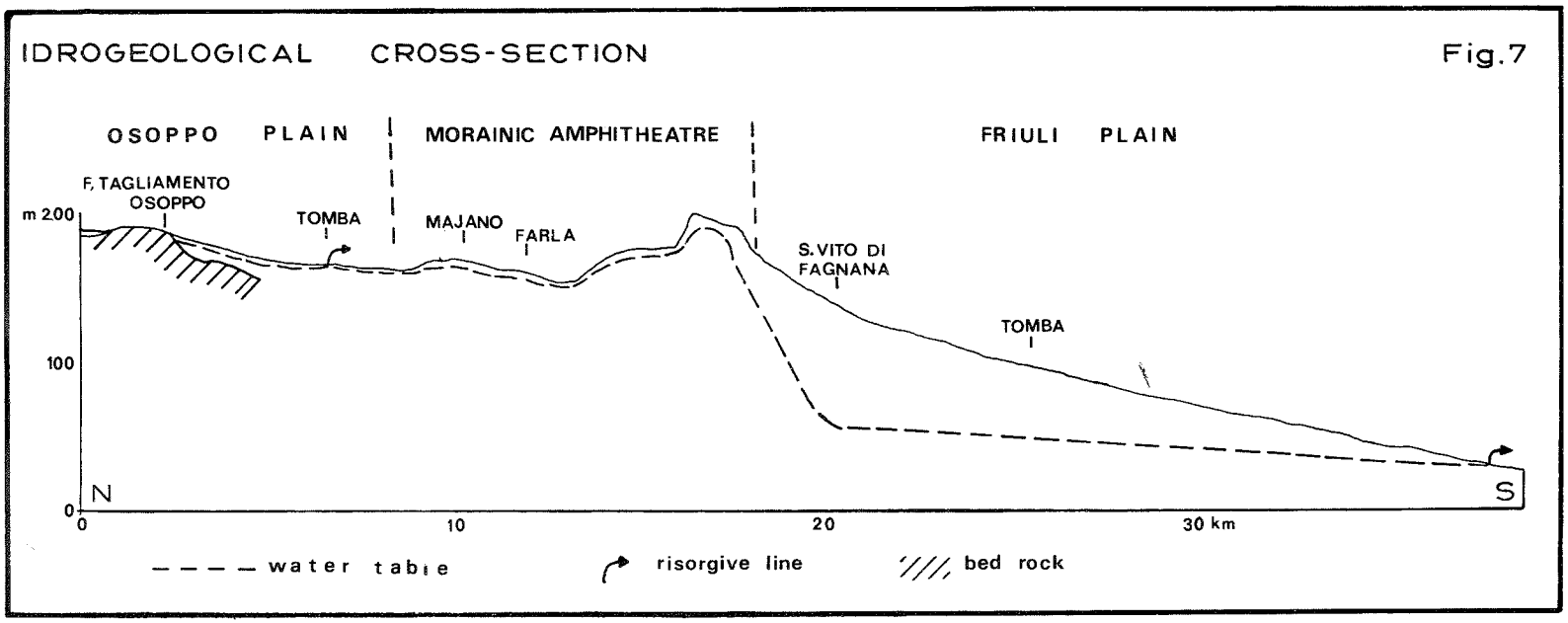

WATER TABLE DEPTH by S. Stefanini
Depth
0
5
10
20
50
o well
—— "risorgive" line
····· morainic amphitheatre
///mountain area
area with artesian aquifer
0 5 km
Osoppo
T. Meduna
Maniago
S.Daniele
Spilimbergo
T. Cellina
UDINE
Cividale
T. Torre
Pordenone
Codroipo
F. Tagliamento
Palmanova

Fig.6


IDROGEOLOGICAL CROSS-SECTION
Fig.7
OSOPPO PLAIN
MORAINIC AMPHITHEATRE
FRIULI PLAIN
F. TAGLIAMENTO
OSOPPO
TOMBA
MAJANO
FARLA
S. VITO DI
FAGNANA
TOMBA
m 200
100
0
N
S
0
10
20
30 km
water table
risorgive line
bed rock

C.N.R.

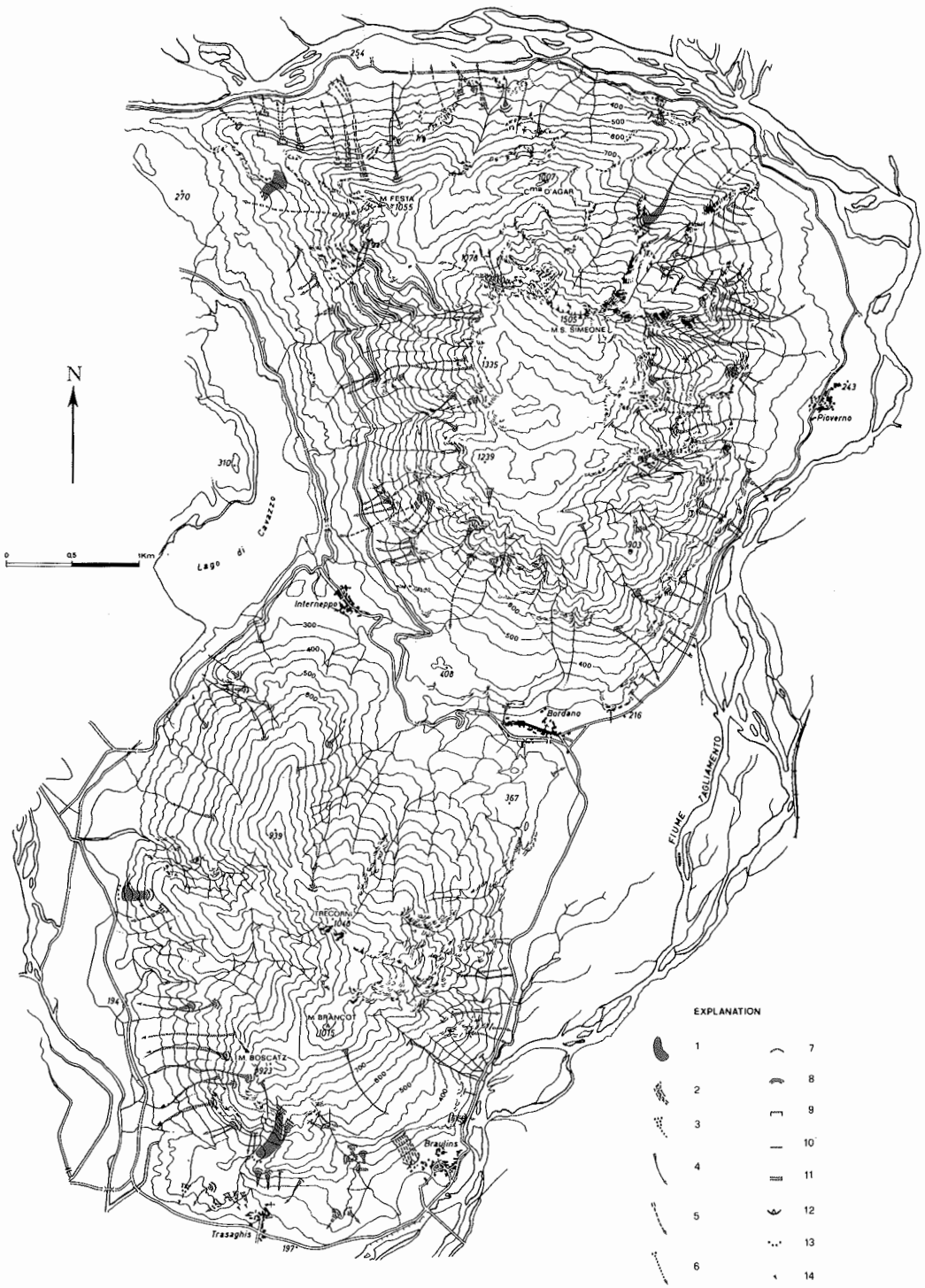
THE LANDSLIDES TRIGGERED BY EARTHQUAKE

ON THE M. S. SIMEONE – M. BRANCOT MOUNTAIN GROUP

From aerial photographs

Fig. 9

M. GOVI*
Dis. E. VIOLA



* LABORATORIO DI RICERCA PER LA PROTEZIONE IDROGEOLOGICA NEL BACINO PADANO

Fig. 9

LANDSLIDES INDUCED BY THE EARTHQUAKE

EXPLANATION

Rockfalls:

1) restarting of processes in recent, active landslides or talus cone.
2) Reactivation of old, quiescent phenomena.
3) Movements in formely undisturbed zones.

Falling of single blocks:

4) restarting of recent, active phenomena.
5) Reaction of old, quiescent phenomena.
6) Movements in formely undisturbed zones.
7) Preexistent niche.
8) Id. preexistent, remarkably extended.
9) Neoformed niche.
10) Steep surface of detaching, without delineated niche.
11) Id. Preexistent, remarkably extended.
12) Prevalently neoformed accumulation.
13) Preexistent resupplied accumulation.
14) Movement of the crashed materials along rovines.

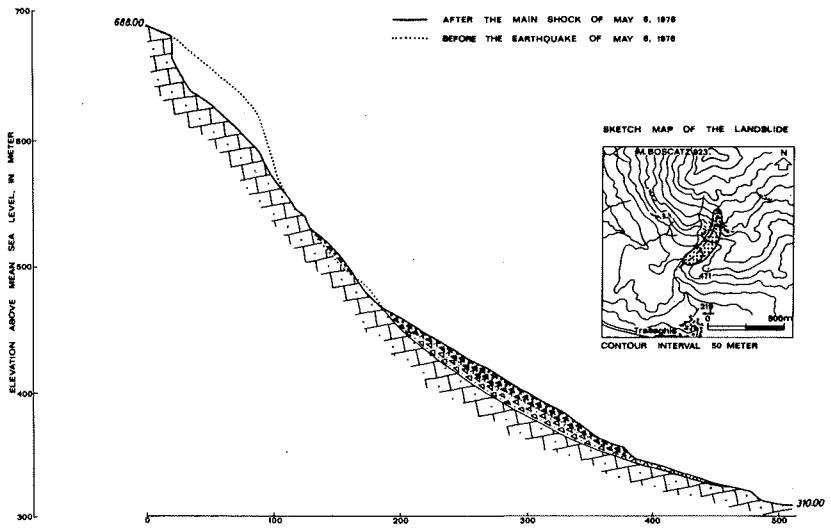
C.N.R.
F. GODONE *
P. F. SORZANA*
Dis. E. VIOLA

LONGITUDINAL PROFILES

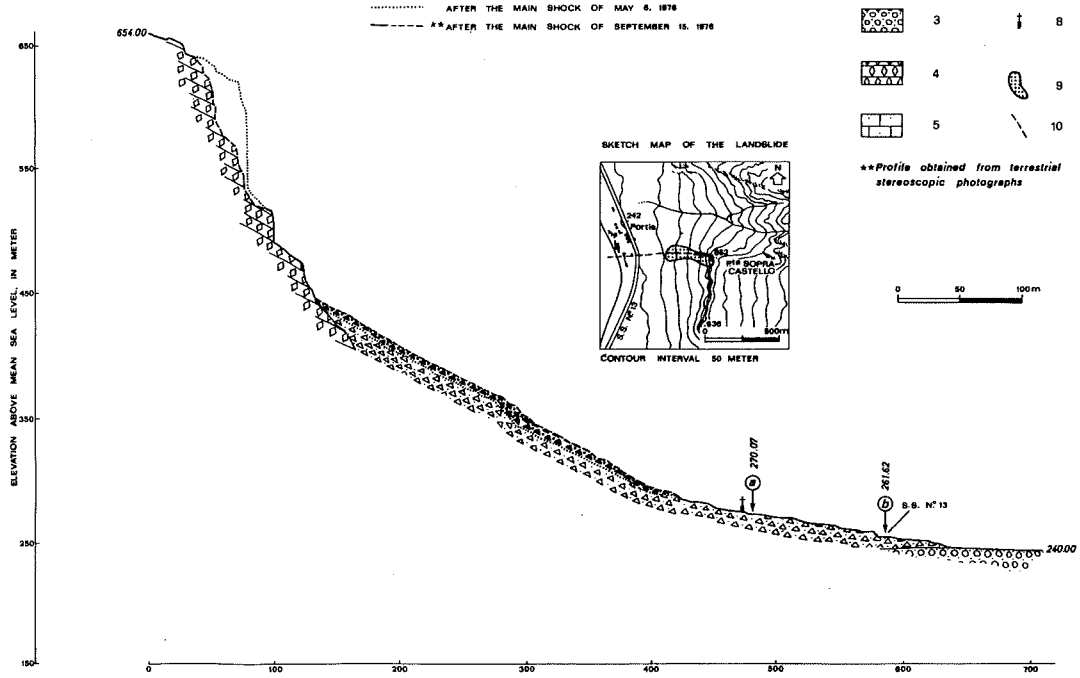
Plotted from aerial photographs

Fig. 10

M. BOSCATZ LANDSLIDE



P.ta SOPRA CASTELLO LANDSLIDE



EXPLANATION

1 — 6
2 — 7
3 — 8
4 — 9
5 — 10

**Profile obtained from terrestrial stereoscopic photographs

0 50 100m

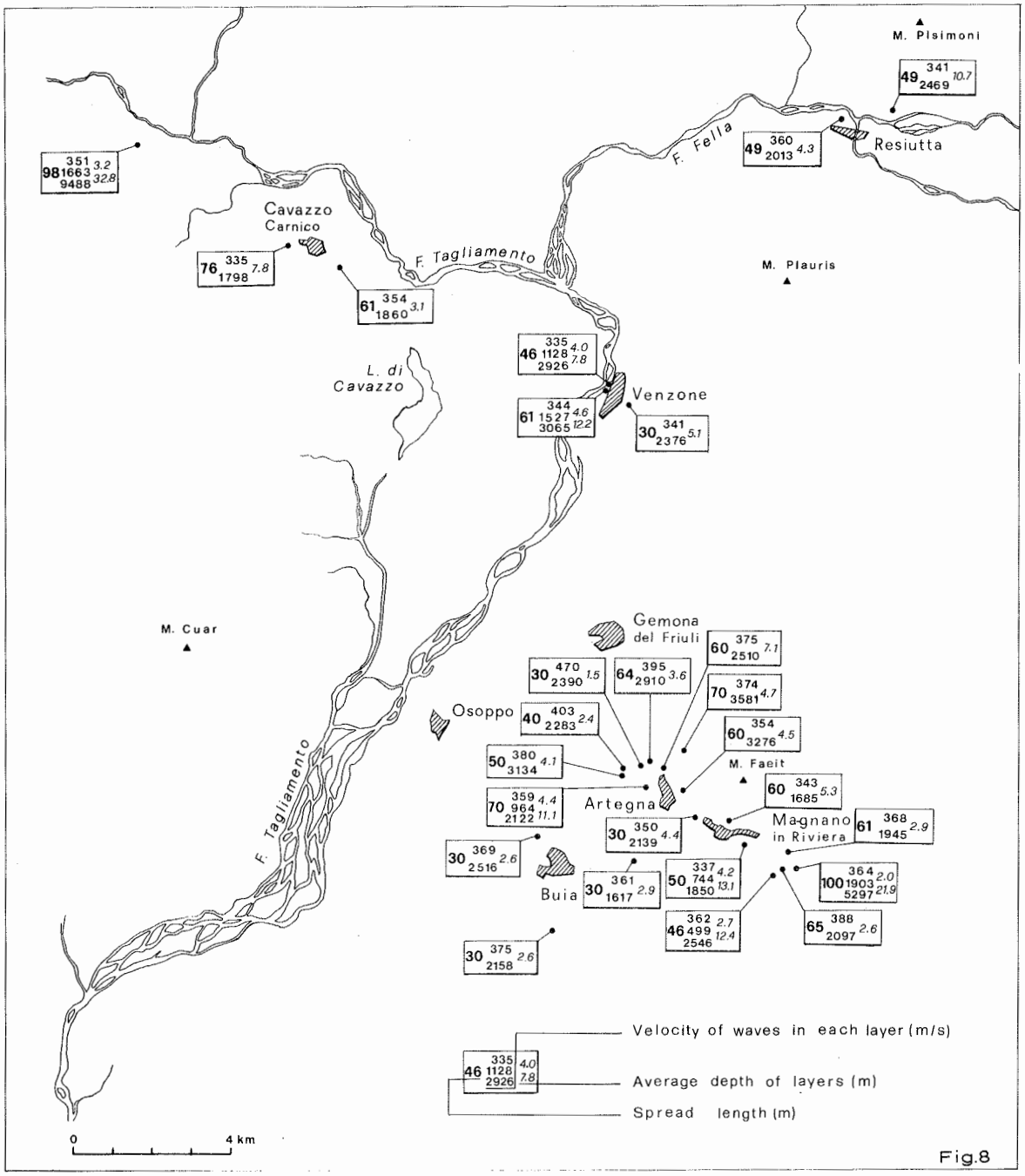
* LABORATORIO DI RICERCA PER LA PROTEZIONE IDROGEOLOGICA NEL BACINO PADANO

Fig. 10

LANDSLIDES CROSS SECTION

EXPLANATION

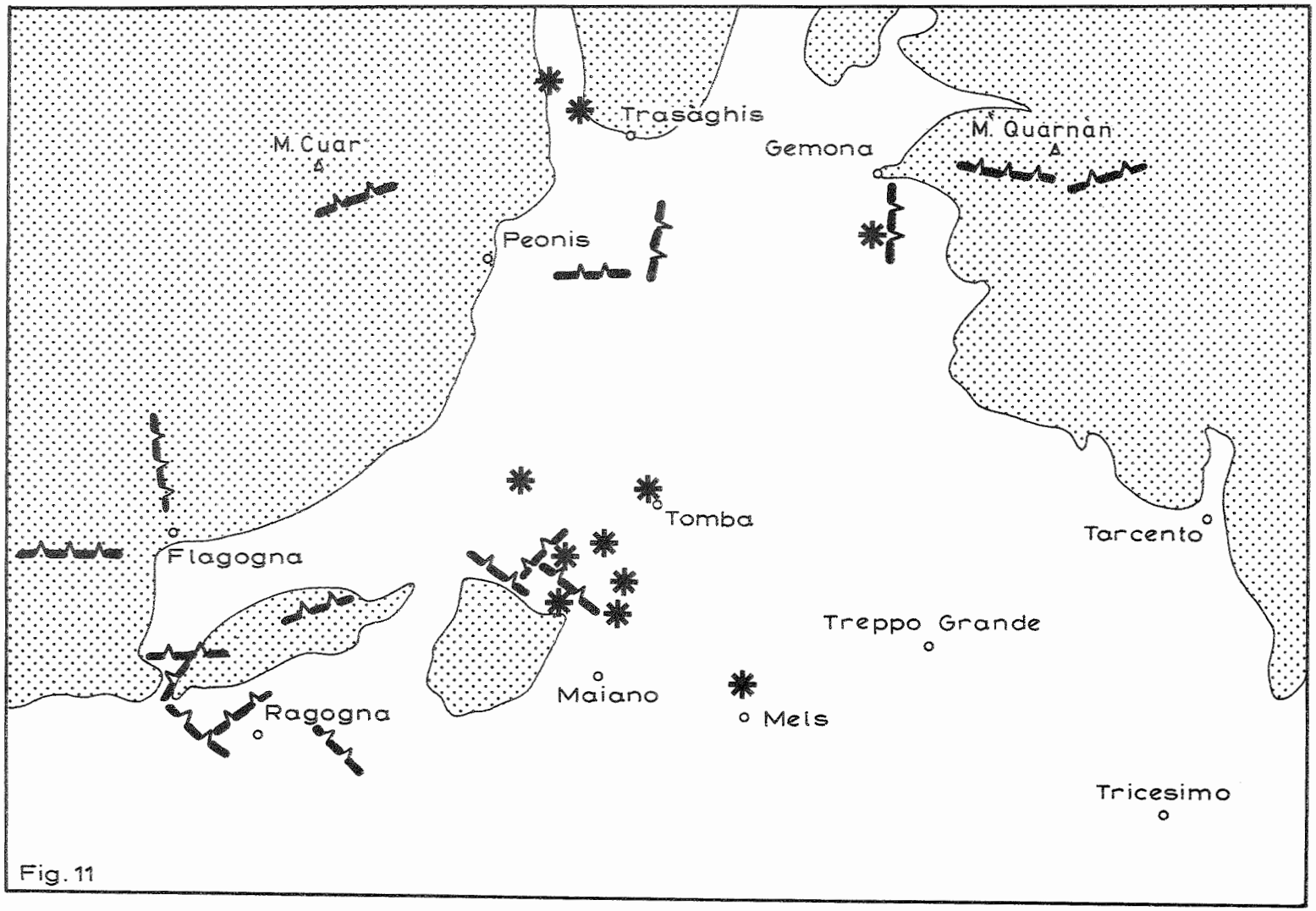
1) Accumulations of rock debris from landslides produced by seismic shaking.
2) Preexistent accumulations of rock debris.
3) Recent alluvial deposits.
4) Cemented breccias (Early Quaternary).
5) Dolomites and dolomitic limestones (Norian).
6) The most advanced position of single blocks fallen in consequence of the main shock of May 6, 1976.
7) The most advanced position of single blocks fallen in consequence of the main shock of September 15, 1976.
8) Church.
9) Rockfalls.
10) Approximate location of longitudinal profiles.



Seismic refraction survey

Location and results of seismic traverses

(See Enclosure 6: Fig. 9 - Landslides induced by the Earthquake. Fig. 10 - Landslides cross section.



GROUND CRACKS AND SAND MOUND INDUCED BY THE EARTHQUAKE

GEOTECHNICAL ASPECTS OF THE RECENT FRIULI EARTHQUAKE

by

Michele Maugeri (°)

1. INTRODUCTION

This paper is essentially based on the data so far made available by the CNEL-ENEL Joint Committee [1] for the Study of Seismic problems associated with the construction of nuclear power stations, and personal observations made during visits to areas damaged in the recent Friuli earthquake. Practically, speaking, attention is here confined to the most violent tremor, which occurred at 15 seconds past 8 on the evening of 6th May 1976, as a prelude to a study of the whole series of shocks. This alone will offer a satisfactory explanation of the causes, origin and progression of the earthquake.

Crude examination of the isoseismal lines showed a far from circular pattern and a heavily damaged area lying in a N-S direction along the Gemona, Cornino, Forgaria and Gemona - Osoppo - Buia -

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Maiano - San Daniele sub-parallels (fig. 1). Particular attention was given to this area. Since it consists of Quaternary deposits, a relation was sought between their geotechnical characteristics, movement of the ground, and damage to buildings.
Because no reliable geotechnical data are yet available, a parametric approach has been adopted. The simplicity of the model chosen makes it particularly clear that soil layer amplification and demagnification govern the transmission of acceleration to structures.

2. FEATURES OF THE EARTHQUAKE OF PARTICULAR INTEREST TO THE ENGINEER

2.1. Magnitude

The most destructive shock was recorded in various parts of the world. The Trieste Geophysical Observatory located its epicentre at 46°16'7" N, 13°6'13" E between Gemona and Mt. Brancot. Since it had a shallow hypocentre (provisionally estimated as about 5-8 Km below the surface), its magnitude was calculated in accordance with the approximate formula:

$$M = AI_o + C \quad (1)$$

where A and C are assigned the values 0.48 and 1.41 proposed by Marcelli & Montecchi [2] for Italy.
If the epicentral intensity in the Gemona area is taken as being of the 10th degree on the international L MM scale [3], M is found to be 6.2-6-4.
There was no accelerograph in operation in the area examined at the time of the main shock. A term of reference has thus been obtained from the tremor that took place at 22 hr 42 min 02 sec on May 11. This was locali

sed at 46° 11' 7""N, 13° 3' 13 E by the CNEN mobile station operating in the Forgoria-Cornino area. A epicentral depth of about 8 Km and a magnitude of 4.8 were also assumed.

2.2. Shaking of the ground

Generally speaking, fragile fracture with numerous shock trains generated high-frequency shaking. This was evident not only in the way buildings were damaged, but also in CNEN and ENEL non-amplified accelerograms recorded in rock (e.g. at Feltre and Malcesine). P and S waves are clearly visible, whereas surface waves are virtually negligible near the epicentre (recordings at Forgaria-Cornino).
By contrast with the Ancona earthquaker, acceleration values were normal for magnitude and slightly above Esteva's curve[5] , which is readily dimensionless for magnitude[6]

$$a = 1230\, e^{0,8M}\, (R + 25)^{-2} \qquad (2)$$

Is should be noted that this curve, like those of Milne & Davenport[7] , offers mean values for a . There are of course, many other formulae in the literature that make use of the mean value of a.
Nevertheless , some points are exceptionally high (fig. 2) and well above the mean (Trifunac[9] and the maximum (Kanai[8] values. These abnormalities lie outside the already wide margins commonly found in this type of analysis (Ambraseys [10] and point to the existence of a different mechanism besides that of the simple transmission of waves. This effect is attributable to the nature of the ground and is the subject of particular attention in this paper.

2.3. Intensity

Earthquake intensity has most commonly been related to the maximum acceleration value. Indeed, the destructive effect of an earthquake is rela-

ted to the maximum acceleration value. Indeed, the destructive effect of an earthquake is related to the energy that the soil manages to transmit. This, in turn, is proportional to the rate of oscillation of soil particles, in accordance with the formula [11, 12]

$$I = \log 14\, V / \log 2 \tag{3}$$

With velocity as the reference parameter, it is an advantage to be able to take duration into account (partly by implication) and taking into account the impulsive nature of seismic forces in structures, to be able to obtain a better evaluation of the forces generated in structures since:

$$F \times dt = m \times V \tag{4}$$

Table 1 shows intensity values calculated with (3) using velocity values given by (6):

$$V = 15\, e^{M} \left(R + 0.17\, e^{0.59M}\right)^{-1.7} \tag{5}$$

Other intensity values are also given using true velocity values obtained by integrating the acceleration values in (3). Comparison between these two sets of values and those determined in the field in accordance with the M.M. scale indicates the extent of the effects of amplification and demagnification of intensity due to the nature of the ground. A more general view of this factor can be seen in fig. 3.

3 - FACTORS CONTROLLING MOVEMENT OF THE GROUND

3.1. Geology

The epicentre areas mostly consisted of occasionally inverted Triassic limestones and sandstones overlain by Quaternary deposits. The overlying rock runs mainly E-W with Jurassic and Eocene plates[13,14] . It proved a good seismic wave carrier and led to considerable damage in quite distant villages (e.g. Tramonti di Sopra). The solid line in fig. 3 indicates the relation between distance and intensity in the E-W direction along which the isoseismic lines of average intensity run.

Very confused Quaternary deposits lie along the more or less N-S line of Tagliamento river in the epicentre and mostly cover sandstone or molassic formations. Considering their limited extent, they greatly amplified the shock, so that high intensities were recorded that were quite independent of the distance from the epicentre in some cases (e.g. Cornino-Forgaria is above the pecked curve in fig. 3, which has a noticeable slope initially).

In addition, the epicentral area is sharply folded (retroflexion) and contains many faults according to the tectonic diagram porposed by Martnis (15). Some of these can be seen on the surface at Buia, Tarcento and S. Pietro di Ragogna. This increased the oscillation amplitude of the ground and so led to catastrophic damage to buildings.

3.2. Topography

The uneven nature of the ground is the second factor that governed the destructive force of the earthquake on both a major and a minor scale. An outstanding feature was the number of landslides that occurred on mountain slopes (S. Simone, Brancot, etc.) and near inhabited areas (Osoppo, Viluzza). Of equal importance and leading to even more serious damage to buildings was the submerged topography of the surface soil

layers.

The frequent occurrence of small mounts (e.g. the 'Fort' of Osoppo) offers a priori evidence of limited soil cover (ranging in a composed fashion from nil near outcrops to about 200-300 maximum) that generally amplified the shock and kept it at catastrophic levels due multiple piling up of reflected waves in the direction of the Tagliamento river as far as San Daniele, where the dissipating effect of the morainic arc and the greater thickness of the ground attenuated the intensity of the earthquake and produced the typical kink shown in fig.3.

Local amplification was noted at the edges of the soil layers along a sloping base. This was attributable to changes in layer depth [16] and to conveyance of the shock waves near the point of insertion into the rock substrate [17]. Still greater effects were observed in or near ground with a twisting base (S. Pietro di Ragogna), since here the factors already mentioned were associated with mainly detritic soil (landslides) or alluvial soil, and the amplifying effect of the mountain itself.

3.3. Geotechnical characteristics of soil layers

From what has already been said it is clear that the most important factor underlying the effects of the Friuli earthquake was the presence of relatively shallow surface layers and, more particularly, their geometric and geotechnical features. Confirmation of this has been obtained experimentally [18] and in the Skopje earthquake.[19]

The position to the East of the Tagliamento is very confused. Here layers vary in thickness (Gemona, for example, stands on a dejection cone behind the mountain) and in structure and composition (at Maiano, layers of silt and clay are intermingled with mainly sandy layers). The layers to the West of the river are more regular. They stretch out as patches at various points and mostly consist of post-glacial detritus (Trasaghis and Peonis), upper Pleistocene alluvial deposits (Forgaria-Cronino), and stratum débris interspersed with plugs of silty clay and morainic conglomerates.

Generally speaking, the sandy soils West of the Tagliamento amplified the shock waves for thicknesses of up to 30-40 metres due to the almost superficial stratum. P wave velocities close to the characteristic 1600 m/sec in water may be postulated, with some signs of liquefaction.
Back analysis was attempted in the Forgaria-Cornino area. Here the situation was such as to permit representation in the form of a single layer.

4 - BACK ANALYSIS AT FORGARIA-CORNINO

4.1. The equation for the simple soil layer model

It was assumed that the shock waves were transmitted via the rocky (molasse and sandstone) substrate and vibrated the surface layer. Soil layer response can now be determined by highly sophisticated methods [20]. However, since there are no reliable data for the tangential modulus of elasticity of the soil, specific gravity γ, shear strength τ and shear wave velocity V_s, a very simple diagram was adopted (fig. 4), in which the preponderant effect of the shear waves in an elastic model (°) was governed by the classic formula:

$$m\,\ddot{u} + c\,\dot{u} = G\,\frac{\partial^2 u}{\partial y^2} \qquad (6)$$

where:

m = mass

u = horizontal displacement

c = damping coefficient

(°) Tests in a non-linear field using an equivalent linear system and the SCLUMP programme [21] did not produce significantly different results bearing in mind the approximate data assumed for the geotechnical caracteristics of the soil.

This equation is equally applicable to a free surface and to one that has been built on; provided such buildings are treated as a rigid mass with specific gravity and infinitely extendable. This schematic representation can be adopted to simulate the presence of e.g. a town on free soil and is compatible with the other representations assumed.

4.2. Back analysis of the may 11 shocks

Solution of equation (6) usually enables the proper period T of the layer and the coefficient of acceleration $K = a/a_s$ (= the ratio between the acceleration a at the top point of the layer and that of the spectrum as imposed by the rock below the layer) to be calculated, in addition, of course, to the deformation and stress generated in the layer by the earthquake, if required.

The presence of a mobile CNEN station equipped with a Kinemetrics SMA 1 accelerograph permitted three-directional recording of the acceleration. The proper N-S and E-W periods of the layer could thus be determined experimentally (presence of several waves with the same amplitude and high peaks due to nil damping on the standard acceleration diagram). The resolutive equations could thus be employed in reverse to find the simple relations linking the depth of the layer H to the velocity of the shear waves V_S.

Accelerograms recorded at 4hr 43 min 53 sec (light shock) on 10 May 1976 and at 22 hr 44 min 2 sec (M 4.8 shock) on 11 May 1976 gave the following period values (°):

$$T_{N-S} = 0.15 \text{ sec}^{(°°)} \quad T_{E-W} = 0.40 \text{ sec}$$

(°) The difference between these values is due to the fact that the layer, through of constant thickness (about 15 m), sloped N-S and was thus confined by the relief. Crossed forcing frequencies occurred together with secondary frequencies due to reflection.

(°°) There was an assembly of selective frequencies around this value.

Lower values were recorded for the lighter shock. The higher values observed for the heavier shock can be put down to plasticisation of the ground, so that the maximum amplification period may have been 0.45 - 0.55 in the E+W direction, along with various lesser amplification periods. Figs. 5 & 6 show the relations between H and Sv for free and loaded surfaces respectively in parametric form. This is because not all the physical dimensions involved are known exactly, and also because the two graphs can be used for the entire Forgaria-Cornino as opposed to that in the immediate vicinity of the CNEN station.

4.3. Evaluation of the May 6th earthquake.

As already stated, no recordings were taken of the major shock that destroyed Cornino and Forgaria. However, an indirect calculation can be made on the assumption that the 11th May shock deviated from Esteva's formula in the same proportion.
This, however, did not occur at Tolmezzo. It was therefore decided to examine the spectra of the two shocks by assigning half the difference in their deviation to amplification during the shock of May 6 and the other half to demagnification of the acceleration during that of May 11. This gave a basic rock acceleration value of 0.32 g at Tolmezzo and 0.33 g at the Forgaria-Cornino station, which was a little nearer the epicentre. The same result is obtained by using Esteva's relation (calibrated as already described) to derive the value for the May 6th shock from the basic rock acceleration value 0.14 (°), obtained from that of 0,19 g recorder at Cornino-Forgaria, less the amplification due to the soil (K = 1.4) observed during the May 11 shock. If the factor given by equa -

(°) This value was obtained by discharding the maximum acceleration reading obtained during the major shock on May 6. (a_{E-W} = - 0.380) as anomalous and perhaps due to interaction with a pre-existing rupture surface.

tion (6) for the May 11 shock is retained for that of May 6, this relation shows that the maximum soil surface acceleration that resulted in the destruction of Forgoria and the two hamlets at Cornino was :

$$a_{max} = 0,46 \text{ g}$$

The ground, however, was not able to support such high accelerations. Slight subsequent rotations of the surface offered signs of internal rupture, favoured (at Cornino) by the slight slope of the ground.
This undoubtedly created differential movements in the foundations of buildings and helped to destroy them.

5. CONCLUSIONS

One of the aims of this study has been to show that an engineering approach to the examination of earthquakes, particularly their epicentres zones, should be based on directly measurable physical quantities, such as the geological and topographical features of the soil and its mechanical characteristics, rather than preconstituted empirical relations between the seismological quantities involved (a,v). The latter are, of course, useful as a point of departure and good calibration for the ground in Friuli will very likely be obtained as soon as the data for the many after-shocks have been collected and processed (°). Yet it would be a mistake to extend these results to other areas of Italy without careful

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(°) As a first approximation, the following expression for the acceleration value of the basic rock can be derived from the analyses of spectrum so far available (compare with equation 2) :

$$(7) \qquad a = \left(5200 - \frac{2000\ M}{R^{0,7}}\right) e^{0,8M} \ (R + 25)^{-2}$$

geological and geotechnical investigation.

It is worth recalling that at Cornino two hamlets (Sompcornino and Ca Dant) about 500 metres from other and consisting of the same types of buildings (stone houses) behaved in a very different manner. The first, which stands on rock, was virtually undamaged; the second, which lay on 15 metres of alluvium, was rased to the ground. It is clear that calibration of the formula for calculating soil response in a non-elastic field at the epicentre requires through geotechnical examination both on the site (to determine H, V_p, V_s, E, G, ν, water level) and in the laboratory (for E, G, ζ, γ, C_u, c', ϕ', G.S.C, e, C_v, K) using undisturbed samples.

It must also be pointed out that effective protection against earthquakes demands that designers take into account the whole data spectrum, not merely the maximum acceleration. Indeed, maximum velocity, duration and the maximum shifts should preferably be allowed for. These last, in fact are essential in achieving a good compromise between rigidity and ductility, since it is a good rule to restrict shifting in the case of loose, saturated soil and create good connections between the bearing parts.

The maximum amplified acceleration (0.367g) was recorded only a few tens of metres away from the recording station at Tolmezzo and the building was undamaged. Had the same spectrum been applied in terms of maximum shifting on alluvial soil, it would certainly have brought about its collapse.

From the geotechnical standpoint, the important requirement for thorough back analysis of the Friuli earthquake is the carrying out of soundings and careful on-the-site and laboratory tests, to determine the seismic parameters of the ground layers that resulted in amplification of its effects. Until this is done, a stochastic approach should be prepared for the characterisation of geotechnical areas (12). The methods carefully checked in this way could then be extended to the whole of Italy.

REFERENCES

1. CNEN-ENEL, Strong motion earthquake accelerograms digitised and plotted data-Uncorrected accelerorgrams. Commissione per lo studio dei problemi sismici connessi con la realizzazione di impianti nucleari , Rome, Italy july 1976.

2. RICHTER, C., Elementary Seismology. W.H. Freemon and Company, San Franciso, 1958, Chap. 11.

3. MARCELLI L., MONTECCHI A., Contributi per uno studio sulla sismicità dell'Italia. Annali di Geofisica, vol. 15, p. 150.

4. FRANZESE G., IACCARINO E., MUSSI F., PERINETTI M., SANO' T., ZAFFIRO C., Italian Earthquake since 1971. Crest specialist meeting on Antiseismic Design of Nuclear Power Plants, Pisa, 3rd-5th October 1972.

5. ESTEVA L., Seismic risk and seismic design decision. Seminar of Seismic Design of Nuclear Power Plants, Cambridge, Massachusetts Institute of Technology Press, 1969.

6. NEWMARK, N.M., ROSENBLUETH E., Foundamentals of earthquake engineering Prentice-Hall Inc., Englewood cliffs, N.J. Chap. 7.

7. MILNE W., DAVEMPORT A., Distribution of earthquake risk in Canada. Bull Seism. Soc. America, Vol. 59 p. 729 1969.

8. TRIFUNAC, M. BRADY, G., Correlation of Peak acceleration, velocity and displacement with earthquake magnitudo, distante and site conditions, Earthquake Eng. and Struct. Dynamics. Vol. 4, N. 5, 1976.

9. KANAI K., Improvved empirical formula for characteristics of strong earthquake motion". Proc. Japan Earthq. Eng. Symposium, p. 1. Tokyo, 1966.

10. AMBRASEYS N.N., Dynamics and response of foundation materials in epi central regions of strong earthquakes Proceedings Fifth World Confe rence on Earthquake Engineering vol. 1 pp. CXXVI - CXLVIII, Rome '74.

11. ESTEVA L., ROSEMBLUETH E., Espectros de temblores a distancias moderadas y grandes.Bol. Soc. Mex. Ing. Sism. Vol. 2(1), p. 1., 64

12. ROSEMBLUETH E., Probabilistic design to resistant earthquakes. Proc. ASCE, vol. 90 (EM5), p. 189, 1964.

13. GORTANI M., DESIO A., FERRUGLIO E., MARINELLI O., STEFANINI G., ZENARDI S., Guida geologica del Friuli, vol. 1, fasc. 1, Stab. Tipograf. "Carnia", Tolmezzo 1976.

14. FERUGLIO E.; Note illustrative della carta geologica delle tre Venezie, foglio "UDINE", 1929.

15. MARTINIS B., The friulan and Iulian Alp and Prealps. In: Structural model of Italy. Quad. Ric. Scient. C.N.R. 1975.

16. DEZFULIAN H., SEED H.B., Seismic response of soil deposits underlain by slopping rock boundaries. Journ. of Soil Mech. and Found. Div., Proc., A.S.C.E., Vol. 96, p. 1893,1970.

17. DEZFULIAN H., SEED H.B., Response of nonuniform soil deposits to travelling seismic waves. Journ. of Soil Mech and Found. Div., Proc. A.S.C.E., vol. 97, p. 27, 1971.

18. GUTENBERG B., Effects of ground on earthquake motion. Bull. Seism. Soc. America, vol. 47, p. 221, 1957.

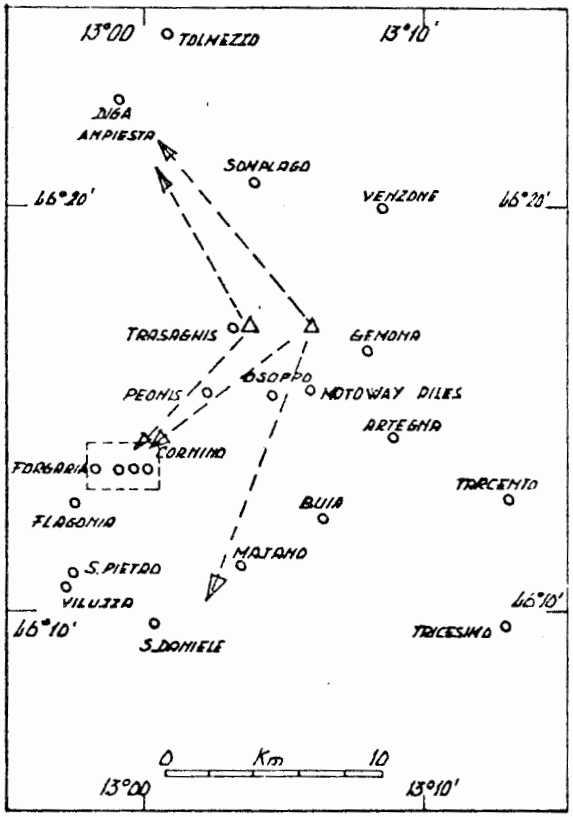
19. POCESKI A., The ground effects of the skopje july 26, 1963 earthquake. Bull. Seism. Soc. America, vol. 59, p.1,1969.

20. MAUGERI M., Discussion on the elastic response of soil Layers. Proc. of the Symposium on Interaction of Structure and Foundation, Birmingham 12-14th July, p. 248, 1971.

21. IDRISS, J.M., DEZFULIAN H., SEED H.B., Computer programs for evaluating the seismic response of soil deposits with non-linear characteristics using equivalent linear procedures. Department of Civil Engineering, University of California, Berkeley, California, April 1969.

22. CRESPELLANI T., LOI A., Approccio stocastico alla caratterizzazione geotecnica del sottosuolo. 1° Convegno del Progetto Finalizzato Geodinamica, ROMA 15-17 dicembre 1976.

Fig. 1 - Epicentral zone examined

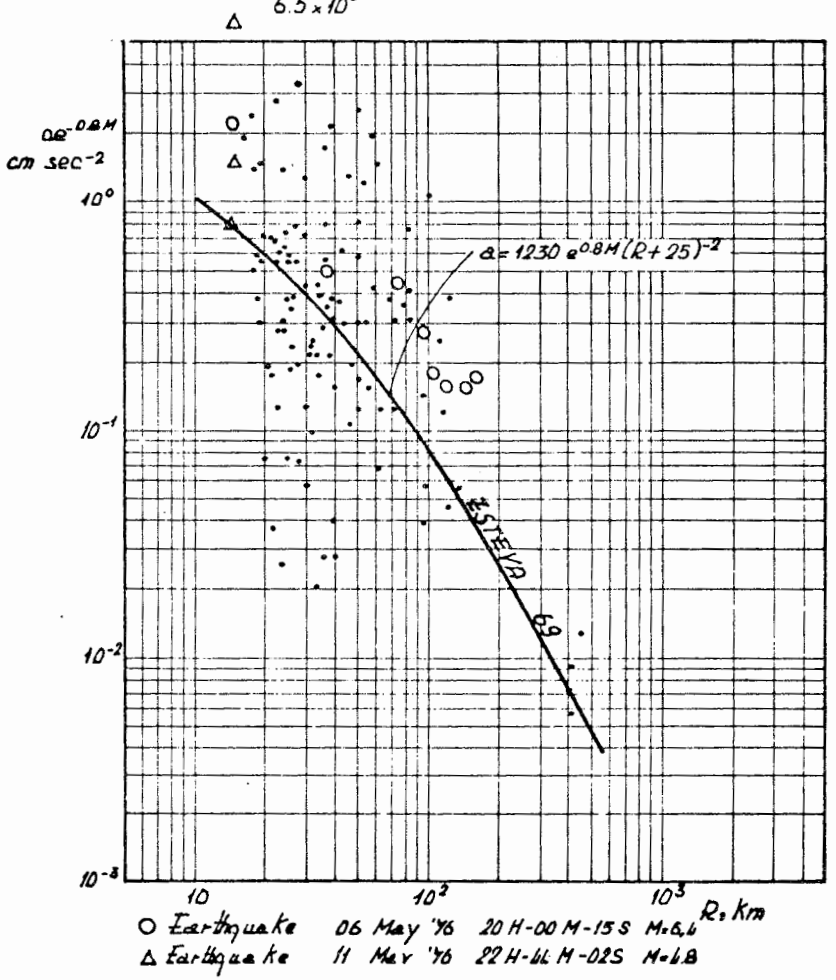


○ Sites investigated

△ Earthquakes considered (Epicentres)

----- Travelling waves examined

Fig. 2 - Recorded maximum ground acceleration with focal distance



○ Earthquake 06 May '76 20 H-00 M-15 S M=6.4

△ Earthquake 11 May '76 22 H-44 M-02 S M=5.8

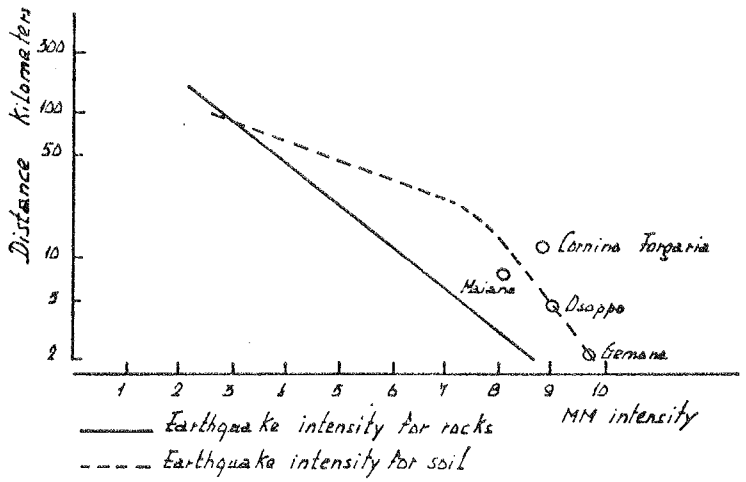
TAB. 1 – Calculated and observed intensity

	D	a_H % g	V Estesa	V integral	I Estesa	I integr.	I_{MM}
Tolmezzo	16	0.367	46	33	9,3	9	6
Codroipo	38	0.087	16	13	8.0	7	5
Cornino – Forgaria	14	0.308 x	15 x	16-17 xx	9.9 x	9 xx	9
Maiano	14	0.082 x	15 x	6-9 xx	7.7 x	6 xx	8

x Values Refered to the Earthquake 11 May '76 22 H-46 M-02 S

xx Approximate values

Fig. 3 – Distance - intensity graph



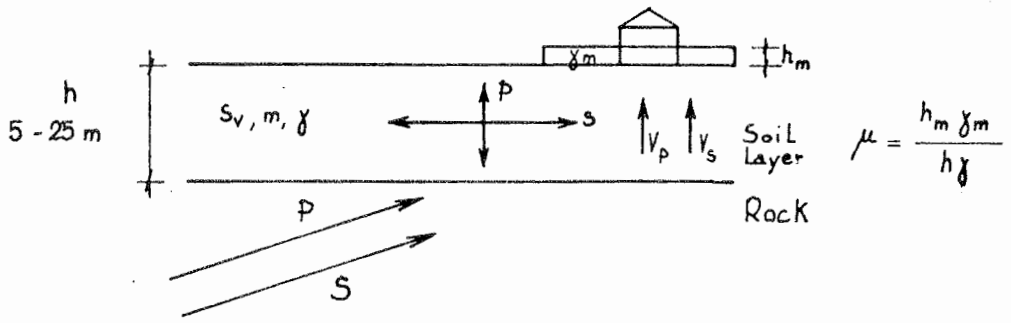


Fig. 4 - Simple Soil Layer model

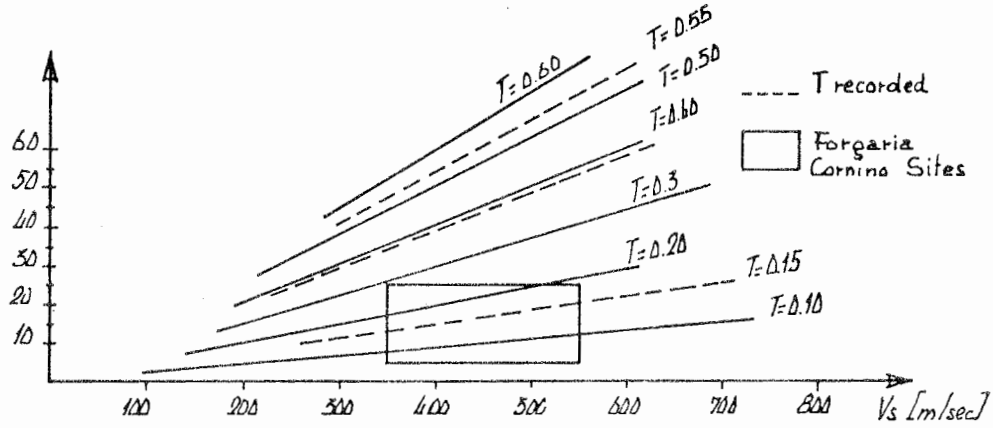


Fig. 5 - Amplification period for free surface

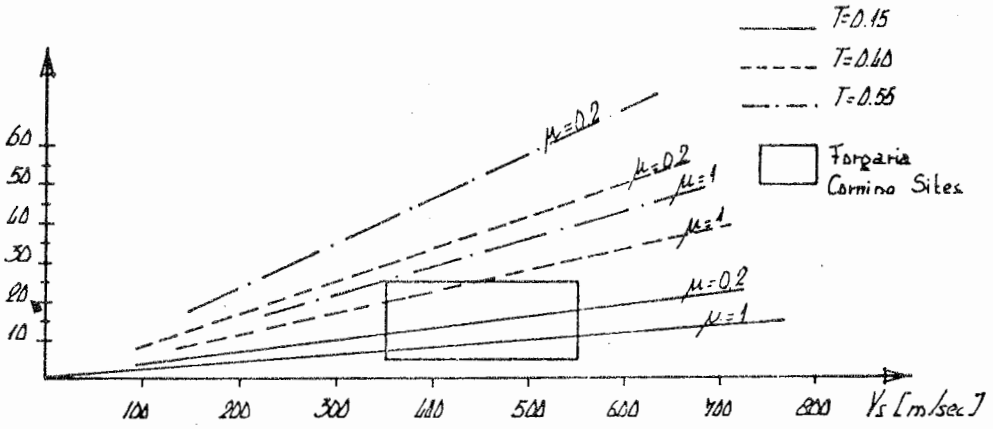


Fig. 6 - Amplication period for loaded surface

AFTERSHOCK-STATISTICS AND FAULT-PLANE SOLUTIONS OF FRIULI EARTHQUAKES 1975 & 1976

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Abstract

The analysis of aftershocks for the earthquakes of May 6 and September 11 in Friuli reveal slopes between 0.85 and 1.15 in the bi-logarithmic relationship of number of events versus time lapse. A first motion study of the March 1975 earthquake in Friuli indicates a North-South orientation of the axis of maximum shortening of the crust.

Aftershock study

The analysis of the time history of aftershock-sequences of Friuli-earthquakes is based on recordings of seismograph-stations in Switzerland, situated about 300 km apart from the epicentral area. Thus, only shocks with magnitude $M \geq 3$ are taken into account for this study. Fig.1 shows on top the sequence after May 6 for the time period until September

(MAYER-ROSA et al.1976) and below the sequence after the large shocks of September 11 and 15 until December 1, 1976.

The method of sampling was chosen in such a way, that always 10 earthquakes were covered by the variable time window. Afterwards these values were corrected to the number of events per 10 hours time window. A total of about 300 shocks with magnitude $M \geq 3$ was included in this study. The decay of activity as recorded in Switzerland is exponential, giving an overall slope of $p = 0.85$ for the May-sequence in Omori's law

$$\log N(t) = K - p \log(t+c)$$

where: N = number of shocks per 10 hours time unit, t = time, K = activity factor, c = time constant.

The September-sequence seemsto have a faster decay-rate of $p = 1.15$. These results fit well into the range of values found by aftershock-studies of earthquakes in other areas such as

- San Fernando 1971: $p = 1.0$ (SCHOLZ 1971)
- Oroville 1975: $p = 0.70$ (MORRISON et al. 1976)
- Kamchatka 1958-1969: $p = 0.8$-1.5 (OLSSON 1974)
- Japan 1968: $p = 0.8$-0.9 (UTSU 1970)

The difference in activity and rate of decay between May and September in Fig. 1 indicates, that the two sequences belong to different families of aftershocks. This hypothesis is also supported by the fact, that the calculated epicenters of the September-shocks are systematically shifted by at least 10 km towards the North-East with respect to the shocks in May and June (CSEM-WORKING GROUP 1976).

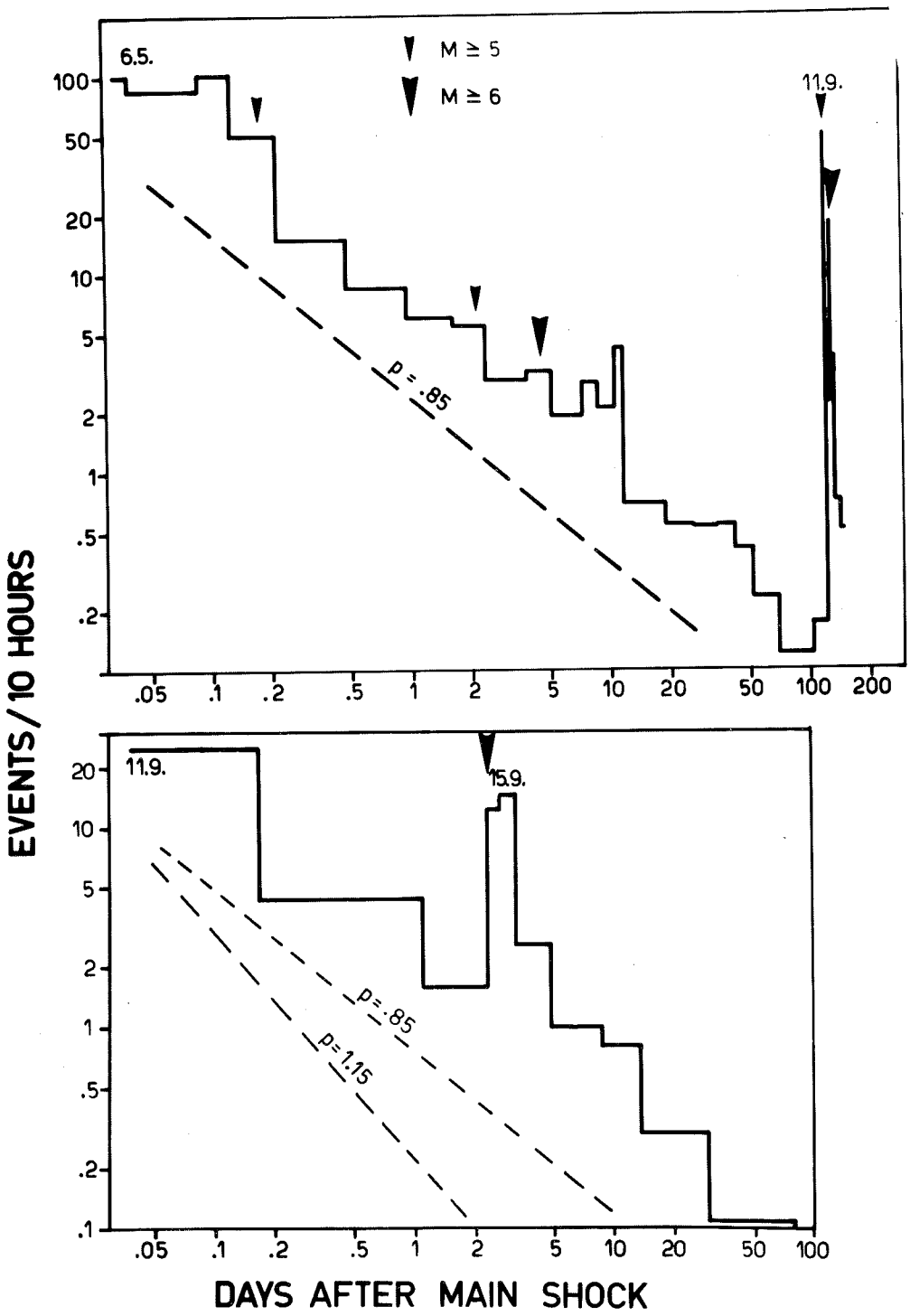

Fig.1: Frequency-time distributions for aftershock sequences ($M \geq 3$) starting on May 6,1976 at 20:00 GMT (on top) and September 11,1976 at 16:00 GMT (below).

Focal mechanisms

All the stations of the Swiss Seismological Service recorded short-period compressional first motion of P-waves of the Friuli earthquake of 6 May 1976. Also most aftershocks of the 1976 Friuli earthquake were recorded in Switzerland with compression. For comparison with the focal mechanism of the destructive1976 Friuli earthquake (MÜLLER 1976), it may be of interest to present the fault plane solution of the Friuli earthquake of 24 March 1975 (M_b = 4.2; Lat. 46.3N, Long. 13.0E). Considering the fact that both, the 1975 and 1976 Friuli earthquakes, originated in the same area and that both were recorded with compression at the Swiss stations, a short discussion of the fault plane solution of the 1975 Friuli earthquake may be of special interest and may shed some light on the focal mechanism of the 1976 event.The solution is given in Fig. 2.

The distribution of compression and dilatation of the 1975 Friuli event shows two different, possible mechanisms:

(a) A strike-slip mechanism with a NNE-SSW striking nodal plane (1) dipping 69° towards WNW (azimuth 302°) with oblique sinistral lateral slip (slip vector az/dip 226°/30°) and a NW-SE striking plane (2) dipping 60° towards NE (az 46°) with oblique dextral lateral slip (slip vector 122°/20°). The P-axis (P') dips 37° towards S (az 171°). The T-axis (T') 6°towards W (az 266°). In addition to the dominant horizontal component of slip there is a component of normal vertical displacement.

(b) A reverse faulting or thrust mechanism with E-W to NE-SW striking thrust planes. In Fig. 2 we assume the same azimuth of the P-axis as in solution (a). One of the thrust

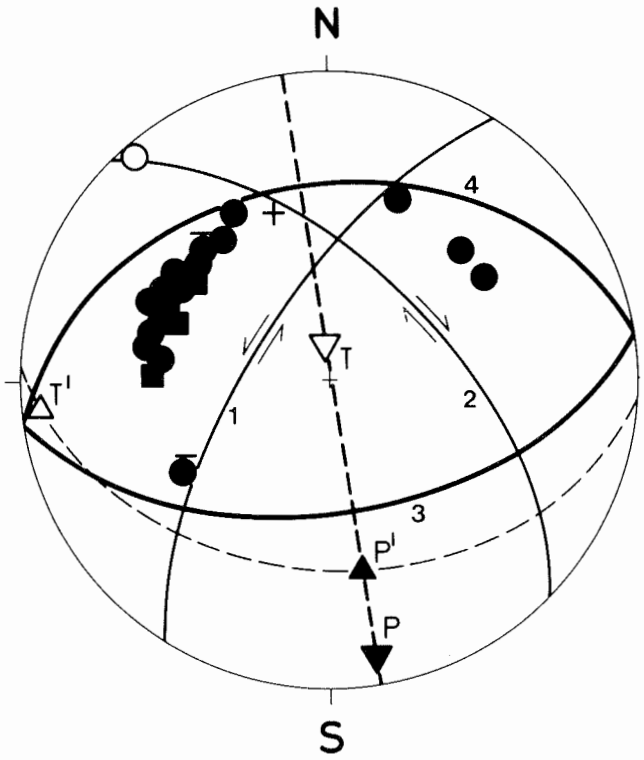

Fig. 2: Fault plane solution of the Friuli earthquake of 24 March 1975; HO = 02:39:19; Lat.= 46.3N, Long.= 13.0E; h = 10 km; M_b = 4.2. Solid circles, squares and + = compressions; open circles and − = dilatations. (a) Strike-slip type solution: Nodal planes (1) and (2), P'= P-axis, T'= T-axis; (b) Thrust type solution: Nodal planes (3) and (4), P = P-axis, T = T-axis.

planes (3) dips to the S (az/dip: $171^{\circ}/54^{\circ}$), the other (4) to the N ($351^{\circ}/36^{\circ}$); P-axis (P: $171^{\circ}/9^{\circ}$), T-axis (T: $351^{\circ}/81^{\circ}$).

Both mechanisms clearly indicate N-S shortening of the crust combined with uplift in the case of solution (b) or E-W extension in the case of solution (a). The maximum horizontal compressive stress is oriented NNW-SSE.

A NNW-SSE orientation of the P-axis was also observed with the Cansiglio earthquake of 18 October 1936 (CALOI 1938, DI FILIPPO and PERONACI 1962). The epicenter of this earthquake (Lat. 46°06.2'N, Long. 12°26.5'E) was situated about 40 km to the W of the 1975 Friuli earthquake. The fault plane solution is of strike-slip type and corresponds very nearly to our solution (a).

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References

1.Mayer-Rosa,D.,Pavoni,N.,Graf,R.,Rast,B. Investigations of intensities,aftershock statistics and the focal mechanism of Friuli earthquakes in 1975 and 1976. Pure Appl. Geophys.,6 (in press),1976.

2.Utsu,T. Aftershocks and earthquake statistics II. J.Fac.Sci.Ser.VII,Hokkaido Univ.3,197,1970.

3.CSEM-Working Group. Revised parameters for the Friuli earthquakes 1976. Proc.Udine 1976,Meeting on Friuli earthquake.

4.Müller,G. Fault plane solution of the earthquake in Northern Italy,6 May 1976, and implications for the tectonics of the Eastern Alps. J.Geophys.(in press)1976

5.Caloi,P. Ricerche su terremoti ad origine vicina:Scosse del Cansiglio dell'ottobre 1936-XIV. Publ.Ist.Naz.Geof., 16,3-41,Roma 1938.

6.DiFilippo e Peronaci,F. Terremoti di frattura e relazioni con la tettonica nelle Alpi orientali. Ann.Geof. XV,195-223,Roma 1962.

7.Scholz,C. Microearthquakes on the S.Andreas Fault and aftershocks of the S.Fernando earthquake. U.S.Geological Survey Professional Paper 773,33-37,1971.

8.Morrison,P.et al. The Oroville earthquake sequence of August 1975. Bull.Seism.Soc.Am.66,1065-1084,1976.

9.Olsson,R. Earthquake activity in the Kamchatka-Kurile Islands-Japan region 1958-1970. Rev.Ital.Geof.XXIII,1974.

STRONG-MOTION RECORDS OF THE MAY 6th AND SEPTEMBER 15th 1976 FRIULI EARTHQUAKES OBTAINED BY THE YUGOSLAV STRONG-MOTION INSTRUMENT NETWORK

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The aim of this paper is to summarise the data obtained from 32 recorded accelerograms of strong earthquake motions (May 6th and September 15th, 1976) and their stronger aftershocks, which occurred in the Friuli are during the period from May to September, 1976. The data have been obtained from the Yugoslav strong-motion instrument network.

The earthquakes of May 6th and September 15th, 1976 that occurred in Friuli near the Yugoslav-Italien bourder, caused great material and human losses, and were felt in an area of about 250 km in radius from the epicentre. In Yugoslavia, these earthquakes were manifested with highest acceleration ever recorded by the strong-motion instruments. The highest acceleration of 0,52 g of the earthquake of September 15th, 1976 at 03 h 15' 22" with M = 5.9 was recorded on the instrument at Breginj at a distance of cca 25 km from the epicenter.

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Introduction

Structural design criteria for zones of high seismic activity should be defined from ground motion records and data concerning the response of structures during strong earthquakes. The only possibility for obtaining such data is installation of strong-motion instrument network.

Therefore, in 1973, Yugoslavia - a country exhibiting considerable seismic activity, was covered by a basic strong-motion instrument network consisting accelerographs and seismoscopes. (Fig. 1).

The Yugoslav strong-motion instrument network is realised by the Institute of Earthquake Engineering and Engineering Seismology, University "Kiril and Metodij", Skopje, Yugoslavia.

Basic Concept of the Yugoslav Strong-Motion Network

One of the largest strong-motion instrument network in Europe is the strong-motion accelerograph and seismoscope network installed in Yugoslavia. This network of instruments provides basic information required for predicting the dynamic response of various types of structures, building codes improvement, ground amplification effects understanding, as well as for better investigation and perceiving of the consequences caused by earthquakes.

Location of Instruments. The distribution of the strong-motion instruments on the territory of Yugoslavia is based on previous studies of geological-tectonic structure and the seismicity of the country. According to these studies it has been concluded that, in the first stage of realisation of this project, the instrument network for recording of strong earthquakes should contain 136 accelerographs, 150 seismoscopes and a certain number of accelerographs for recording maximal acceleration.

The selection of detailed locations (Fig. 1) for the establishment of these instruments makes possible to obtain records on 1) bedrock, 2) on a surface of characteristic soils (alluvial and diluvial sediments), 3) on structures (multistorey buildings, dams, bridges, etc.).

In this way, the designed network enables obtaining of data of the following type by measuring the radiation pattern of seismic waves, by measuring the effect of the soil condition and the response of structures.

The Yugoslav instrument network mainly contains two types of instruments:accelerographs SMA-1, produced by Kinemetrics, USA, and seismoscopes, type WM-1, produced by the Astronomic-Geophysical Observatory in Ljubljana, Yugoslavia.

Operation of the Network During the Friuli Earthquakes

The ear-hquakes of May 6th and September 15th, 1976 which occured in Friuli, North-East Italy, close to the Italian-Yugoslav bourder, and the numerous aftershocks, have caused enormous loss in goods and human lives, particularly in Italy. In Yugoslavia these earthquakes created considerable damage in material properties, especially in the North-Western part of Slovenia (Posocje), where some villages as Breginj, Podbela and other were completely destroyed.

In Yugoslavia these earthquakes were felt in an area with a radius of 250 km from the epicenters. As it is evident in Fig. 1, this area had been covered by a large number of accelerographs and seismoscopes which were in operating state during the earthquakes. Within few days after the earthquake of May 6th, three temporary accelerographs were additionally installed at the following locations: Breginj, Kobarid and Robic (Fig. 2), which were most severely affected by the earthquake. A number of aftershocks have triggered these instruments.

In the period from May 6th through September 15th, 1976 32 accelerograph records and 6 seismoscope records have been obtained from the Yugoslav strong-motion network.

Table 1 gives the characteristics of the instruments which recorded the Friuli earthquakes.

Table 2 gives data of the more important recorded earthquake's of maximal acceleration larger than 5% g.

INSTRUMENT CHARACTERISTICS

TABLE 1

Station location		Instrument		Components								
				N - S			E - W			V		
No.	Address	Type	Serial No.	Sens. (cm/g)	Period (sec)	Damp. (%crit)	Sens. (cm/g)	Period (sec)	Damp. (%crit)	Sens. (cm/g)	Period (sec)	Damp. (%crit)
501	Ljubljana ZRM	SMA-1	673	1.80	0.038	55.9	1.98	0.041	57.4	1.88	0.038	60.8
503	Ljubljana IMFIM	SMA-1	696	1.86	0.038	60.8	1.86	0.039	60.8	1.75	0.038	57.4
592	Breginj Needle Production Factory	SMA-1	681	1.80	0.041	60.8	1.95	0.039	59.1	1.90	0.040	60.8
593	Kobarid Prim. School	SMA-1	700	1.85	0.039	57.4	1.92	0.040	57.4	1.86	0.039	55.9
594	Robič Customs	SMA-1	657	1.71	0.038	56.2	1.81	0.038	54.4	1.86	0.035	56.4

EARTHQUAKE DATA

TABLE 2

Date	Time (GMT)			Epicentre coordinates		Magnitude	Epicentral intensity	Accelerograph station	Max. recorded acc.
	H	M	S	ϕ	λ	M	I_o		(g)
May, 06,1976	20	00	14.7	46.31 N	13.31 E	6.2	IX-X	Ljubljana-INFIM	0.040
May,06,1976	20	00	14.7	"	"	6.2	IX-X	Ljubljana - ZRM	0.022
Jun,08,1976	12	14	38.3	46.28 N	13.27 E	4.3		Breginj	0.103
Sept.11,1976	16	31	13.6	46.32 N	13.18 E	5.4		Kobarid	0.101
Sept.11,1976	16	31	13.6	"	"	5.4		Breginj	0.171
Sept.11,1976	16	35	42.4			5.5		Kobarid	0.099
Sept.11,1976	16	35	42.4			5.5		Breginj	0.123
Sept.11,1976	16	35	42.4			5.5		Robič	0.057
Sept.13,1976	18	55	23.5			4.1		Robič	0.050
Sept.15,1976	03	15	22.1	46.32 N	13.16 E	5.9	IX	Breginj	0.525
Sept.15,1976	03	15	22.1	"	"	5.9	IX	Kobarid	0.126
Sept.15,1976	03	15	22.1	"	"	5.9	IX	Robič	0.105
Sept.15,1976	04	39	32			4.6	VI-VII	Breginj	0.071
Sept.15,1976	09	21	20.4	46.33 N	13.17 E	5.7	VIII-IX	Kobarid	0.143
Sept.15,1976	09	21	20.4	"	"	5.7	VIII-IX	Breginj	0.419
Sept.15,1976	09	21	20.4	"	"	5.7	VIII-IX	Robič	0.088

The Event of May 6th. Fig. 3 shows the isolines of the May 6th,1976 earthquake. As it can be seen this earthquake was felt on a larger territory of Yugoslavia. The same figure also shows the state of the strong-motion instrument network in Yugoslavia during the earthquake. A total number of 5 accelerographs and 7 seismoscopes had been installed in the area where the earthquake was manifested with $I \geq VI$ degrees according to the MCS scale.

The earthquake of May 6th, 1976 activated 2 accelerographs and 4 seismoscopes altogether. Both activated accelerographs are located in Ljubljana on a distance of cca 100 km from the epicenter of the earthquake. The peak acceleration of this earthquake recorded in Ljubljana amounted 004 g (Fig. 4). Table 2 shows the basic data of this earthquake obtained from the recordings of these accelerographs and the seismological data obtained from the recordings of the Yugoslav seismological stations in Ljubljana, Zagreb and Skopje. This earthquake has also been recorded by two seismoscopes installed in Tolmin at a distance of cca 40 km and two in Ljubljana at a distance of cca 100 km from the epicentre. On Fig. 5 are shown the seismoscope records obtained in Tolmin and Ljubljana.

Some Aftershocks of Greater Importance during the period from May 6th to September 15th, 1976. A greater number of aftershocks with magnitude of M = 3.6 to M = 5.5, which occured during the period from May 10th to September 15, 1976, have been recorded by the additionally installed accelerographs in Breginj, Kobarit and Robic.

The following Table 3 gives data on the location and number of triggering of each accelerograph separately durimg this period, as well as the maximal recorded acceleration of these aftershocks.

Table 3.

Instrument location	type of soil	Approximate epicentral distance (km)	Number of triggering	Maximal recorded acceleration (g)	
				Horiz.	Vert.
Breginj	Soft	20 - 25	4	0,171	0,052
Kobarid	Soft	25 - 30	8	0,101	0,058
Robic	Rock	20 - 25	3	0,057	0,025

Maximal acceleration at Breginj and Kobarit was caused by the aftershock of September 11th, 1976 at 6h 31m p.m. with M = 5,4, and at Robic by the aftershock of September 11th, 1976 at 4h 35m with M = 5,5. Seismoscope records of the above aftershocks are not available.

The remaining instruments located in an area of 100 km in radius from the epicenter of these aftershocks were not trigged. All instruments were in good working condition controlled each month.

The Event of September 15th, 1976. The earthquakes which occured on September 15th, 1976 were the stronger ones after that of May 6th, 1976. Both strong earthquakes at o3h 15m (M = 5,9) and at o9h 21m (M = 5,7) as well as the numerous afteshocks which occured at the same day caused great material damage in Italy as well as at Posocje (Yugoslavia). The occurence of these earthquakes was a surprise both for the seismologists and earthquake engineers because such events in this part of Europe are not known in the seismological history.

These earthquakes were also recorded by the accelerographs installed at Breginj, Kobarid and Robic,and the seismoscopes at Tolmin and Ljubljana.

At Breginj were recorded 5 earthquakes, at Kobarid 6 and at Robic 3 all of September 15th, 1976.

Table 4.

Location of accelerograph	Epicentral distance (km)	Magnitude M	Maximal acceleration (g)		
			N - S	V	E - W
Earthquake of September 15th, 1976 at o3h 15m (GMT)					
Breginj	20 - 25	5,9	0,487	0,198	0,525
Kobarid	25 - 30	5,9	0,108	0,088	0,126
Robic	20 - 25	5,9	0,105	0,049	0,074
Earthquake of September 15th, 1976 at o9h 21m (GMT)					
Breginj	20 - 25	5,7	0,166	0,126	0,419
Kobarid	25 - 30	5,7	0,143	0,065	0,109
Robic	20 - 25	5,7	0,088	0,046	0,058

Of special interest are the records of the earthquakes of o3h 15m (M = 5,9) and o9h 21m (M = 5,7) which are recorded by all three accelerographs at the same time. Table 4 shows the results (data) of these earthquakes.

As it can be seen from the above table, the instrument at Breginj recorded two very important records (Fig. 6 and 7) with maximal acceleration od 0,525 g., i.e. 0,419 g, which is of special interest for the earthquake engineers. Further more, because the instrument is located at a distance of cca 20-25 km from the epicenter in a structure which did not suffered significant structural damage due to these earthquakes, while all other structures at Breginj were completely destroyed. At the same time, at Kobarid and Robic, which are at the almost the same distance from the epicentre, acceleration of 0,126 g and 0,109 g, i.e. 0,105 g and 0,088 g was recorded.

All these data add to the fact that more studious investigations of the mechanism of these earthquakes;of the radiation pattern of the seismic waves; of the acceleration attenuation depending on the epicentral distance, as well as of the effect of the local soil conditions on the acceleration growth, is necessary. The results of these investigations under procedure will be announced in special publications of IZIIS.

Acknowledgement

The author of this paper expresses his gratitude to Eng. Vladimir Ribaric, Director of the AGO - Ljubljana, and to Eng. Dragutin Cvijanovic from the Geophysical Institute - Zagreb, for their coolaboration and assistance in the selection of locations for the instruments and collection of seismological data. The author also expresses his gratitude to the Institute staff members Mr.Milan Gjurgjevic and Mr.Nenad Vitanovski for their collaboration in the installation and maintenance, and collection of data of recorded earthquakes.

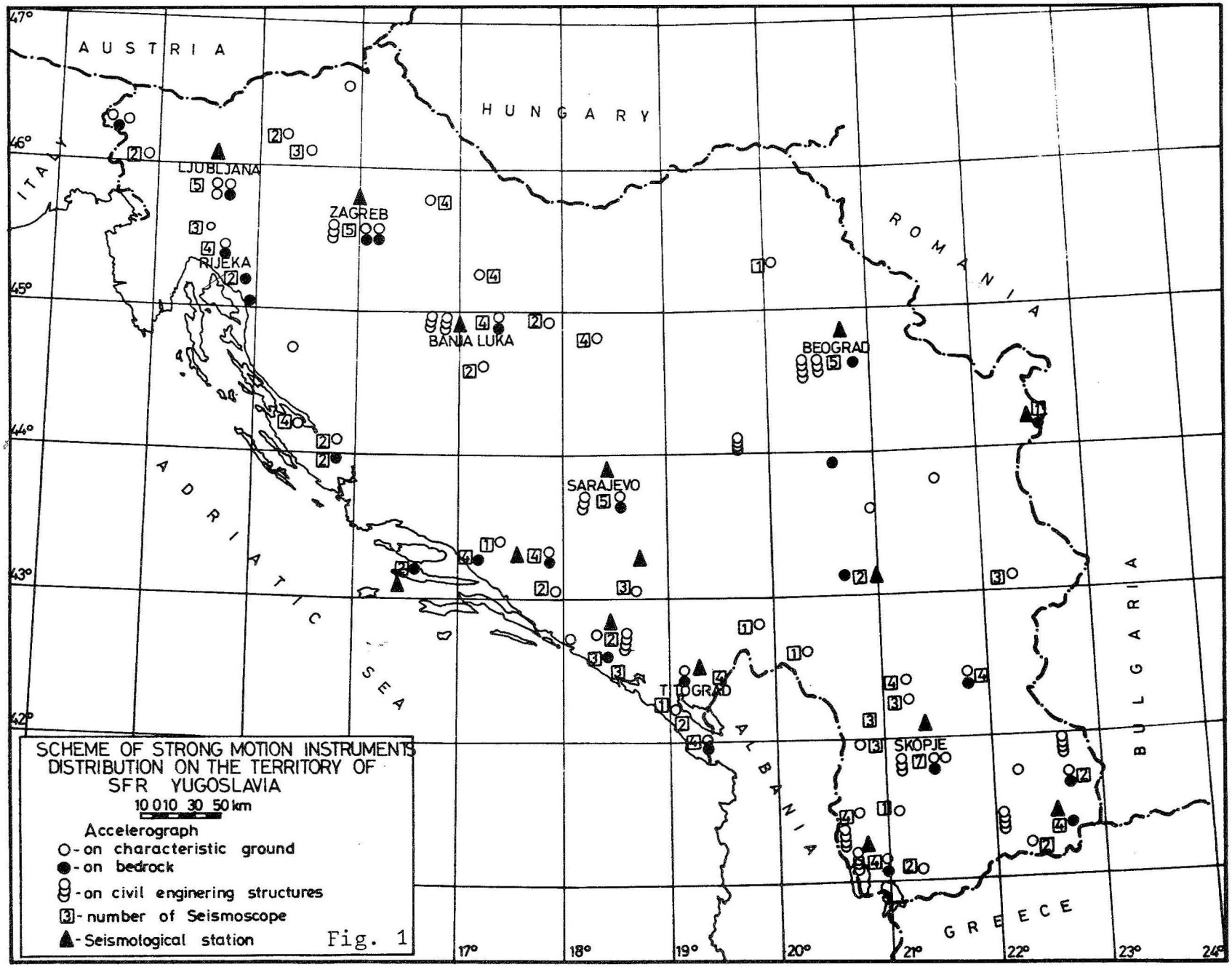
AUSTRIA
HUNGARY
ROMANIA
BULGARIA
GREECE
ALBANIA
ADRIATIC SEA
ITALY
LJUBLJANA
ZAGREB
RIJEKA
BANJA LUKA
BEOGRAD
SARAJEVO
TITOGRAD
SKOPJE
47°
46°
45°
44°
43°
42°
17°
18°
19°
20°
21°
22°
23°
24°
SCHEME OF STRONG MOTION INSTRUMENTS DISTRIBUTION ON THE TERRITORY OF SFR YUGOSLAVIA
10 0 10 30 50 km
Accelerograph
○ - on characteristic ground
● - on bedrock
○○ - on civil enginering structures
[3] - number of Seismoscope
▲ - Seismological station

Fig. 1

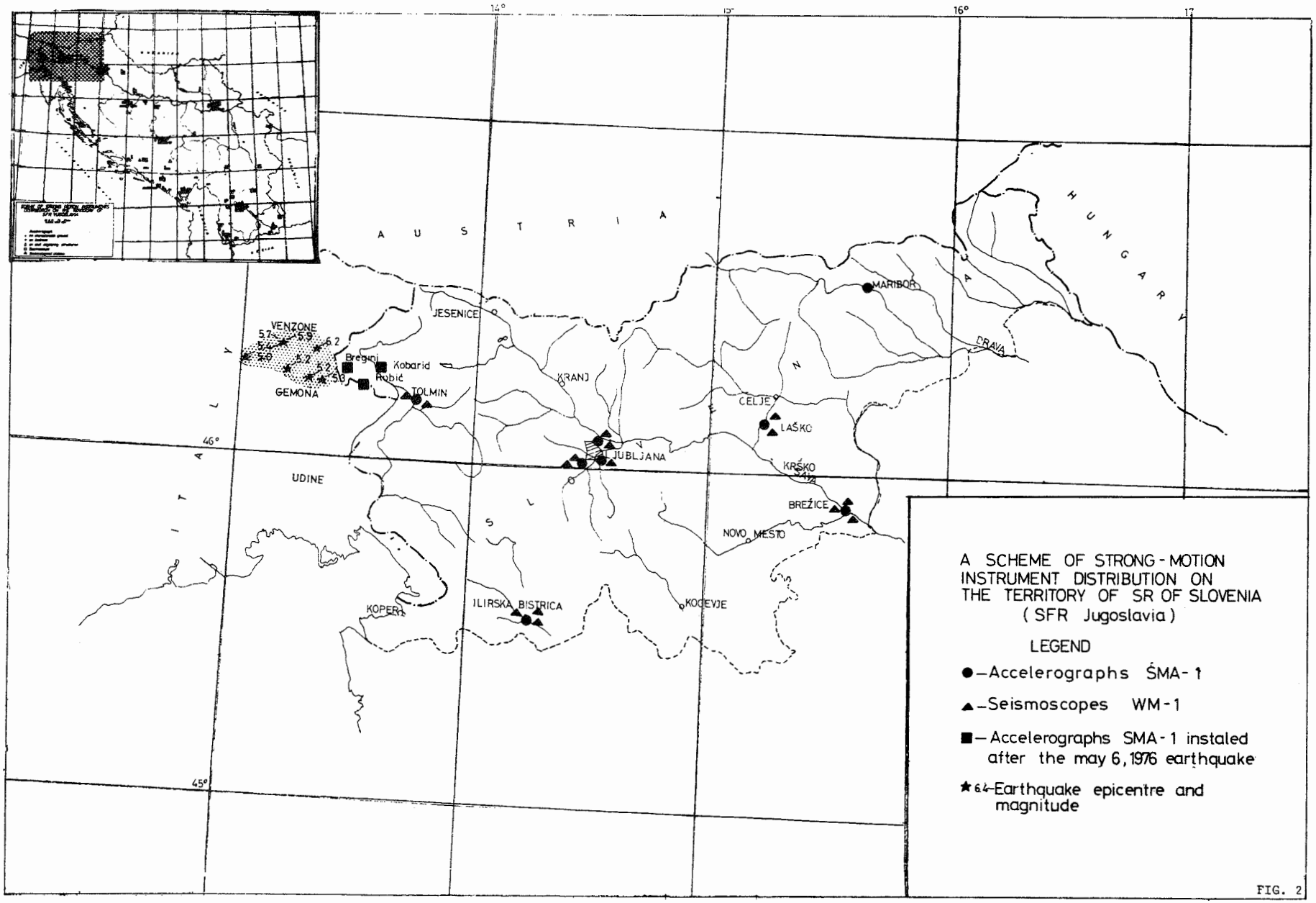
14°
15°
16°
17°
46°
45°
A U S T R I A
H U N G A R Y
I T A L Y
S L O V E N I J A
VENZONE
5.7
5.9
6.2
5.0
5.2
5.2
5.0
GEMONA
Bregini
Kobarid
Robić
TOLMIN
JESENICE
KRANJ
MARIBOR
DRAVA
CELJE
LAŠKO
JUBLJANA
KRŠKO
BREŽICE
NOVO MESTO
UDINE
KOPER
ILIRSKA BISTRICA
KOČEVJE
A SCHEME OF STRONG-MOTION INSTRUMENT DISTRIBUTION ON THE TERRITORY OF SR OF SLOVENIA (SFR Jugoslavia)
LEGEND
●–Accelerographs ŚMA-1
▲–Seismoscopes WM-1
■– Accelerographs SMA-1 instaled after the may 6, 1976 earthquake
★6.4–Earthquake epicentre and magnitude

FIG. 2

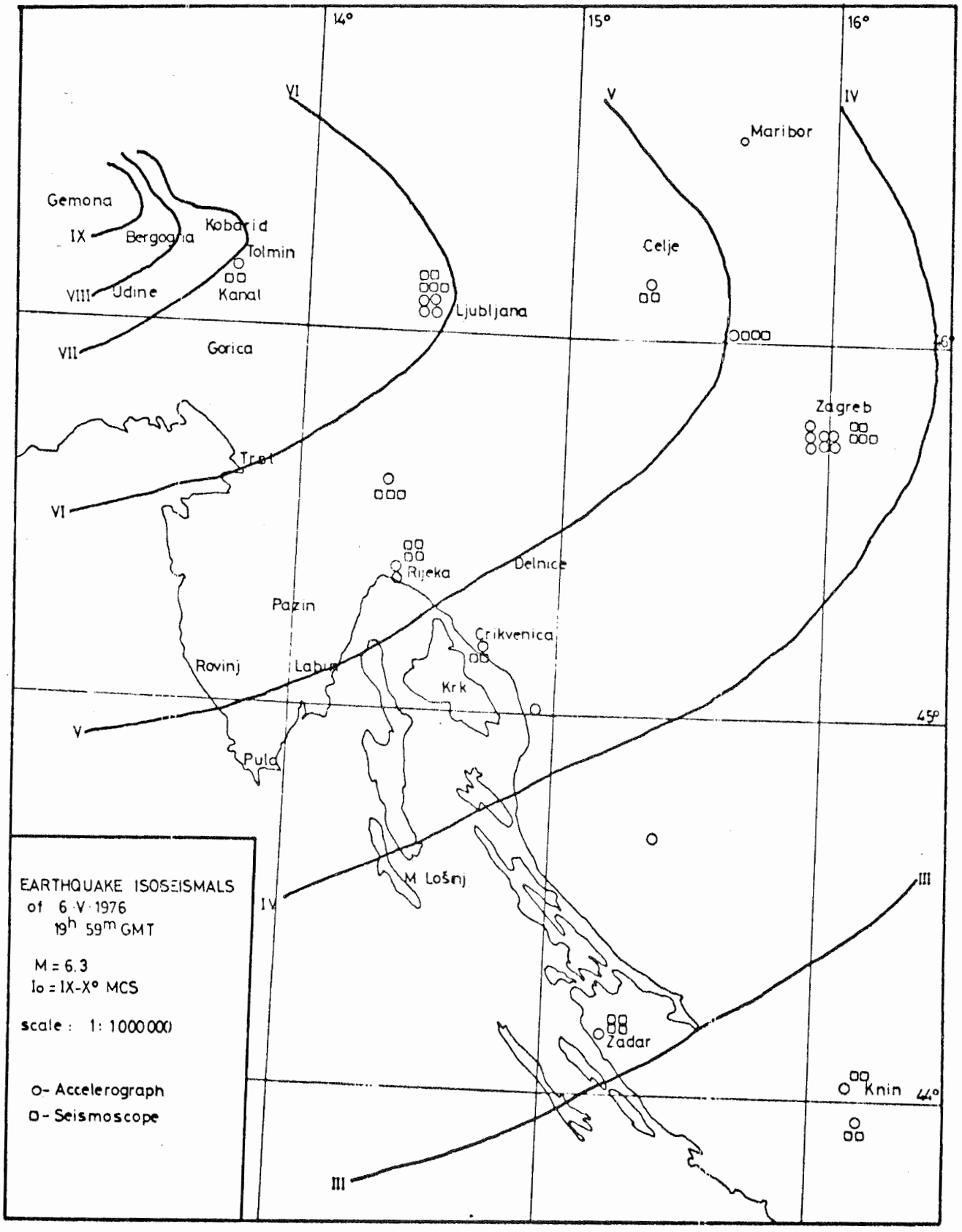
14°
15°
16°
VI
V
IV
Maribor
Gemona
IX
Bergogna
Kobarid
Tolmin
Celje
VIII
Udine
Kanal
Ljubljana
VII
Gorica
46°
Zagreb
Trst
VI
Rijeka
Delnice
Pazin
Crikvenica
Rovinj
Labin
Krk
45°
V
Pula
M Lošinj
IV
III
Zadar
Knin
44°
III
EARTHQUAKE ISOSEISMALS
of 6·V·1976
19h 59m GMT
M = 6.3
Io = IX-X° MCS
scale : 1: 1000000
o- Accelerograph
□- Seismoscope

FIG. 3

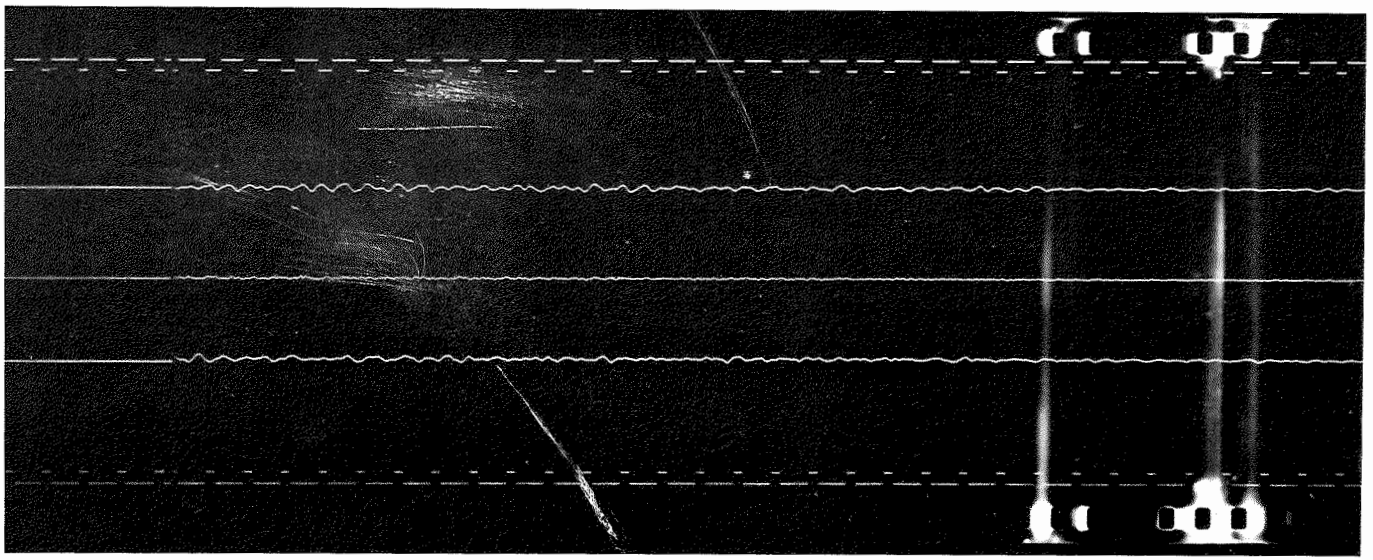

Fig. 4 FRIULI EARTHQUAKE OF MAY 6th, 1976 20h 00m 14,7 sec. M = 6,2 LJUBLJANA - INFIM

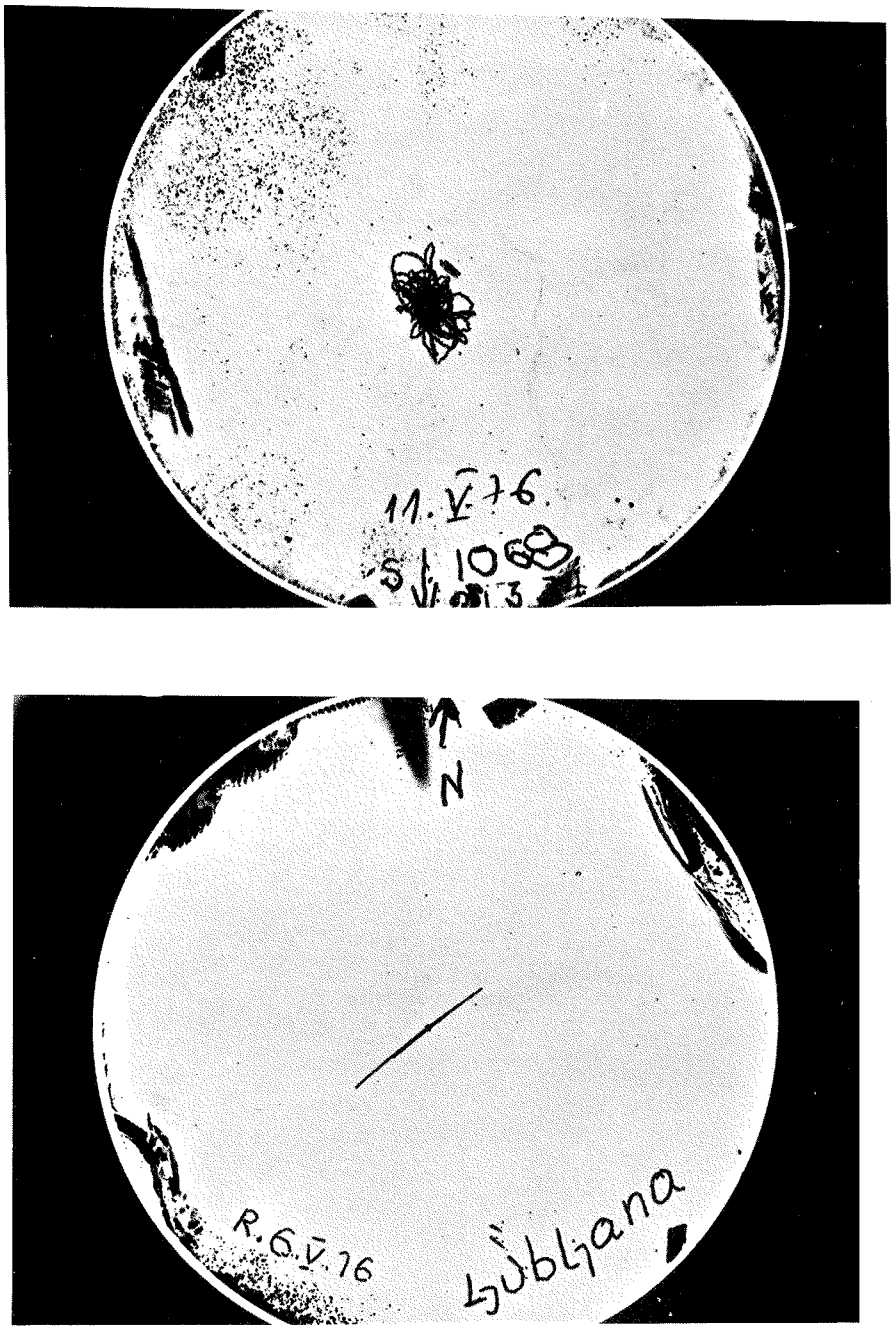

Fig. 5 SEISMOSCOPE RECORDS OBTAINED IN TOLMIN AND LJUBLJANA

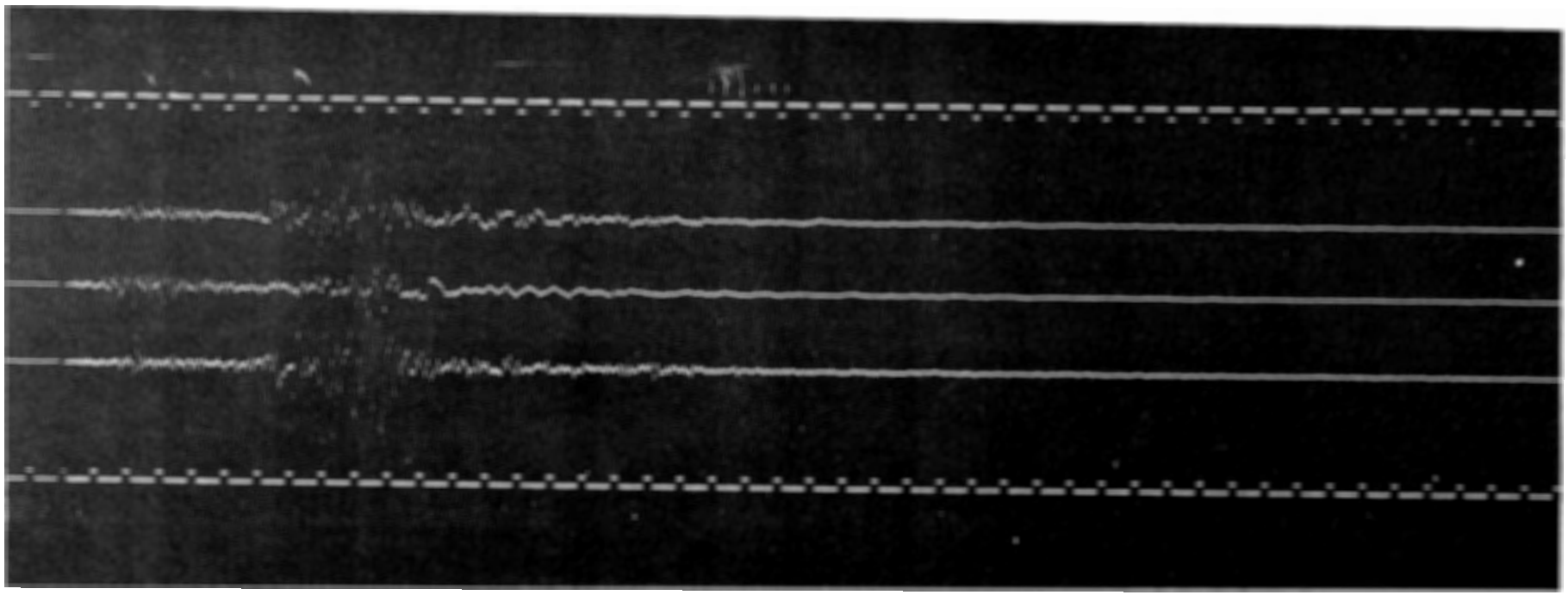

Fig. 6 FRIULI EARTHQUAKE OF SEPTEMBER 15th, 1976 03 h 15m 37,9 sec. M = 5,9 BREGINJ

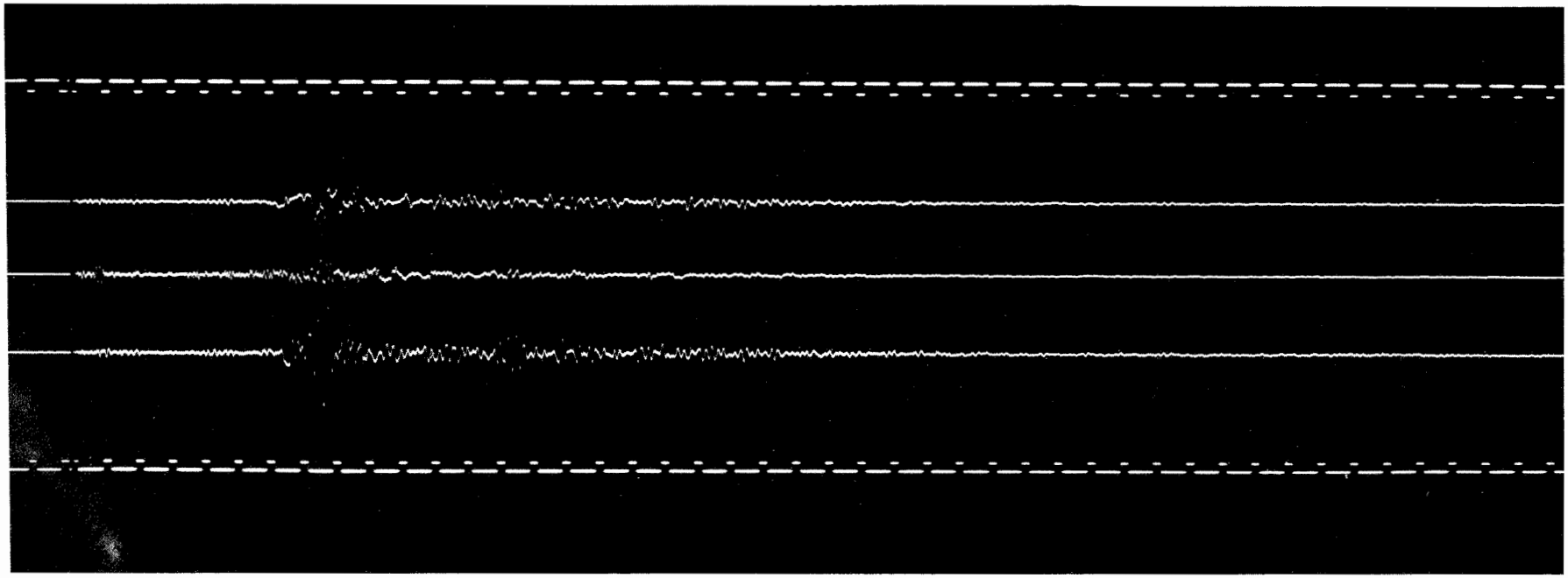

Fig. 7 FRIULI EARTHQUAKE OF SEPTEMBER 15th, 1976 09 h 21m 37,4 sec. BREGINJ

MAY 6, 1976 FRIULI EARTHQUAKE : FIELD MEASUREMENTS

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ABSTRACT

Slip vectors were measured in the field in an effort to extend ground motion description from the strong motion network into the epicentral area. In this presentation the field data are discussed in terms of intensity of ground motion and distribution in space. An attempt is also made to correlate with damage in the epicentral region.

INTRODUCTION

Although many strong motion instruments recorded the May 6 main shock, none of them was close enough to sample the ground motion that inflicted the heavy damage in the epicentral area. In this area, however, severe shaking produced a diversified slip vector field. The slip vectors were asociated with furniture inside houses, electrical equipment on the ground, bridge slabs, etc. Among the various vectors in the field, measurements were performed of the base motion of small distribution transformers. The distribution transformers were selected for their instrument qualities as well as their uniform distribution in the epicentral area.

The field work and the obtained measurements have been reported elsewhere [1]. This presentation discusses the field record. The discussion covers the intensity of ground shaking as well as the distribution of the slip vectors in space. For the space distribution the small transformer slip vectors are implemented by the direction of slip of three large transformers.

INTENSITY OF GROUND SHAKING

As in a previous preliminary analysis [1] the transformers are analysed as sliding blocks. The block is subjected to a square pulse of peak acceleration K and duration $T_{o/4}$ where T_o is the predominant velocity period. Assuming zero initial velocity, the peak velocity corresponding to this configuration is:

$$\dot{u}_{max} = Kg \frac{T_o}{4} \qquad (1)$$

On the other hand the peak ground acceleration is related to the maximum block displacement through:

$$d = \frac{1}{32} Kg T_o^2 (\frac{K}{Q} - 1) \qquad (2)$$

where Q = base friction.

Appropriate values for T_o and Q are selected as follows:

Predominant velocity period T_o: This period is selected as the mean of the log between a low corner period of .12 and a high corner period of 3.0 sec (thought appropriate for an $M_s = 6\frac{1}{2}$ earthquake)

$$\text{i.e. } \log T_o = \frac{\log .12 + \log 3.0}{2} = -.22$$

$$\text{and } T_o = .6 \text{ sec.}$$

Base Friction Q: The field vectors were calibrated on the basis of the observation that transformers did not move around the strong motion instrument at Diga de l'Ambiesta. Moreover, it was assumed that a base motion as small as 3 centimetres could not be detected in the field. A threshold base motion of 3 centimetres at Diga de l'Ambiesta, where the peak ground acceleration was around 30%, corresponds to Q = .15.

The field data were analysed for T_o = .6, Q = .15 and the results are shown on Table I. The obtained peak ground accelerations range from 27 to 71%g. Almost all the transformers were on alluvium. It is interesting that the alluvial cone material at Gemona showed an angle of free deposition of 35^o [2] (tan 35^o = .70). The averages at the bottom of Table I are based on the assumption that "REMOVED" cancel out "DID NOT MOVE". If we take [3]

$$\log a = .014 + .30\, I_{MM}$$

$$\log v = -.63 + .25\, I_{MM}$$

then: $\ddot{u}_{ave}$ corresponds to I_{MM} = 9

and $\dot{u}_{ave}$ corresponds to I_{MM} = 10

An attempt is also made to correlate peak ground motion with damage by grading the damage on the cabins housing the transformers. The grading is done on the basis of the damage index as follows:

0	no damage
1	closed cracks
2	cracks and spalling
3	open and shear cracks
4	distorted.

Each cabin is evaluated, using the above classification, on Table I. No apparent correlation appears on this table. That may reflect the variation in both the transformer sliding coefficients and the structural characteristics of the cabins. It is worth noticing that three out of the four severely damaged cabins (Nos. 7, 8 and 22) showed field evidence of a vertical component of motion.

TABLE I - SUMMARY OF FIELD MEASUREMENTS

No.	Station	Total Base Displ (cm)	Peak Ground Accel (%g)	Peak Ground Velo (cm/sec)	Cabin* Damage Index	Remarks
1	Tarzento Uffitci	DID	NOT	MOVE	2	
2	Tarzento Pret. Vechia	16	56	82	0	Non-standard Cabin
3	Tarzento smistamento	Did	Not	Move	0	Non-standard Cabin
4	Bilerio	20	60	88	1	
5	Bilerio via Magnano		REMOVED		3	
6	Magnano Ferovia		REMOVED		0	
7	Artegna Sotto Castello	13.5	50	74	3	
8	Gemona Sotto Stazione	6	38	56	3	Non-standard Cabin
9	Savorniano de Torre	DID	NOT	MOVE	1	
10	Gemona-Piovega		REMOVED		0	
11	Gemona-Taboga	30	71	105	2	
12	Gemona via Sofia Pecol	20	60	88	0	
13	Amaro Aquedoto	DID	NOT	MOVE	0	
14	Amaro Centre	2.5	27	40	0	
15	Tolmezzo via Calvi	13.0	50	74	0	Non-standard Cabin
16	Somplago	7.5	42	61	1	Ret. Wall Failed
17	Osoppo-Albaredo	15.0	54	79	0	
18	Buia-Sottocostoia	12.5	50	74	0	
19	Chiacis Verzegnis	DID	NOT	MOVE	0	
20	Villa di Verzegnis	DID	NOT	MOVE	0	
21	Ceslans	6	38	56	1	
22	Casali Furmie	23.5	63	92	4	
			51	74		Ave

* For explanation, see text.

THE VECTOR FIELD OF GROUND MOTION

The vectors, showing only the predominant direction of motion, are plotted on Figure 1. Apart from the vectors obtained from the small distribution transformers the following directions of motions are also shown:

T1 : Twin 68t transformer at San Daniele

T2 : 14.5t transformer at Tomba di Buia

T3 : 48t transformer at Ferio factory in ZIRO

The overall direction appearing on Figure 1 is N-S. However, the orientation seems to change across the dashed W-E line: north of the line vectors are predominantly oriented to the south, whereas south of the line the predominant orientation is to the north. These predominant orientations would be compatible with either normal faulting or the stopping phase of a buried thrust.

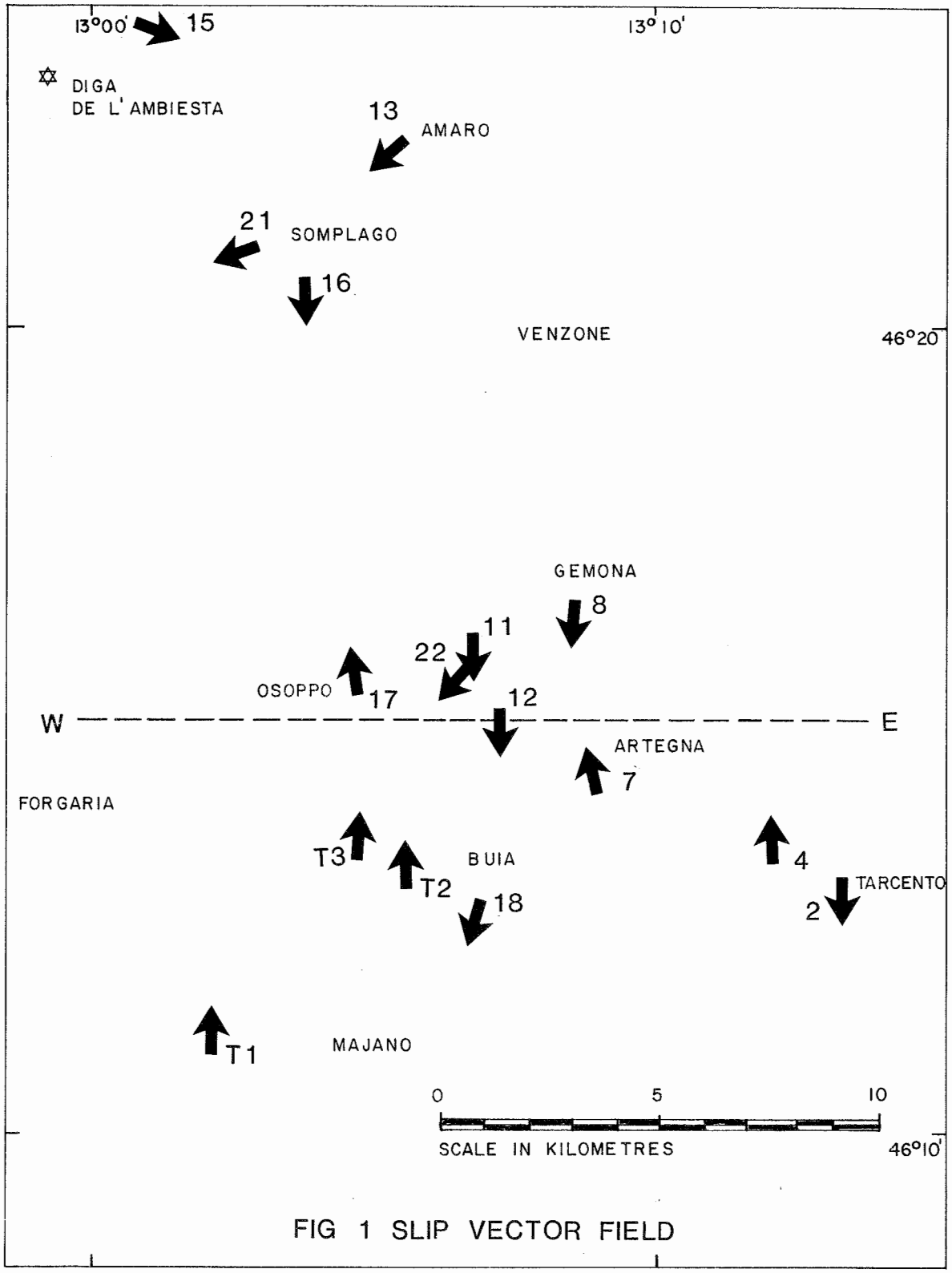

FIG 1 SLIP VECTOR FIELD

REFERENCES

1. Papastamatiou D., Sept. 1976.
"The May 6, 1976 Friuli earthquake: field measurements".
15th ESC Gen. Assembly, Krakow.

2. Dames & Moore, July 1976.
"The May 6, 1976 Friuli (North Italy) Earthquake".
Preliminary Report I

3. Trifurac M. and Brady G., 1975.
"On the correlation of seismic intensity scale with the peaks of recorded strong ground motion".
BSSA, 65, No. 1, pp 139-162.

THE EARTHQUAKE IN FRIULI, MAY 6, 1976

A Contribution to the Study of Seismic Fields in Slovenia

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University of Ljubljana

Abstract

Detailed examination of the macroseismic effects due to the May 6, 1976 event in Friuli presents a very accentuated correlation with the direction of tectonical structures of the pleistoseistic region in western Slovenia.

Regarding the focal depth of this earthquake, unusual high degrees of seismic intensities have been observed along the direction of a west-east axis, being strongly dependent of the properties of subsoil.

Some geometrical and dynamical parameters have been calculated from available data. The need for involvement of studies of seismicity of adjacent countries for the preparation of national seismic zoning maps is stressed upon.

Introduction

Disposing of preliminary data about the earthquake parameters provided by the CSEM and other agencies and seismological centres, as well as with macroseismic reports and field investigations results it was possible to reconstruct some basic features of the consequences of this event in Slovenia.

For macroseismic field representation totally 769 observations have been used and a map of felt intensities in Slovenia drafted. The shape of macroseismic areas was generally asymmetrical in respect to various azimuths from the focal zone.

This particular fact made possible to draw some conclusions on behalf of the absorption qualities of tectonical structures in respect to changing azimuths.

Macroseismic fields

Four profiles with changing azimuths 0° to 90°, 110° and 135° (from N to E direction) have been studied, using also materials provided by the Austrian Zentralanstalt für Meteorologie und Geodynamik in Vienna.

The method of Sponheuer-Ullmann, which represents a development of the Kövesligethy method, was used to determine the absorption coefficients for seismic intensity decay along various paths, as indicated by the azimuths from the focal zone.

As a first step the focal depth was determined tentatively by using Karnik's formula:

$$M = 0.66\ I_o + 1.7 \log h - 1.6\,,$$

and putting for $I_o = 9.5°$ MSK and for $M = 6.67$, a focal depth of 15.63 kms was calculated.

Secondly following data for the Sponheuer-Ullmann's method have been used:

Direction to :	Austria	Yugoslavia	Yugoslavia	Yugoslavia
Azimuth :	0°	90°	110°	135°
Radius of isoseismal:				
s_9 (km)	10	16	20	18
s_8	19	24	32	28
s_7	42	54	72	56
s_6	77	120	138	130
s_5	120	168	204	216

Following focal depths and absorption coefficients have been obtained in connection with the azimuthal changes:

Direction from the focus to :	h(km)	Absorption coeff. α km^{-1}
1. Austria, Az.0°	12	0.018
2. Yugoslavia, Az. 90°	13.5	0.005
3. Yugoslavia, Az. 100°	14	0.003
4. Yugoslavia, Az. 135°	13	0.006

A significant variation of α is evident and in respect to the accuracy of the Sponheuer-Ullmann method satisfactory results presenting focal depth have been obtained.

As a comparison the method of J. Martelly was used and an orientational focal depth of 15 kms has been obtained. Checking these results N.V. Shebalin's relation from 1972, valid for the Balkan region was used and for M = 6.7, I_o = 9.5° MSK a focal depth of 14 kms for the main event was calculated.

Blake's procedure for focal depth determination which is often used for macroseismical data elaboration lacks the explicit possibility of proper selection of coefficient ν . As generally known this procedure is based upon the formula:

$$I_o - I_i = \nu \cdot \log (1 + s_i^2 / h^2)^{0.5}$$

To verify the above mentioned depth determinations a procedure was used to obtain proper values of ν combating various ratios of D_i and D_k (in original notation), and was calculated from sets of values for all four azimuths from the expression:

$$\nu = I_k - I_i / \log D_i/D_k$$

Following results have been obtained:

$$\nu = 3.635 \pm 0.114$$

$$h = 11.8 \text{ kms}$$

With respect to the damage experienced in Slovenia the following conclusions can be derived on the basis of the macroseismic field studies, tectonics, geomorphological parameters, sub-soil conditions and of course the initial parameters, i.e. the input function in the origin zone.

The transfer function along determined paths from the focus is transformed by:

a) the influence of the direction of the faults or faulting systems as evident by

b) neotectionical morphology (4)

In this case the faults Mt. Festa-Mt. Plauris to Zaga passing in the vicinity of Mt. San Simeone, Mt. Brancot-Kobarid-Cerkno and periadriatic fault Gemona-Kobarid had a strong influence upon the seismic intensities.

The axis of maximal damage is pointing from the epicentre to the east and south-east and is in Slovenia limited mainly by the azimuth interval from 90° to 110°.

Damage was observed at distances up to 130 km east from the epicentre and was conditioned mainly by the subsurface quality and less by the quality of buildings. Also new and according to earthquake building code constructed buildings, suffered at these distances some damage. A contemporary built structure founded on piles on a marshy ground 110 km from the epicentre suffered some damage in Ljubljana.

At shorter distances new structures built according to regulations of the building code of Slovenia survived with minor damage if situated on good ground and in spite of vicinity of the focus.

Others being situated on moraine and flysch layers or on subsoil with high water table, suffered important damage. This is particularly true for Breginj, Podbela, Kobarid, Idrsko, Ladra, Kamno and Volarje, while Tolmin for instance experienced much less damage because of its relatively hard rocky underground.

Seismic accelerations of ground*

Blume J.A. (5) presented an extension of the known Gutenberg-Richter's relation for the acceleration at the epicentre a_o (in cm/s^2) and magnitude M:

$$a = a_o / 1 + (R/h)^2 \text{ , and}$$

$$\log \left(\frac{a_o}{g}\right) = -(\bar{b} + 3) + 0.81.M - 0.027.M^2$$

*) The author is presenting only a brief informative report. Detailed investigation is due to IZIIS from Skopje, which operates the strong-motion network in Slovenia too.

with the factor $\bar{b} \approx 7.35 + 3.94 \log (\rho \cdot V_s) - 0.41 [\log (\rho \cdot V_s)]^2$ which characterises local site conditions. ρ is here density of the material V_s shear wave velocity.

Thus the study of factor b should be important for establishing values of a_o in the epicentral zones.

Adopting a mean value of seismic body-wave magnitude m for the event of May 6, 1976, which is equal to 6.5, we may according to various authors obtain following ranges of accelerations in Slovenia as a function of distances of some localities:

$m_b = 6.5$ locality	Distance to the focus km	Range of accelerations * in cm/s^2 (mean)	Donovan N.C. (1972) cm/s^2
Breginj	26 km	39–501 (251)	187.6
Robic	32	20–200 (160)	157.0
Kobarid	36	16–160 (125)	141
Volarje	41	14–152 (120)	124
Tolmin	52	8–112 (95)	97
AGO Ljubljana	115	2–50 (35)	37

Donovan's formula is presented by:

$$a = 1300 \cdot e^{0.67M} (R + 25)^{-1.6} ,$$

and gives a in cm/s^2, where R is the distance to the causative fault.

Evaluating the records of some stronger shocks from Friuli region, having unfortunately not available the records of the mainevent on May 6, we may derive some simple and only informative data about the accelerations as recorded by three events in September 1976.

Following results have been obtained without zero-line corrections of the SMA-1 records:

*) Authors: Gutenberg-Richter, 1956, Blume, 1965, Housner, 1965, Kanai, 1966, Schabel-Seed, 1973, Trifunac, 1975.

Input : Earthquake No. 1 : September 11, 1976, 16 h 35 m M = 5.66
Earthquake No. 2 : September 15, 1976, 03 h 15 m M = 6.21
Earthquake No. 3 : September 15, 1976, 09 h 21 m M = 6.28

Locality	Event No.	Comp.	Maximal acceleration cm/s^2	% g
Breginj, 26–30 km	1	N–S	141	0.144
Moraine deposits (h =		E–W	92	0.094
= 5–10 m) on limestone		Z	44	0.045
rock	2	N–S	411	0.419
		E–W	138	0.141
Kinemetrics SMA–1		Z	87	0.089
	3	N–S	463 (0.18 s)	0.472
		E–W	389 (0.29 s)	0.397
		Z	185 (0.15 s)	0.189
Kobarid, 36–40 km	2	N–S	87	0.089
Dolomite with 0.5–2.5		E–W	84	0.086
proluvial deposits		Z	55	0.056
Kinemetrics SMA–1	3	N–S	122	0.124
		E–W	82	0.083
		Z	59	0.056
Robic, D = 32–35 km	2	N–S	34	0.035
hard, massive limestone		E–W	62	0.064
(dolomite)		Z	37	0.038
Kinemetrics SMA–1	3	N–S	86	0.088
		E–W	62	0.063
		Z	32	0.032

The acceleration range: In dependence of M,D and subsoil condition seem not to be the only governing factors contributing to the excessive values of a/g. Reflections of waves, resonances and interferences may give very important contributions to the general picture of the acceleration fields and they are certainly a locality's "specialities".

Nevertheless, authors like Trifunac and Brady (7) have pointed out, that for a given intensity level peak accelerations recorded on a hard rock site are on the average higher than the same recorded on alluvium. Peak accelerations of strong ground motion do not grow linearly with M and the rate of growth becomes very small in the M range from 6.5-7.0.

According to these authors high acceleration amplitudes should *not necessarily* be associated with a proportionally higher *destructive potential.* Extended *duration* of strong ground motion *and* high acceleration amplitudes are important for destructive effects of shaking, while one or several high frequency and high acceleration peaks may, in fact, lead only to a minor excitation of the structure.

Acceleration's dependance on distances

Ribaric (8) has obtained some preliminary results of the A/T dependance of distances, studying materials of low senstivity seismograph network in Yugoslavia from about 1900 up to today. However the uncertainty of period determination has posed a serious problem to the task of establishing local acceleration's dependance on distances. Introducing $(A/T)_o$ for a normalized period of 1 s earth motion and considering that practically all available observational data for Yugoslavia during this period was valid for bed-rock which is the fundament of most seismological stations, the author has obtained, using trend-analysis techniques following relation:

$$(A/T)_{6.5} = 8596 \exp(-0.0049\, D), \quad A \text{ in microns}$$

valid for $M = 6.5$, base-rock and for distances greater than 30 kms; 8596 is $(A/T)_o$ for period of 1 sec, D is distance in km.

The absorption coefficient for the velocity parameter is also a function of M and can be written as:

$$k_M = -0.04550 + 0.006247.\ M$$

However it is impossible to introduce this function into our problem, having in mind that no "harmonic motion" laws are applicable unless only extremely simplified information should be desired.

With diminishing distances the problem of determination of basic dynamical parameters meets further difficulties. Theoretically the single amplitudes of earth motion in Breginj, about 30 kms from the focus, should be about 8.10^4 microns, in Kobarid 5.10^4 in Tolmin $2{,}9.10^4$ and in Ljubljana $1{,}2.10^4$ microns. Approaching to the focal zone the situation is probably much less clear. An earthquake of M = 6.5 has for instance a volume of an equivalent sphere with radius 10.12 kms. It means that about 3-5 km below the earth's surface we could reach the focal zone, itself, reaching theoretically to the depths of 25 kms or so.

The case of a seismoscope record

A modified seismoscope of the Willmot type with 0.75 s own period and damping of 10% of the critical was in operation in a private house (one storey) in the suburbs of Ljubljana. The subsoil was clayey, marshy with gravel inlets and unusual high level of subsurface water table.

A double amplitude of 1.8 cm was recorded on smoked glass, and taking into account a typical sensitivity of this instrument being about 6.0 cm/rad, we have obtained a velocity spectrum value S_v = 17.6 cm/s which corresponds to an intensity over 7° MSK, although no damage was noted in the building itself. The water level was −0.5 to −1.0 m, S_v value of 3,9 cm/s was recorded.

Some remarks and recommendations

The earthquake of May 6, 1976 and following events in Friuli have posed some serious problems to be considered in future research on these topics.

P. Feliziani and L. Marcelli (9) have derived from historical and contemporary files the sum of total released seismic energy in northeastern Italy for the period of the beginning of our era up to the year 1963.

This sum equals to:

$$15.39.\ 10^{21}\ \text{ergs}\ ,$$

which means that about *one half* of the energy spent in nearly 20 centuries has been released in one year in Friuli alone. The author has considered the released energy of 21 largest events in this year, because they constitute the largest part of the total sum, i.e. $7.507.10^{21}$ ergs.

Sporadic events (Basel 1356, Villach 1348, Italy/Yugoslavia zone 1511, Belluno 1873, Zagreb 1880, Ljubljana 1895) to mention only some of them, compel us to reconsider some present risk and probability theories and to include much more quantitative geotectonical and geophysical data to the problems of estimating seismic danger. This problem has been in Central Europe always underestimated.

Acknowledgement

The author is indebted to express his acknowledgement to the staff of the Seismological Institute of Belgrade, headed by Dr. B. Sikosek, and to the group of seismologists from the Geophysical Institute of Zagreb University, who helped him to explore zones in western Slovenia, damaged by the May 6, 1976, earthquake.

Many thanks also to the staff of Zentralanstalt für Meteorologie u. Geodynamik in Vienna for providing necessary data and to the colleagues from the strong-motion laboratory of the Skopje Institute for Earthquake Engineering and Engineering Seismology, particularly to Ing. V. Mihailov, for lending copies of strong-motion records.

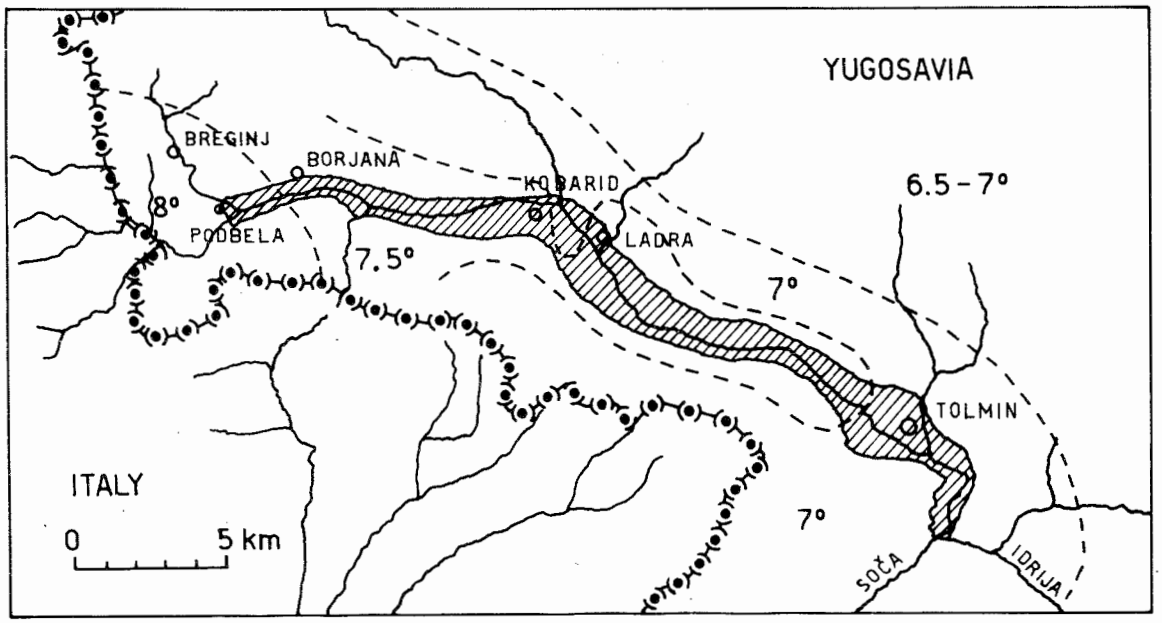


Fig. 1 A sketch of the pleistoseistic region of May 6, 1976 earthquake in western Slovenia. Shadowed zone represents regions with soft fluvioglacial deposits.

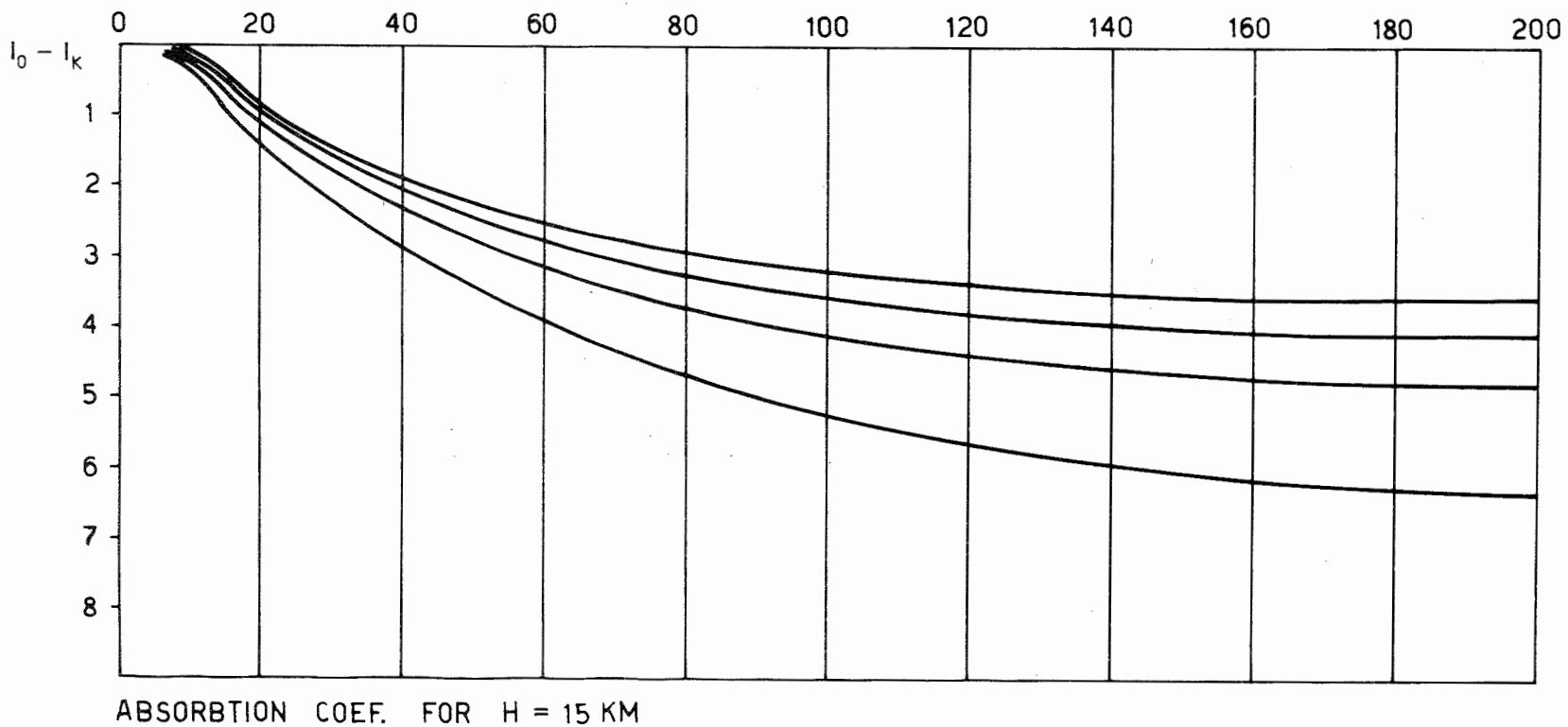
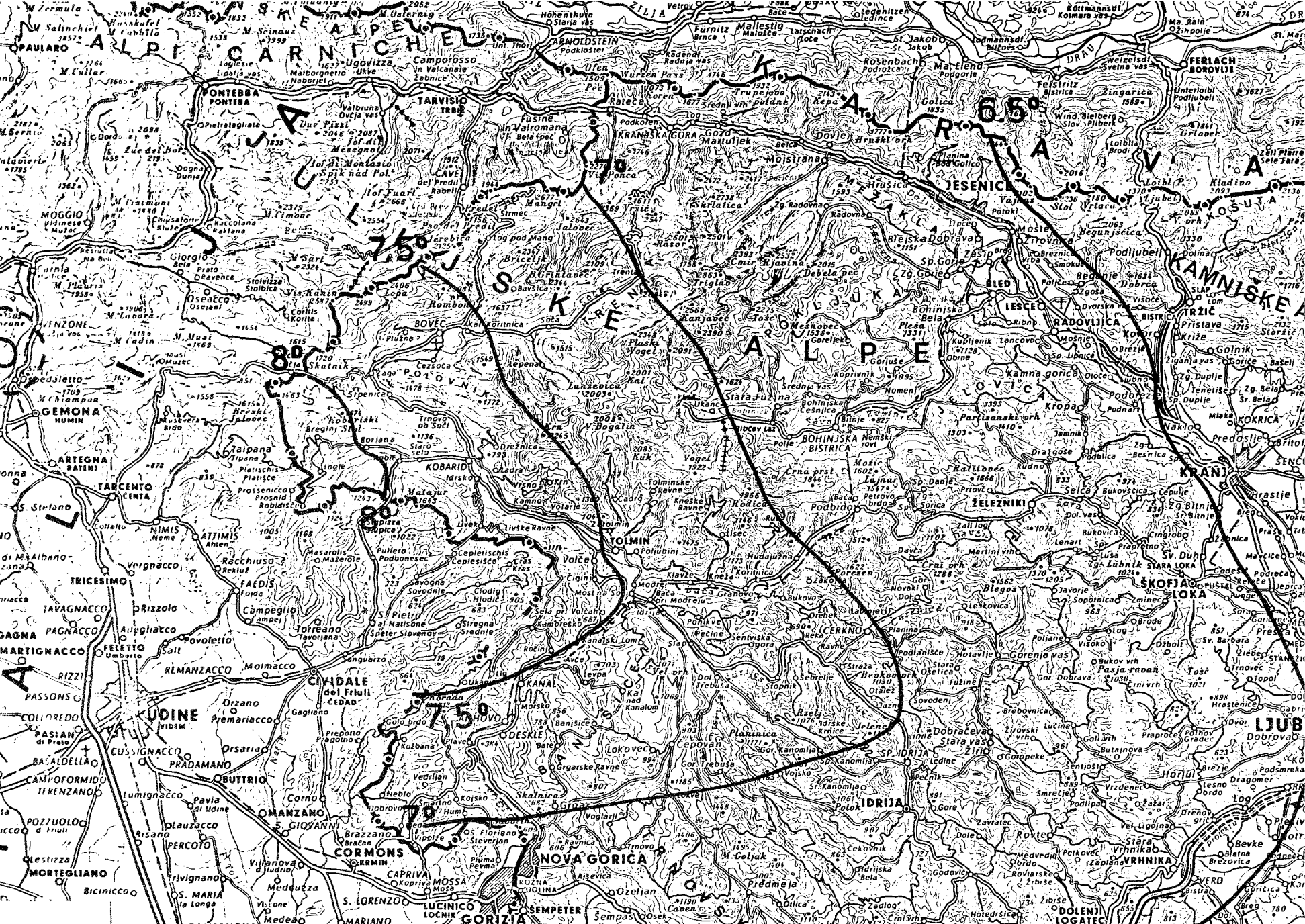


Fig. 2 Sponheuer-Ullmann method for determination of absorption coefficients (for h = 15 km)


ALPI CARNICHE
ALPI GIULIE
JULIJSKE ALPE
KARAVANKE
KAMNIŠKE ALPE
KAMNIK-SAVINJA ALPE
POHORJE
PONCA
MEŽAKLA
KOSUTA
PODNANOŠKO
HRUŠICA
PREDEL
MANGRT
KRANJSKA GORA
JESENICE
RADOVLJICA
BLED
BOHINJSKA BISTRICA
TRŽIČ
KRANJ
ŽELEZNIKI
ŠKOFJA LOKA
TOLMIN
KOBARID
CERKNO
IDRIJA
NOVA GORICA
GORIZIA
SEMPETER
UDINE
CIVIDALE del Friuli
CEDAD
CORMONS
MANZANO
BUTTRIO
PRADAMANO
TARCENTO
GEMONA
TARVISIO
PONTEBBA
PAULARO
MOGGIO
VENZONE
ARTEGNA
OSOPPO
TRICESIMO
FAEDIS
NIMIS
ATTIMIS
MARTIGNACCO
PASSONS
COLLOREDO
CAMPOFORMIDO
MANZANO
S. GIOVANNI
PERCOTO
MORTEGLIANO
TRIVIGNANO
S. MARIA la Longa
CAPRIVA
MOSSA
LUCINICO
LOČNIK
SEMPETER
ROŽNA DOLINA
AJŠEVICA
OZELJAN
SEMPAS
OSEK
DOLENJI LOGATEC
VRHNIKA
LJUB
Dobrova
Horjul
Dragomer
Log
Lesno brdo
Podsmreka
Vrzdenec
Smrečje
Podlipa
Ožbalt
Drenov grič
Bevke
Blatna Brezovica
Stara Vrhnika
Petkovec
Zaplana
Roviše
Žibrše
Medvedje Brdo
Godovič
Idrijska Bela
Predmeja
Otlica
Zadlog
Črni Vrh
Hotedršica
Cerkno
Gorenja vas
Poljane
Visoko
Ozboli
Sv. Barbara
Pasja ravan
Črnivrh
Tošč
Topol
Trnovec
Podlanišče
Hotavlje
Brekovrh
Oselica
Fužine
Sovodenj
Dol. Trebuša
Stopnik
Sebrelje
Straža
Otalež
Dazn
Rovte
Dole
Čekovnik
Ravnica
Trnovo
Vojsko
Kanomlja
Sp. Idrija
Cerkno
Jelenk
Dobračeva
Žirovski vrh
Stara vas
Žiri
Goropeke
Sentjošt
Praprotno
Polhov Gradec
Dobrova
Butajnova
Goli vrh
Lučine
Brebovnica
Hrastenice
Gabrje
Dvor
Hrastje
Mavčiče
Podreča
Jeprca
Pšenična Polica
Sv. Duh
Lubnik
Stara Loka
Puštal
Loka
Sopotnica
Javorje
Zminec
Davča
Martinj vrh
Lenart
Praprotno
Bukovica
Cerkljanski vrh
Crngrob
Zg. Bitnje
Sp. Bitnje
Bitnje
Zalog
Sorica
Petrovo brdo
Bačan
Podbrdo
Rodica
Kneške Ravne
Tolminske Ravne
Kladra
Kamnom
Volarje
Livek
Livške Ravne
Volče
Tolminski Lom
Kanalski Lom
Kanal
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Deskle
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Oš. Floriano
Števerjan
Brazzano
Bračan
Villanova di Udine
Medeuzza
Vicinale
Medeo
Mariano
Lorenzo
Pevma
Moša
Oslavje
Ravnica
Trnovo
Vojščica

LITERATURE

[1] Zentralanstalt für Meteorologie und Geodynamik, Wien, Letter from June 18, 1976.

[2] Sponheuer W.: Methoden der Herdtiefenbestimmung in der Makroseismik, Freiberger Forschungshefte, C 88, Adakemie Verl. Berlin, 1960.

[3] Martelly, J.: Une méthode d'évaluation de la pronfondeur de l'hypocentre. Application au tremblement de terre de Pelileo (Ecuador), 1949.

[4] Gams I.: Potres 6.maja 1976 in neotektonska morfologija Starijskega podolja, Geografski Obzornik, XXIII, 1–2, Ljubljana, 1976.

[5] Blume J.A.: Earthquake Ground Motion and Engineering Procedures, Third World Conference Earthquake Engineering, New Zealand, IV, pp. 53–67, 1965.

[6] Donovan N.C.: Earthquake Hazards for Buildings, Nat. Bur. Stand., Build.Science Series, 46, Building Practices for Disaster Mitigation, Boulder, Col., 1972.

[7] Trifunac M.D., Brady, A.G.: On the Correlation of Peak Acceleration of Strong Motion with Earthquake Magnitude, Epicentral Distance and Site Conditions, Proc. Nat. Conf. Earthquake Engineering, 43–52, Ann Arbor, Mich., 1975.

[8] Ribaric, V.: Dynamic parameters of some stronger Yugoslav earthquakes as recorded by low sensitivity seismographs, Proc. Seminar on Seismic Microzoning and Strong-motion Data Processing, Thessaloniki, 21–25 June 1976, UNESCO, Skopje, 1976.

[9] Feliziani P., Marcelli L.: Il terremoto di Tolmezzo del 26 aprile 1959. Ann. Geofis. XVIII, 3, Roma, 1965.

Preliminary analysis of Friuli earthquake records

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GENERAL

Records of about 100 Friuli earthquakes of the Netherlands seismic stations DBN (De Bilt), WIT (Witteveen), HEE (Heerlen) and WTS (Winterswijk) at epicentral distances of 800-900 km in the azimuth N30-40°W were studied. Nearly 80 of these shocks took place in the year 1976. The Galitzin seismographs of DBN, operating continuously since 1909, recorded 18 shocks in 1976 and 15 in the remaining years of the period. The three heaviest shocks of the twentiest century in the region took place in 1976, the fourth in sequence was that of 1928. The energy radiation of the 1976 sequence alone was an order bigger than that of the accumulated energy radiation of the former 75 years of activity in the region. On this relatively short time basis thus, the Friuli activity of 1976 is clearly anomalous.

With respect to location the Friuli activity of 1976 is not so anomalous however. Both on a short time scale of the years since 1900 (with microseismic epicenters), and on the longer time scale since the

year 1000 (with historical records of felt earthquakes), there exists the clear tendency for epicenters to concentrate in localized clusters. And the particular centre occupied by the activity of the year 1976 is just one of the main sectors of activity along the elongated seismic zone from Verona in the WSW to the South of Krakow in the ENE.

The magnitude distribution of the 1976 sequence is not that of a single main shock with a long series of aftershocks of gradually declining magnitude. The activity is better described by two separate sequences, the first one triggered by the main shock of May 6 of magnitude $6\frac{1}{2}$-$6\frac{3}{4}$, and the second one by the group of September 11 and 15 shocks of magnitude 5.1, 5.6, 6.1 and 6.3 respectively. Such double activity of earthquakes in the region with an observed epicentral intensity of IX or more on the MMS scale did also occur in October 1788/January 1790, and in March/August 1511. On a total number since 1500 of 12 earthquakes reaching intensity IX or more, this is a high percentage of double events, and it seems likely therefore, to be regionally determined. Earthquakes like the main shock of May 6 with an intensity of $\geq$ X did occur in the region in the years 1873, 1695, 1348 and 1117, thus about once in two centuries. According to this evidence it is clear that neither the place, nor the time of occurrence or magnitude of the May 6 earthquake and the 1976 sequence in general can be classified as abnormal.

P WAVE (see fig. 1 and 2)

The P wave form recorded by the long-period instruments is very much identical for the shocks of 76050620, 76091509, 76091503, 76050700, 76060812, 76050900, 76051122, 76091511, irrespective of magnitude. When clear, the onset is always compressional, with the exception of 76091503 which shows a clear dilatation on all instruments. The duration of the wavetrain is always of the order of 40-50 sec independent of magnitude and the predominant period is 9-10 sec. Superimposed upon this P wave there is also a PL component of $\sim$25-35 sec period, especially obvious on

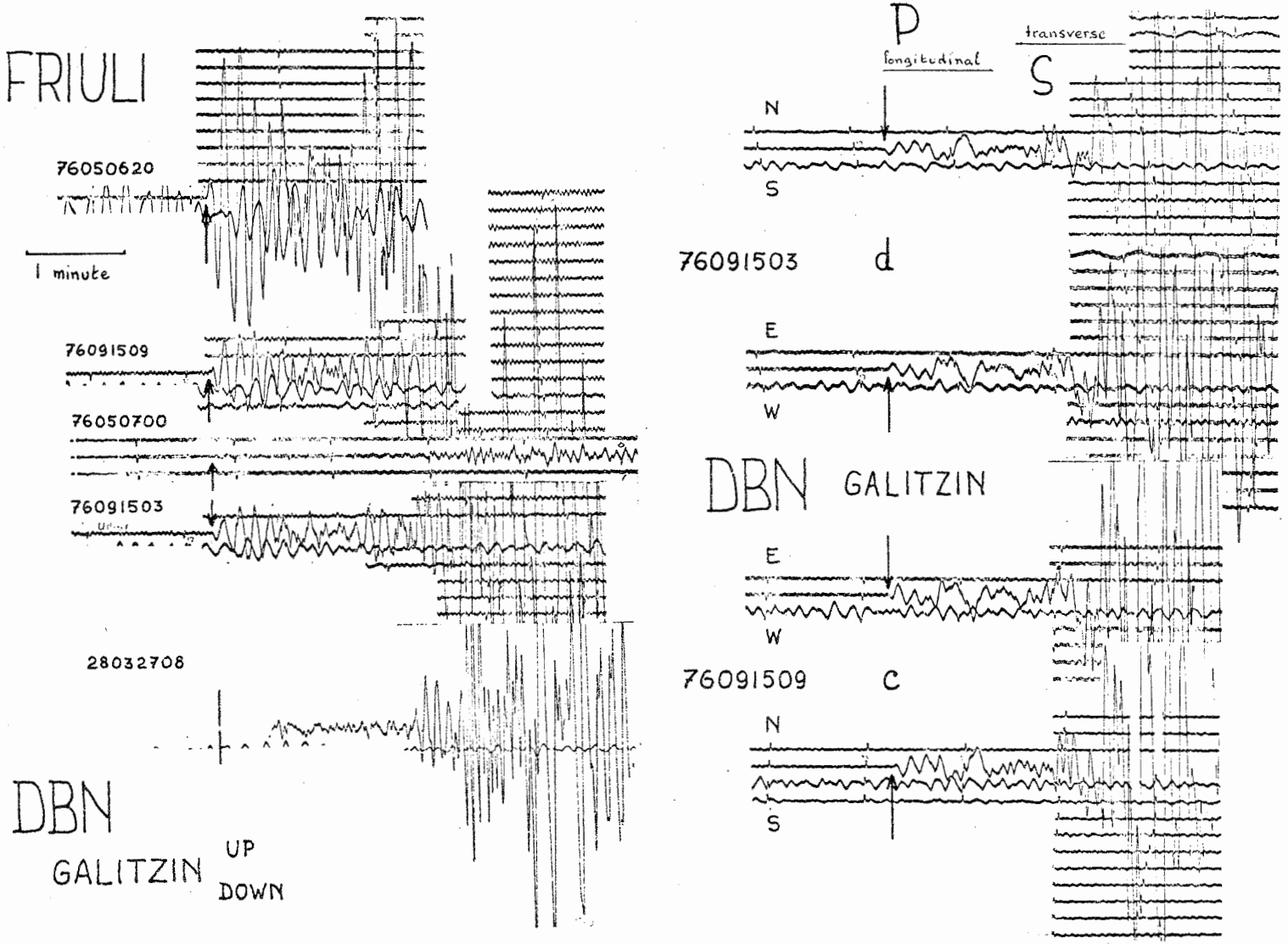

fig. 1 - Vertical Galitzin (∿12 sec) and horizontal Galitzin (∿24 sec) seismograms of DBN.

the horizontal Galitzin and vertical Press-Ewing records. The short-period records always are emergent, there are no clear onsets and the P wavetrain is not clearly separated from the subsequent S and R wavetrains. The envelope shown is typical for the beginning of most of the recorded Friuli events.

S WAVE (see fig. 1)

The S wavetrain is also very nearly identical for the different shocks as for example 76050620, 76091509, 76091503, 76050700, 76091511, 76060812 and 28032708. In the vertical component there is a reasonably sharp downward first motion and a wavetrain of 8-9 sec period and at least 40 sec duration and an amplitude equal to that of the P_z wavetrain. The waveform of this S_z wave is a nearly exact upside-down replica of that of the P_z wave recorded by the same instrument.

In the horizontal components every peak and trough can be traced from the records of one earthquake to those of another. The onset of S is emergent. Striking is an SL component of period ∿25-30 sec starting with about equal amplitudes to E and to N. The amplitude of this long-period component is at least three times larger than that of the LP wave recorded at the same instrument.

At the short-period instruments S cannot be traced.

LOVE WAVES (see fig. 3)

The maximal amplitudes in the long-period horizontal records of Galitzin and Press-Ewing are those of the Love waves with periods of ∿25-15 sec. This relatively short, G-type, wave group can easily be recognised down to very small magnitudes. The type and form is identical from the main shock of $M6\frac{1}{2}$-$6\frac{3}{4}$ down to the smallest recorded events of about M4.

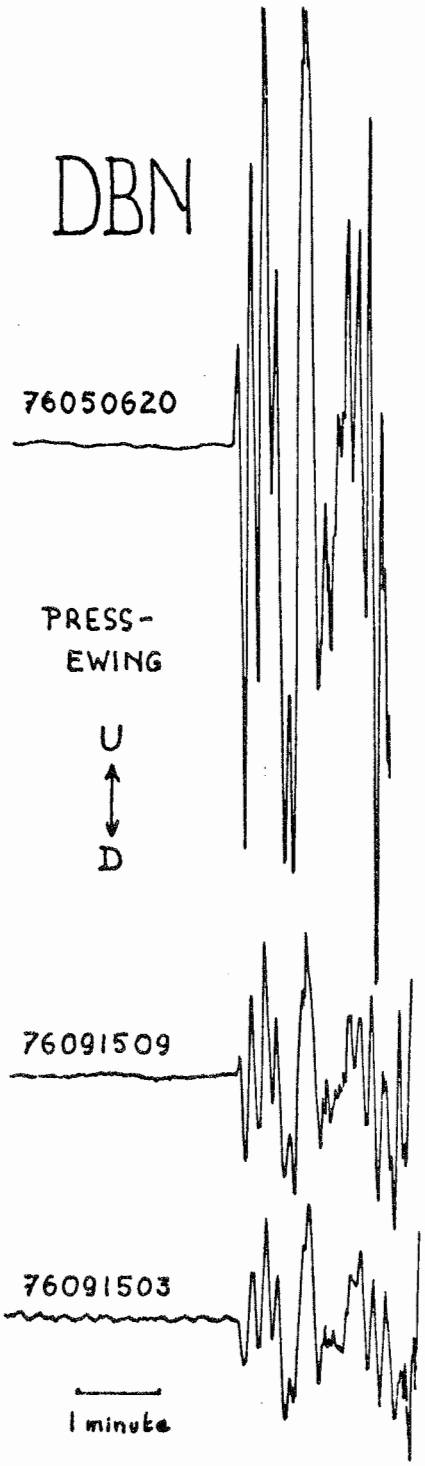

fig. 2a - Vertical Press-Ewing (30-90 sec) seismograms of DBN.

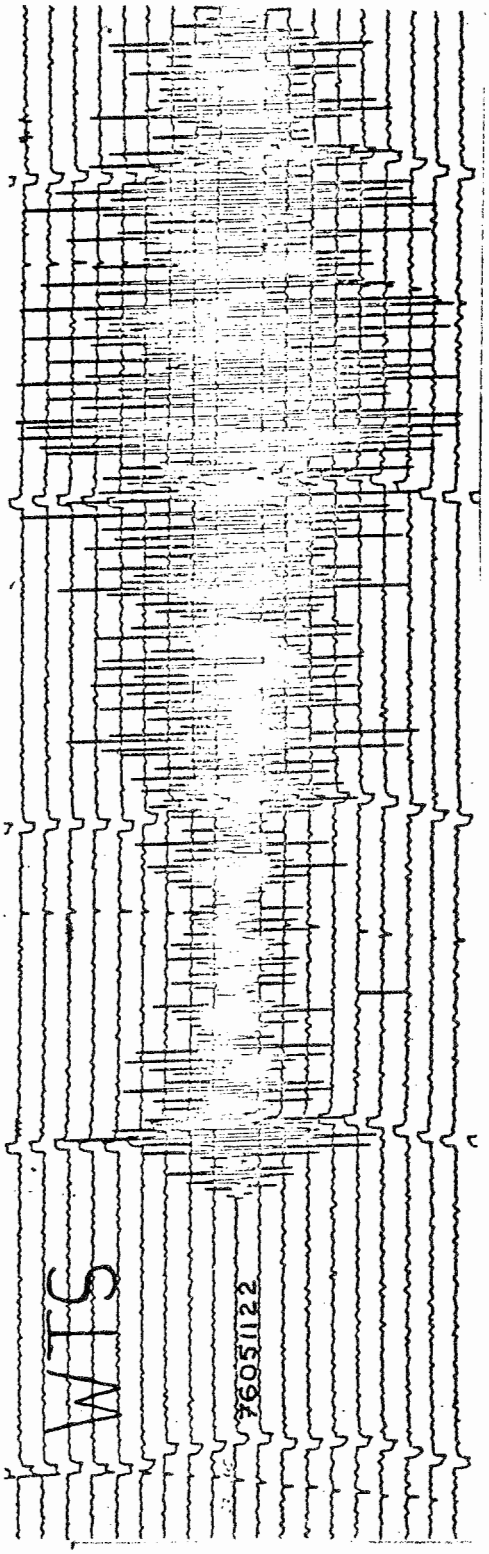

fig. 2b - Vertical Willmore (1.5 sec) seismogram of WTS.

RAYLEIGH WAVES (see fig. 3)

The maximal amplitudes in the long-period vertical records are those of Rayleigh waves of periods ∿30-18 sec. They are about half as great as those of the Love wave maximum. Also in this case the wave forms to the finest details are comparable to each other down to the very smallest recorded shocks.

FAULT PLANE SOLUTIONS (see fig. 4 and 5)

The EDR data for 76050620 and 76050900 both are in good agreement with the Müller solution with a nearly flat-lying and a nearly vertical nodal plane both striking about ENE. More data are needed for a more strict determination of the position of nodal planes and stress axes.

The earthquakes of 76051122 and of 36101803 etc. have a somewhat different solution with one nearly vertical nodal plane striking about ESE and one plane inclined towards W and striking about N. Especially in the earthquake of May 11 there are many inconsistent observations, so that the solution (or its alternative - dashed line in the figure) cannot be regarded as of great reliability.

The direction which is common to all four given solutions is that of the maximum principal stress axis. This particular main pressure stress, inclined over about 25° in N160°E direction, seems to be the major driving agency for these Friuli earthquakes in general (see also Van Bemmelen, this Volume).

MAGNITUDE

m_b (see fig. 6)

The more than 50 m_b-values for the 76050620 earthquake reported through EDR do not show any correlation with the theoretical radiation

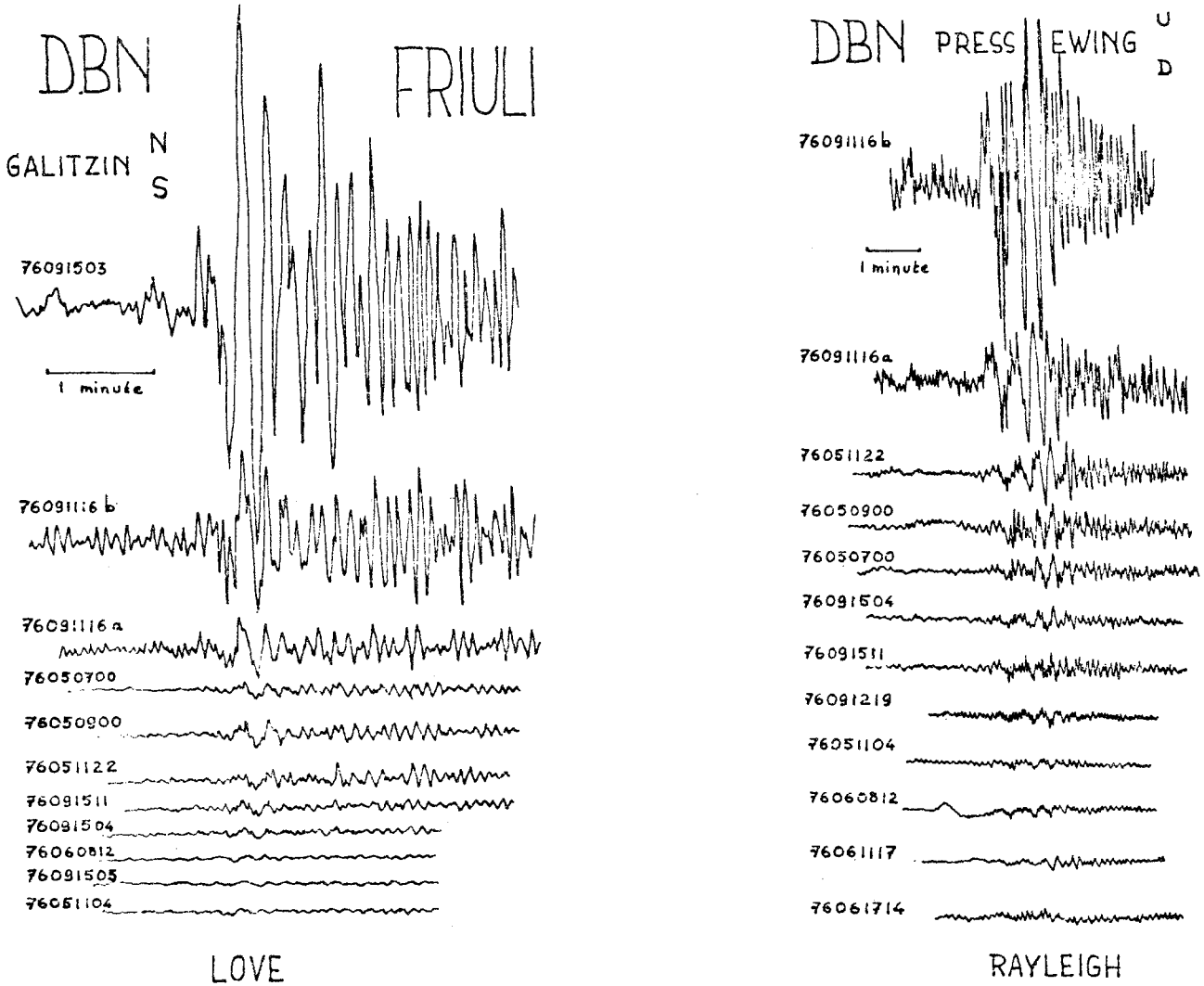

fig. 3 - N-S component Galitzin and Up-Down Press-Ewing records of DBN.

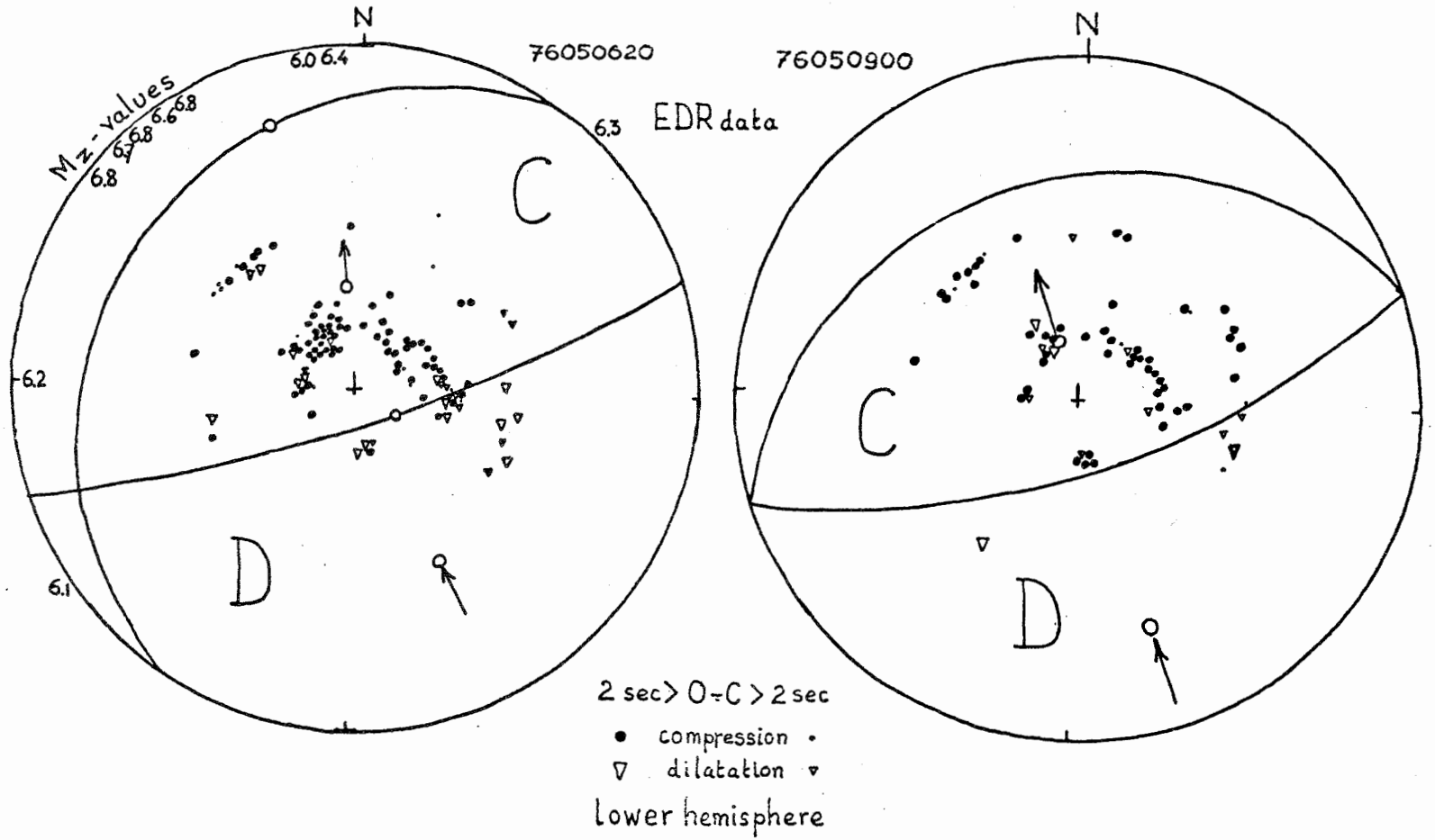

fig. 4 - Fault plane solutions of earthquakes 76050620, with M_z-values plotted in the azimuth of the recording station, and 76050900.

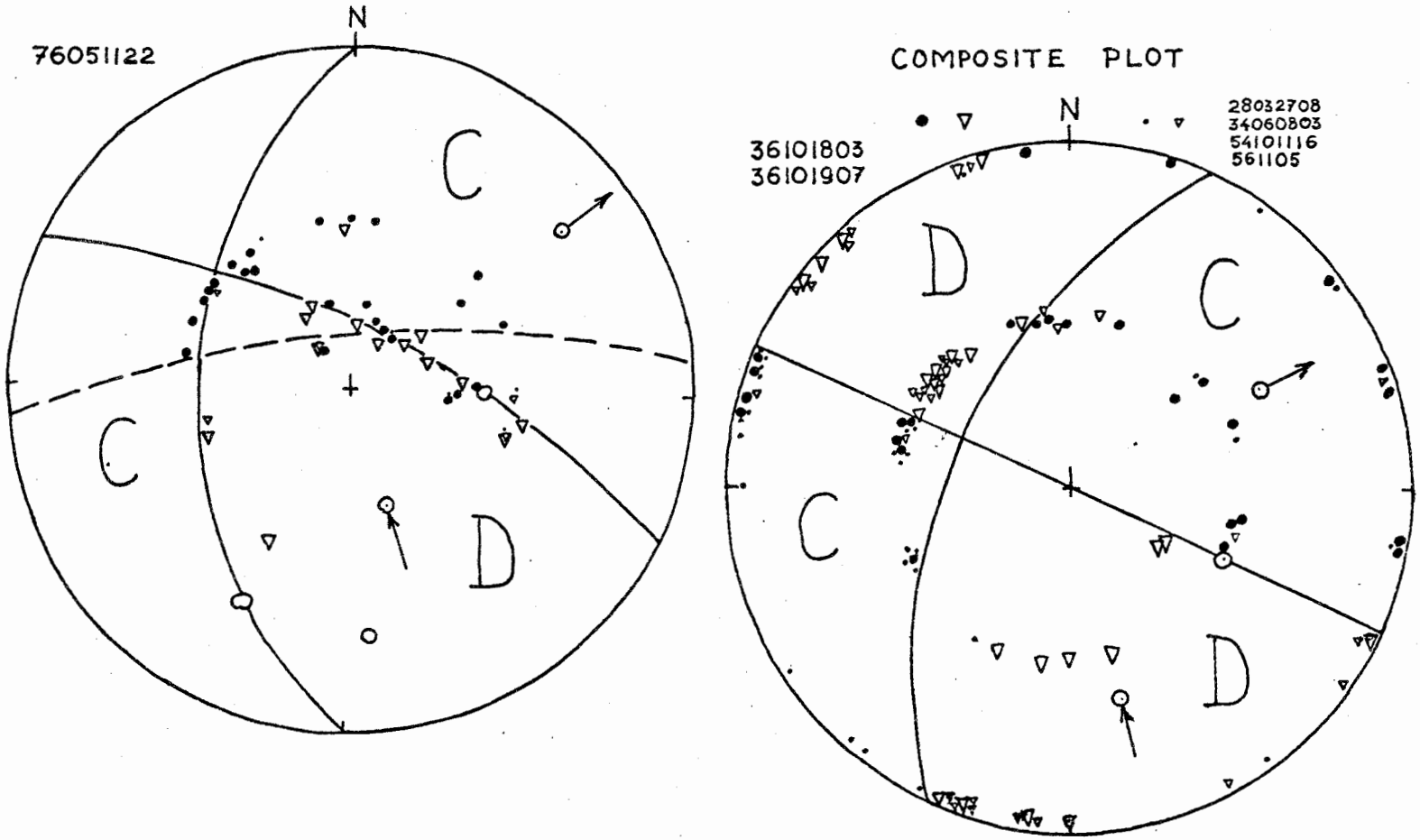

fig. 5 - Fault plane solutions for earthquake 76051122 and for 6 historical earthquakes of the region (see Ritsema - 1974).

of longitudinal waves from a focus with the mechanism that is found to be valid for this shock. In fact, the values are uncorrelated with any possible fault plane solution of the quadrantal type. There is, however, a clear relation between the m_b-values and the period of the wave used in the determination of m_b. The values of m_b increase regularly from about 5.6 at 0.7 sec to about 6.7 at 2.0 sec period. This clearly is in accord with the relatively minor amplitudes at short periods and the very emergent P waves at short-period records. Most energy is radiated in the longer periods and these Friuli earthquakes apparently are of the low-stress type.

Other earthquakes outside the region do show different m_b-T relations. The Ionian Sea shock of 76051116 for example gives m_b-values that are nearly equal at 5.8-5.9 all through the period range of observation of 0.6-2.1 sec.

M_z (see fig. 4)

The EDR M_z-values of the main shock of 76050620 on the other hand do show a distinct relation with the azimuth of the recording station, which is compatible with the found fault plane mechanism. Higher values of 6.6-6.9 are found in the NW direction conformable with the maximum in radiated Rayleigh wave energy in the direction of the fault plane motion in the flat lying nodal plane. Lower values of 6.1-6.3 are found in W and NE directions near to the intersection line of the two nodal planes, where theoretically no energy is radiated at all.

REMARKS AND CONCLUSIONS

1. On a time scale of 200 years or more the occurrence and strength of the 1976 sequence of Friuli earthquakes is not at all exceptional.

2. The fault plane solution based upon short-period EDR data is conformable with that of the long-period P waves (fig. 4). The long-period S wave in DBN with an initial downward motion and a clear SH

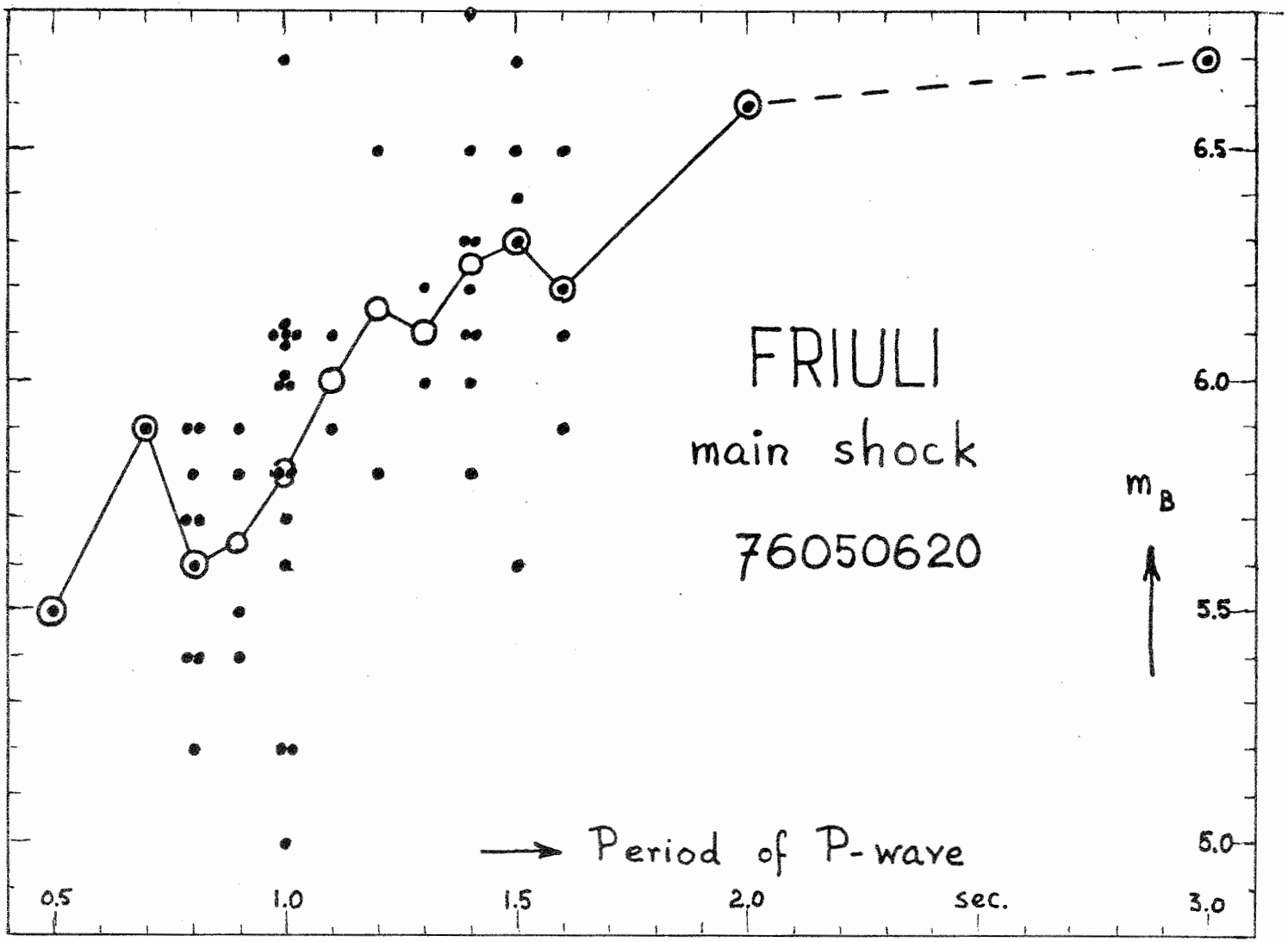

fig. 6 - Dependency of the m_b-values on the period of the used P wave.

component to the right as seen from the focus (fig. 1) is in complete harmony with the fault plane solution (in fact better than most of the S waves used by Müller).

3. The form of the P wavetrain is not at all changed by a reversal of initial motion from compression (which is normal) to dilatation (earthquake 76091503). Apart from the amplitude which determines the magnitude, the waves remain exact duplications of each other. The sole exception is the simple absence of the very first compressional swing in the earthquake 76091503. A change in station location from one quadrant to another, thus, does not mean an expected reversal of the complete P wavetrain, but only the addition or subtraction of a very first swing in the train.

4. The short-period m_b-values are not indicative for the fault plane mechanism, but they give insight in the frequency spectrum of the focal process.

5. The long-period M_z-values, based upon the vertical component of the Rayleigh waves, are clearly related to the fault plane mechanism. It seems obvious that in general the highest values will be the ones that are optimally used when comparing magnitudes of different shocks.

REFERENCES

1. Müller, G., Fault-plane solution of the earthquake in Northern Italy, 6 May 1976, and implications for the tectonics of the Eastern Alps, this Volume 1977.
2. Van Bemmelen, R.W., Note on the seismicity of North Eastern Italy (Friuli area), this Volume 1977.
3. Georgetti, F & Iaccarino, E., Italian earthquake catalogue from the beginning of the Christian age up to 1968, Appendix to Boll.Geof. Teor. Appl. XIII, 50, June 1971.
4. Karnik, V., The seismicity of the European area (2 Parts), Reidel Publ. Comp. 1969, 1971.

5. Ritsema, A.R., The earthquake mechanisms of the Balkan region, UNDP/ UNESCO Survey of the seismicity of the Balkan region, Techn. Rep. no. 4, 87, 1974.

ON THE COMPUTATION OF FOCAL MECHANISM OF FRIULI EARTHQUAKES

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DATA.

The sense of first movement used in the present study have been taken from different bulletins addressed to CSEM and also those which were published by NEIS. The data concern the observations on the vertical component for both long and short period. For the three principal earthquakes - 6th May 20h00, 15th September 03h15 and 09h22 - the total data are more than 100.

METHOD.

The program of Wickens-Hodgson was modified, to take into account the propagation effects in the crust and to allow the introduction of angles of emergence resulting from the structures adopted. For each earthquake, the best 16 solutions have systematically been compared. In general, there are 2 to 3 distinct types of focal mechanism solutions corresponding to similar score.

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[**] C.S.E.M.

RESULTS.

In general our study shows very large dispersion of data, consequently the score does not exceed 80 %. Here are presented only the results concerning the two earthquakes of May 6.

For the foreshock of the 6th May, two fault plane solutions can be retained (table 1). In the first case, the P axis is practically horizontal in the east direction ; the resulting movement is either along a fault plane dipping in the southeast direction at about 60° (plane A_I in the fig. 1) or along a fault plane dipping in the southwest direction at about 45° (plane C_{II} in the fig. 1). For the second case, the P axis is in the south direction and the movement could correspond to an underthrusting, northward, of Italy under the Alps (C_{II} on the fig. 1 is then taken as fault plane).

Table 1. Foreshock

		nodal planes (dip direction)		Axes		
		A	C	P	B	T
Sol. I	Azim.	170°	346°	169°	259°	350°
	dip.	76°	14°	31°	1°	58°
Sol. II	Azim.	119°	244°	94°	189°	351°
	dip.	60°	45°	8°	30°	58°

For the main shock of the 6th May, two very distinct solutions are obtained (table II, fig. 2). One of the two planes (A_I or A_{II} in the fig. 2) is quite well defined and is nearly the same for both solutions, the other plane in difficult to precise (C_I or C_{II} in the fig. 2).

Table 2. main shock

		nodal planes (dip direction)		Axes		
		A	C	P	B	T
Sol. I	Azim.	153°	271°	133°	236°	5°
	dip.	75°	31°	25°	26°	52°
Sol. II	Azim.	121°	4°	147°	48°	255°
	dip.	67°	43°	13°	34°	52°
Sol. III	Azim.	153°	354°	150°	64°	320°
	dip.	75°	15°	27°	6°	60°

But if we give more weight to the direction of first motion observed of P_g phase at the three stations, Ljubljana (Lju), Triest (TRI), and Padova (PDA), the plane becomes better defined (Sol. III and fig. 3). The mean solution (corresponding to plane $C_{III,2}$) is close to the second solution of the foreshock and agrees with the fault plane solution obtained from the long-period observations of P and S waves (Muller, 1976).

Our results show evidence of incompatibility of many published data; they require the study of original documents. For the moment, the possibility of a completely automatic determination of the focal mechanisms is ruled out.

REFERENCE

MULLER, G. (1976) - Fault plane solution of the earthquake in Northern Italy, 6 May 1976, and implications for the tectonics of the eastern Alps. J. Geophys. - preprint.

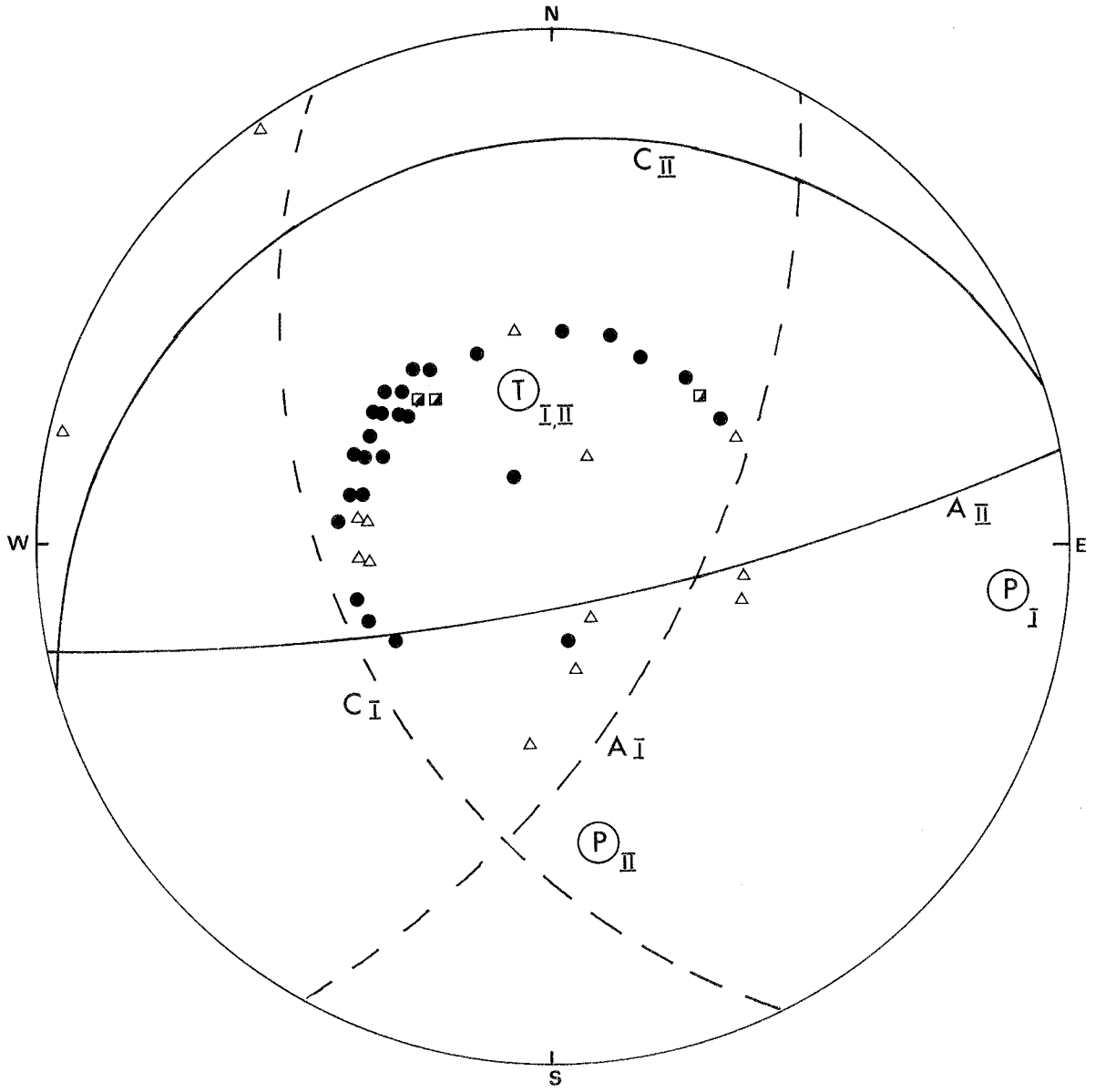


FIG.1 P NODAL SOLUTIONS (FORESHOCK OF 6 MAI 1976 H_o 19^h59 ca)

- ● compression
- △ dilatation
- ◪ 2 oï more inconsistent data

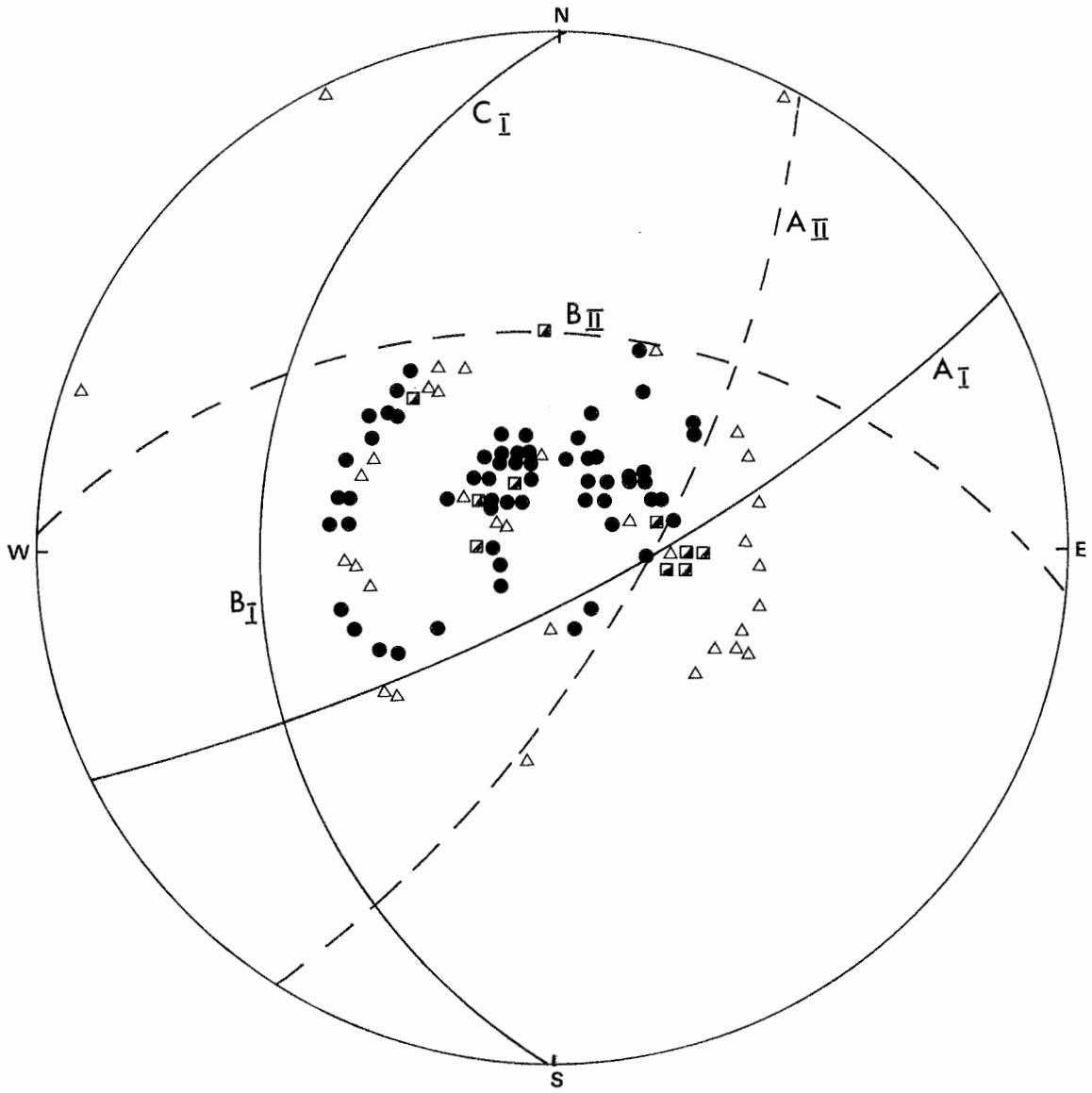


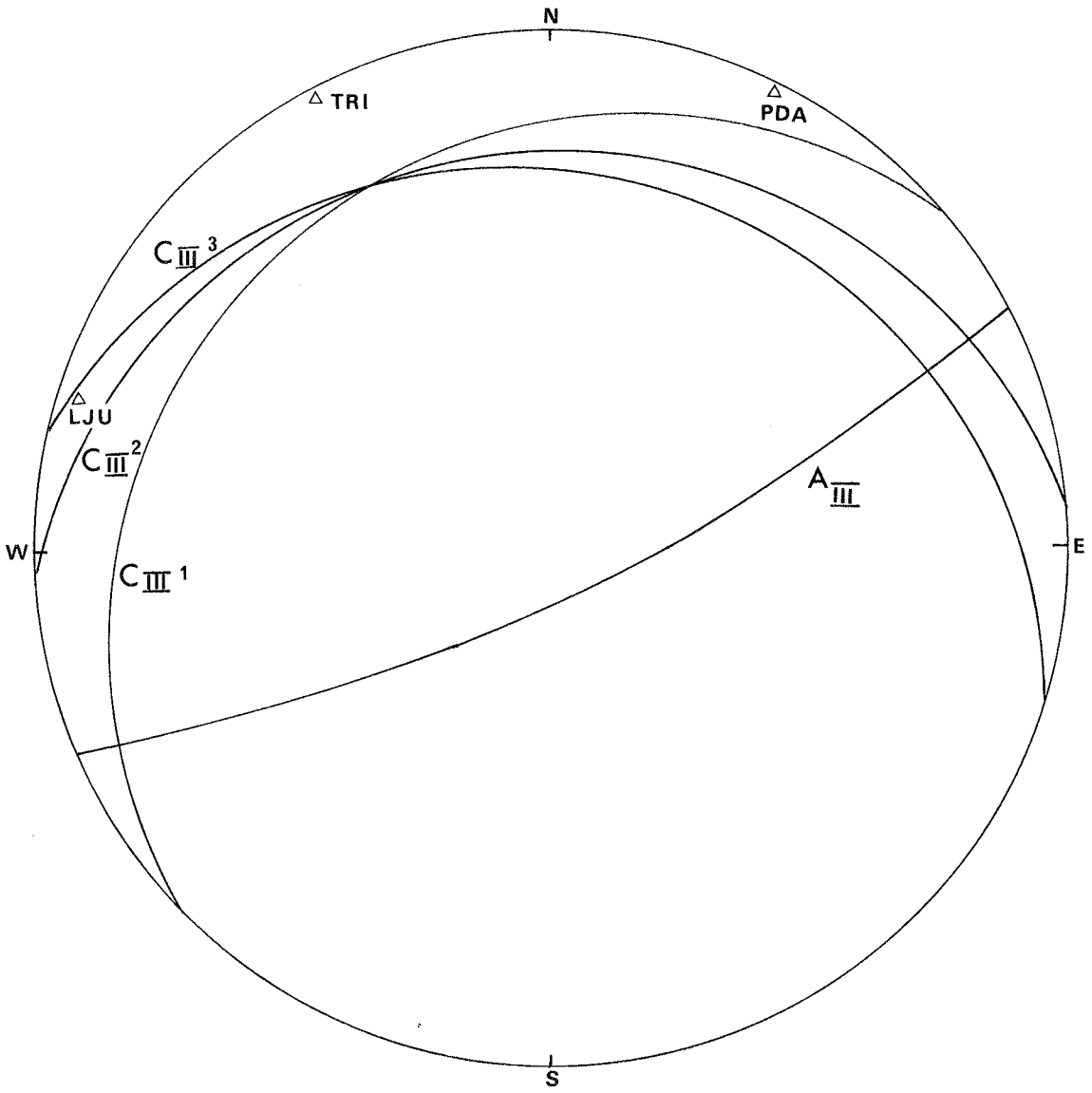
FIG. 2 EXTREMAL P-NODAL SOLUTIONS

(MAIN SHOCK OF MAY 6, 1976, $H_0 = 20^h00$)

● compression

△ dilatation

◪ 2 or more inconsistent data



FIG·3 P NODAL SOLUTION (MAIN SHOCK)
POSSIBLE VARIATIONS OF PLANE C

PRELIMINARY REPORT ON THE RECORDING OF SOME AFTERSHOCKS ALONG THE PROFILE GEMONA-TRIESTE

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B.COLOMBI-Ist.Geofisica Litosfera-C.N.R.-Milano
I.GUERRA-Osservatorio Vesuviano-Ercolano(Napoli)
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D.SLEJKO-Osservatorio Geofisico Sperimentale-Trieste

ABSTRACT. During the period 2I-26 October I976 some aftershocks in the Friuli region were recorded along the profile Gemona-Trieste. The report shows some examples of recorded events, some record-section and travel-time curves, as a preliminary presentation of results obtained. Terrains with high velocity value should be present at relatively small depths.

During the period 2I-26 October I976 some aftershocks in the Friuli Region were recorded along the profile Gemona-Trieste, by means of I3 stations, working in continuous recording (fig.I).

The length of the profile was about 90 Km, and spacing between stations about 6-8 Km. Most of the stations where equipped with three components geophones (vertical, longitudinal and transversal component). Institutions participating in this experiment were:

Research carried out in the frame of CNR's Italian Geodynamics Project. Pubbl. n. 26.

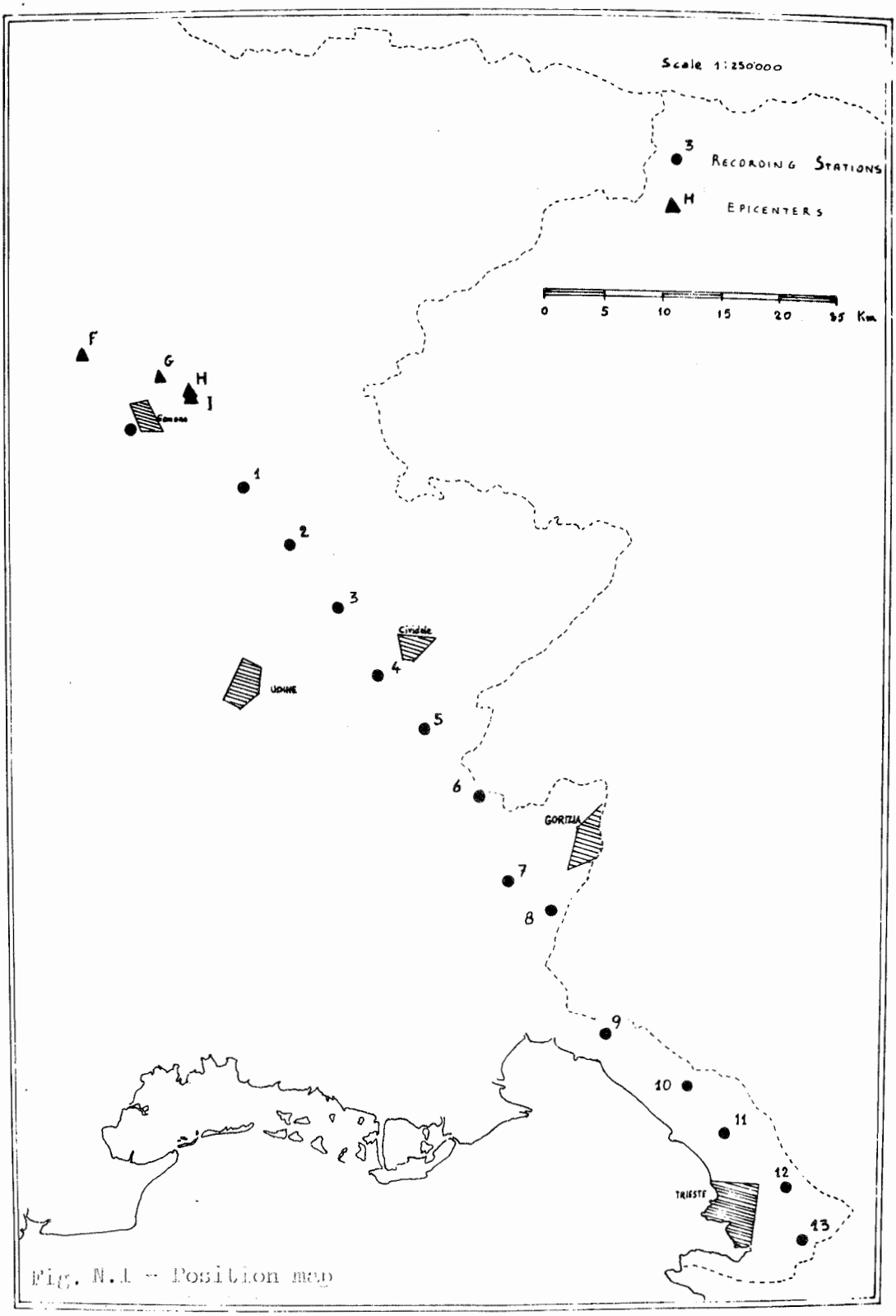

Fig. N.1 - Position map

- Istituto per la Geofisica della Litosfera, C.N.R. - Milano
- Osservatorio Vesuviano - Ercolano (Napoli)
- Osservatorio Geofisico Sperimentale - Trieste

The purpose was the exploration of the Crustal Structure along the profile by employing the same field technique as in deep seismic sounding by explosion, and taking advantage of a possible occurrence of some after shock with intensity great enough to be recorded also in the farthest stations.

Actually some events occurred with sufficient intensity which provided good quality data for interpretation.

The main events in the considered period are listed in the following table.

EVENT N.	DATE	ORIGIN TIME (GMT)	COORD. EAST	NORD	DEPTH (Km)
F	2I-X	$03^h 30^m 25,93^s$	I3°03,89'	46°I9,55'	2,97
G	2I-X	$03^h 34^m 49,54^s$	I3°09,00'	46°I8,47'	4,58
-	24-X	$04^h II^m$	- - - - -	- - - - -	- - -
H	26-X	$06^h 02^m 48,74^s$	I3°I0,64'	46°I7,72'	8,77
I	26-X	$06^h I0^m 00,02^s$	I3°I0,73	46°I7,6I'	9,00

Data on the table are a gentle courtesy of I.P.G. (Institut de Physique du Globe) of Strasbourg, which is operating in the Friuli region with a net of 7 recording stations.

Events F,G,H and I are located near Gemona and are well aligned with the profile.

Owing to the very short time from the period when the experiment was carried out (about one month ago) it was impossible up to now to attempt any interpretation. This report illustrates only some example of the re

corded events and some example of record-section, which show, even if incomplete, the success of the experiment carried out and the possibility to obtain, after interpretation, some interesting results.

Fig.N.2 shows records on station N.I from event H, 9,5 apart. Clear P and S events are recorded, with time-delay about I.7 sec, in all components.

From the same event, records of the station N.5 (fig.3), at a distance of 35.5 Km, show P and S arrivals with time-delay about 5.6 sec.

All records show clear P and S arrivals, but in some records other events of different kind were detected, as later arrivals.

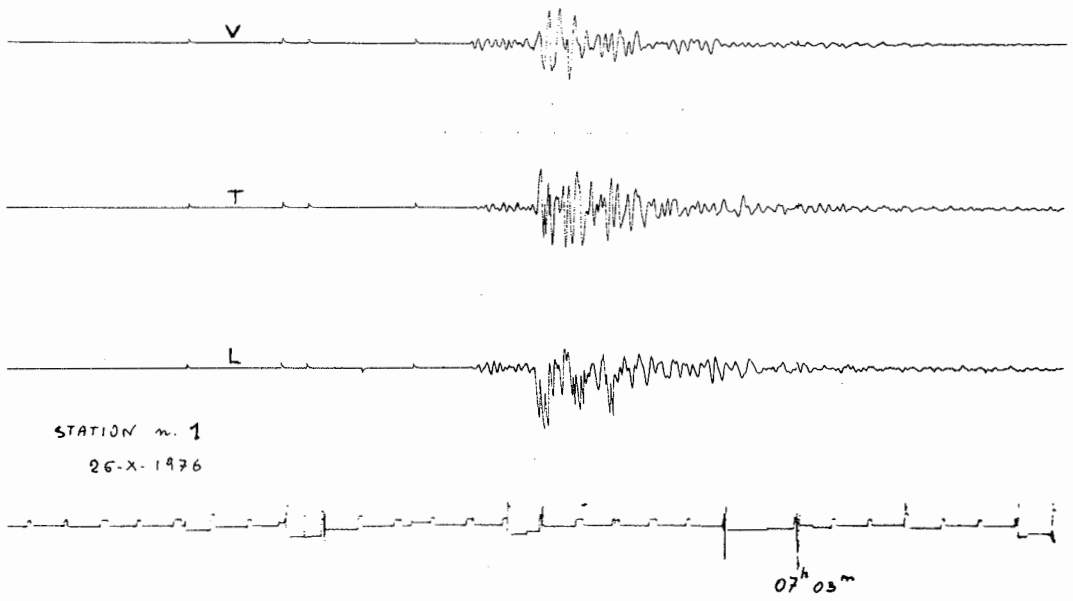

Fig.N.2 - Records on station n.I of event H

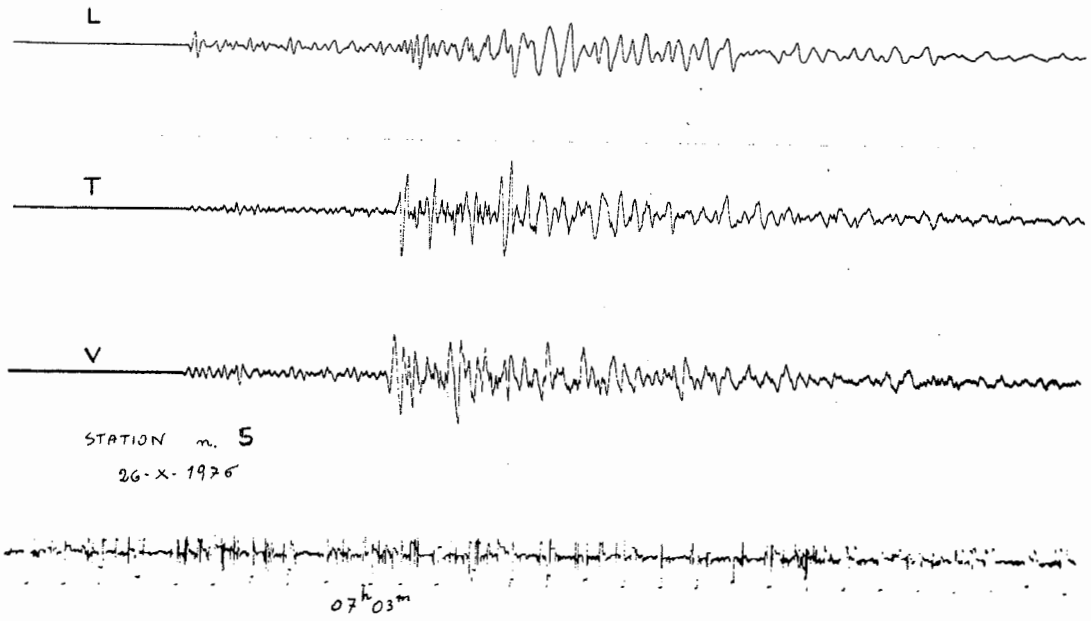

Fig.N.3 - Records on station n.5 of event H.

Fig.4 is the record-section referred to aftershock H. Records of the farthest stations, up to a distance of 93 Km, are missing. Time scale is normal and referred to the origin time. Distances of stations are horizontal distances from the position of the epicenter. Records belong to vertical traces, which are plotted without any filtering of the signal. First arrivals can be easily correlated, from the beginning to the end of the section. S arrivals are correlable with some difficulty. In some records other arrivals are visible too.

Correlation of S arrivals can be made easily on record-section of fig.5, where transversal traces T have been plotted.

Fig.N.6 is another example of record-section (V traces), referred to the event I. Also in this section clear first arrivals appear that are correlable along all the profile. S arrivals are evident too, but they are better correlable in the record section of fig.7 where transversal traces T have been plotted. Also in these two last record-sections arrivals of different kind are visible.

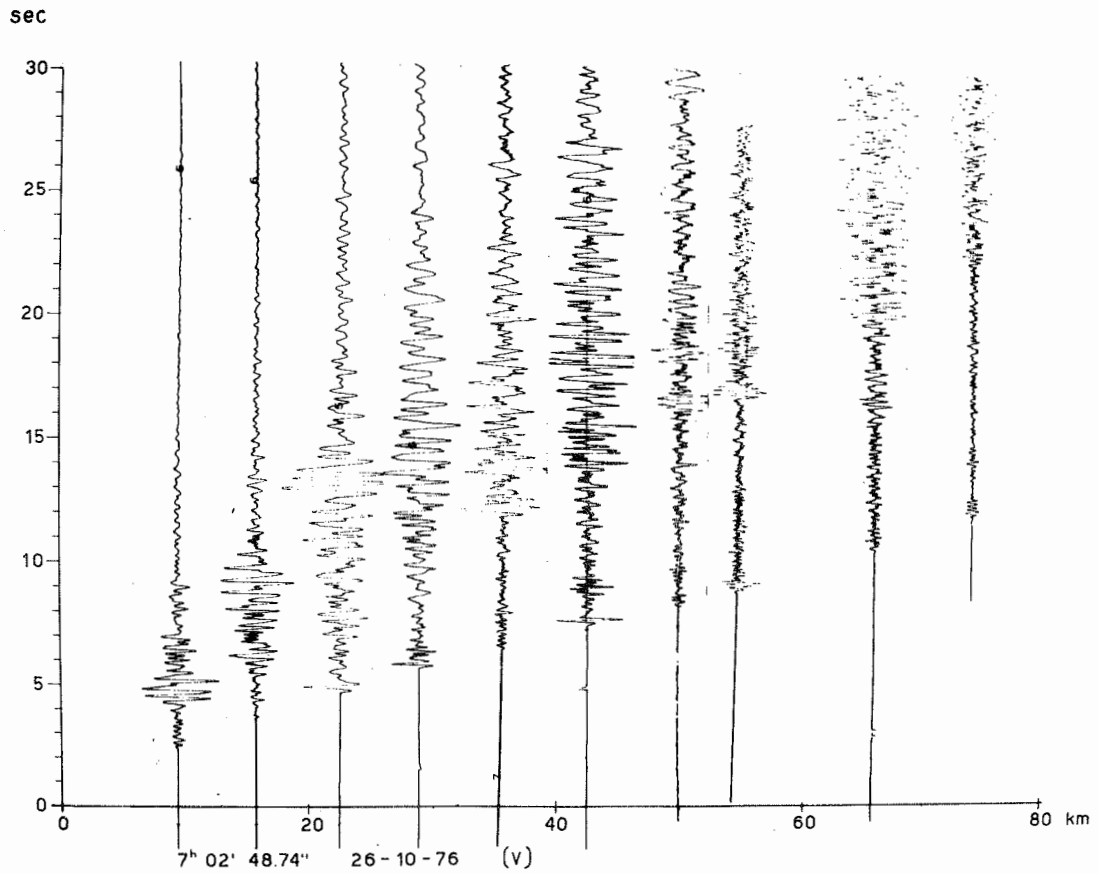

Fig.N.4 - Record-section of event H (V traces)

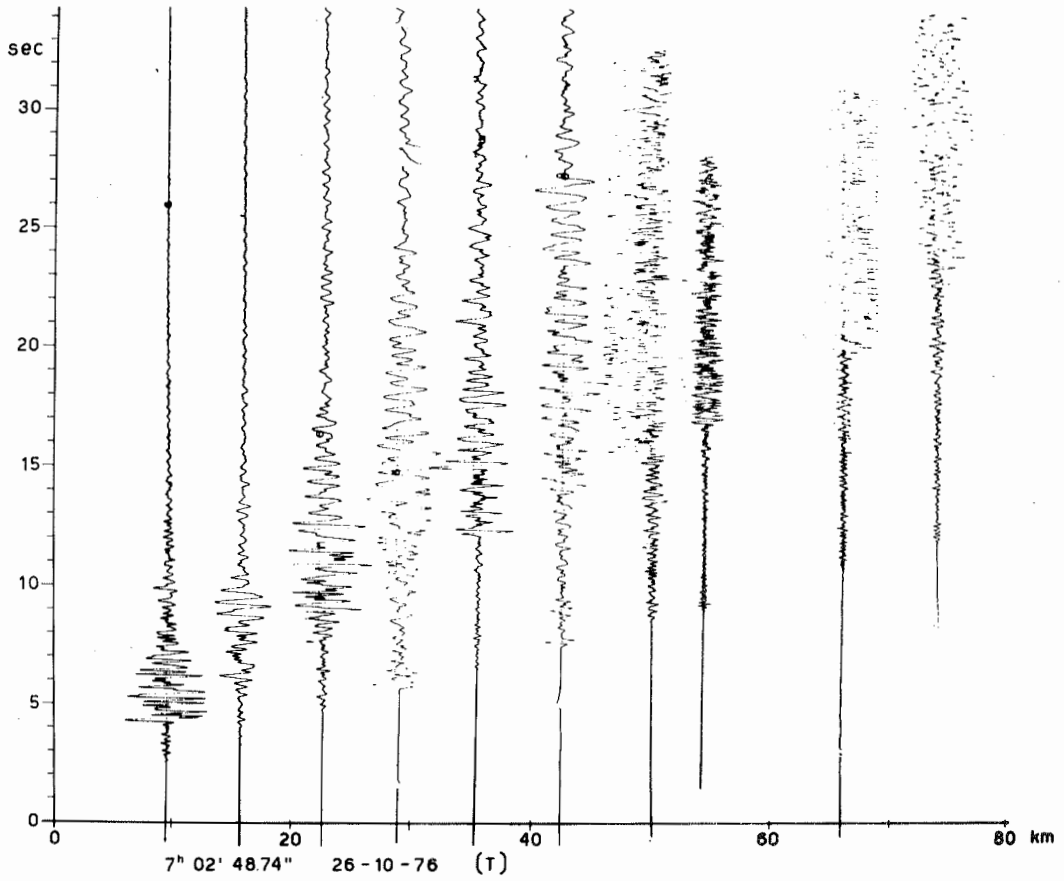

Fig.N.5 - Record-section of event H (T traces)

The next figures show travel - time curves related to the main events evidenced in the record-sections, that is P and S arrivals.
In fig.N.8. travel-time curves related to the event F are shown. A clear corrispondence between apparent velocity values of P and S waves is evi denced. Travel-time curves can be divided in two main branches. The first one, from the origin up to a distance of 30 Km is clearly a curve of hy perbolic type and represents the direct arrivals from the hypocenter to the recording stations. By extrapolation an intercept-time of 0.65 sec and I.I sec can measured, for P and S arrivals respectively, which give

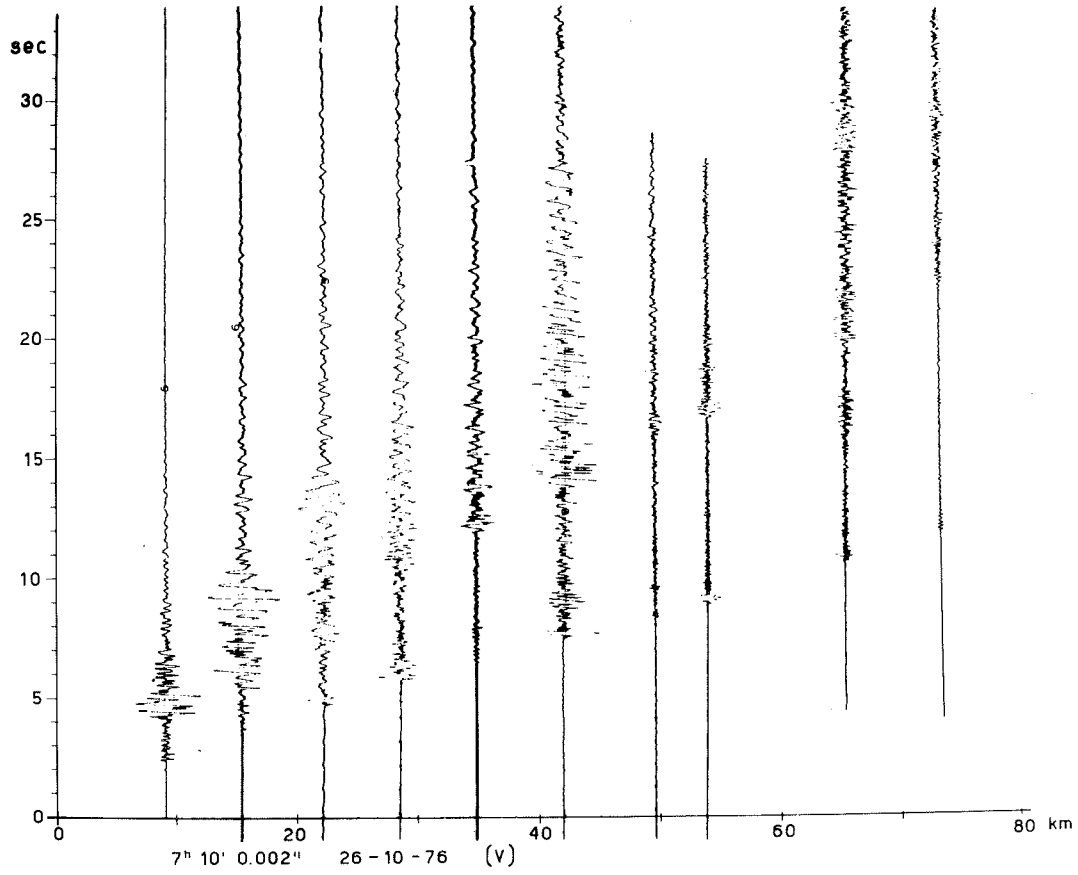

Fig.N.6 - Record-section of event I (V traces)

a mean velocity value from 3 Km (depth of the hypocenter) to surface, of about 4.6 and 2,7 Km/sec.

The second branch runs from a distance of 40-50 Km up to the end of the profile, and shows an high apparent velocity value, of more than 7 Km/sec. It should be studied with more accuracy if this branch belongs to an intermediate refracting horizon or if it must be considered as a P^m phase (reversed branch), that is a common phase in deep seismic sounding by explosion. Actually a slight decrease of apparent velocity with distance appear in the travel-time curve.

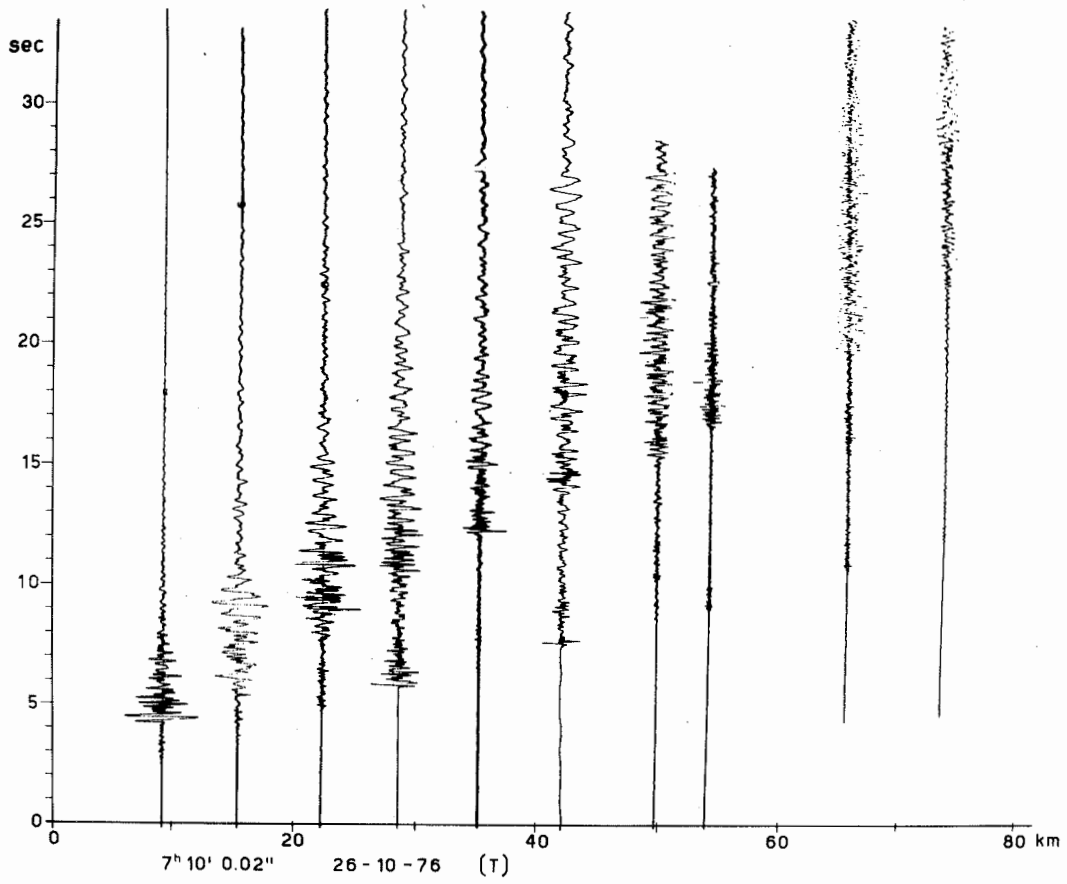

Fig.N.7 - Record-section of event I (T traces)

A similar picture is shown in the diagrams of fig.N.9, referred to the event G (depth of the hypocenter 4,6 Km). The extrapolated intercept-times give a mean velocity value of 5.I and 2.8 Km/sec respectively for P and S waves. Also in this figure the second branch show high apparent velocity values and some evidences of a decreasing velocity with increasing distance.

Diagrams in figg. IO-II, related to the events H and I, that are at about the some epicentral position and the same hypocentral depth (9 Km) look of course very similar each other. We may distinguish the same bran

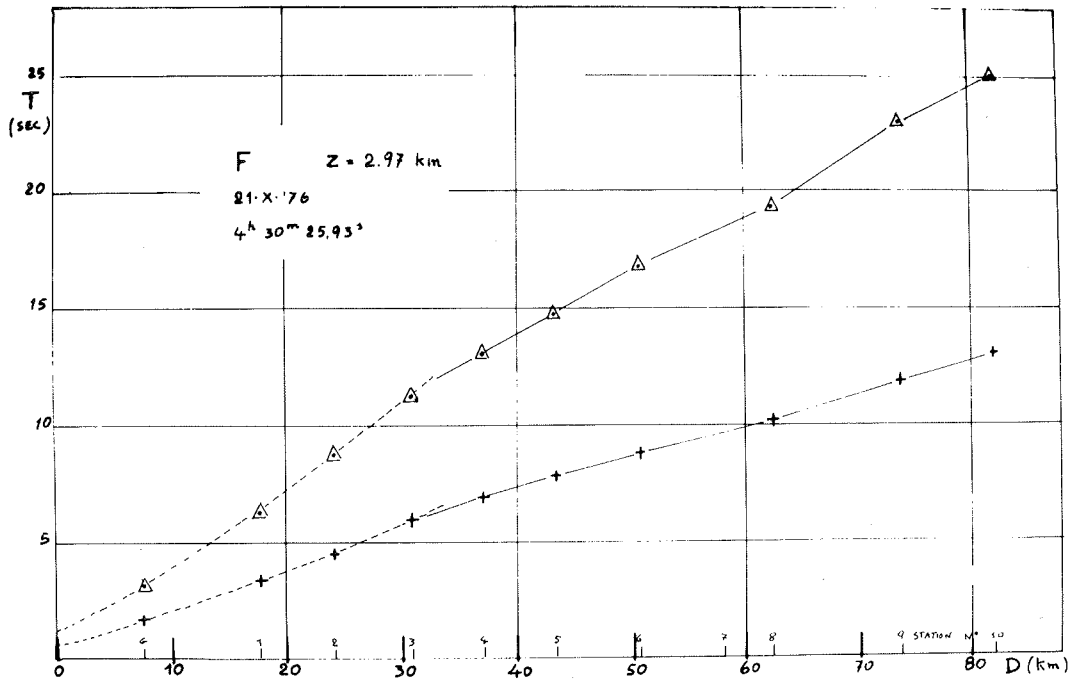

Fig.N.8 - Travel-time curves of event F.

ches in the travel-time curves as seen in the previous diagrams; direct arrivals from the hypocenter, refracted or reflected events in the longer distances, with high apparent velocity values. Moreover a correlation of other arrivals has been attempted.
Referring to the extrapolated intercept time, we find a mean velocity value, in the interval depth from 9 Km to the surface, of about 6 Km/sec for P waves, and of about 4.5 Km/sec for S waves.

As told at the beginning of this report we do not attempt any interpretation of data at present, because they should be studied with more

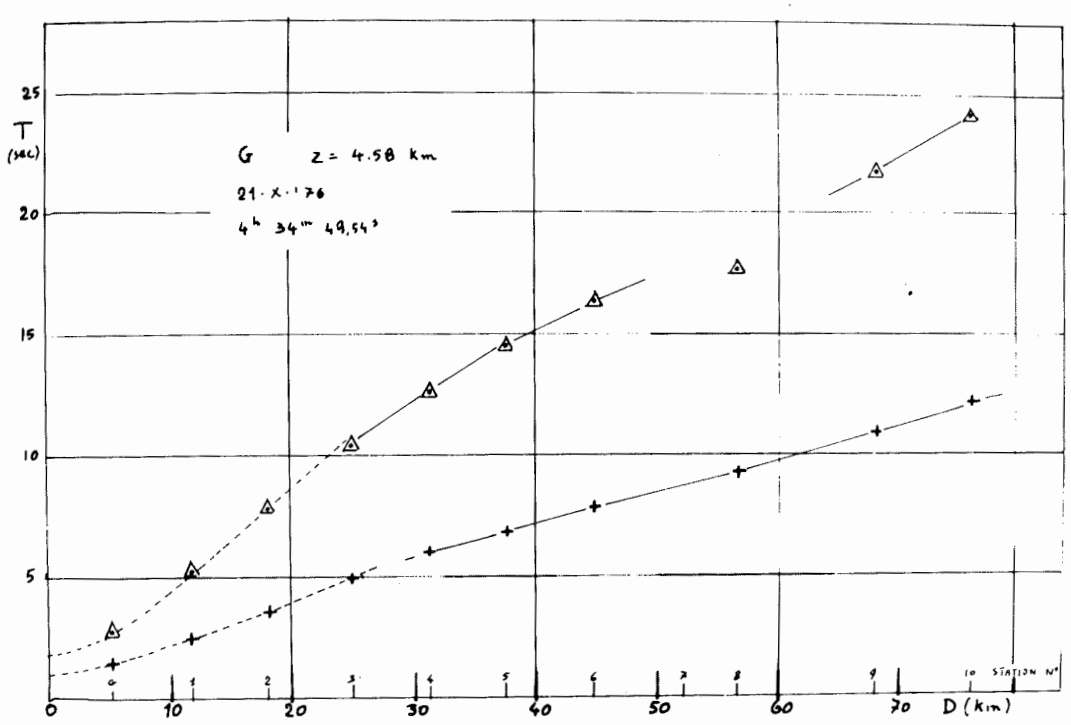

Fig.N.9 - Travel-time curves of event G.

accuracy, after an appropriate and complete elaboration, that we could not make up to now. On this experiment a complete report will be published in the next months. What we can say now is only that in the Friuli region terrains with high velocity value should be present at relatively small depth, which seems unusual if compared with results obtained by the deep seismic sounding experiments carried out in eastern Alp and other regions of Italy,

In this same area the " Geodynamic project" has planned a seismic profile to be explored in 1977. So we can expect other results to be compared with results of this experiment. At the end, to obtain

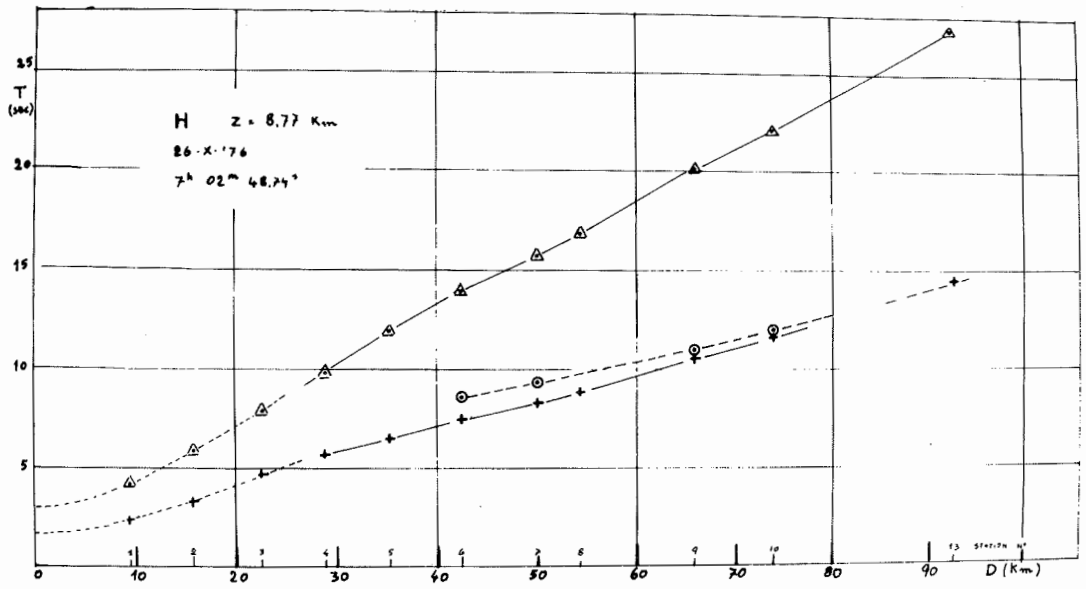

Fig. N°10 - Travel-time curves of event H

a reliable model of the Crustal Structure, as a valid contribution to the complex of geological and seismological studies undertaken in the Friuli region.

BIBLIOGRAPHY

BEHNKE, C.; GIESE, P; PRODEHL, C,&DE VISENTINI, G.: "Seismic refraction investigations in the Dolomites for the exploration of the Earth's Crust in the Eastern Alpine area", Boll.Geof.Appl.,4, II0-I32 (I962)

CLOSS, H.&MORELLI C.: "Seismic experiments in the Dolomites (Lago Lagorai) to investigate the Earth's Crust in the Eastern Alpine Area", Z.Geophys.,28,249-257,Boll.Geof.Teor. ed Appl., 4, 99-I09 (I962)

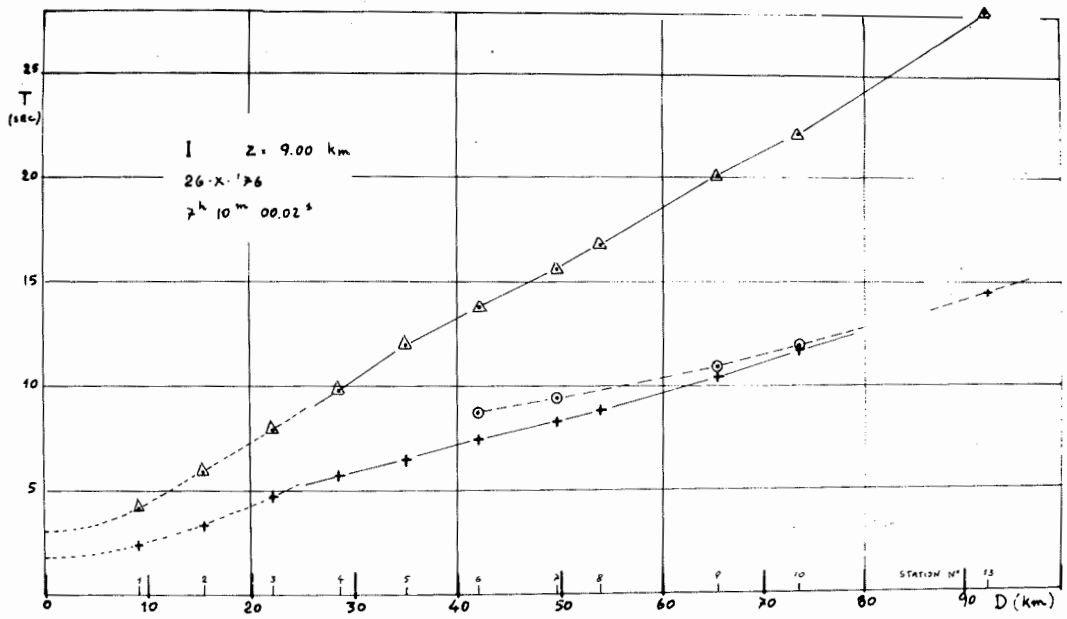

Fig.N.II - Travel-time curves of event I

BEHNKE,C.: "Explosion seismology data generalization, Examples from Eastern Alps", Assemblé Générale de la Commission Séismologique Européénne, Luxembourg,p.II7-I8I (I970)

CHOUDHURY,M.; GIESE,P.&DE VISENTINI,G.: "Crustal structure of the Alps some general features from explosion seismology", Report IUGG General Assembly Zurich (I967); Boll,Geof.Teor.ed Appl., I2,n,5I-52, 2II-240, (I97I).

SCARASCIA S.&COLOMBI,B.: "Interpretazione preliminare del profilo sismico a rifrazione profonda in Calabria", Lab.Geof.Litosfera CNR,I-35 (I97I)

ANGEHNEISTER,G. et al.: "Recent investigations of surficial and deeper crustal structures of the Eastern and Southern Alps", Geol. Rundsch, 61,2, 349-395 (1972)

FINETTI, I.&MORELLI,C.: "Deep seismic refraction exploration on Eastern Alps", Boll.Geof.Teor.Appl., 14, 53-54 (1972)

COLOMBI,B. et al.: "Preliminary report on the seismic refraction profile Gargano-Salerno-Pantelleria". Boll.Geof.Teor.ed Appl.,215-225 (1973)

COLOMBI,B. & SCARASCIA S.: "Sulla interpretazione dei profili sismici crostali. Calcolo diretto delle funzioni velocità-profondità", Rivista Italiana di Geofisica, 22, 213-226 (1973)

GIESE, P.&MORELLI, C.: "Crustal structure in Italy", Quaderni de "La Ricerca Scientifica", n.90 (1975)

MORELLI, C. et al.: " Crustal structure of Southern Italy a seismic refraction profile between Puglia-Calabria-Sicily, Boll.Geof.Teor. ed Appl., Vol. XVII, n.67, 183-210 (1975).

LIQUEFACTION OF SANDS IN FRIULI DURING MAY 6 AND SEPTEMBER 15 1976 EARTHQUAKES

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SONDATER SpA, Trieste, Italy, and Research Cooperator in Soil Mechanics at POLITECNICO DI TORINO. Nov. 1976.

ABSTRACT

The Author gives a state of the Art of the most recent knowledges on liquefaction of sands (*). A short explanation of deterministic and statistic approaches to the problem is given, referring also to Berkeley's and Harvard's different theories. Fourteen sites in Friuli where the Author found interesting even if not dramatic examples of liquefaction are shown. First data and a survey on the study which the Author is carrying on, are given.

(*) The term is not exact, in reality (see fig. 1) medium sands and sandy silts can liquefy too.

State of the Art - Early Knowledges

The first qualitative descriptions of the liquefaction of sands had been given by Terzaghi and Casagrande. The latter Author noted different results coming from simple shear tests, performed on satured sands, dipending on density of samples. In 1935 Casagrande saw that, when loose sand is sheared, it decreases in volume and is tending to reach a steady state volume (i.e. void ratio or density); on the contrary, a sand in dense state dilates until it also reaches a steady state condition.

We know that also neutral pressure changes: it becomes higher when testing, with no drainage, a loose sand and lower when testing a dense sand.

Grain size has great importance too; summary of many Author's data is given in fig.1.

Definition of Phenomena

The shearing resistence τ_f of a sand may be written, using Coulomb's criterion:

$$\tau_f = \bar{c} + \bar{\sigma} \operatorname{tg} \bar{\phi}$$

where $\bar{\sigma}$ is effective stress and $\bar{\phi}$ is the effective angle of internal friction. When we saturate a sand with water , the effective stress becomes $\bar{\sigma} = \sigma - u$ where σ is total stress and u is porewater pressure, therefore τ_f becomes:

$$\tau_f = (\sigma - u) \operatorname{tg} \bar{\phi}$$

Actual, Cyclic and Induced Liquefaction.

When testing a loose sand, whith drainage prevented, u increases as long as sand fails. A similar behaviour is shown if there is drainage, but stresses are very quickly or cyclically applied. Dinamic stresses in the field cause a sudden change in total stresses, inside the sandy deposit; phenomenon is fast enough not to allow drainage of water during contraction (there is a reduction in volume of loose sand, depending on a rearrangement of grains). Stresses are no more supported by the material's solid skeleton and are transferred to water,

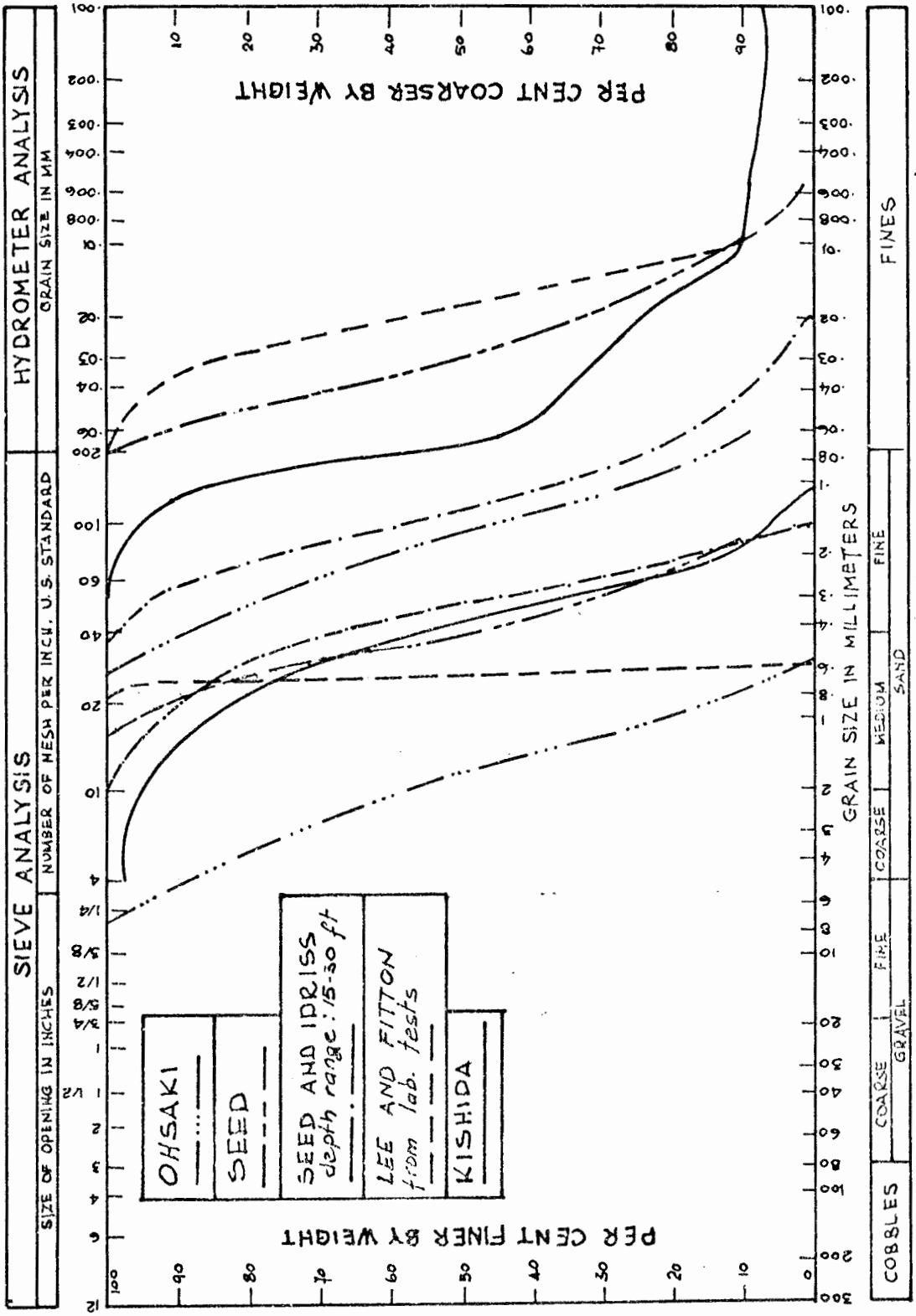


FIG. 1 Soils susceptible to liquefaction (from Finn et al.)

with a total loss of strength. This is what we call "actual liquefaction", according to Casagrande (1976).

A dense sand has, on the contrary, a dilatative behaviour, i.e. it shows negative increments in pore water pressure and positive increments in effective stress (and in τ_f). Dense sand therefore doesn't show actual liquefaction. During triaxial cyclic loadings, on dense (dilatative) sands, pore pressure can temporarily reach the confining pressure and then the sand shows "cyclic liquefaction".

Then there is another phenomenon, which can occur in the field and which needs deeper examination. Pore water pressure can be increased in a fine cohesionless material in the field, also through raising of the water table; this can happen during an earthquake (see also L. Finn, 1973). Induced pore water pressure can accelerate liquefaction of these materials. Therefore the particular genesis of the described phenomenon, to be better studied, may suggest the new term "induced liquefaction". The Author thinks that some of the frequent local symptoms of "boils" in medium sands and coarse sands during earthquakes, could be related to induced liquefaction as well as to syphon-effects.

Deterministic Approaches to Liquefaction

H.B. Seed and I.M. Idriss, from Berkeley's University, pay special attention to the problem of evaluating liquefaction potential, taking account of dynamic stress history in the field and dynamic characteristics developed during cyclic loading triaxial tests.

The method proposed by Seed and Idriss can be summarized in four steps:

I) Evaluation of dynamic stress history of the investigated site

II) Research of a number of uniform stresses equivalent to the estimated dynamic stress

III) Determination of shear stresses necessary for liquefying the deposit at various depths. Dynamic Triaxial apparatus is used for this analysis.

IIII) Determination of sand susceptibility of liquefying at various depths with comparison of shear stresses caused by the project earthquake, with results obtained in III

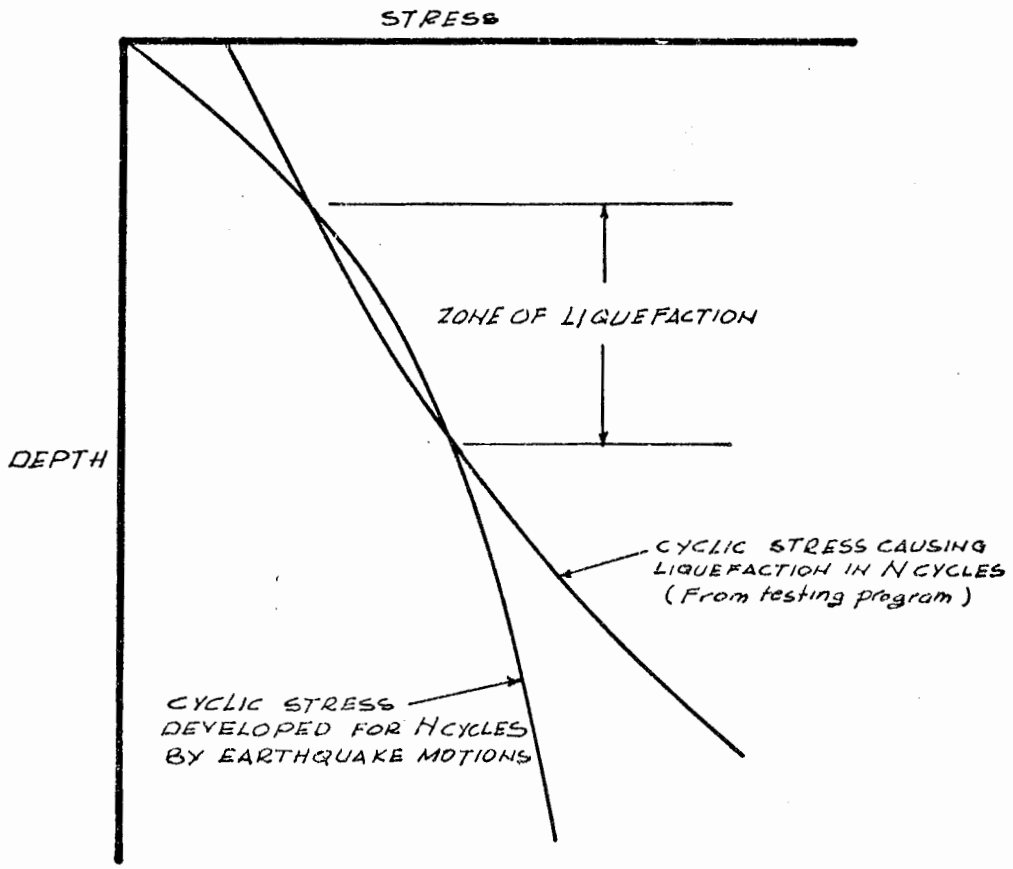


FIG. 2 METHOD OF EVALUATING LIQUEFACTION POTENTIAL - From Seed and Idriss (1971)

liquefaction of sands in Friuli

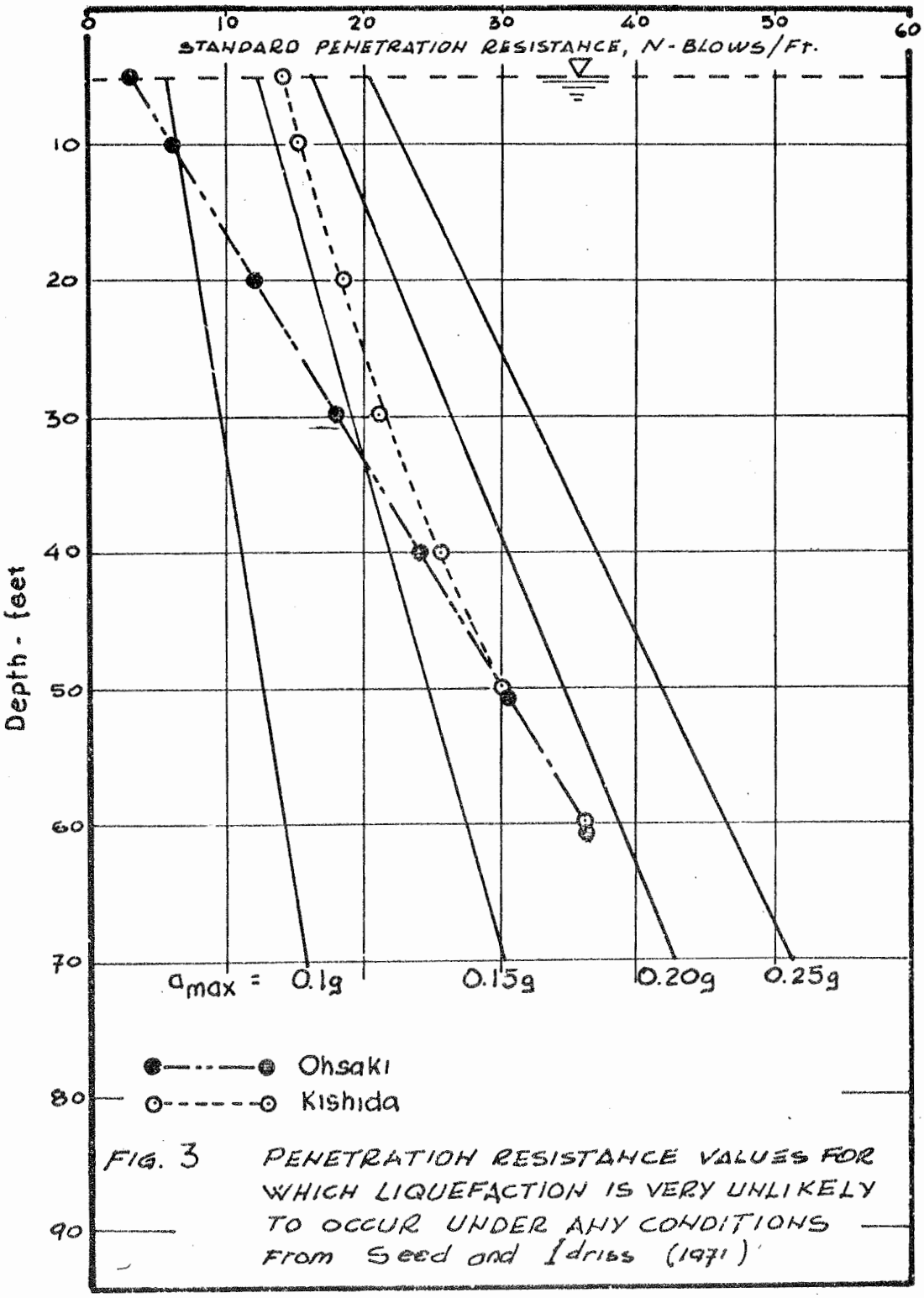


FIG. 3 PENETRATION RESISTANCE VALUES FOR WHICH LIQUEFACTION IS VERY UNLIKELY TO OCCUR UNDER ANY CONDITIONS From Seed and Idriss (1971)

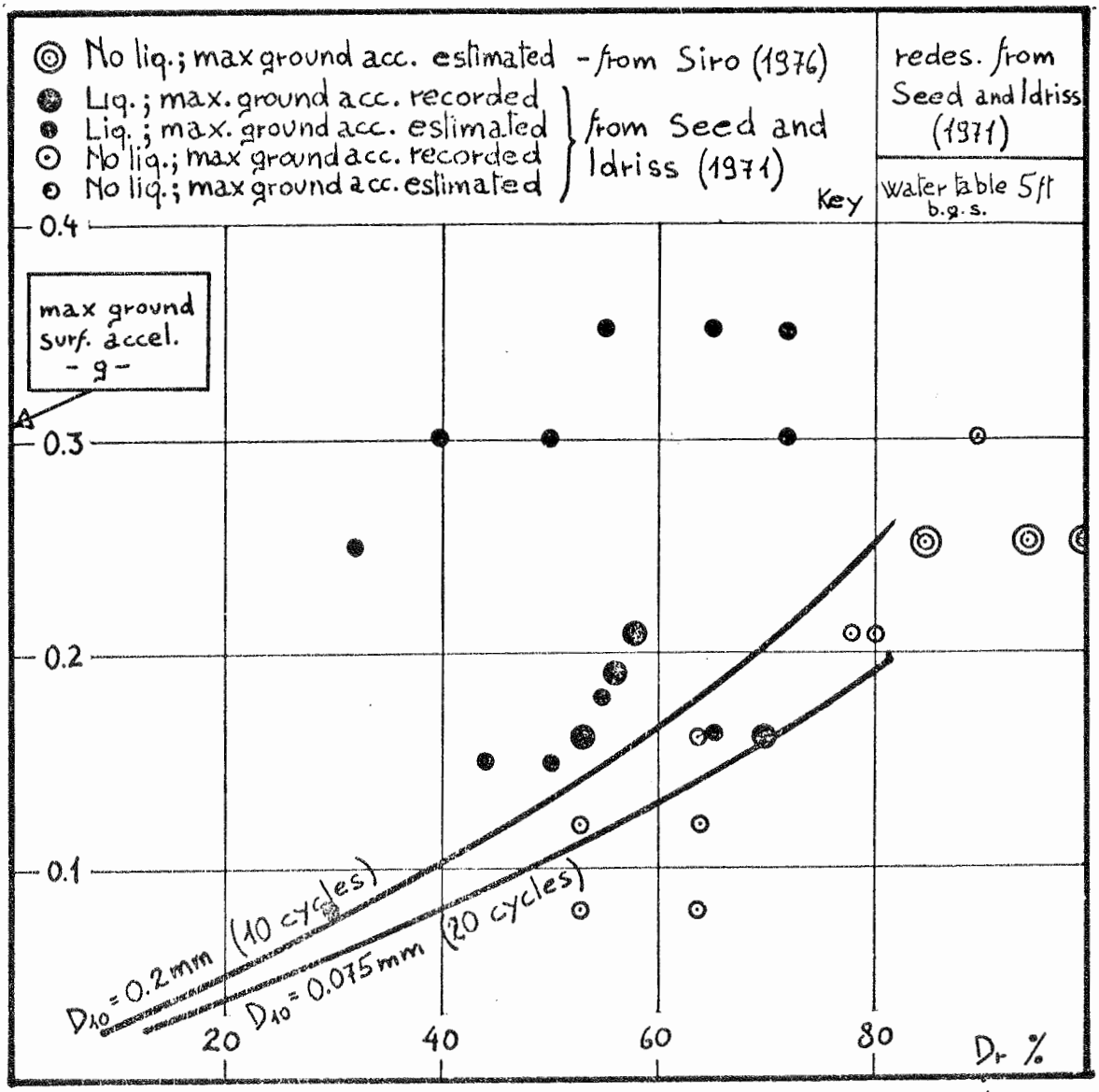


Fig. 4 EVALUATION OF LIQUEFACTION POT. - FINE SANDS -

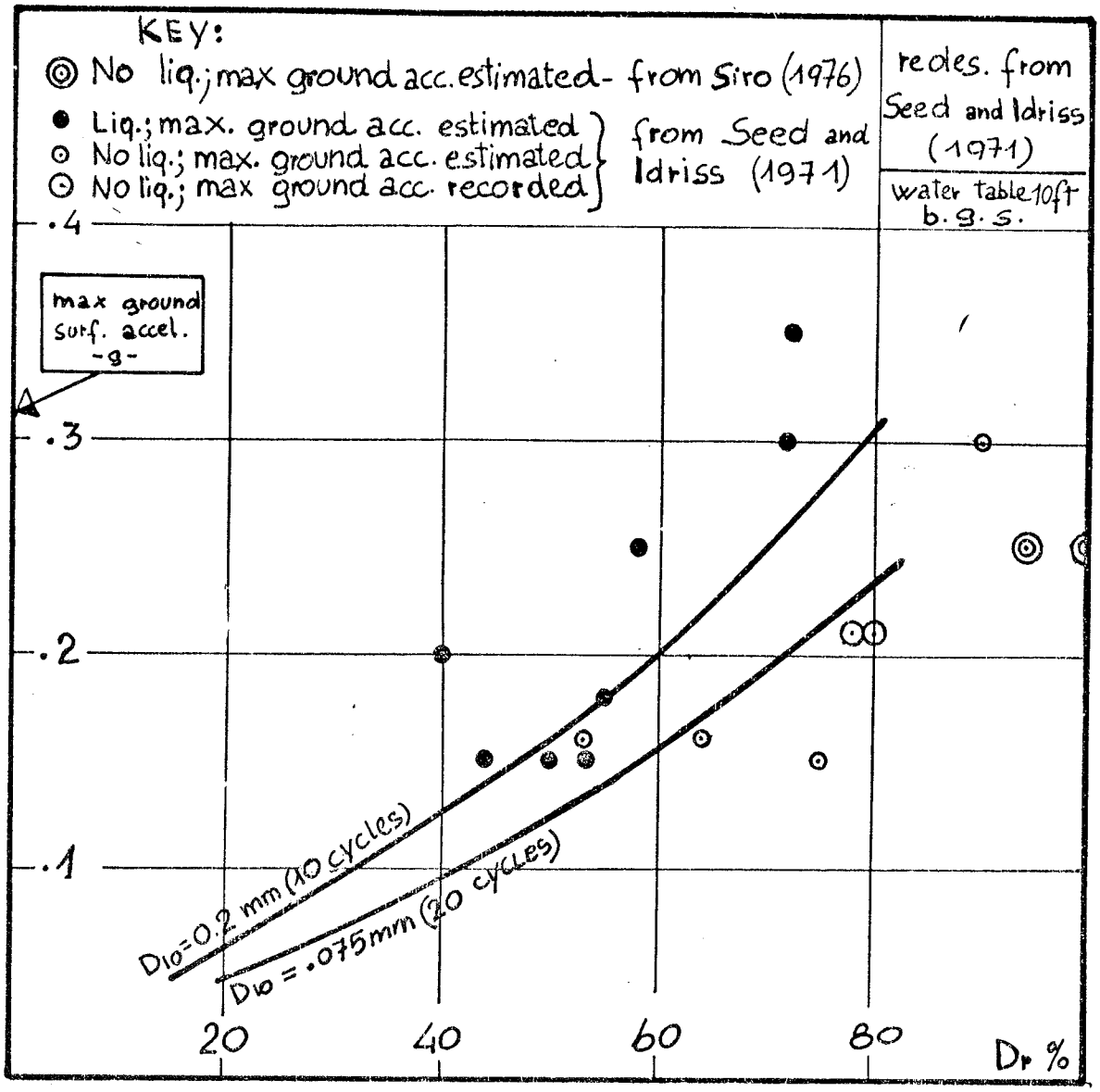


Fig. 5 EVALUATION OF LIQUEFACTION POT. - FINE SANDS-

stage (see fig. 2).

This kind of approach is very interesting and it leads to interesting results, based on the effective grain size too (see fig. 3-4-5), but there are some doubts about the stress conditions of those triaxial tests. For example, during an earthquake, there is a rotation of major principal stress in the field, around vertical position. During cyclic tests performed at Berkeley there is a cyclic inversion of stresses, which is very far from in situ conditions.

The method leads to interesting but hard to accept conclusions: dense sands (dilative) even with high effective consolidation pressure can liquefy too. There can be also dilatative liquefaction.

A. Casagrande and G. Castro support a deterministic approach which is a consistent development of 1936 work of Casagrande. Castro performed a series of monotonic dead load and strain control Triaxial tests. He succeeded in producing actual lab. liquefaction and he drew some very interesting conclusions: There is a relationship (line F in fig. 6) between void ratio (i.e. Dr) and effective minor principal stress at liquefaction, during an undrained dead load Triaxial test.

A similar relation can ben noticed between void radio and (line Esc in fig. 6) $\bar{\sigma}_3$ developed, on liquefaction, in tests run with strain control loadings. Therefore the liquefaction potential can be expressed as a ratio between the initial minor principal effective stress and the same stress as of line F, on liquefaction.

Castro separates (see fig. 6) a dilatative zone (no actual liquefaction) from a contractive zone.

This method doesn't help us to evaluate the stress level necessary for causing liquefaction in a sand, but gives us very good informations about susceptibility of a sand of liquefying, under certain dynamic excitations.

On the other hand, it is now possible to evaluate liquefaction potentials performing not too difficult tests.

Statistic Approaches

Both the following two methods consist in a statistic analysis of behaviours of sites where S.P.T. Tests had abready been performed, and where maximum accelerations had then been

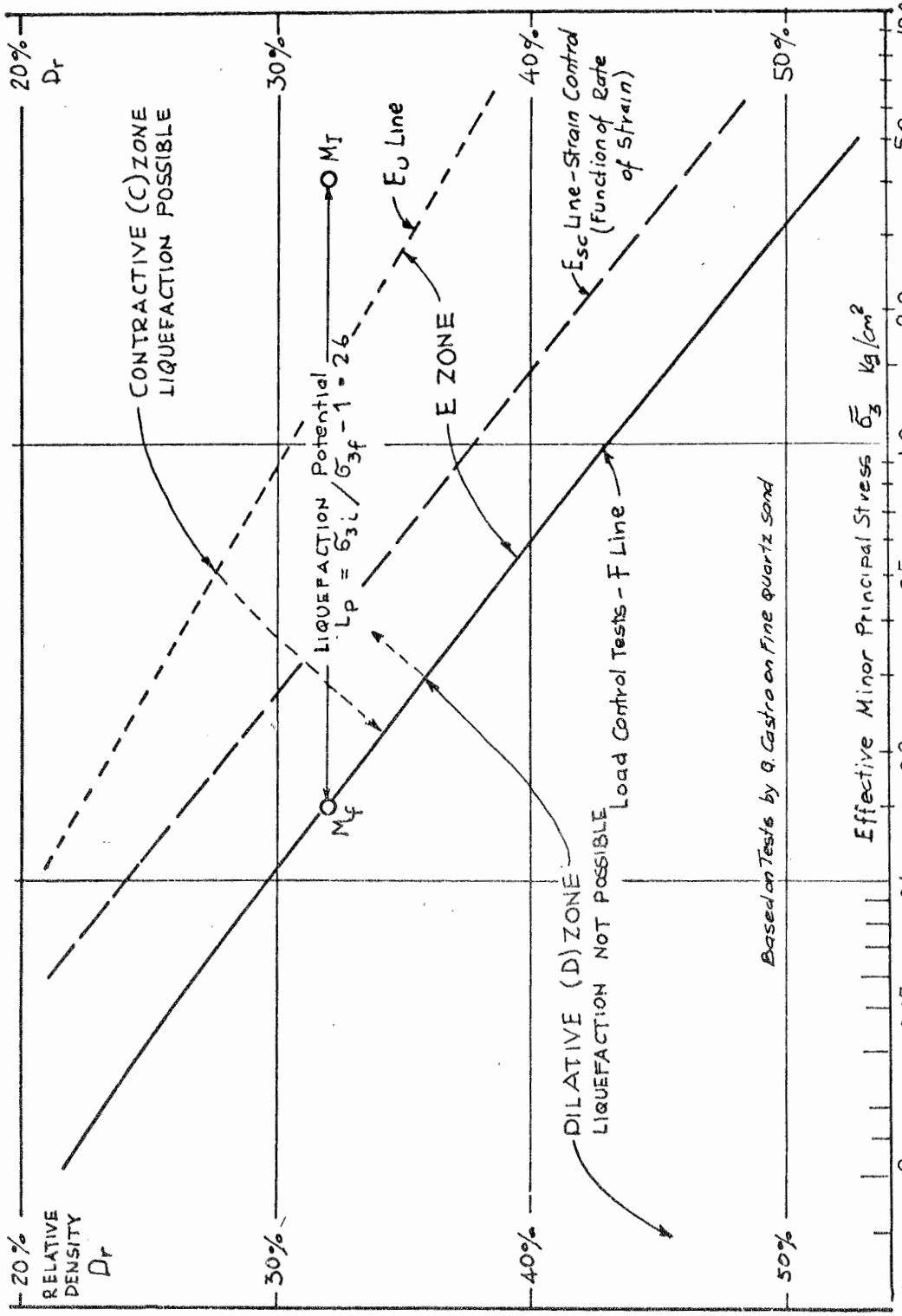


FIG. 6 Variables controlling potential for actual liquefaction of banding sand (Based on data by G. Castro; rep. by A. Casagrande)

registred, or well estimated during an earthquake. In situ densities and max. horizontal accelerations are considered though with different evaluations.

J.T. Christian and W.F. Swiger evaluate relative densities (Dr) from Gibbs and Holz's correlation between N S.P.T., effective minor principal stress $\bar{\sigma}_3$ and Dr. They use a corrected maximum ground acceleration accounting for different water-table depths (i.e. different effective pressures), by multiplying α (maximum ground acceleration) by the ratio between the total vertical stress (at the considered depth) and the effective vertical stress.

Thus: $$A = \frac{\sigma_v}{\bar{\sigma}_v}\,\alpha$$

Note that the nearer the water table to the ground surface the greater A.

The above statistic analysis suggests the interesting consequence that Dr is more important than A, to evaluate liquefaction potentials. A discriminant analysis is then carried out, to separate different site-situations into one of two categories:
1) sites which showed liquefaction; 2) sites which didn't. Relative density together with corrected acceleration are considered (see fig. 7) both on arithmetic and logarithmic scales.

As you can see, distribution of points is not perfect but rather satisfactory if we take into account the high variance (see Tavenas et al. 1972) of Dr. Probabilities calculated by Christian and Swiger obviously are not probabilities of liquefaction, but only multivariate statistics for splitting data into two kinds of phenomena. These statistic distributions are an important key for classifying and analysing different site-situations. Like those made by M.K. Yegian, these statistics need many more data, to enable the study of not yet considered parameters.

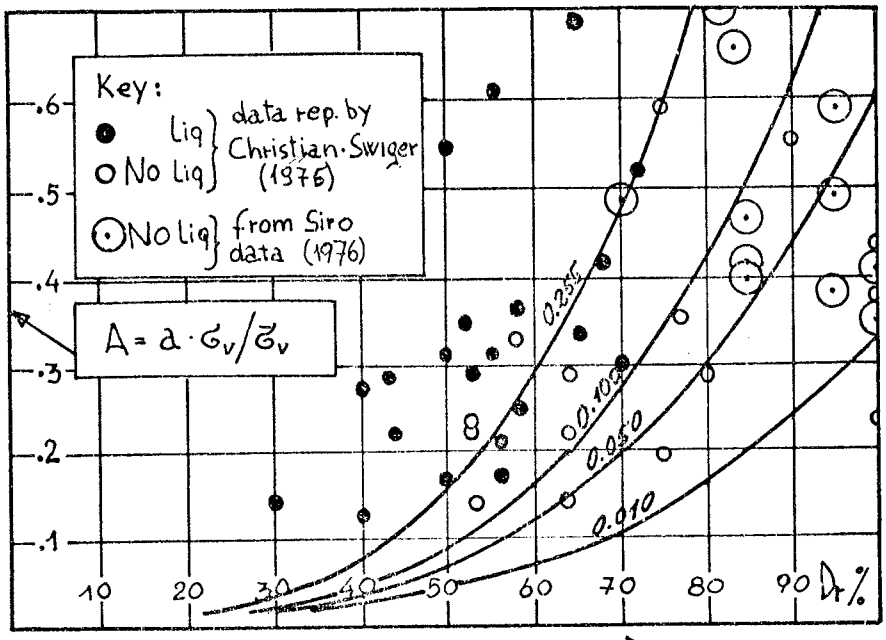
M.K. Yegian and R.V. Whitman introduced in 1976 a new kind of statistic approach based on parameters Sc (which is proportional to maximum dynamic shear stress induced by an earthquake) and on N'(corrected value of N S.P.T.). Equations are:

$$S_c = \frac{e^{\alpha s M}\, H}{(R+16)\,\bar{\sigma}_v} \qquad N' = \frac{50\,N}{\bar{\sigma}_v + 10}$$

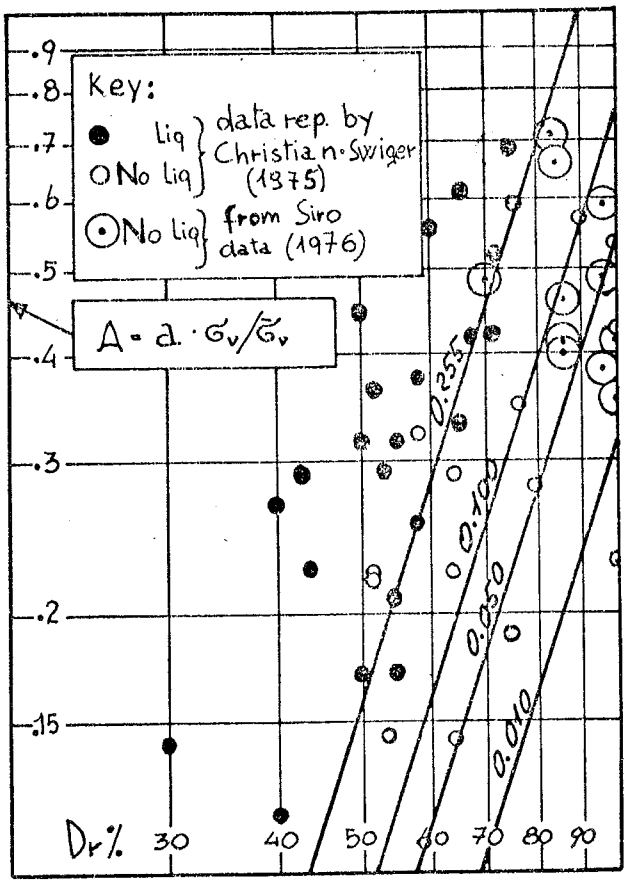
a	b	c	d	e	f	g	h	i	l	m	n
I	FRIULI	1976	BUIA	2	25	120	105	0,35	0,65	83	NO
2	FRIULI	1976	BUIA	2	66	120	105	0,35	0,71	82	NO
3	FRIULI	1976	BUIA	27	34	120	105	0,35	0,40	85	NO
4	FRIULI	1976	BUIA	27	49	120	105	0,35	0,49	70	NO
5	FRIULI	1976	ARA GRANDE	5	34	120	105	0,25	0,46	85	NO
6	FRIULI	1976	ARA GRANDE	5	15	120	105	0,25	0,41	85	NO
7	FRIULI	1976	ARA GRANDE	5	20	120	105	0,25	0,41	100	NO
8	FRIULI	1976	ARA GRANDE	5	56	120	105	0,25	0,49	95	NO
9	FRIULI	1976	ARA GRANDE	5	34	120	105	0,25	0,46	85	NO
10	FRIULI	1976	BUIA	2	10	120	105	0,35	0,59	95	NO
11	FRIULI	1976	ARA GRANDE	8	20	120	105	0,25	0,35	100	NO
12	FRIULI	1976	ARA GRANDE	8	25	120	105	0,25	0,38	95	NO

FIG. 7 New Data for Christian and Swiger Statistics of Fig.8 .

Key: a = case number
b = earthquake
c = date
d = site
e = depth to ground w. level in feet
f = critical depth, in feet
g = satured unit weight in p.s.f.
h = unsatured unit weight in p.s.f.
i = acc. in g
l = A in g
m = relative density %
n = liquefaction



DATA POINTS AND DISCRIMINANT CURVES (arithmetic scales)



DATA POINTS AND DISCRIMINANT CURVES (log. scale)

redes. from Christian and Swiger (1975)

FIG 8

Liquefaction of sands in Friuli

where: M is Richter scale magnitude; H is the depth at the testing point in feet; $\bar{\sigma}_v$ is vertical effective stress in p.s.i. and R is hypocentral distance in miles (very close to epicentral distance, if hypocentre is not very deep). This kind of formulation of maximum induced shear stress and of state of aggregation (i.e. penetration resistance) of sand, is very useful because a site can be classified even if good acceleration records are not available; N' takes into account water table depth. These Researchers define liquefaction potential as the ratio between the stress parameter Sc, depending on the earthquake induced stress, and $\bar{S}c$ which is a function of the average soil strength against liquefaction. The plotting (see fig. 8) of all available data enables to draw the boundary line $\bar{S}c$ through the "least square of misclassified points" method, between points with liquefaction and points with no liquefaction.

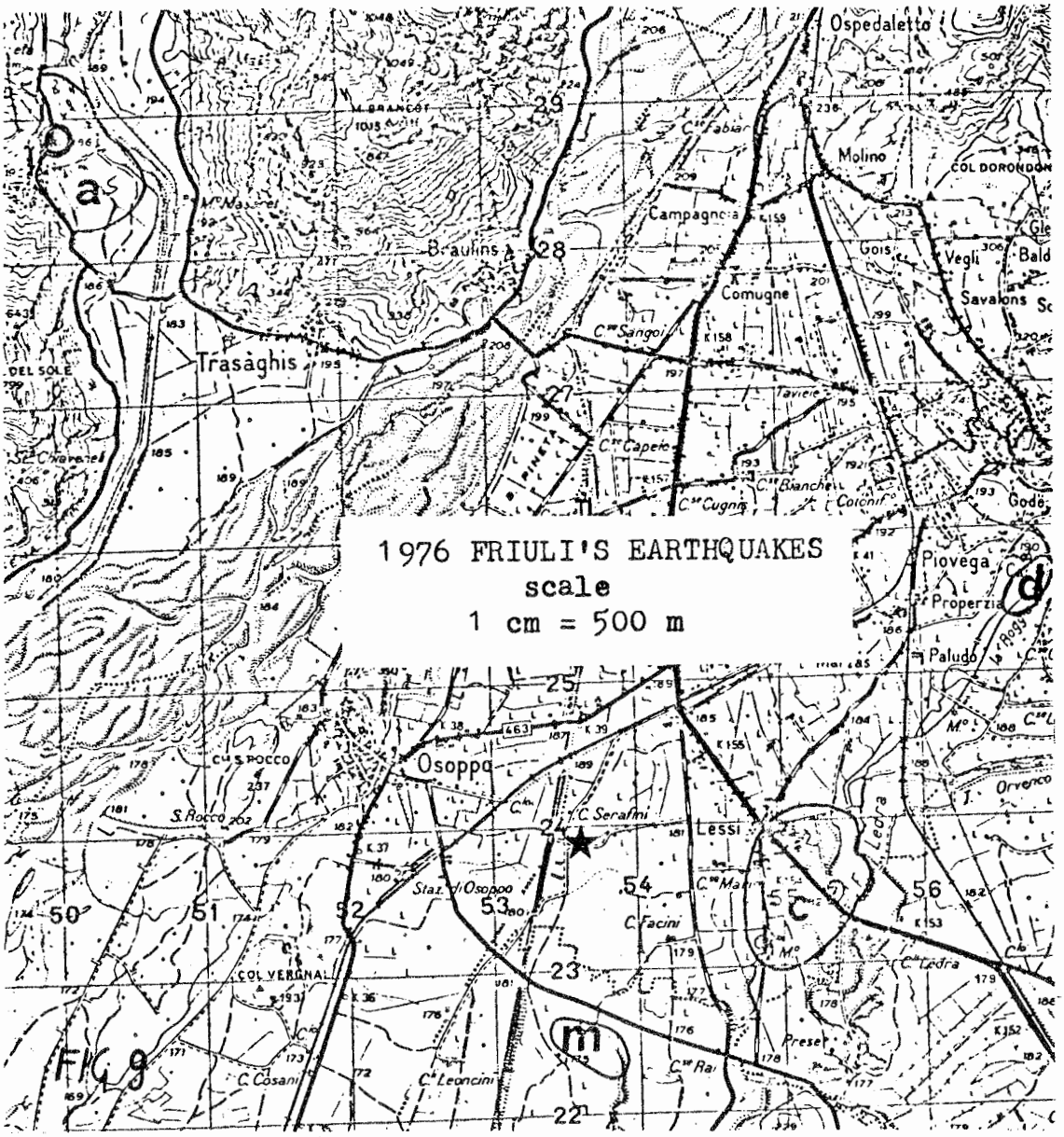
Many more data are needed in order to draw precisely line $\bar{S}c$, yet a satisfactory method of probabilistic study of liquefaction is now available.

Deterministic, together with statistic ways of analysing liquefaction potential of fine cohesionless materials enable us today to treat this phenomenon with good approximation.

Description of Phenomena of Liquefaction in Friuli.

A map of observed liquefactions in Friuli in shown in fig. 9 and 10 together with sites where damages and settlements due to liquefaction were observed and with some of the sites where S.P.T. tests, made before the May 6 earthquake, are available. Some of these sites show actual liquefactions in fine sands. In these areas (a; b; c; d; h; in fig. 9 and 10) there are craters of sands (see picture1,2,11) and sandy cracks (see picture 3). It has been locally reported that on May 6 and Sept. 15 sand and water spurted from soil as high as 15 meters.

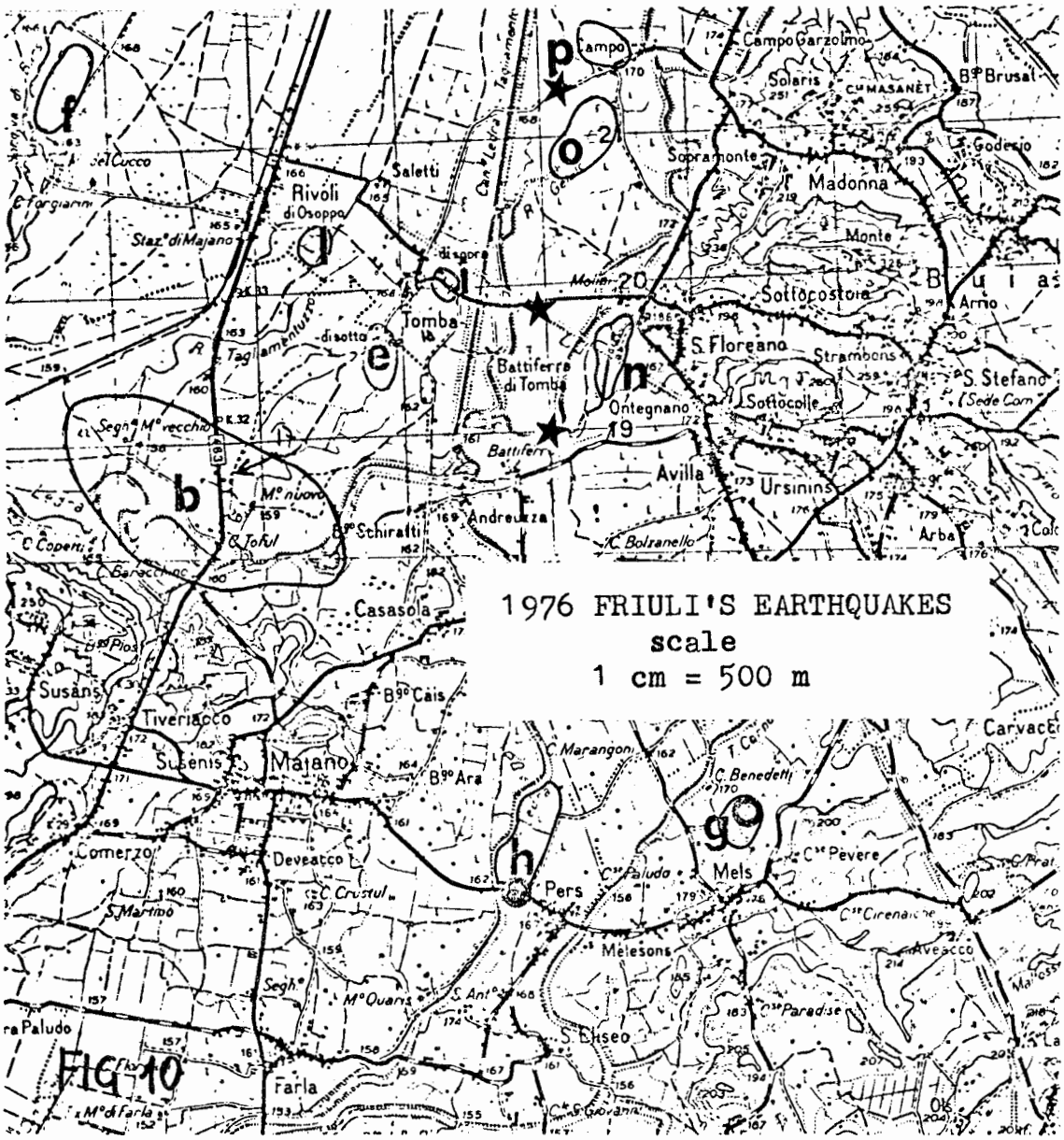
Very often water and sand sprung from the very same craters in May and September. Water table is everywhere at a depth of 1-3 meters. In zone "a" there is also a one hectar field, which is reported to have settled 0,5-1,0 m lower; in this area some houses (see fig. 9 and picture 4,5 and 6) had



b SITES WITH LIQUEFACTION SYMPTOMS

O SETTLEMENTS AND DAMAGES ON HOUSES DUE TO LIQUEFACTION

★ SITES WITHOUT LIQ; AVAILABLE DATA



SITES WITH LIQUEFACTION SYMPTOMS

SETTLEMENTS AND DAMAGES ON HOUSES DUE TO LIQUEFACTION

SITES WITHOUT LIQ.; AVAILABLE DATA

liquefaction of sands in Friuli

a settlement of about 30 cm on May 6. The settlement increased in September and now these houses are 20-30 cm inclined and total settlement has been doubled. Concrete slabs of first floors have been lifted and broken by water pressure (see picture 4 relating to May 6 and picture 5 relating to Sept. 15).

Water with sand spurted out from little craters located 10 meters away from houses. Observation of these effects are possible because these houses (made of good masonry with continuous footings) suffered great differential settlements with no structure collapse. Sediments of"a" area are alluvial sands deposited by an extinguished post-glacial river near a gentle alluvial cone. It is a plane, amelioration area. In "b" area sand boils and sandy cracks (see picture 7 and 8) are very frequent. In "d" area a typical one meter sandy crater (see picture 1) and a settled field with sandy cracks have been observed (see picture 9).

Zone "h" shows long alluvial sandy cracks and a settled house.

Zones "e", "f","i", "m", "n", "o", "p" show a few liquefactions of medium and coarse (seldom fine) sands (see picture 10).

It can be assumed that this second group of areas suffered not only limited actual liquefactions but also induced liquefactions due to raising of water table, and siphonings.

Zone "g" would be source of very interesting results, for future in situ testings and analysis which could be carried out, if field detected symptoms will be confirmed. In this area there is a gentle sloped hill made by glacial deposits. On May 6, several little craters and cracks opened all around the hill, on its slopes, and water with dark grey very fine sand spurted out from soil.

On the top of the hill there was a masonry, 30 years old, doubled storied house; it collapsed completely. The tenants did not feel any vibration: the house collapsed instantaneously.

Near the house there was a fourteen and a half meter deep well which during the first earthquake had been filled by sand coming from the bottom of the well: now it is four meters deep. Water table is about four meters deep under soil surface.

The above symptoms lead us to think that liquefaction of overconsolidated (from glacial deposit load) fine sands occurred.

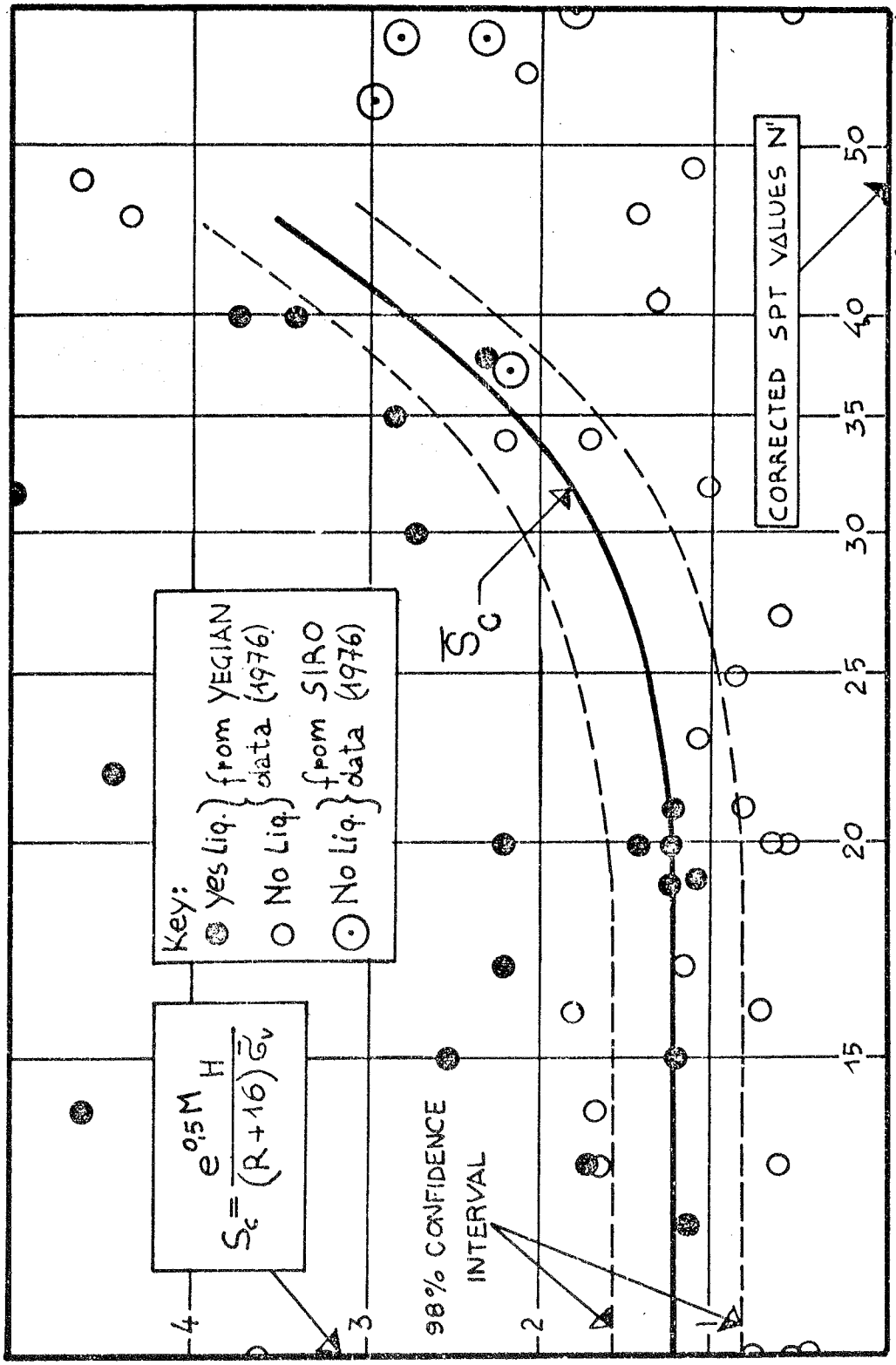
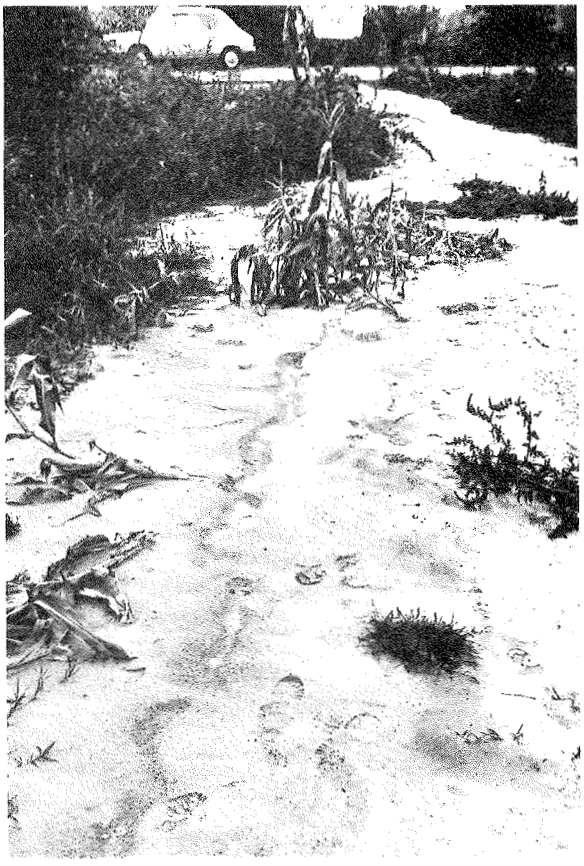


FIG. 11 STRENGTH PARAMETER S_c WITH CONFIDENCE INTERVAL

picture 1

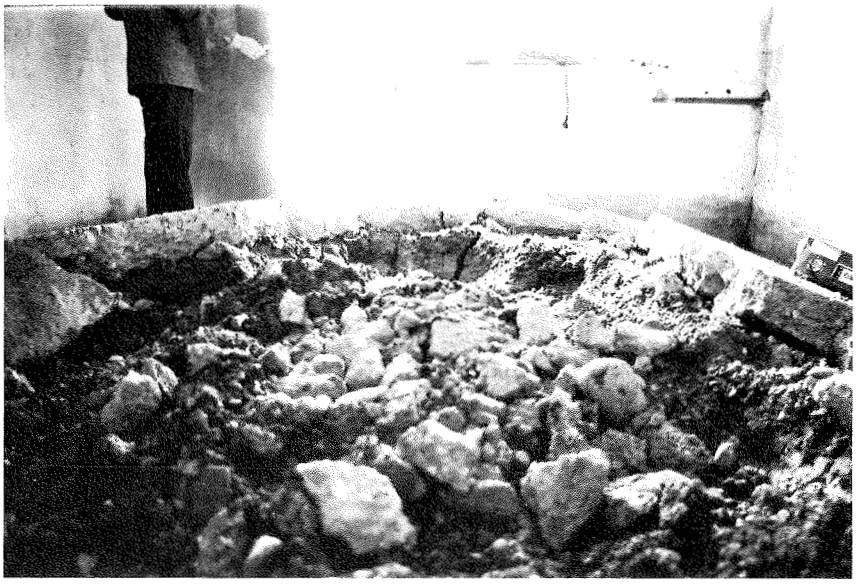
picture 2



picture 3

liquefaction of sands in Friuli

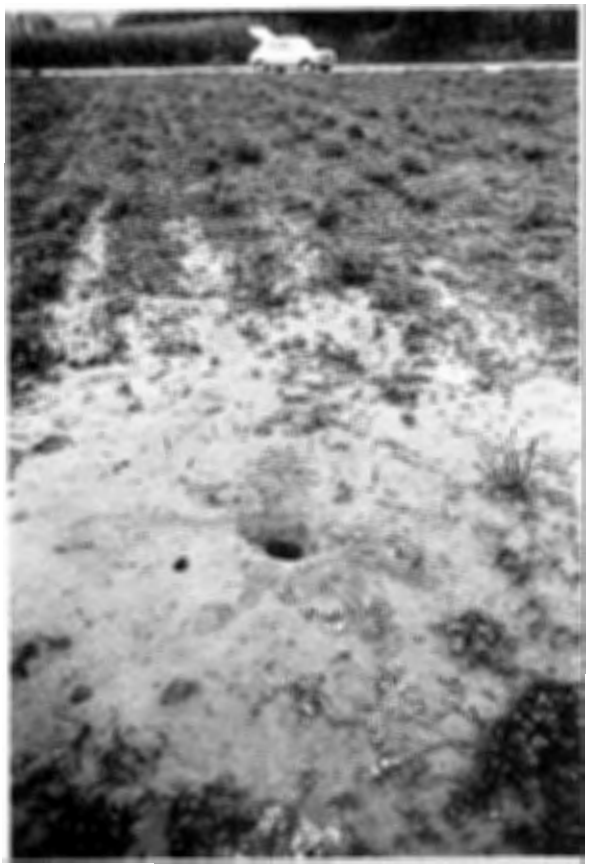
picture 4



picture 5

liquefaction of sands in Friuli

picture 6



picture 7

liquefaction of sands in Friuli

picture 8

picture 9

picture 10

picture 11

liquefaction of sands in Friuli

Data Derived from First Analysis of Sites with no Liquefaction.

S.P.T. data and stratigraphyes, made before May 6, in Friuli sites with sandy silts and sands have been used. Data were interpreted according to statistic analysis of M.K. Yegian and R.V. Whitmann (1976), and of J.T. Christian and W.F. Swiger (1975) (see fig. 7,8,11).

Satisfactory results were achieved: new "non liquefied points" fall with fairly good precision within the no liquefaction zones. New data are now available for statistic purposes. Yegian's criterion seems to be more suited for analysing liquefaction and no liquefaction characteristics; i.e. corrected values of N S.P.T. and parameter Sc seem to be more useful than A and Dr.

Furthermore N'appears to be particularly interesting because it takes into account overburden pressure.

Some tables by H.B. Seed and I.M. Idriss (1971) were of satisfactory use (see fig. 4 and 5).

It should be noted however that D_{10} values not being available, the use of fig. 4 and 5 is slightly indicative.

Conclusions

A state of the Art of recent knowledges on sand liquefactions has been given. First data, coming from the analysis of sites which didn't show liquefaction on May 6 and Sept. 15 earthquakes, confirm recent statistic results.

New data are now available for statistic purpouses.

A description of fourteen sites where sand liquefactions have been found in Friuli, has been given. Some of these phenomena (in fine sands) have been attributed to actual liquefaction and some others (single symptoms of liquefactions in medium and coarse sands) have been attributed both to induced liquefaction and to siphonings.

A future study is planned to be carried out. It comprehends SPT and Static Penetration tests which will be performed into some of the most interesting sites above mentioned.

Monotonic and cyclic Triaxial tests will be carried out, trying to perform a deterministic analysis of liq. features.

References

1. Finn, W.D. Liam; Pickering, Dennison J. and Bransby, Peter L. (1971), "Sand Liquefaction in Triaxial and Simple Shear Tests", Jour. of the Soil Mech. and Found. Div., ASCE, Vol. 97, No. SM4, April, pp. 639-659.

2. Tavenas, F.A. (1971), Discussion, "The Standard Penetration Test", by Victor F.B. de Mello. Proceedings, 4th Pan. Am. Conf. on Soil Mech. and Found. Eng. Vol. III, pp. 64-69.

3. Castro, G. (1975): "Liquefaction and Cyclic Mobility of Saturated Sands", American Society of Civil Engineers GT6, Vol. 101.

4. Seed, H.B. and I.M. Idriss (1971): "Simplified Procedure for Evaluating Soil Liquefaction Potential," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, SM9.

5. Yegian, M.K. (1976): "Risk Analysis for Earthquake-Induced Ground Failure by Liquefaction," Thesis submitted to the Massachusetts Institute of Technology in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

6. Casagrande, A. (1976): "Liquefaction and Cyclic Deformation of Sands, a Critical Review"; presented at Fifth Pan. Am. Conf. on Soil Mech. and Found. Eng., Buenos Aires, Argentina, November 1975.

7. Yegian M.K., Whitman R.V. (1976): "Soil Liquefaction Analysis Based on Field Observations". Conf. on "Risk and Decisions in Geotechnical Engineering", M.I.T., Cambridge, Massachusetts.

8. Christian J. T., Swiger W. F. 1975: "Statistics of Liquefaction and S.P.T. Results". A.S.C.E., Journal of the Geotechnical Division. Vol. N. GT 11.

v_p/v_s Ratio and Implications for Hypocenter Determinations of Aftershocks of the Friuli Earthquake, May 6th, 1976.

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Abstract

Aftershocks of the Friuli earthquake were recorded by up to four self-triggering three-component seismic stations, which have been installed in addition to the Italian and Austrian networks immediately after the main shock. A marked anomaly of the v_p/v_s ratio was found within and surrounding the epicentral area. Origin time and hypocenter determinations are given. The effect of different v_p/v_s ratios on hypocenter determinations is demonstrated.

Introduction

During the period of May 8th to June 14th, 1976 a small network of seismic stations was installed by the Institute

of Pure and Applied Geophysics and Geophysical Observatory, University of Munich, in order to extend the Italien and Austrian station networks. The aim was, to obtain precise focal parameters (origin time and hypocenter location) for studies of crustal structure.

At first two stations were set up near the Austrian-Italian border at Nassfeld and Arnoldstein and between May 29th and June 14th, 1976 a third station was set up north of Tarcento in Malemaseria (see figure 3). Each station consisted of a three component event-triggered automatic PCM unit (Gebrande, Miller, Schmedes[1]) with Geospace HS10-1 Seismometers with a natural period of 1 Hz.

Results

Typical three-component records of a Friulian aftershock obtained at stations Malemaseria, Nassfeld and Arnoldstein are shown in figure 1. One may note, that at Malemaseria only two onsets are observed, corresponding to Pg and Sg waves. At Nassfeld and Arnoldstein the seismograms become more complicated. S-wave arrivaltimes become more ambiguous and some intermediate phases between p- and s-arrivals may be observed. For this reason s-wave arrivals have been used only from the station Malemaseria to calculate origin times.

If the origin time is determined from the time difference of s- and p-wave arrivals at one station, the v_p/v_s ratio

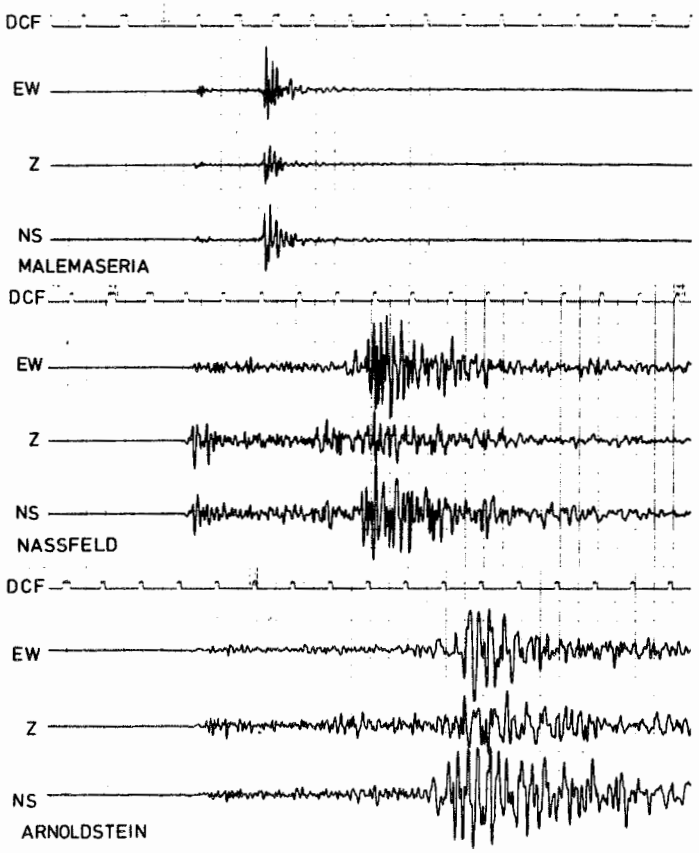

Fig. 1: Typical three-component seismograms of a Friulian aftershock at the stations Malemaseria, Nassfeld and Arnoldstein.

must be known. This ratio was obtained by arranging seismogram sections in the form of a Wadati plot. Figure 2 shows four typical examples of such plots, each of them for a different event but the same stations. One may see that a v_p/v_s ratio of 1.9 best fits the data.

The hypocenters were then determined graphically from the three p-wave travel times assuming a constant p-wave velocity of 6.0 km/sec. The result of the hypocenter determinations for some selected events of the period June 1st

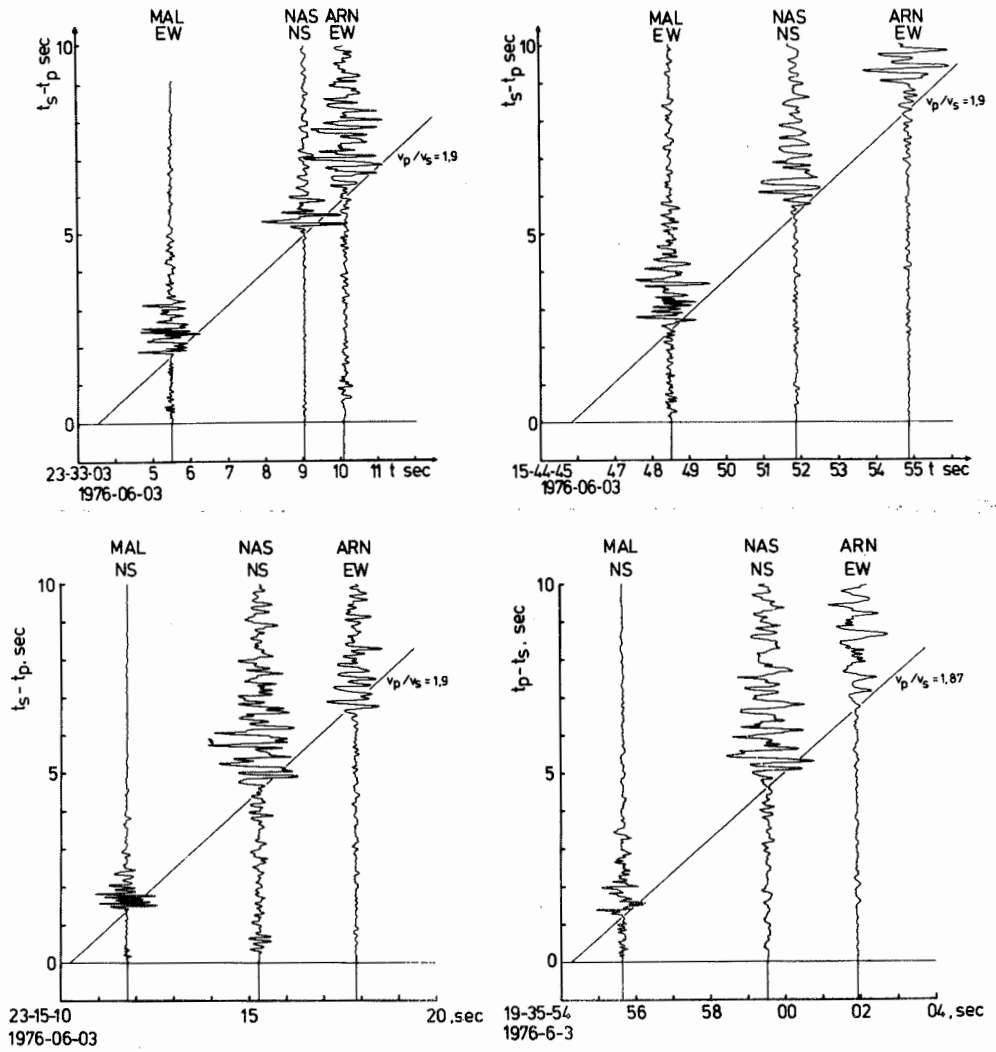

Fig. 2: Seismograms of four different events arranged similar to a Wadati diagram. A v_p/v_s ratio of 1.9 is deduced from these plots.

to June 13th is shown in figure 3. Closed circles indicate epicenter locations and numbers give focal depth in kilometers. Origin times, focal coordinates and depth are given in table 1.

As the value of 1.9 for the v_p/v_s ratio seems rather high another check was made to see whether this ratio was

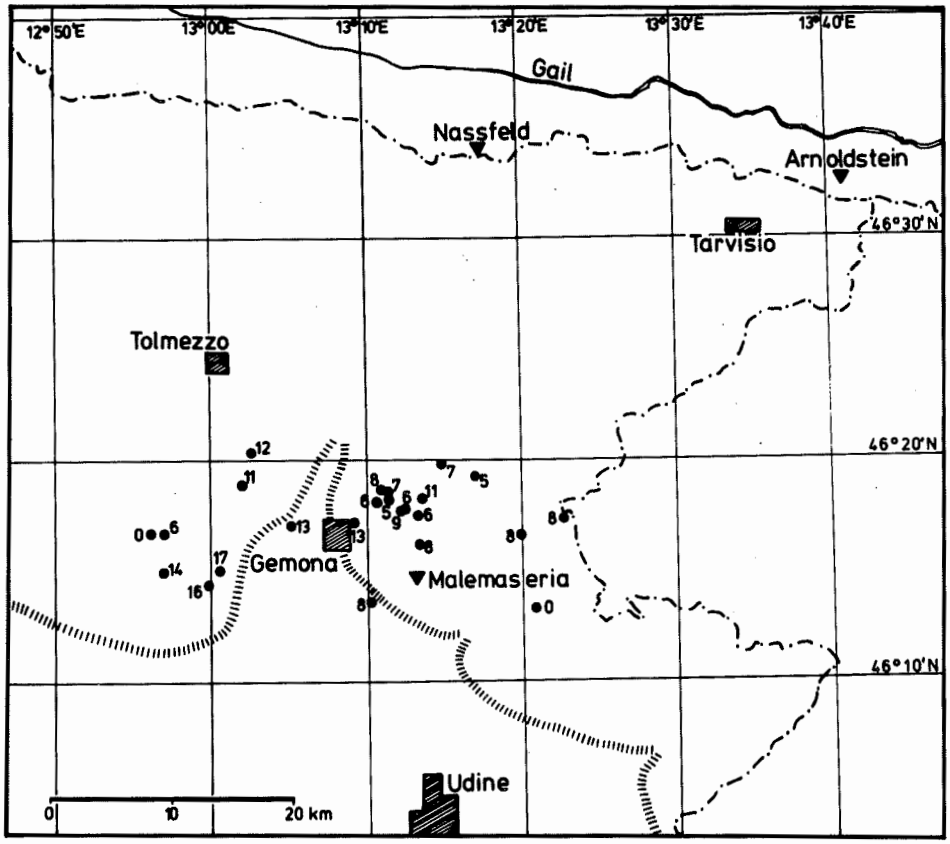

Fig. 3: Outline map showing location of stations and epicenters. Triangles: seismic stations, closed circles: epicenters. Numbers indicate focal depth.

determined correctly. Seismogram sections similar to a Wadati diagram this time were plotted for some of the localized events recorded at the same station. Such plots are shown in figures 4, 5 and 6 for the stations Nassfeld, Arnoldstein and Sylvenstein, respectively. One may note that for the stations Nassfeld and Arnoldstein the value of $v_p/v_s = 1.9$ fits the data very well (see figures 4 and 5), which indicates that the abnormal high value holds true

Table 1

Date	Origin time h m s	Latitude	Longitude	Depth km
01.06.76	17-21-08,5	46°15' N	13°01' E	17
	19-16-03,0	46°14' N	13°10' E	8
	21-29-34,2	46°17' N	13°09' E	13
02.06.76	09-26-59,3	46°15' N	12°57' E	14
	11-09-36,2	46°19' N	13°11' E	8
03.06.76	15-44-45,6	46°17' N	13°05' E	14
	19-35-54,3	46°18' N	13°12' E	6
	20-22-11,0	46°17' N	13°13' E	6
	22-33-03,5	46°17' N	13°20' E	8
	23-15-10,2	46°19' N	13°11' E	7
04.06.76	02-49-37,8	46°19' N	13°02' E	11
	11-56-56,6	46°14' N	13°00' E	16
07.06.76	03-15-08,4	46°18' N	13°11' E	5
	03-34-16,6	46°18' N	13°10' E	6
	03-44-32,0	46°13' N	13°21' E	0
	07-55-20,1	46°16' N	13°13' E	8
12.06.76	17-15-32,9	46°20' N	13°15' E	7
	18-05-32,8	46°17' N	13°23' E	8
	18-40-45,5	46°20' N	13°03' E	12
13.06.76	01-18-47,1	46°17' N	12°57' E	6
	01-20-57,8	46°18' N	13°14' E	11
	04-48-43,2	46°19' N	13°17' E	5
	08-47-15,9	46°17' N	12°56' E	0
	13-08-29,3	46°18' N	13°12' E	9

for at least the area within the station network as shown in figure 3 which is much larger than the aftershock region. For the more distant station Sylvenstein (Lat.: 47°35'30"N, Long.: 11°32'54"E, Elev.: 727m) however, which is situated

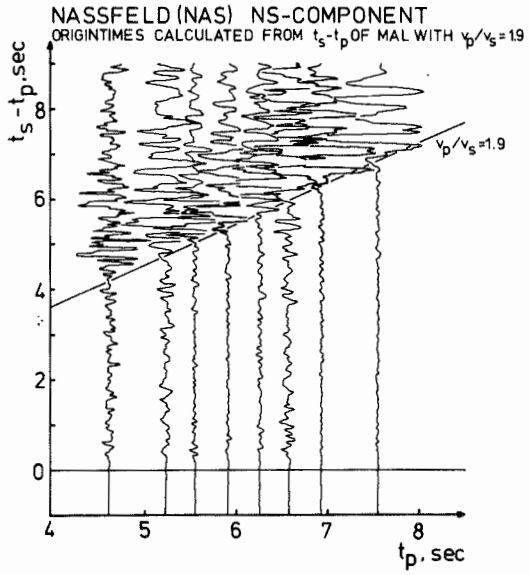

Fig. 4: Seismogram section similar to a Wadati diagram for different events recorded at Nassfeld. The line corresponding to $v_p/v_s = 1.9$ fits the s-wave arrivals.

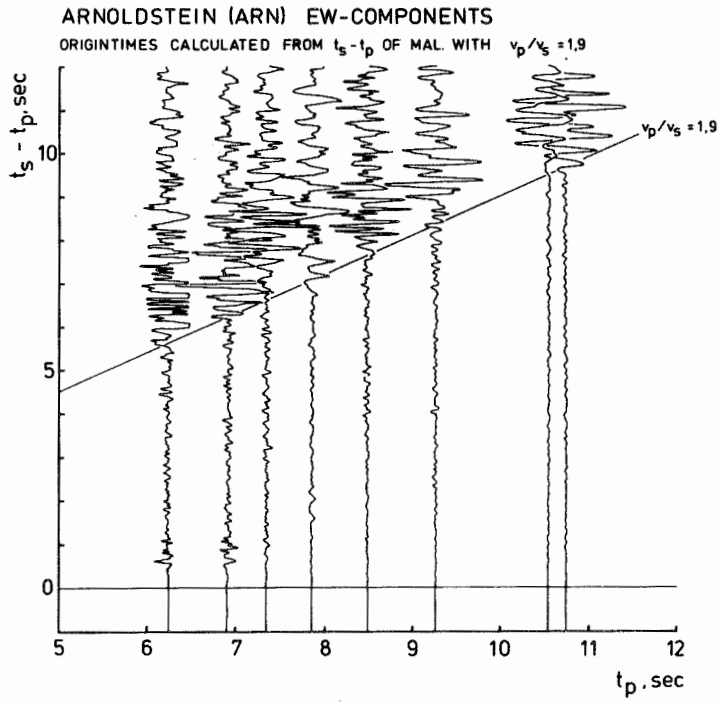

Fig. 5: Seismogram section similar to a Wadati diagram for different events recorded at Arnoldstein. The line corresponding to $v_p/v_s = 1.9$ fits the s-wave arrivals.

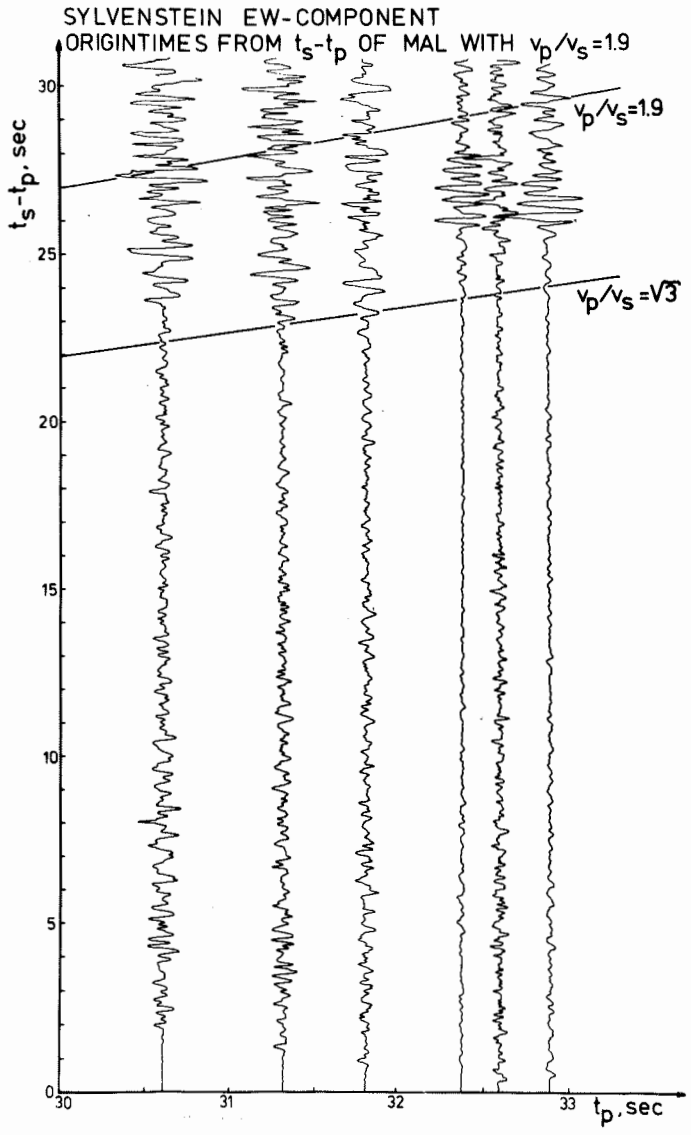

Fig. 6: Seismogram section similar to a wadati diagram for different events recorded at Sylvenstein. The line corresponding to $v_p/v_s = 1.9$ doesn't longer fit the s-wave arrivals. The line corresponding to $v_p/v_s = \sqrt{3}$ now better fits the data.

in the Northern Calcareous Alps, a v_p/v_s ratio of 1.9 does not longer fit the data. A ratio of $\sqrt{3}$ gives a better fit. This indicates that for larger distances the normal value of $v_p/v_s = \sqrt{3}$ becomes valid.

The effect of different v_p/v_s ratios on calculated epicenter locations and focal depths in the area under investigation is shown in figure 7. Open circles indicate epicenters

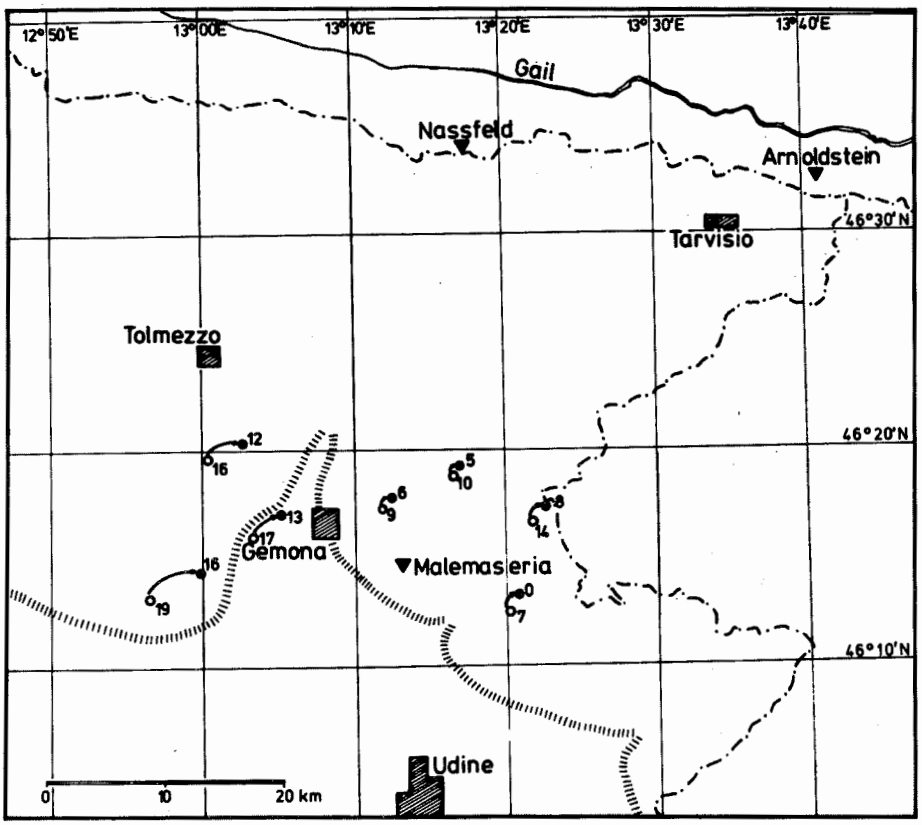

Fig. 7: Different v_p/v_s ratios effecting hypocentral calculations. Open circles: Epicenters obtained with $v_p/v_s=\sqrt{3}$, closed circles: Epicenters obtained with $v_p/v_s=1.9$. Numbers indicate focal deths.

localized with $v_p/v_s = \sqrt{3}$ and closed circles again give the true position obtained with $v_p/v_s = 1.9$. Numbers again indicate focal depths. It may be noted that for hypocenters outside of the station triangle positions of epicenters vary more than focal depth, whereas for hypocenters within the network it is the other way around, that is, focal depth varies more than epicenter position.

Conclusion

In a very inhomogeneous area as much information as possible should be extracted from the seismograms of nearby stations and shear wave arrivals should be used whenever possible. In that case the regional v_p/v_s ratio must be taken into account for precise origin time and hypocenter determinations.

For the region under investigation we found that a ratio of $v_p/v_s = 1.9$ best fits the data. The investigation of this ratio using more distant stations like for instance Sylvenstein gives results consistent with the standard value of $v_p/v_s = \sqrt{3}$ which is also confirmed by refraction seismic measurements (Zschau and Koschyk[2], Miller unpublished).

Considering the importance of the v_p/v_s ratio as a premonitory indicator of earthquakes the question arises, whether the abnormal high value found for Friul is a regional anomaly only or varies also with time. Further investigations will be necessary to study this phenomenon

in more detail not only through aftershock studies but especially by detailed refraction seismic measurements.

Acknowledgements

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Prof. Dr. G. Angenheister, Institute of Pure and Applied Geophysics has supported our study by raising funds as well as valuable discussions.

References

1. Gebrande, H., H. Miller and E. Schmedes, Digital registration of aftershocks of the Friuli earthquake 1976, Proc. 15th ESC General Assembly, Krakow 1976, in press.
2. Zschau, J. and K.G. Koschyk, Results from an evaluation of both longitudinal and transverse waves on a seismic profile along the northern margin of the Alps, in Explosion Seismology in Central Europe, Giese, P., C. Prodehl and A. Stein, Springer Verlag, Heidelberg, 1976.

CRUSTAL DEFORMATION AFTER FRIULI EARTHQUAKE, NORTHERN ITALY

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GENERAL REMARKS

The epicentre of the earthquake is situated nearly in the Alpine boundary fault in the region of Hauptdolomit or Dolomina Principiale. The disasters, however, are distributed not only in the dolomitic region, but also in the Flysch and Molasse of the fore land regions. Venzone in the dolomite, Gemona in the Flysch and Osoppo in the Molasse are 3 towns where damages are among the most serious in the earthquake region. Although these 3 towns are arranged in a lineament directed in N20°E, Heavy damages are distributed not only along the lineament, but also widely distributed in the Alpine border regions, especially in the quadrangular including Gemona, Tarcento, Majano and Tolmezzo, where in the quadrangular after-shock epicentres were concentrated.

The strongest earthquake shock, indicated as 10 of the Melcali grade, is found in a narrow zone, which include the 3 towns and transverses the general structural trend of the Alps. The area of the grade 7 is however extended to the east, almost parallel to the trend and covers

the area damaged.

As an effect of deformation, folded rocks are anisotropic both in texture and physical properties. Shock waves transfer most easily and most rapidly along the b- or folding axis. The area damaged covers thus wide areas extending E - W along the Alpine structural trends and N - S along the fault or fracture zone. Large cracks and rock falls are found also in wide areas including Moggio/Udine, Amaro, Flagogna, Trasaghis, Majano, Tarcento and Lusevera besides Gemona, Braulins and Osoppo. Therefore the crustal deformtions took place at least within these areas, covering over 500 km^2. According to the energy calculation, an earthquake of the magnitude 6.7 is followed by an area of crustal deformations of about 300 km^2 wide.

Faults, open cracks and shear fractures, which are produced by the earthquake are found in Osoppo, Braulins, Gemona and in a valley to the east of Carnia, Draggs along the fault planes of these area suggest following sense of movements.

1. N15°E - 20°E	left lateral movements
2. N70°W - 80°W	right lateral movements
3. N30°W	tension crack

Therefore, the earthquake is concluded to be produced by the stress system of the crust, provided with the maximum compressive axis directed in NW - SE.

1. FAULT ZONE TO THE EAST OF CARNIA

A wide fracture zone of a strike-slip fault is found along a valley to the east of Carnia, north of Venzone. Fracture zones are directed either in N15°E - 20°E or N70° -80°W. Nets of small branches of valley are parallel to wither of the 2 directions. A fresh and mior-like polished surface of a small fault in N15°E crops out along a small branch parallel to the fault. It displaces a film of a nother fault clay of N80°W direction about 15 cm in left lateral sense. The fault plane is inserted in a fault breccia composed of fragments and powder of marl. Because grains of breccia are partly very fine, the fault plane is polished like

miror surface when moved. Small and narrow grooves of slickensides are measured less than 10 miclons under the electro-scanning microscope. Because such small details are preserved on a fresh fault plane, the fault is suggested to be newly produced. If it is old, planes must be fused by ground water in the fault zone.

The fracture zone is composed of narrowly spaced and parallel shear plane, directed in N20°E (parallel to the main fault) and E-W.
The Triassic Megarodus-bearing limestone is deformed anisotropically due to the alpine folding. As shown in the table below, urtra sonic wave is passing along the folding axis more rapidly and more intensely than in the axis a. In the fractured rock along the fault zone, the shock wave passes more slowly and less intensely in the direction parpendicular to the fault plane than along the fault plane. The rate of reduction in the velocity and intensity is larger in the direction perpendicular to the fault plane (E-W) than parallel to the fault (N-S), because fractures are denser spaced along the fault than in the perpendicular direction.

	thickness in mm	delay in sec	velocity km/sec	intensity in volt	intensity in 5 cm
Original bedded muddy limestone					
parallel to b (E-W)	83.7	12.2	6.86	4.60	11.2
perpendicular to b (N-S)	80.4	12.3	6.54	4.15	10.0
fractured limestone					
perpendicular to fault	55.6	11.9	4.67	3.15	4.1
parallel to fault (N15°E)	63.2	23.3	4.75	2.90	5.8

Table: Urtrasonic measurement showing anisotropy of rocks

Heavy rock falls occured along the road E7 and on the rail road between Carnia and Resiutta in the northern extension of the fault. It is therefore evident, that the fault or the fracture zone moved at the

the time of earthquake. Serious disasters in Venzone must be related to the strike-slip fault.

2. FAULTS AND OPEN CRACKS

On the northern edge of the Osoppo hill to the north of San Pietro a large crack opened in N20°E, along which very large rocks were fallen by the earthquake shock. It reveals a left lateral movement along the fault plane. The church San Piedro lies on the tension crack directed in N30°W. The roof was probably fallen down in the inside when the crack opened.

this fault extends father to the north beyound the Tagliamento river to Braulins, where sheared zone with large crack are found on a field near small chapel to the west of the town. A heavy rock fall occured in the midnight of 9th of May, 3 days after the main shock, by an after-shock. They have been fallen along pairs of planes directed in NS and EW, which represent the conjugate set of shear fracture on the basement.

The highway A23, which has been under construction, was damaged in traverse point of the river Tagliamento, where the fault crosses. The bridge piers are destroyed in the junction, and sometimes they were dragged.

It is characteristic that the fault removed at the time of after-shock. It is suggested that the earthquake energy did not completely be discharged near the surface of the crust, although discharged completely in the underneath.

Cracks and faults or shearing fractures are distributed widely in the earthquake region, where damages are serious.

In the Flysch zone of Gemona a large tension crack was open in the direction of N30°W. It is found in the main parking place of Gemona and extends to the underneath of the old castel, which was destroyed and fallen by the opened crack. Its extension is traced to the opposite side of the place, where along the crack damaged houses are arragnged in a line of extension.

In Osoppo Rocco several parallel tension cracks of N30°W are

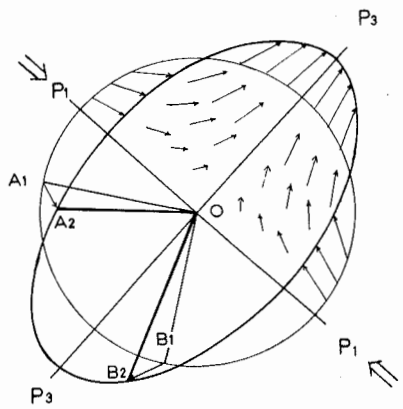
are found in the Molasse conglomerates. Heavy rock falls are found also in the Molasse conglomerate near Flagogna, where the conjugate sets of shearing fractures moved in two directions, N20°W and N70°W.

In the Flysch zone, rock falls occurred in Trasaghis and to the north of Tarcento, due to conjugate coupples of shearing planes. Rock falls are found also in the dolomitic region such as in Moggio/Udine.

3. TWO TYPES OF CRUSTAL DEFORMATION AFTER EARTHQUAKE

It is characteristic in this earthquake, that tension cracks and pairs of conjugate faults or shear fractures are distributed in wide region. They are distributed not only in the Alps or in the dolomitic region, but also in the Flysch and Molasse. It is suggested that the crustal deformation took place in wide region.

In case of the 1974 Earthquake of the Izu Penninsula in Japan (Tokuyama, 1975) nets of small conjugate faults directed in N70°W -80°W (right lateral) and in N10°E-20°E (left lateral fault) beside tension cruck of N40°W are distributed widely in the area damaged. In this case, the basement is probably devided into small blocks by conjugate sets of lateral faults, along which each block slips after the earthquake shock, like the clay experiment of H. Cloos (1936). Although displacement of a single fault is not large, sum of the total displacements balances the earthquake magnitude (M 6.7). In this case the circle O is stressed from the direction P_1, and compressed in this direction. It is elongated in the direction of P_3 and deformed into an elipsoid.(fig.1). The point A_1 moves to A_2, and B_1 to B_2, so that OA_1 is elongated and transferred to OA_2, and OB_1 is shortened to OB_2. It is confirmed after the precise geodetic measurement that the area deformed was restricted within an area 10 km times 10 km wide, where cracks and small faults moved. The areal crustal movements have been prolonged in at least 2 years after the main shock.



A. Tokuyama

If the strain energy is discharged gradually from block to block, the earth movements will be prolonged in a long duration. The strain in the underneath will be discharged at once by the main shock, but gradually in the upper crust, which is composed from many small anisotropic blocks. The energy will be discharged by small and multiple displacements among the blocks.

On the other hand, if the crust moves like "elastic rebound theory, the strain energy is discharged by 1 fault movements, and no strain remains after the movement along the fault (fig.2, beneath). The Neodani fault, which moved in the Nobi earthquake of 1891(M 8.4) may be an elastically rebound fault, displaying the total displacement of 5 km.

In the Friuli earthquake, the wide distribution of the crust and long dulation of the after shock are similar to those in the Izu earthquake.The crustal movements have been probably longer ranged after the main shock. Sometimes new cracks have been added by the after shock. If so, the earthquake energy should not have been discharged completely by the main shock. It is suggestive that another small amount of strain energy is still remain in the shallow surface of the crust. It is therefore recommended to carry out the precise geodetic measurement in the earthquake region in order to observe the after shock.

REFERENCES

Cloos, Hans; Einführung in die Geologie, Unveränderter Nachdruck Borntraeger, 1963.

Tokuyama, Akira, Crustal Deformation after the Earthquake off the Izu Peninsula,1974,Geosc. Rept,1-1, 1975.

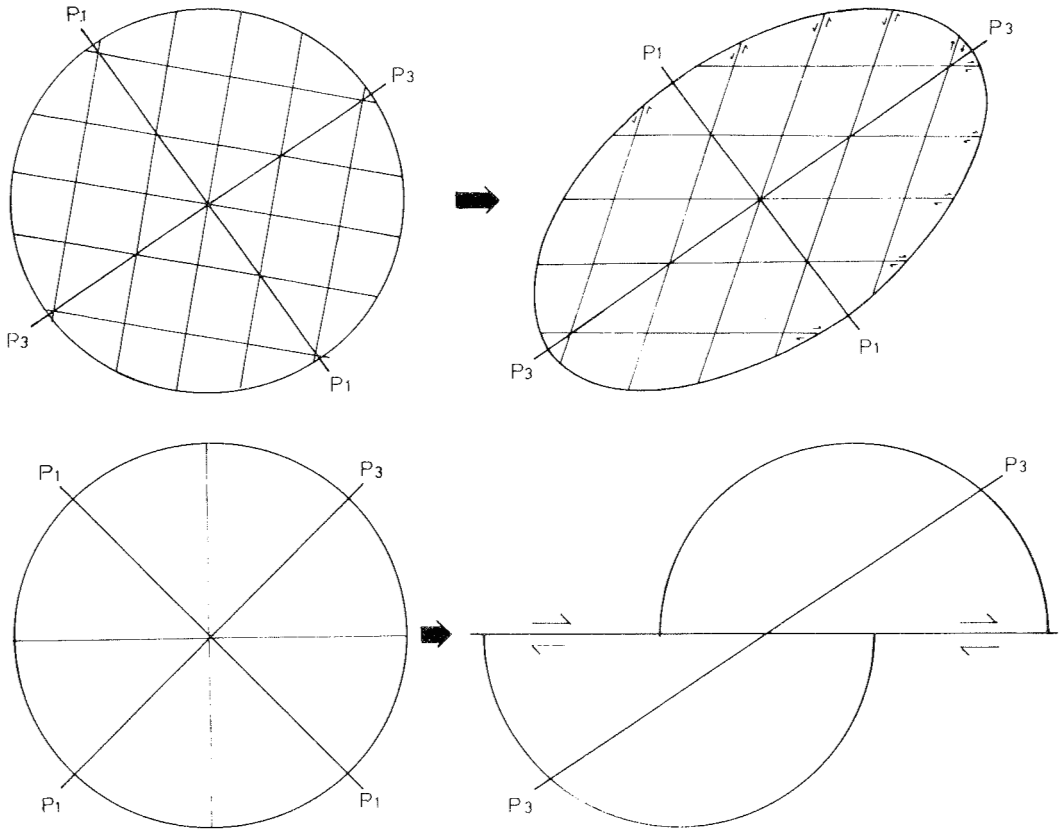


Fig 2: Two Types of Crustal Movements after the Earthquake.

Fig.3: Opencrack at Osoppo Rocco in N30W

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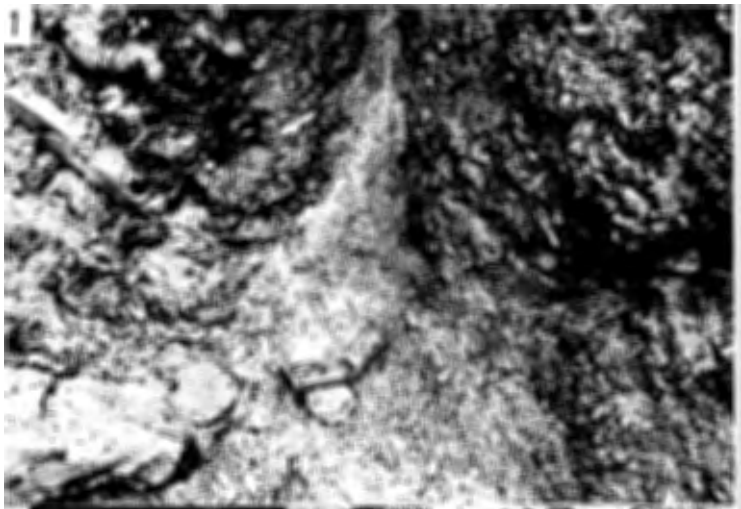

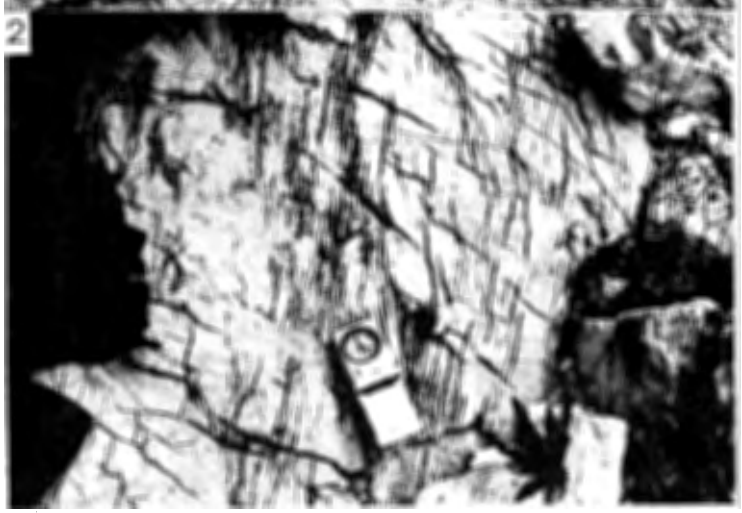

Fig.1: Left lateral displacement in fracture zone (Carnia Valley)

Fig.2: Fracture zone in Carnia Valley

Fig.3: Rock fall at Braulins

Fig.4: Damage along a tension crack at Gemona

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THE LEVEL OF THE MACROSEISMIC FIELD FOR THE TERRITORY OF FRIULI

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The most reliable determination of the earthquake intensity in epicenter, or in any locality out of epicenter could be obtained after the value of the level of macroseismic field.

The general form of the level of macroseismic field was given by N.V. Shebalin (1969):

$$I_o = b\,M - v \log h + c \qquad (1)$$

where:

M – magnitude,
h – focal depth,
v – coefficient of intensity decrease with the epicentral distance,
b – coefficient related to the magnitude,
C – constant.

According to macroseismic data, using the data of earthquake intensity, the value of coefficient of the intensity decrease with the epicentral distance was determined. This coefficient for the investigated terrain was:

$$v = 4.4$$

According to N.V. Shebalin (1969) the coefficient b (dependent on magnitude) varies at least, and in the most region of the Earth, taken as the average value, is:

$$\bar{b} = 1.5$$

If one knows the intensity in epicenter, as well as the focal depth (the value determined after to macroseismic and instrumental data), the constant C was determined, and for the investigated terrain it was:

$$C = 3.6$$

So, with the knowledge of these values, it was possible to realize the formula for the determination of the intensity in epicenter in any position out of epicenter.

The determination of the intensity in epicenter could be performed by the relationship as follows:

(2) $$I_o = 1.5\,M - 4.4 \log h_{I_o,M} + 3.6$$

and, the intensity out of epicenter by the relationships as follows:

(3) $$I_i = 1.5 - 4.4 \log D + 3.6$$

namely:

(4) $$I_k = 1.5\,M - 4.4 \log \sqrt{\Delta_k^2 + h^2} + 3.6$$

Moreover, the nomogram for the determination of the epicenter-intensity, as well as for the positions out of epicenter was obtained, when the values for magnitude, focal depth, epicentral distance, or the area touched by the corresponding isoseismal were known (Fig. 1).

In addition, if one knows the level of macroseismic filed, the formula for the determination of the magnitude value could be defined. So, for the investigated terrain the relation is as follows:

(5) $$M = 0.67\,I_i + 2.93 \log D - 2.4$$

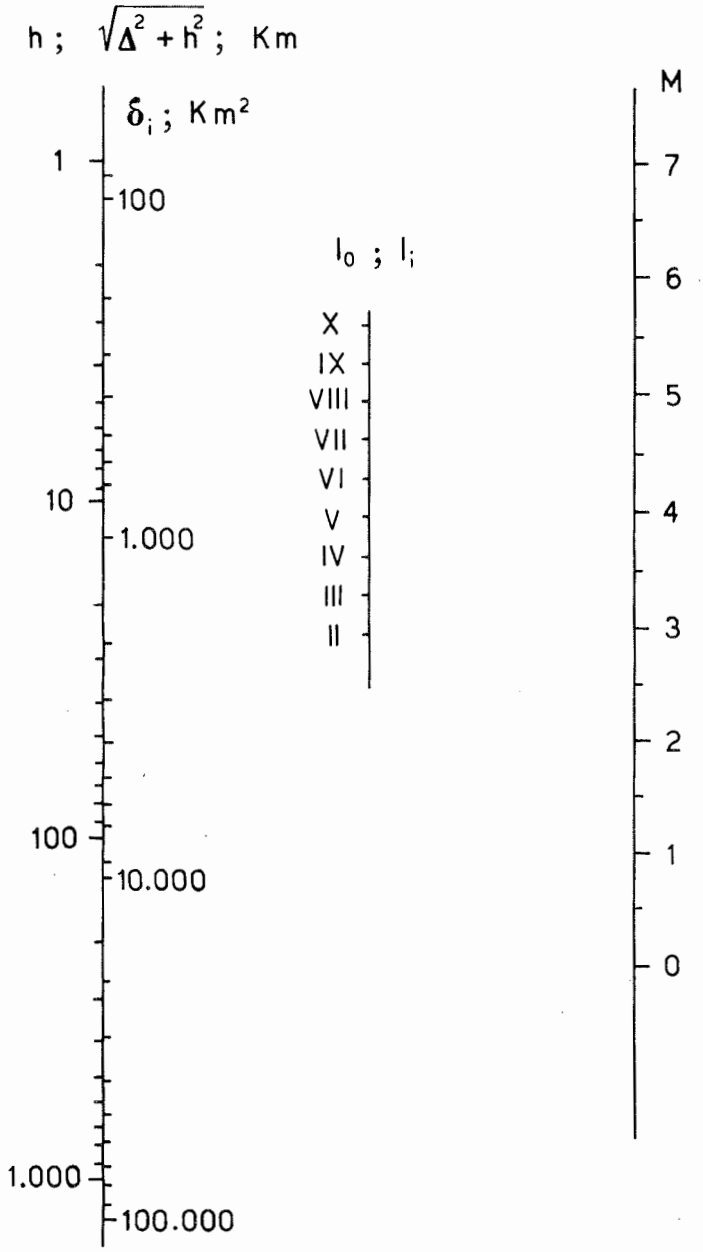

Fig. 1 Nomogram for the determination of the earthquake intensity of the territory of Friuli

Similarly, the formula for determination of the magnitude value, when the area touched by corresponding intensity is known, was given:

$$M = 0.67 I_i + 1.47 \log S_i - 3.48 \quad (6)$$

Summary

The investigation of the main parameters of the individual earthquakes, touching the territory of Friuli, especially the earthquakes occurring in 1967 year in this area, permits to determine the level of macroseismic field.

According to the level of macroseismic field, determination of the intensity in epicenter and any other position out of epicenter can be achieved. Moreover, the nomogram and the relationships are given, which serve for determination of the main parameters of the earthquakes in this area.

REFERENCES

[1] Gutenberg, B., Richter, C.F. (1956): Earthquake, magnitude, intensity, energy and acceleration. Bull. Seism. Soc. Amer., vol. 32, No. 3.

[2] Shebalin, N.V. (1961): Ball'nost', magnituda i glubina ocaga. V. Kn. "Zemletrjasenija v SSSR", gl. 5, Izd-vo AN SSSR, Moskva.

[3] Shebalin, N.V. (1969): Makrosejsmiceskoe pole i ocag sil'nogo zemletrjasenija. AN SSSR In-t Fiziki Zemli, Moskva.

THE SOIL ACCELERATION EXCITED BY THE EARTHQUAKE OF MAY 6, 1976

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In recent times in the laboratory of strong earthquake of the Institute of Physics of Earth (Academy of Sciences of Soviet Union) the investigation of the dependence of the acceleration of maximal amplitude a max and the corresponding rocky masses on the earthquake magnitude (M) and the epicentral distance (Δ) was performed.

For the determination of amplitude and period, about 100 accelerograms of the oscillation of hard rocky masses, produced during the earthquakes of the intensity of 5–9 degrees were elaborated; the magnitude was 4,5 – 7,6, but the epicentral distance of 5–400 km.

The determination obtained by this method, permitted to N.V. Shebalin (1975) to obtain the dependence of the amplitude of maximal acceleration a max and the period T on the epicentral distance Δ in the different intervals of magnitude. It was established that at the small epicentral distances $\Delta \leqslant \Delta$ at the changing of distances, the amplitudes of acceleration are practically constant. In the same case $\Delta_0 < \Delta < \Delta_1$ the amplitude of acceleration with the epicentral distance slowly decreases, but at $\Delta > \Delta$ the value of maximal accelerations (a max) decreases after the law as follows:

$$a\,max = a_o \cdot \Delta^{-b} \qquad (1)$$

In the zones of the small epicentral distances ($\Delta \leqslant \Delta_o$) with the increase of magnitude (M) (starting with $M \geqslant 6$), the amplitudes of acceleration practically does not increase.

Period of the acceleration of oscillation slowly increases with the increase of magnitude and epicentral distance. In the range of magnitude of 4,5 – 7,6 and the epicentral distance of 5–100 km and over, 90% of the value of periods in the interval of 0,1 – 0,1 sec was observed, but at the greater distances ($\Delta > 100$ km) the periods of maximal accelerations usually reach the value of 2–2,5 sec.

M.D. Trifunac and A.G. Brady (1975) discovered the dependence between the specter of soil oscillation (loosy sediments) and the intensity. This dependence was obtained after the records of the greater number of earthquakes by the accelerograph, and this dependence – for the range of 4 to 10° in the modified seismic scale – has the validity.

(2) $$\log a_V = 0.18 + 0.3\, J_{MM}$$

(3) $$\log a_H = 0.014 + 0.3\, J_{MM}$$

where: a_V – the acceleration, vertical, cm/sec^2; a_H – acceleration, horizontal, cm/sec^2.

The velocity of the oscillation was given in the dependence on the intensity as follows:

(4) $$\log V_v = -1.10 + 0.28\, J_{MM}$$

(5) $$\log V_H = -0.63 + 0.25\, J_{MM}$$

where: V_v – vertical velocity of oscillation, cm/sec.; V_H – horizontal velocity of oscillation, cm/sec.

And, the soil displacement in the dependence on the intensity is presented:

(6) $$\log d_V = -1.13 + 0.24\, J_{MM}$$

(7) $$\log d_H = -0.53 + 0.10\, J_{MM}$$

where: d_V – vertical displacement, cm.; d_H – horizontal displacement, cm.

Using these data and information, the map of soil acceleration for the terrain touched by the earthquake of May 6, 1976 was elaborated.

For this map elaboration, the data are used as follows:

- the parameters of shock of May 6, 1976;
- the distribution of the main dislocations;
- the values of the decrease of acceleration amplitude with the epicentral distance in the direction of the geological structures striking, and perpendicularly;
- the value of the maximal possible magnitude in the dependence on the seismic activity;
- the value of the duration of basic phase;
- the most probable range of the periods of maximal accelerations.

The values of acceleration are given in the range of 0,05 – 0,3 of the "gravity" parts. In fact, on the map the data of average values of accelerations are given $\bar{a}/g$ ($\sigma \approx 0.6\ \bar{a}/g$).

The duration of shock after the impulse ($a \geqslant a/max/2$) was determined.

The most probable period of maximal acceleration was in the range of 0,25 – 1,3 sec.

With the informations of seismic impedance for the bed-rock and the loosy sedimentary cover over the hard rocky mass, as well as the corresponding accelerations, the seismic microzoning of certain area, using the method by A.B. Maksimov (1973) could be performed.

Exactly with the informations of the velocities of seismic waves on the standard soil (Vs_1) and on the investigated soil (Vs_2), as well as the acceleration on the standard soil, the relative increment of the degree of seismic intensity, after the relationships could be defined as follows:

1. when the relationship is: $a_1^2\ Vs_1 / Vs_2 \leqslant 0.4$ the relative increment of the degree of seismic intensity by the formula could be calculated as follows:

$$\Delta n = 1.67 \log (Vs_1 \rho_1 / Vs_2 \rho_2) \tag{8}$$

2. when the relationship is: $0.4 < a_1^2\ Vs_1 / Vs_2^2 \leqslant 0.75$ the relative increment of the degree of seismic intensity, by the formula could be calculated as follows:

$$\Delta n = 1.67 \log (\rho_1\ Vs_1 / \rho_2\ Vs_2) + 1.67 \log (a_1^2\ Vs_1 / Vs_2^2) + 0.88 \tag{9}$$

3. and, when the relationship is: $a_1^2\ Vs_1 / Vs_2^2 > 0.75$ relative increment of the degree of seismic intensity by the relationship could be calculated as follows:

Summary

According to the dependence of the acceleration of maximal amplitudes and the corresponding periods of oscillation on earthquake magnitude and the epicentral distance, the elaboration of map of soil acceleration for the terrain touched by the earthquake of May 6, 1976, was performed.

Moreover, the most probable periods of maximal acceleration in dependence on the epicentral distance, as well as the shock duration a $\geqslant$ a max/2 was determined.

With the information of seismic impedance for the bedrock and the investigated rock, the seismic microzoning, after the determination of relative increment of the degree of seismic intensity could be performed.

$$\Delta n = 1.67 \log (\rho_1 Vs_1 / \rho_2) - 2 \tag{10}$$

or

$$\Delta n = 1.67 \log (\rho_1 Vs_1 / \rho_2 Vs_2) + 1.67 \log Vs_2 - 2 \tag{11}$$

REFERENCES

[1] Maksimov, E.A. (1975): O reakcii gruntov na intensivnye kolebanija. Fizika Zemli, No. 10. Izd-vo "Nauka", Moskva.

[2] Nazarov, A.T., Darbinjan, S.S. (1974): Osnovy kolicestvennogo opredelenija intensivnosti sil'nyh zemletrjasenij. In-t geofiziki i inzenernoj sejsmologii AN Arm. SSR. Izd-vo AN Arm SSR, Erevan.

[3] Trifunac, D.M., Brady, G.A. (1975): A study on the duration of strong earthquake ground motion. Bull. Seism. Soc. Amer., vol. 65, No. 3.

[4] Shebalin, N.V. (1971): Znacenija o preobladajuscem periode, spektre i ocage sil'nogo zemletrjasenija. V sb. "Sejsmiceskie issledovanija dlja stroitel'stva". Vopr. inz. sejsm.. Vyp. 15, Izd-vo "Nauka", Moskva.

[5] Shtejnberg, V.V., Karmynin, I.P. (1975): Parametry kolebanij zestkih gruntov pri sil'nyh zemletrjasenijah. Refcrativnyj sbornik. Sejsmostojkoe stroitel'stvo. Vyp. 3, Moskva.

SEISMIC SHAKEABILITY AND SEISMIC RISK FOR THE TERRITORY OF UDINE (ITALY) AND VICINITY

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Seismic shakeability is represented as a mean value of the earthquake frequency of the given intensity on the defined surface. In this case determination of seismic shakeability stipulate the determination of seismic activity and earthquake intensity.

The concrete calculation of seismic shakeability for the investigated territory, as preliminary – the following was arranged:

1. the theoretic isoseismal maps of the earthquake touching the investigated territory of the intensity Jn $\geqslant 6^{o}$ MCS
2. the main isoseismal map of the intensity: Jn $\geqslant 6^{o}$ MCS
3. the level of macroseismic field was established;
4. the average radius of the corresponding isoseismals was calculated;
5. the delineation of the zones of different intensity was performed;
6. the generalization of these zones was accomplished;
7. the delineation of zones according to intensity for various periods of observation was achieved;
8. the delineation of the zones of seismic sheakeability was performed.

In regard to the lacking of the basic data for the elaboration of the isoseismals of the individual shocks, according to data of the intensity decrease and epicentral distance, the

theoretic isoseismals for the shocks occurred on the investigated territory of the intensity of 6° and over were prepared.

The determination of the value of the epicentral distance of the individual isoseismals was elaborated by the relationship (after N.V. Shebalin-1959), as follows:

(1) $$\Delta i = bi \cdot hi$$

where:

(2) $$b_i = \sqrt{10^{2/s(I_o - I_i)} - 1}$$

Geometrical relationship between the focus (h), epicentral distance (Δ , km) and hypocentral distance (r, km), by the formula (S.V. Medvedev – 1959) was defined as follows:

(3) $$r^2m - h^2 = \Delta^2 , km$$

where:

rm – radius of isoseismal;

h – focal depth;

Δ – isoseismal distance.

And, the dependence of the focal depth (h) on the epicentral distance (Δ , km) for the m-th isoseismal from the epicenter, according to formula (S.V. Medvedev – 1959) was obtained:

(4) $$h = jm \cdot \Delta m$$

where:

(5) $$jm = \frac{1}{\sqrt{2^{\frac{2(m-0.5)}{n}} - 1}}$$

The coefficient value of the intensity decrease with the epicentral distance, according to the relationship was obtained as follows:

(6) $$\eta = \frac{I_o - I_i}{\log \frac{\sqrt{\Delta_2^2 + h^2}}{\sqrt{\Delta_1^2 + h^2}}}$$

where:

η – coefficient of intensity decrease with the epicentral distance;

I_o – intensity in epicenter;

I_i – the same, out of epicenter;

h – focal depth;

Δ_1 , Δ_2 – epicentral distance closer and farther of the measured locality.

The earthquake frequency according to the formula, for the territory of Friouli

(P ≈ 2000 km) was calculated as follows:

$$\log N_{\Sigma} = 8.38 - 0.56\,Kn \tag{7}$$

Seismic activity (standardized number of shocks on the surface unit for the time unit. T = 1 year; S ≈ 1000 km^2) after the relationship was defined as follows:

$$A_{13} = 0.09\bar{N}^{*}_{12} + 0.33\bar{N}^{*}_{13} + 1.2\bar{N}^{*}_{14}$$
$$A_{13} = 0.06 \tag{8}$$

The maximal possible earthquake intensity by the correlative dependence between K max and A was calculated by the formula by Ju. V. Riznitchenko – 1969:

$$\log A = 2.84 + 0.21\,(K\max - 15) \tag{9}$$

By this formula the maximal possible energy class of the investigated territory could be:

$$K\,\max \approx 15$$

If one knows these relationships the outline of the maps of seismic shakeability for the terrain of Udine could be obtained.

On the map (Fig. 1) seismic shakeability for the terrain of Udine and vicinity for the intensity of 9 degrees is represented.

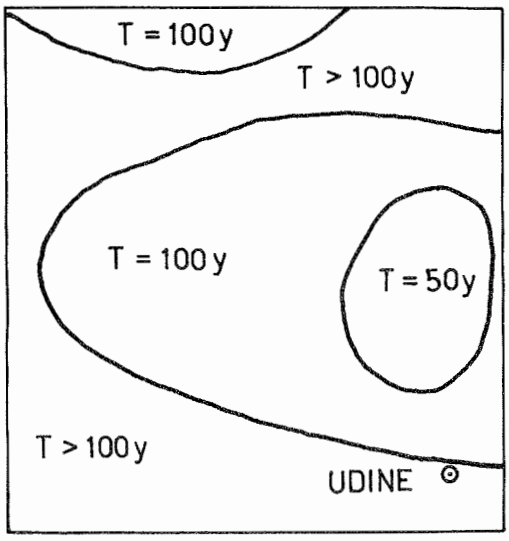

Fig. 1

Map of the seismic shakeability for the terrain of Udine and vicinity for the intensity of 9 degrees.

On the map (Fig. 2) the seismic shakeability for the intensity of 8 degrees is represented.

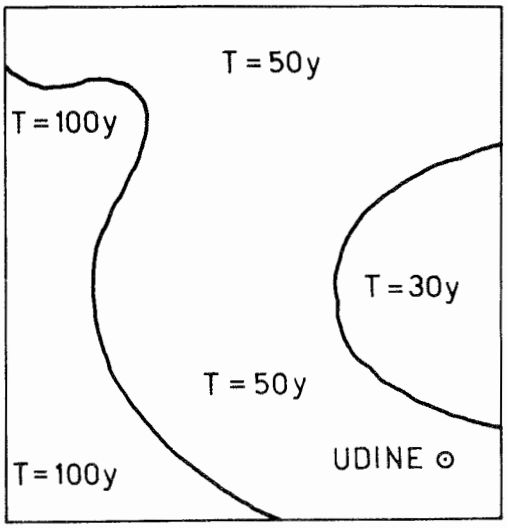

Fig. 2

Map of the seismic shakeability for the terrain of Udine and vicinity for the intensity of 8 degrees.

On the map (Fig. 3) seismic shakeability of the intensity of 7 degrees is represented.

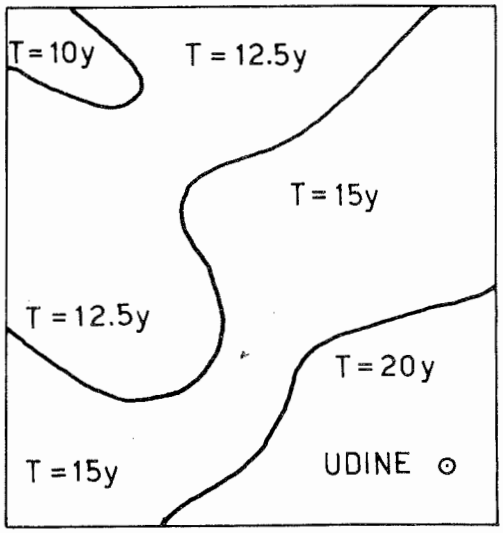

Fig. 3

Map of the seismic shakeability for the terrain of Udine and vicinity for the intensity of 7 degrees.

And, on the map (Fig. 4) seismic shakeability of the intensity of 6 degrees is represented.

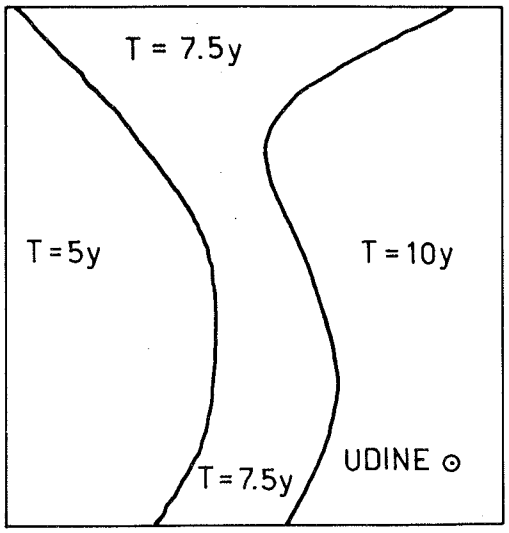

Fig. 4

Map of the seismic shakeability for the terrain of Udine and vicinity for the intensity of 6 degrees.

By the analysis of these maps it could be seen that Udine will be touched by an earthquake of the corresponding intensities in the periods of time as follows (as an average value):

- for the 9th degree:

  $T > 100$ year

- for the 8th degree:

  $T = 50$ year

- for the 7th degree:

  $T = 20$ year

- for the 6th degree:

  $T = 10$ year

The determination of seismic risk for the investigated territory, by the expression (after C. Lomnitz – 1973) as performed:

(10) $$R_i = [1 - (\exp - N_i/D)]$$

where:

N_i — number of shaking with the intensity of 6 degree and over;

$D = t \mid Tn \mid t$ — time period, the estimation of risk refers to this period;

T_n — time of the observation of the earthquake occurrence.

Different values of seismic risk for the investigated territory, on the map (Fig. 5) is represented:

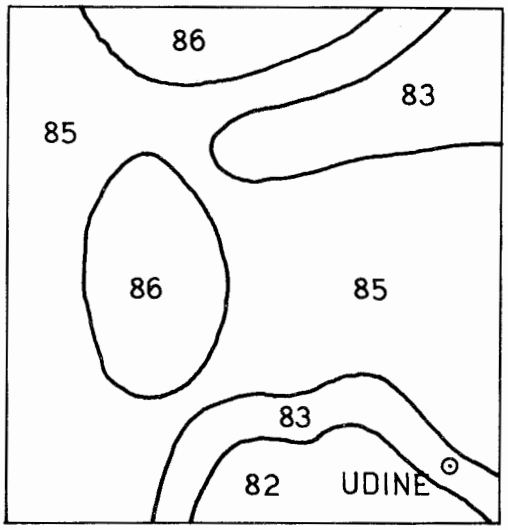

Fig. 5

Map of the seismic risk for the territory of Udine and vicinity

By the analysis of this map it could be seen that there are the zones of 82, 83, 85 and 86 % of seismic risk probability. It practically means, that the corresponding regions (delineated on this map) will probably be touched by the earthquakes of 6 degrees and over in the period of 10 years, with the probability denoted on the map above mentioned.

In addition, after seismic shakeability seismic danger could be estimated. In this case the seismic risk, after the formula could be defined, as follows:

$$R_i = \frac{t^*}{\frac{S_1 \cdot 10^{\gamma(I_i - I_o)}}{S_2 \cdot A_7}} \qquad (11)$$

where:

t^* – time; for this time determination of seismic risk is required;

S_1 , S_2 – surface; for this surface determination of seismic activity is required, as well as the required surface;

A_7 – seismic activity determination for the 7th degree ;

γ – angle of the straight of inclination on the graph of earthquake frequency;

I_i – intensity, the time interval is required for this intensity;

I_o – intensity; used for the determination of seismic activity.

Herefrom, the probability of intensity was obtained, that is, seismic risk for the terrain of Udine and vicinity. On the map (Fig. 6) the According to the analysis of this map it could be seen that the different zones of expected earthquakes of various intensitites, with the corresponding probability, by the isolines are defined.

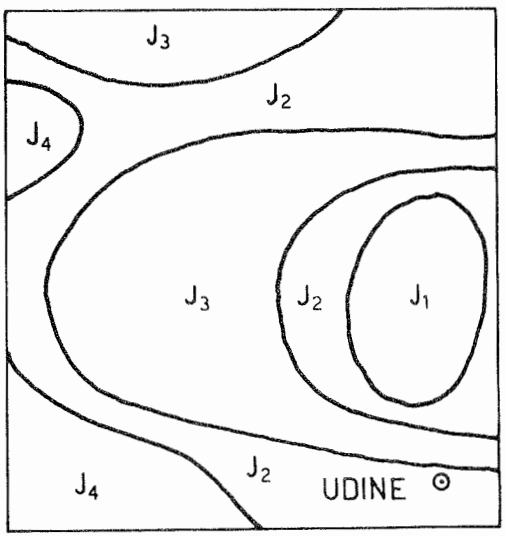

Fig. 6

Map of intensity probability for the terrain of Udine and vicinity, calculated for the time of expectation

Summary

To determine the value of seismic risk for the investigated territory, the earthquake frequency, seismic activity, maximal possible earthquake intensity and seismic shakeability was calculated primarily.

With the informations of these values, it was possible to determine the probability of seismic risk for the terrain of Udine and vicinity. The obtained values are represented on the enclosed maps.

The obtained values of seismic risk, point out to the obliged application of paraseismic construction in this region.

REFERENCES

[1] Dzibladze, A.E. and all. (1976): Utocnenie kart maksimal'nyh vozmoznyh zemletrjasenij i sotrjasaemosti Kavkaza. Fisika Zemli, No. 8, Moskva.

[2] Lomnitz, O. (1973): An earthquake risk map of Chile. Sovremennoe sostojanie teorii sejsmostojkosti i sejsmostojkie soomtrenija. Izd-vo "Strojizdat", Moskva.

[3] Medvedev, S.V. (1959): Sootnošenija mezdu glubinoj ocaga zemletrjasenija i izosejstami. Trudy In-ta Fiziki Zemli, No. 5(172). Vorposy inz. sejsm. Vyp. 2, Izd-vo AN SSSR, Moskva.

[4] Shebalin, N.V. (1959): Opredelenie glubiny ocaga zemletrjasenija sa izosejstami. Trudy In-ta Fiziki Zemli No. 5(172). Vopr. Inz. sejsm. Vyp. 2(172). Izd-vo AN SSSR, Moskva.

[5] Riznitchenko, Ju.V. (1969): Sejsmiceskaja sotrjasaemost' Krymskogo regiona. Izd-vo AN SSSR, I.F.Z. No. 8, Moskva.

THE DURATION OF OSCILLATION AS A FACTOR IN THE EARTHQUAKE INTENSITY DETERMINATION

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In the instrumental data of strong earthquake description, in the present time, the more and more attention is paid to the value representation of the duration of oscillation; so, in this paper an attempt was made to point out to some effects of the duration of oscillations in the determination of earthquake intensity.

It is well known that the duration of oscillation depends on the earthquake intensity, that is, the greater is the duration of oscillation, the greater is the earthquake intensity. And, vice versa, the smaller earthquake intensity is related to the smaller duration of oscillation.

Generally, after F.F. Aptikaev (1975) in oscillation an absolute and relative duration should be distinguished.

An absolute duration of oscillation includes the time interval from the first arrival of seismic waves till to their disappearance. Here, there are two cases.

The first, if the sensitivity of the device is great enough, than the moment of the record disappearance could be taken as a time moment, when the level of record becomes equal to the phone level of microseisms. In such case, the estimation of duration does not depend on the device amplification, but on the level of microseisms in the given locality and given time.

The second one, when the duration of record is also taken into account in engineering seismology. But, the moment of the diminution of the record level till to some boundary

value is taken for the end of the record.

A relative duration, after F.F. Aptikaev (1975) includes the time interval in which the amplitude of oscillation fulfills with a condition:

$$[A(t)] > K(A\ max) \tag{1}$$

where: K – some constant ($0 < K < 1$).

The relative duration of oscillation does not depend neither on the device amplification, nor on the level of microseisms, but only on the form of the seismic oscillation.

Instead the term "relative oscillation", the term "time impulse", or "impulse width" could be used.

In many papers it was noticed that in the estimation of seismic intensity, the relative intensity of oscillation should be used.

In relative seismic oscillations it is necessary to use the groups of waves, separated by the time interval (Δ t), where the amplitude of oscillation is smaller for one half of the maximal amplitude ($A < A\ max/2$).

The impulse in the case $\Delta t \leqslant 2T$ by the maximal amplitude A_1 and width $\tau = \Delta t_1 + \Delta t_1 + \Delta t_2$ is characterised.

If $\Delta t > 2T$ we have the case with two impulses. If one measures the parameter of second impulse, in general case, there will be the other values for $A, \Delta t_1, \Delta t, \Delta t_2$.

Partly, the second impulse could include the time interval, related to the first one.

It must be emphasized that the impulse of the smaller amplitude, but the greater width, could expose the greater danger than the impulse of a greater amplitude but of smaller width.

It is well known that the amplification of magnitude of 2/3, or the amplification of energy of 10 times, corresponds to the amplification of intensity of 1 degree of the MCS (or MSK-64) scale. So, for example, according to formula by N.V. Shebalin (1956) the relation of intensity in epicenter (I_o), magnitude (M) and focal depth (h) could be obtained:

$$I_o = 1.5M - 3.5 \log h + 30 \tag{2}$$

If we take that:

$$\log E_{(joul)} = 1.5M + 5 \tag{3}$$

than

$$I_o = \log E_{(joul)} - 3.5 \log h - 2.0 \tag{4}$$

So, after N.V. Shebalin (1971), if we take two earthquakes with the foci on the same depth (about 10 km), and the intensity, for example, 5–6 degrees, then we obtain the seismic energy of 3.10^{10} and 3.10^{11} joule, and the energy relation 1:10 and the amplitude.

In fact, this relation of amplitude is taken in observation in the remote zones of epicenter, at the distances of 10 and 100 km of the epicenter, that is, at the distances where an earthquake was recorded by seismic devices.

To have the equal relation of energy density (it also means the amplitude of oscillation) for two earthquakes in any locality, the energy should also be the same. But, the building and soil oscillation indicate the other thing. In the "engineering" range of period near to epicenter, when the intensity changes for 1 degree, the amplitude becomes greater not for 3 times, but for 2 times. When the interval is 4°, instead the expected relation of $1:3^4 = 1:81$, the observed relation is $1:2^4 = 1:16$. As it could be seen, the error is 5 times greater than for 2°.

On the contrary, when the distances from the epicenter are greater, "engineer's" oscillation is taken as a "seismological".

After F.F. Aptikaev (1975) the impulse width for the epicentral distances of 3–50 km, according to the relationships could be calculated as follows:

$$\log \tilde{\imath} = 0.3 \log \Delta \tag{5}$$

And, in the range of 50–300 km, the impulse width increases proportionally to the distance:

$$\log \tilde{\imath} = 1.2 + \log \Delta \tag{6}$$

So, for $\tilde{\imath} > 0.6$ sec the approximation could be performed by the empirical formula:

$$I = 2.5(\log a + 0.03\,\tilde{\imath}) + 6.5 \tag{7}$$

where: I – intensity in degrees; a – acceleration; $\tilde{\imath}$ – impulse width in sec.

Fig. 1 represents the earthquake seismogram of May 6, 1976, with the epicenter in Friouli, recorded by the Seismological Institute of SR of Serbia in Belgrade.

As it could be seen on the seismogram, the separation of many impulses was executed, which corresponds to some number of shocks and to the whole process of this event.

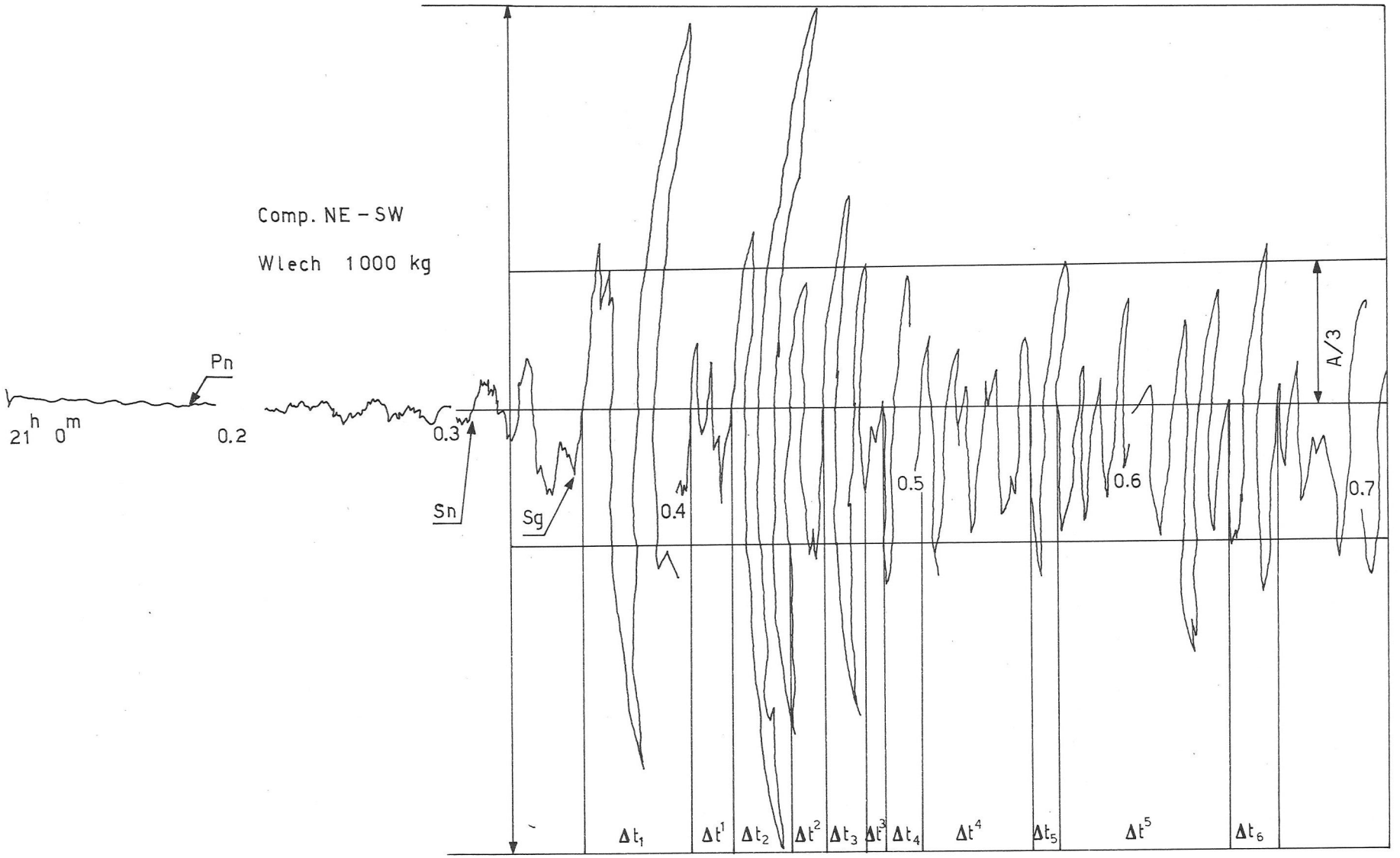
Comp. NE – SW
Wlech 1000 kg
Pn
21h 0m
0.2
0.3
Sn
Sg
0.4
0.5
0.6
0.7
A/3
Δt1
Δt'
Δt2
Δt''
Δt3
Δt'''
Δt4
Δt''''
Δt5
Δt'''''
Δt6

Fig. 1

Summary

The results of this report are only an attempt for the determination of shock intensity, according to the duration of oscillation.

With regard to that according to seismogram of May 6, 1976, the separation of many impulses was performed, and it could be taken that the event above mentioned had many shocks, that is, the intensity on surface was the result of a sum of many shocks.

Surely, this is only an attempt to solve this problem. How this method is appropriate to improve the determination of earthquake intensity estimation, and what is the effect of the impulse width on it, now is a question for discussion and further investigations.

REFERENCES

[1] Aptikaev, F.F. and all. (1967): Rezul'taty naucnyh nabljudenij pri vzrvvah v Medo. Vestnik AN Kaz. SSR , No. 5.

[2] Aptikaev, F.F. and all. (1975): Ucet dlitel'nyh kolebanij pri instrumental'noj ocenke sejsmiceskoj intensivnosti. Sejsmiceskaja skala i metody izmerenija sejsmiceskoj intensivnosti. Izd-vo "Nauka", Moskva.

[3] Shebalin, N.V. (1971): Paradoksy sil'nyh zemletrjasenij. Semlja i Vselonnaja, No. 1, Izd-vo "Nauka", Moskva.

THE ESTIMATION OF THE DEGREE OF BUILDING'S DAMAGE ACCORDING TO NEW SEISMIC MSK–64 SCALE

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It is well known that the general criteria of the estimation of the earthquake intensity is the degree of building's and other construction's damage. Except these manifestations, occurring during an earthquake, in the estimation of the earthquake intensity the soil deformations, changing the regime of the ground waters, etc. must be taken into consideration.

The new International seismic scale of the UNESCO, for the determination of the earthquake intensity, which can be shortened as MSK-64 (S.V. Medvedev-Moskow; W. Sponheur-Jena; V. Kárnik-Praha) is in usage from the 1964 year. The difference between the other seismic scales, which are in usage nowadays, is that this new scale in the estimation of the seismic intensity takes into account more details of the earthquake effects, very specific effects. Consequently, this seismic scale gives more correct appraisal of the degree of seismic intensity in comparison to other seismic scales, as well as to the seismic MCS scale (Mercalli–Cancani– Sieberg– 1917).

The application of this scale for the estimation of intensity is designed on the following:

- type of construction;
- characteristics of quantity;

– classification of damage;
– arrangement of scale.

1. **Type of Construction** (the buildings are constructed without any necessary antiseismic conditions)

Type – A: the buildings made of unworked stone, village buildings, buildings of adobe and of mud.

Type – B: the simple buildings built of brick, buildings of great blocks and buildings of manufactured materials, buildings of natural worked stone, as well as the framehouses.

Type – C: armoured-concrete buildings, framehouses, well constructed. And,

Type – A': houses constructed of mud. This type of buildings was established by N.V. Shebalin – 1970.

II. Characteristics of Quantity

– single : about 5%
– planty : " 50%
– majority : " 75%

III. Classification of damage

1 degree: light damages: small fractures in mortar; crumbling of mortar grains from the walls and roof-beams.

2 degree: moderate damages; smaller fractures in the walls, falling of rather great blocks of mortar, falling of tiles from the roof, fractures in chimneys, falling of parts of chimneys.

3 degree: hard damages: greater and deeper fractures in the walls, crumbling of chimneys.

4 degree: destruction: wide openings in the walls, the buildings partly fall down, crumbling of the particular parts inside the buildings, falling down of the inner walls and the walls filled by steel.

5 degree: total damages: complete crumbling of constructions.

IV. Arrangement of scale

a) people and surroundings;

b) constructions of all kinds;

c) natural phenomena.

As it could be seen, in the seismic MSK–64 scale 5 degrees of building's damage are established, and N.V. Shebalin (1970) introduced the 6th type of damages d = 0 (d = damage); this type designates the absence of visible damages

In general, it can be seen that the distribution of the number of buildings, according to the degree of damge, in all cases is very near to the normal Gauss' distribution.

The distribution of relative number of buildings according to the degree of damage, after the seismic MSK–64 scale, is represented on the Fig. 1.

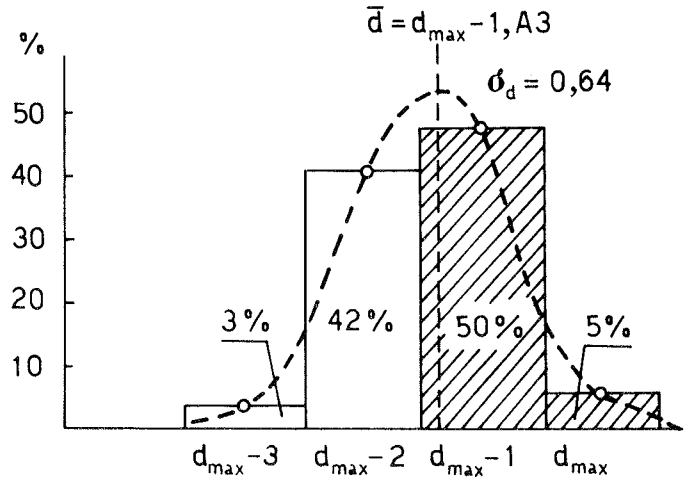

Fig.1

(after N.V. Shebalin)

The distribution of the relative number of buildings, according to the degree of damage, after the seismic MSK–64 scale, on on the basis of the presumption of the Gauss' distribution

Herefrom, N.V. Shebalin (1970) demonstrated the types of distribution, given in the seismic MSK–64 scale, and represented them in the form as follows:

d	;	$d\,max^{-3}$	;	$d\,max^{-2}$	;	$d\,max^{-1}$	;	d max
p	;	(3%)	;	(42%)	;	(50%)	;	(5%)

This distribution corresponds to the given damage, equal $\bar{d} = d\,max - 1.43$ and to the standard deviation of particular appraisal σd, equal to $\sigma d = 0.64$ and accordant to the estimation σd in real cases (Fig. 1).

According to the defined parameters of the type of damage, given in the seismic MSK–64 scale, the transition from the given damage to the intensity could be performed. The seismic MSK–64 scale gives the total system of relationships between d and I, and this scale permits an easy transition to the relation between $\bar{d}$ and I (Fig. 2).

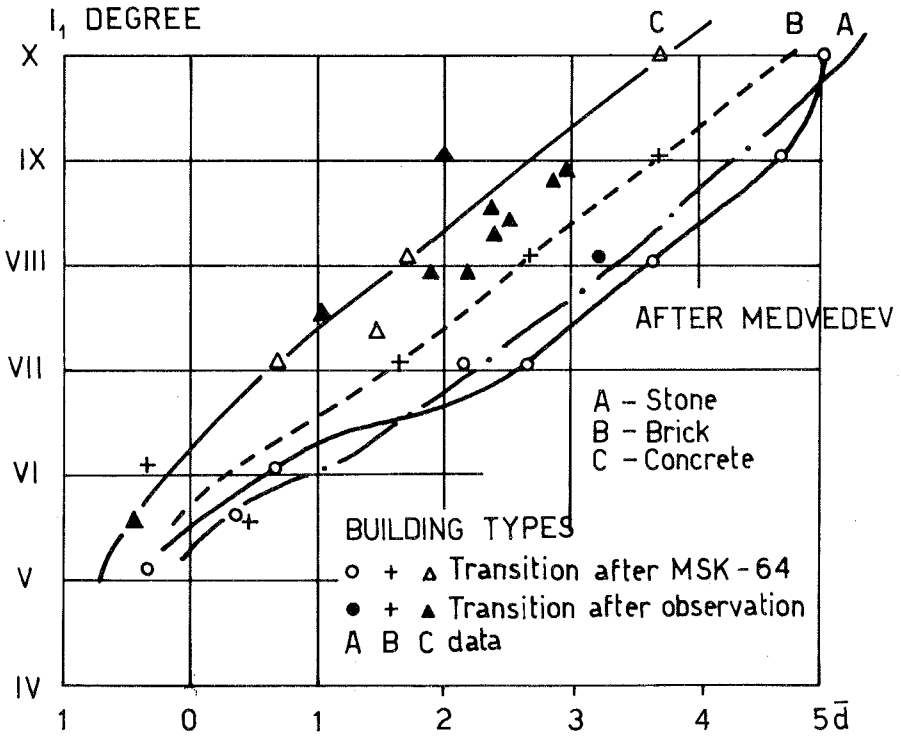

Fig.2 (after N.V. Shebalin)

The transition from the degree of damage ( ) to earthquake intensity according to MSK–64.

According to N.V. Shebalin (1970) it is known that the variation of the dispersion of the particular estimations of the degree of the damage (values) is small from one case to the other. So, the dispersion of the given damage almost exclusively depends on the number of observation. Almost in all ranges the increase $\bar{d}$ is equal to the increase I and this is a basis for the determination of the number of buildings, necessary to examine in order to get the estimation $\bar{d}$ and I with a given accuracy (Table 1).

TABLE 1 (after N.V.Shebalin)

I	σd	N at σd (= σd)		
		± *1/2*	± 1,4	± 0.1
VI–X	3/4	3	10	60
III–VI	1/2–3/4	2	6	40

In the smaller settlements these examinations could comprise the total number of buildings.

In the other cases it is necessary to define the method of the examination of constructions.

In such case the selection of buildings must exclude the possibility of systematic error (for example: the official documents of examination rest without any attention for the undamaged structures). The best method is to perform the building's selection according to geometrical network, or according to some other principals; but, it is necessary to choose some appropriate method before the beginning of terrain investigation.

The relations above mentioned, between $\bar{d}$ and I represent the averageing of the results. In the accordance with these relations $\bar{d}$ for buildings of the A, B and C type always differ for 1. In the meantime, the cases of the declination are known, related to the significant periods of variation. Exactly, the greater amount of documents is necessary for the detailed transition from $\bar{d}$ to I; now is present only the quantitative character of the relationships between $\bar{d}$ and I at various periods of action.

Consequently, the application of the seismic MSK–64 scale for the estimation of the degree of seismic intensity in every case permit to have the distribution of N from d, nearly to the normal (Causs') distribution.

For that, the very important is the fact that the variation of the standard deviation of

the particular estimation (σ d) from one case to the other is very small, in the boundaries of 0,6 to 0,8. The cases with the greater dispersion were observed only when the choise is restricted, or when the distribution of buildings is over the different soil conditions, or when there exists a very significant difference in building's construction within the same type of buildings (A, B and C).

This is a reason to introduce the values, characterizing the total choice of the building for examination, and they are: average value, degree of damage ($\bar{d}$) and the error (standard deviation) of particular estimation (σ d) as well as the average error (σ $\bar{d}$):

(1) $$\bar{d} = \frac{\Sigma d\, Nd}{\Sigma Nd}$$

(2) $$\sigma d = \sqrt{\frac{\Sigma (d - \bar{d})^2}{N-1}}$$

(3) $$\sigma \bar{d} = \frac{\sigma d}{\sqrt{N}}$$

By the application of the method of the estimation of the degree of seismic intensity after seismic MSK–64 scale, one settlement was taken as an example (Novo selo). The total sum of buildings was 820, and from this: 50 buildings of type A, 150 of type A_2, 600 of type B, and 20 of type C. Among them 10 buildings of the type A_1, 20 of type B and 10 buildings of type C were examined.

The estimation of the degree of damage was performed after the least square method. The result of these examinations, as well as the error of the individual and average standard deviation is represented on the table 2.

Accordingly, the estimation of the seismic intensity degree for various building types was as follows:

$$I_{A_1} = 6,5 \pm 0,27$$

$$I_{A_2} = 7,0 \pm 0,16$$

$$I_B = 7,0 \pm 0,22$$

$$I_C = 7,0 \pm 0,17$$

The average value of the estimation of seismic intensity degree for the whole settlement (taking into account every type of building) was as follows:

$$I_{av} = 6,88 \pm 0,21$$

TABLE 2

Settlement	Building type	Total sum of build.	Examined	d						$\bar{d}$	I	σd	$\bar{\sigma} d$
				0	1	2	3	4	5				
Novo Selo	A_1	50	10	0	1	5	3	1	–	2,4	0,5	0,84	0,27
	A_2	150	20	0	3	10	7	–	–	2,2	7,0	0,095	0,156
	B	600	20	3	6	7	4	–	–	1,6	7,0	0,993	0,22
	C	20	10	4	6	–	–	–	–	0,6	7,0	0,36	0,17

A_1 – buildings made by mud;

A_2 – " " " stone;

B – " " " brick;

C – " " " armoured concrete.

Summary

Taking into account the degree of damage of the various building types, the estimation of the seismic intensity degree, according to the new seismic MSK–64 scale was performed.

Except the estimation of seismic intensity, determination of the error of the standard deviation – individual (σ d) and average (σ d) was achieved.

According to the values of the intensity, defined after the examination of damage of the individual building types, the appraisal of the intensity for the total settlement, included in this investigation, was executed.

The appraisal of seismic intensity after the seismic MSK–64 scale is more correct, than the other seismic scales, because in the examination of the intensity after MSK–64 not only the degrees of building damages were taken into account, but also the other quantitative characteristics of the appraisal of the seismic intensity.

At the same time, the correct estimation of the degree of seismic intensity after the seismic MSK–64 scale could be used in seismic microzoning. In this case, in the estimation of the intensity, the constructive peculiarities of buildings were taken into account and in the estimation of damages, the influence of the microgeological soil conditions is more present, than in the estimation of the intensity after the other seismic scales.

REFERENCES

[1] Medvedev, S.V. (1961): Opredelenie ball'nosti (intensivnosti) zemletrjasenija. "Zemletrjasenija v SSSR", gl. 4, Izd-vo AN SSSR, Moskva.

[2] Medvedev, S.V. (1968): Mezdunarodnaja skala sejsmiceskoj intensivnosti. "Sejsmiceskoe rajonirovanie SSSR" gl. 9, Izd-vo "Nauka" Moskva.

[3] Shebalin, N.V., Kuliev, F.T. (1969): O vozmoznosti statisticeskoj interpretacii ball'nosti. "Sil'nye zemletrjasenija Srednej Azii i Kazanstana". i. Dusance.

[4] Shebalin, N.V. (1970): K statisticeskomu opredeleniju intensivnosti zemletrjasenij. International Union of Geodesy, and Geophysics, European Seismological Commission (ESC). Proc. of the ESC, Leningrad 3–11 September 1968. Academy of Sciences of the SSSR, Moscow.

GEOLOGICAL EMERGENCY INTERVENTIONS IN THE EARTHQUAKE STRICKEN ZONES OF FRIULI: THE EXAMPLE OF OSOPPO TOWN

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Foreword

Following the earthquake of the 6th May 1976 the Assessorship of Public Labours of the Friuli-Venezia Giulia Region, acting through its Assessor and the Director of the Service for Natural Disasters, set up a commission of experts to plan the action to be taken in the area.

After the state of emergency and the need to intervene promptly in order to guarantee the safety of civilians and the state of main roads, the Assessorship, backed by the providence of the Regional Act 33/1976 ,through the commission, organized teams of geologists. One part was instructed to intervene immediately where extremally critical situations

prevailed (landslides, rockfalls etc.) the other part had to carry out prompt surveys on the worst hit or greatly damaged towns. These surveys (mapped using scale 1:5.000) firstly involved a geological and geomorphological survey of the surface, secondly a survey of the landslides and an evaluation of the geostatic situation, thirdly the trend of the water table and the definition of hydrogeological characteristics, lastly information on the stratigraphy of the first 10-15 m of the subsoil.

This second type of intervention was mainly confined to the immediate singling out of the most suitable areas from the geological point of view in order to supply initial information, even though very approximate, to choose new zones for settlement near the existing ones. These measures however must be seen in the light of the state of emergency; therefore they by no means give the final answer to land utilization under the pending situation of seismic and geological risk, but only give a broad indication in order to choose a plan of action. In fact the law provided for the carrying out of the above mentioned measures within 60 days over and area of 11,000 ha and furthermore the singling out, for each inhabited centre, of an area for the immediate construction of prefabricated buildings.

All measures carried out were done so together with the

opinion of the commission and allowed us to single out 94 areas judged suitable for the instalation of prefabricated buildings and allowed us to form opinions on the land utilization of 23 communes making up a total of 127 among chief towns and hamlets.

About 600 work days/geologist were needed to complete all interventions and over 150 work days/expert commission.

As an example of work carried out in the region, on the following pages are the data relevant to the investigation carried out in the Comune of Osoppo, from 11th to 13th/7/76.

The field work was carried out by the following geologists: Feruglio E., Iacuzzi R., Siro L., Ulcigrai F., Vaia F., Zorzi P. (field geology); Marocco R., Stefanini S. (hydrogeology); Bertozzi E., Broili L., Onofri R.(geostatics) Casati E., Facchin F., Giorgetti F. (subsurface geology and geophysic).

This report was used by the commission to express its opinion on land utilization, an opinion presented to the authorities.

1 - Surface geology

The so-called "Colli di Osoppo" are a hilly range located immediately South of the point where the River Tagliamento enters the Friuli Plain.

The hills in question, proceeding from North to South are Colle Carantan (212 m.a.s.l.), Colle di Osoppo (310 m.a.s.l.) Colle di S.Rocco (236 m.a.s.l.),the nameless hill (193 m.a.s.l.) which rises immediately NE of Col Vergnal (193 m.a.s.l.), the most southerly of this range (Fig.1).

The "Colli di Osoppo", have been the subject of geological studies conducted by several authors and in particular by B. Martinis (1955)[1] as three of them are characterized by the presence of Oligocene outcrops which are rather scarce in Friuli. These outcrops represent the local oldest terms of the stratigraphic succession and are predominantly made up of "sands, molasses and sandstones usually of medium grain size including quartz siliceous elements, and with jagged or subrounded edges" and of "subordinate marls and clays"(B.Martinis, 1955). The above mentioned lithotypes, for the most part, can be chromatically described as yellowish, with blue-grey or grey-black patches due to different coloured

1) Martinis B., L'Oligocene friulano- Atti del I° Conv. Friul. di Sc. Nat., pp. 336-395, Udine, 1955.

substances (containing carbon, clay and iron hydroxides). The cement is carbonatic or argillaceous.

The Oligocene outcrops are found only on the Hills of Carantan, Osoppo and S.Rocco (Fig.1). The first of these, Col Carantan, is formed entirely of these deposits,which are also characterized by conglomerate interbedding (especially towards the top part) and by limited lignite lenses at the foot.

In the extreme North of Colle di Osoppo there lies a confined outcrop, compared to that in the SW which is more extensive. From the lithological point of view the outcrops of Colle di Osoppo are predominantly made up of sands.

On Colle di S.Rocco the Oligocene outcrops are visible discontinuously at the foot of the eastern slope. Also here, sands are predominant, containing very limited lignite lenses. "In Osoppo the total thickness of the Oligocene varies from 25m on Colle di S.Rocco, to 50m on Colle di Osoppo. Instead on Colle Carantan, the thickness is about 35m" (B.Martinis, 1955).

The direction of Oligocene is pratically constant, about NNE-SSW, dipping towards the WNW; instead inclination varies slightly from 14° to 20°.

The Oligocene outcrops mentioned above are chrono-stratigraphically correlated to those from the adjoining zones of Peonis, Trasaghis and Monte Prat found to the West of the

Tagliamento. Among these, the most significant outcrop is withouth doubt that of Peonis which was also of a certain economic interest due to the presence of lignite beds mined in the past.

The Oligocene succession is covered everywhere, except on Col Carantan, by very thick quaternary deposits, made up of conglomerates of fluvio-glacial origin, with well rounded pebbles lithologically very variable (with a prevalence of the calcareous-dolomitic facies), ranging in size from a few centimeters to 50 cm, the most frequent thickness being between 10-20 cm. The cement is of carbonate nature ocasionally pitted. The stratification is not well distinguishable and of variable thickness. The general arrangement of strate is subconcordant with that of the underlying stratified Oligocene deposits. The conglomerate masses are notably rigid from a geomechanic point of view, and have been affected by several diaclase systems with a frequency of a meter or more.

The slopes of the highest hills are flanked to a greater or lesser extent by deposits of detritus from the disintegration and crumbling of the conglomerate outcrops above.

Colluvial material ("ferretti" and residual clays) is found at the foot of the hills; between Col Vergnal and the nameless hill to the East there stretches a limited peat

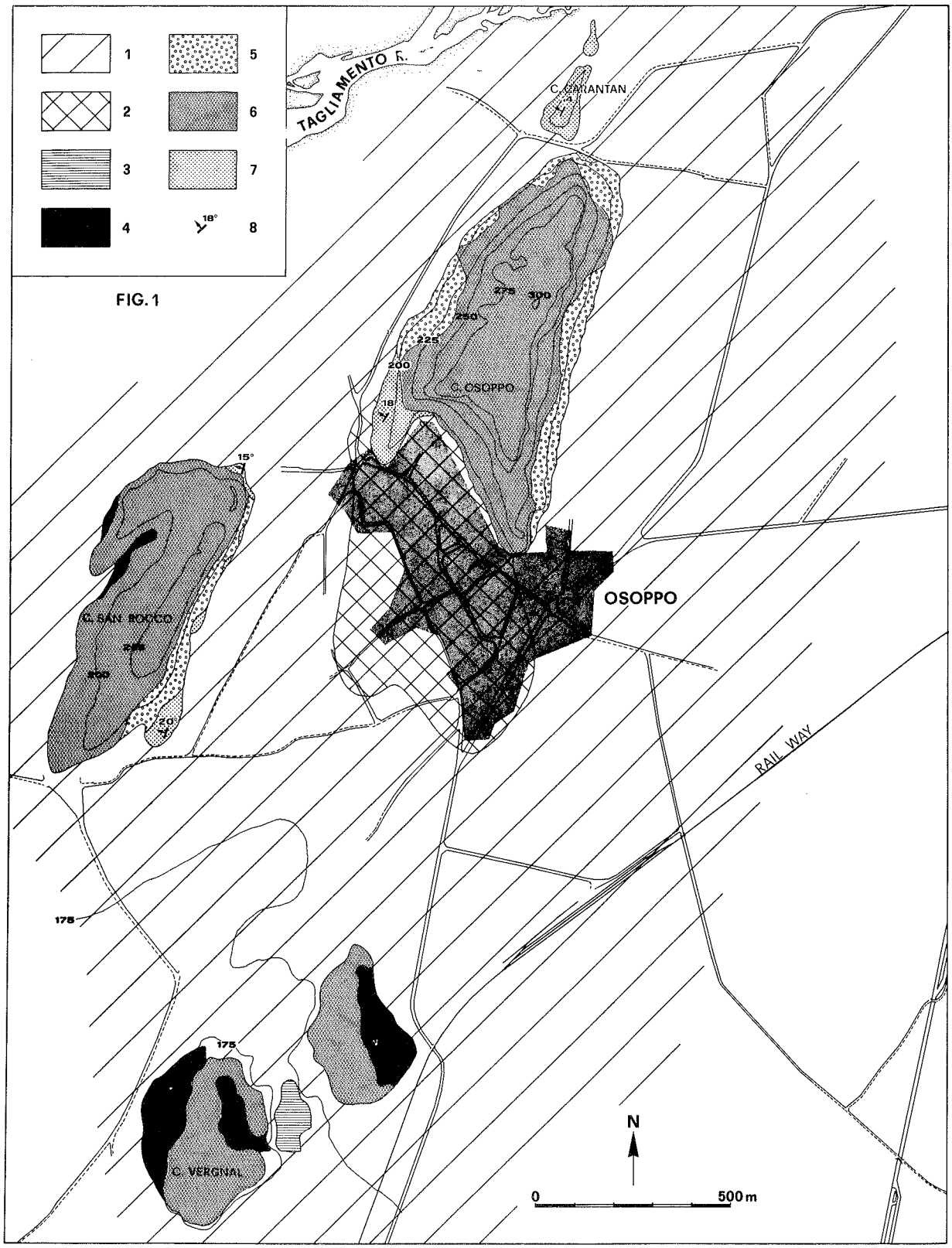
deposit.

The alluvial deposits of the plain surrounding the hills are made up of clays. Immediately South of Colle di Osoppo, corresponding to the location of the inhabited areas, they are made up of more or less sandy gravels to the East and South. To the West they are made up of gravels from the River Tagliamento bed.

Due to the scarceness of the outcrops in these zones, it was not possible to indentify any particular tectonic form. According to E. Feruglio (1926)[2] the above mentioned Oligocene outcrops correspond to the upper part of the series of the so-called "Sinclinale meridiana di Osoppo", whose axis is orientated NNE-SSW and which ends a little further North of Osoppo, almost at the foot of the Friuli Prealps.

As is known, the most southerly hills in the alpine chain have been influenced by the great tectonic line, of regional importance, known in the literature as the "peri-adriatic fold-fault". In the zone found immediately to the North of Osoppo it runs along the Mount Corno-Brancot-Ciampon alignment. In reality the "peri-adriatic fold-fault" is made up of a belt of dislocations complicated by minor systems,

3) Feruglio E., - Le prealpi fra l'Isonzo e l'Arzino - Boll. Ass.Agr.Friul.,s. 7,vol.39,pp.1-96;vol.40,pp.97-301,Udine, 1925.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18°
TAGLIAMENTO R.
C. CAMANTAN
C. OSOPPO
OSOPPO
C. SAN ROCCO
C. VERGNAL
RAIL WAY
N
0
500 m
15°
18°
175
200
225
250
275
300

FIG. 1

orientated in different directions and related to different "tectonic moments". A structural study, together with photogeological research allowed us to identify for example, post Oligocene faults (E.Amadesi, 1968)[3] which affected the Oligocene marls and sandstones of Trasaghis, also the fluvio-glacial conglomerates and occasionally the quaternary breccae on the slopes of the southern pre-alpine belt, proof of tectonic activity, which according to the Author continued at least till the upper Pleistocene.

Legend of Fig.1 Geological map of the surface

Quaternary: 1)alluvial sandy gravels,2)alluvial sandy clays, 3)peats, 4)eluvium,5)talus,6)conglomerates

Oligocene: 7) sands, molasses and sandstones

8) dip and strike symbol of strata.

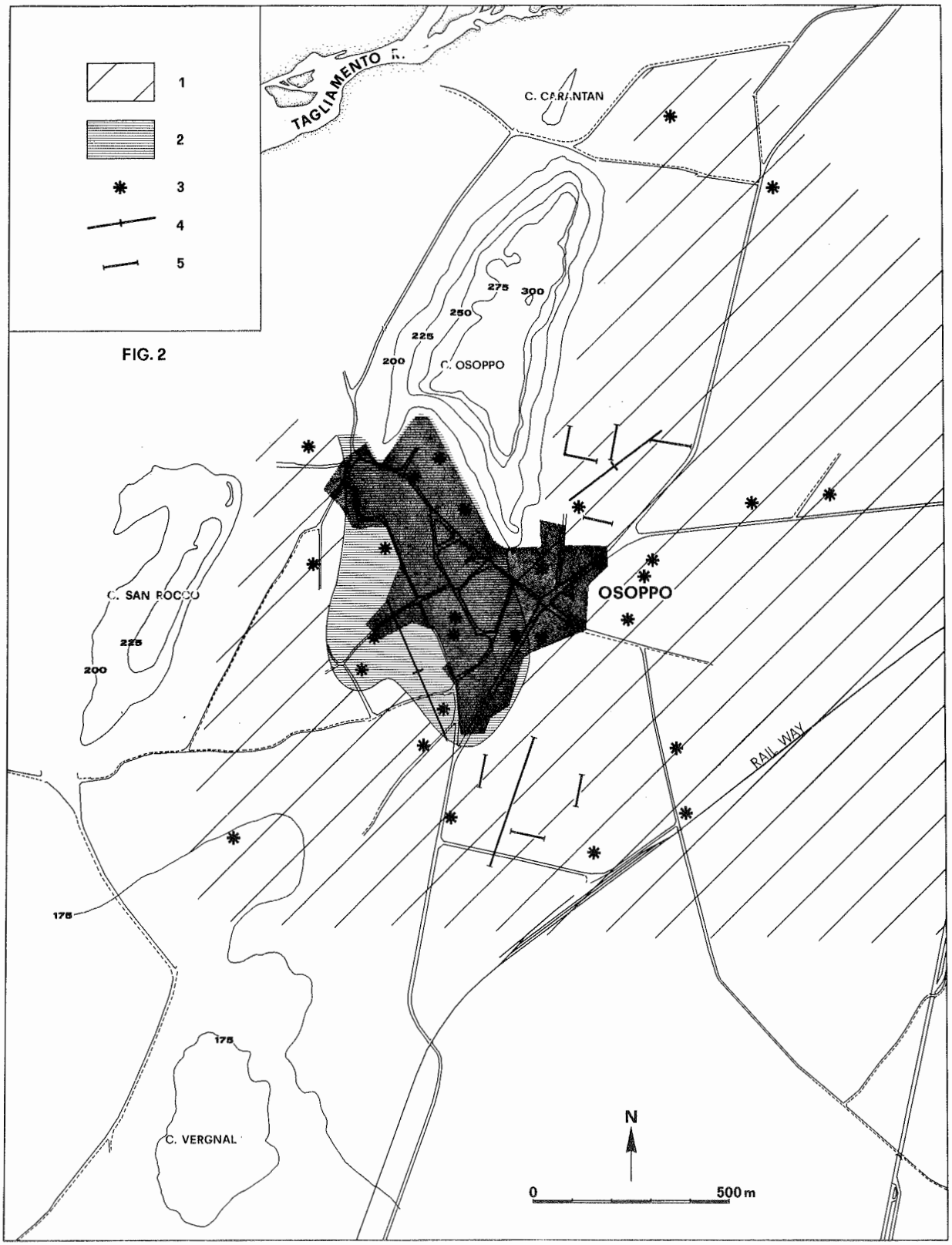
3) Amadesi A., - La geologia dei gruppi di M.Brancot e M. S.Simeone (Friuli udinese)-Giorn.di Geologia,s.2, vol.36, pp. 1-68, Bologna, 1968.

- Subsurface geology

Information on the subsurface was inferred from bibliographic data, from the survey of treches and cuttings, from mechanical, seismic and electric prospectings as well as from local information.

Firstly, from the information and data obtained from cuttings and small borings, it results that part of the inhabited centre is situated in an area where the first few meters of ground are prevalently clayey-silts varying in depth from one to four meters from the soil-surface. The sorrounding area is instead prevalently gravelly (Fig.2).

Secondly, from the three electric soundings carried out to the SW of the town, to the South (where it is planned to build most of the temporary settlements) and to the NW (where apart from prefabricated buildings it is planned to build a school), it results that the soil has a thickness which varies from 3m to a few centimeters, under which there are 2 to 6m of dry gravels with a resistivity of between 1,400 and 4,000 ohm/m followed by a thick deposit of wet gravels with a resistivity of between 200 and 300 ohm/m. Moreover, while clays were encountered (with a resistivity of 1 ohm/m) in the sounding located to the SW of the inhabited area at a depth of 38 m from the soil surface, elsewhere, at a depth of between 20 and 35m from the soil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TAGLIAMENTO R.
C. CARANTAN
275
300
250
225
200
C. OSOPPO
C. SAN ROCCO
225
200
OSOPPO
RAIL WAY
175
175
C. VERGNAL
N
0
500 m

FIG. 2

surface, the gravels become sandy silts and turn into silty sands with a varying reistivity of between 50 and 66 ohm/m. Lastly, the data inferred from the 8 seismic refraction profiles taken to the South and NE of the inhabited area,as well as confirming the depth of the water table (about 5 m to the South and from 6-8 in the NE, with values of 450 m/s for dry gravels and 2,200 m/s for wet gravels), indicate an increase in seismic activity, calculated for limestone, according to Medvedev's formula, of 1,14 to the South and a slightly lower value to the NE.

Legend of Fig.2 Geological map of the subsurface

1) gravels and sandy gravels, 2) gravels below clays with a thickness of 1-4 m, 3) mechanical or manual prospecting, 4) electric prospecting, 5) seismic prospecting.

- Geostatics

Geostatic conditions of Colle di Osoppo and of the northern part of Colle di S.Rocco have been examined (Fig.3).
Because of the earthquake all the slopes of Colle di Osoppo have been affected by numerous phenomena of instability, the most part of which are represented by rockslides of generally well cemented conglomerate material. However, limited, relatively safe landslides of the upper covering soil took place, especially on the southern part of the hill.
Initially the rockfalls were a dynamic process of free fall for only few meters, or a process of rolling, accompanied by rebounds down the highly inclined rock walls. Subsequently, rocks mainly began to roll down a more or less irregular surface (scree material) along slopes inclined between 35° and 50°, which were sometimes covered by abundant vegetation of low or medium height. In many cases the final course of a few blocks, before coming to rest, took place on almost subhorizontal ground, lacking vegetation; in these cases, the maximum distance these blocks could roll on level land from the foot of the slope was about 27 - 30 m.
The most macroscopic events of instability took place on the eastern side of the hill (from point No.9 to No.25 of Fig.3) where well located rockslides of variable volume, from a minimum of about 2-3 m3 to a maximum of about 500-600 m3,

are present. Along this stretch of slope, the upper edge of the hill is morphologically and structurally predisposed to phenomena of instability, as there exist subvertical extension fractures, which are sub-parallel to the slope, associated with other planes of separation (sometimes neo-formations) of the rocky mass. These joints, which cross each other with greater or lesser continuity, can more or less comletely outline blocks of varying volumes with different constraints.

The most part of the rockslides on the 6th May, began at between altitude 250-280 m. Several blocks fell to altitude 185 m, reaching the positions indicated on the Fig.3. The size of these blocks, whose form is usually sub-prismatic, more or less elongated or flattened, with rounded edges, vary from a minimum volume of a few cubic decimeters to a maximum of about 350 cubic meters. The biggest block fell towards the East from the North eastern spur of the hill.

On the eastern side there still exist instable rocky masses whose volume varies from about 70 to 21,000 m3 (points no.24 and 25).

It is to consider that almost all this zone at the foot of this slope is extremely dangerous.

Along the southwest slope of Colle di Osoppo (from point no.1 to point no.6) diffuse, more or less isolated rockfalls

have taken place from the steep rock walls. The sizes of the individual blocks vary from about 0.25 to 1 m3. Most of them have stopped at the road beneath, which leads to the fortress and only in some rare instance have they rolled further afield. It was not possible to determine the maximum distance these blocks rolled in the direction of Osoppo, as at the time of the survey it was impossible to reach the zone because of the search for victims and possible survivors. Along this South western slope a rockslide of medium size took place at about altitude 225 m (point no.6). The rock which fell came to rest well beyond the road to the fortress and a few large blocks (a maximum of about 30 m3) came to rest on the artificial terraces immediately above the houses built close to the slope.

From what has been written above, it results that along this stretch of slope, the road to the fortress contributed in halting the majority of blocks which came down. Despite this it must be borne in mind that the whole of the area under this slope is highly dangerous.

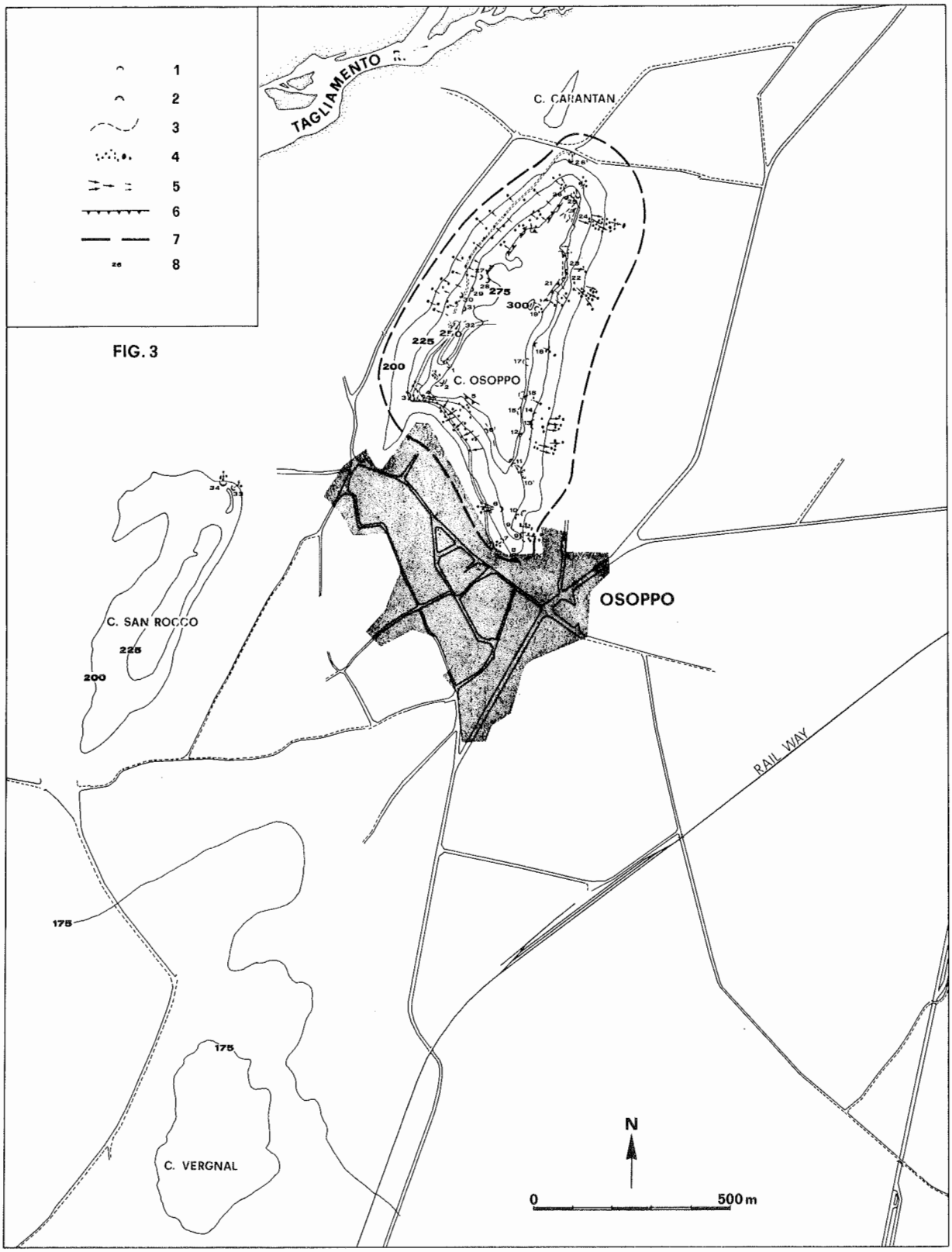
Along the NW slope of Colle di Osoppo (from point no.26 to no.32) more modest rockfalls took place, or only detachments of single blocks of a maximum volume of about 1 m3. In this area it seems that the falls did not reach further afield than the foot of the slope, both due to the

lesser total inclination of the slope and, in some instances, to the presence of minor roads and cartways which in many cases helped to halt the rolling of falling masses, and in part due to the abundant vegetation.

Finally, on Colle di S. Rocco, two rockslides of medium size must be mentioned. The blocks in this case rolled down as far as near the back of the cemetery.

From above, it results that safety on all slopes of Colle di Osoppo is extremely precarious. Firstly because of the presence of rocky masses, also big ones, which are still proof of a state of imbalance. Secondly because of the presence of blocks, which fell because of the earthquake, in a condition of imbalance on all the slopes (a few are held precariously in place only by the vegetation). Lastly because a few portions of the fortress walls have been seriously damaged and hang dangerously over the underlying slopes.

Recovery and rearrangement of Colle di Osoppo and of the zones immediately below it, will need accurate and skilled geostatic and geomechanical studies to reclaim and rearrange the slopes. At the moment the setting up of a safety zone at the foot of the hill seems indispensable together with, according to the circumstances, defence measures against the fall of rockslides. The planning and accomplishment of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TAGLIAMENTO fl.
C. CARANTAN
C. OSOPPO
OSOPPO
C. SAN ROCCO
C. VERGNAL
RAIL WAY
N
0
500 m
200
225
250
275
300
175

FIG. 3

the most urgent defence and reclaimation works will have to take in account future land-use both in the short and long-term.

Legend of Fig.3 Geostatic map

1) rockfalls, 2) landslides, 3) extension fractures, 4) fallen rock blocks, 5) indicative route of rock blocks, 6) unsafe stone walls, 7) safety limit, 8) reference point.

4- Hydrogeology

4.1 Springs

There are no springs to be found in the town of Osoppo. Only one spring, of little importance, is situated on the eastern slopes of the Colle di Osoppo (Fig.4) . Its yield is very low, calculated at a few cm^3/sec. The spring water is collected in a pond and is absorbed into the ground.

During the destructive earthquake shock of the 6th May, no unusual phenomenon was noted at the spring and no new springs appeared in the area.

4.2- The phreatic water

The study of the phreatic surface consisted in measuring the depth of water in 20 wells by means of a calibrated electric sounder [4]. The results of the survey can be seen in the two adjoining contour maps (Fig.4,5) which show the trend of the isopiestic lines and the curves of equal depth of the water table from the soil surface respectively.

It resulted that the isopiestic lines are oriented, to the East of Colle di Osoppo, from NW to SE which indicates a preferential direction of flow from NE to SW. These waters without doubt derive from seepage from the River Tagliamento which flows a little to the North of Colle di Osoppo.

In relation to the inhabited centre, the phreatic waters flow firstly from NW to SE and then from North to South, showing their origin to be respectively the Tagliamento, across the gap between Colle S.Rocco and Colle di Osoppo, and Colle di Osoppo itself.

The trend of the isopiestic lines further points out the

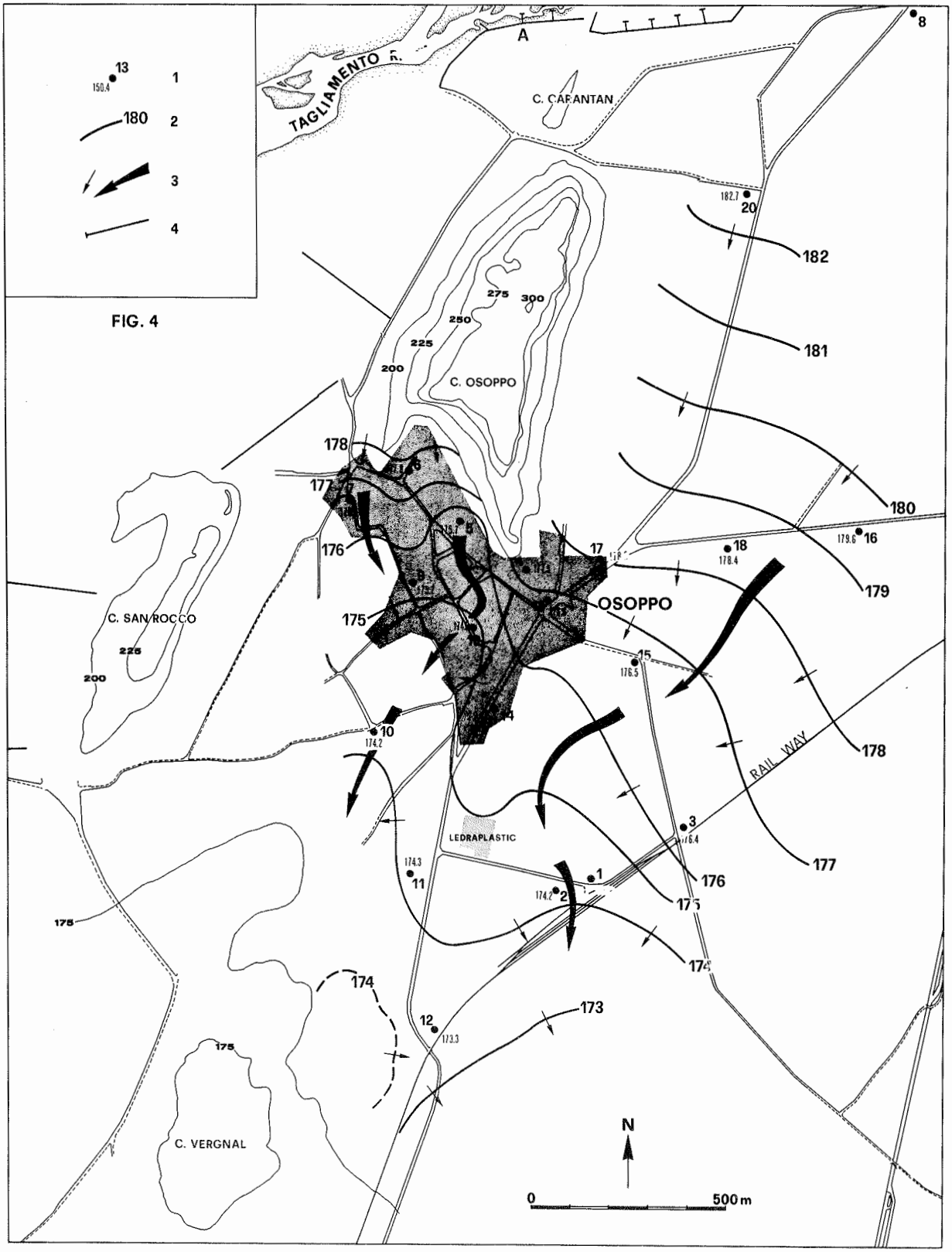
5) The wells no.1 and 8, during the period of the measurements, were dry.

presence of a phreatic ridge having a N-S axis, passing under the Ledraplastic Factory, which divides the two main flows to the East and West of Colle di Osoppo respectively. The map of the curves of the depth of the water table from the soil surface (Fig.5) shows that during the period the measurements were taken (11th-13th July 1976)the level of the water in the area examined was between -3.6 m and -6.6 m from the surface and in the inhabited centre between -3.8 m and -5.8 m. Therefore the level is not deep and this in past years brought considerable inconvience, when the water table was high. For example cellars were flooded in the area indicated on the map. By taking into account the depth at which the water table was measured and the depth of the flooded cellars, one can estimate that the phreatic fluctuations are in the order of +2,+3 m compared to the values obtained during the survey period (a period when the water table was low).

During the earthquake of 6th May no water was reported to have emerged from the soil surface in the area under examination.

4.3 - Water courses

The water course which could have some influence on the area under examination is the Tagliamento which flows a little to the North. It is however completely contained


13
150.4
1
180
2
3
4
FIG. 4
TAGLIAMENTO R.
A
C. CAPANTAN
8
182.7
20
182
181
180
179
178
177
176
175
174
173
275
300
250
225
200
C. OSOPPO
OSOPPO
18
178.4
179.6
16
17
15
176.5
10
174.2
3
176.4
1
2
174.2
11
174.3
12
173.3
LEDRAPLASTIC
RAIL WAY
C. SAN ROCCO
225
200
C. VERGNAL
N
0
500 m

by embankments along the stretch which flanks the area of Osoppo, (Fig.4) either man-made or natural (Colle di Osoppo). These embankments are considered sufficient to hold back the spate of the river given that they sufficiently hold back the exceptional spate of November 1966 which gave us a means of comparison.

The existing artificial defences (embankments, groynes and current fenders) are in good condition and show no sign of having felt the effect of the earthquake. Only one current fender (point A on map of the Fig.4) is in poor condition at the top but this is not due to the earthquake.

Legend of Fig.4 Map of the isopiestic lines

1) Well with the identification number and height in meters of the water table from the average sea level, 2) isopiestic lines, 3) flows of the phreatic water, 4) artificial defences from the River Tagliamento.

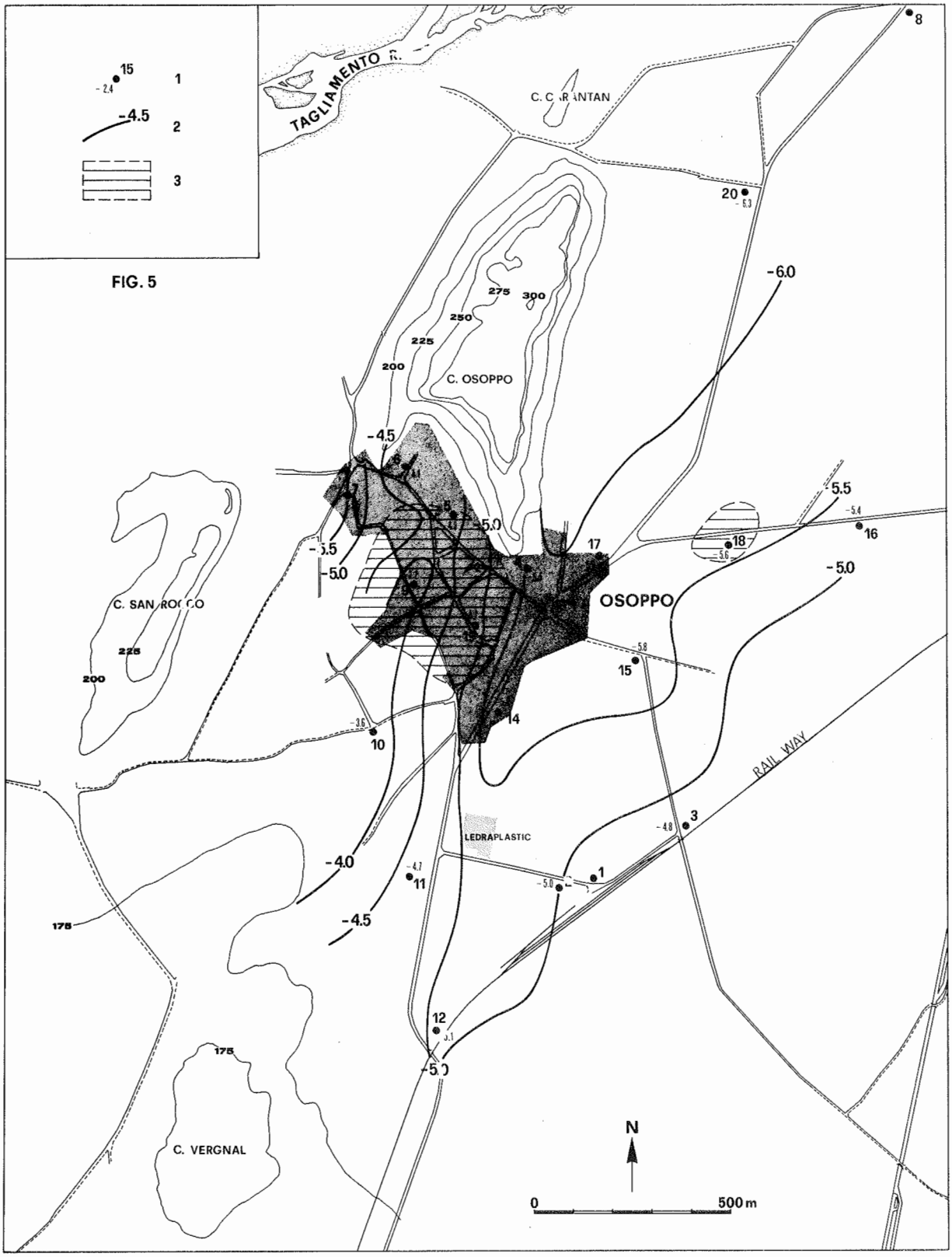

15
-2.4
1
-4.5
2
3
TAGLIAMENTO R.
C. CARANTAN
8
20
-6.3
-6.0
275
300
250
225
200
C. OSOPPO
-4.5
-5.5
-5.0
-5.0
17
18
-5.6
-5.5
-5.4
16
C. SAN ROCCO
225
200
OSOPPO
-5.0
15
-5.8
14
-3.6
10
RAIL WAY
LEDRAPLASTIC
-4.8
3
-4.0
-4.7
11
1
-5.0
-4.5
175
12
-5.1
-5.0
175
C. VERGNAL
N
0
500 m

FIG. 5

Legend of Fig.5 Contour map of the depth of water table from the soil surface

1)well with the identification number and the depth of the water table, in meters, 2)contour lines of the depth of the water table, 3)area subject to the flood of the cellars.

5. - Land Utilization

From the data collected the area of Osoppo was subdivided into the four categories (A,B,C,D) adopted in the Friuli to guarantee a homogeneous evaluation of the land utilisation (Fig.6). Each category presents "a different degree of suitability" which slowly decreases to total unsuitability. In other words the land was penailzed on the basis of the combination of few fundamental parameters which were taken into consideration from all the research carried in the region of Friuli, that is: the nature of the ground, the velocity of the seismic waves measured, estimated or deduced from other parameters, the thickness of the series immediately below the surface, its lower surface (horizontal

or inclinated), the depth of the water table, existing or potential landslides and more generally the geostatic problems.

The four categories have been defined as follows:

Category A- homogeneous and compact ground, characterized by a seismic wave velocity greater than 1,500 m/sec, a thickness of over or equal to 10 m with a subhorizontal lower surface, the depth of the water table greater than 5 m and a lack of landslides or geostatic problems;

Category B- not very homogeneous or compact ground with a seismic wave velocity of about 1,500 m/sec, a thickness less than 10 m with a subhorizontal lower surface, the depth of the water table of about 5 m and a lack or limited presence of geostatic problems;

Category C- ground having little cohesion with a low relative density or soft ground, with a seismic wave velocity of less than 1,500 m/sec, with a thickness less than 10 m and a horizontal or inclined lower surface, the depth of the water table less than 5 m, and with a lack or limited presence of landslides or geostatic problems;

Category D- instable ground, areas subject to landslides or rock falls, the edge of terraces, ground characterized by liquefaction which have taken or may take place, marshes, peat deposits, zones where the water table could reach

the surface.

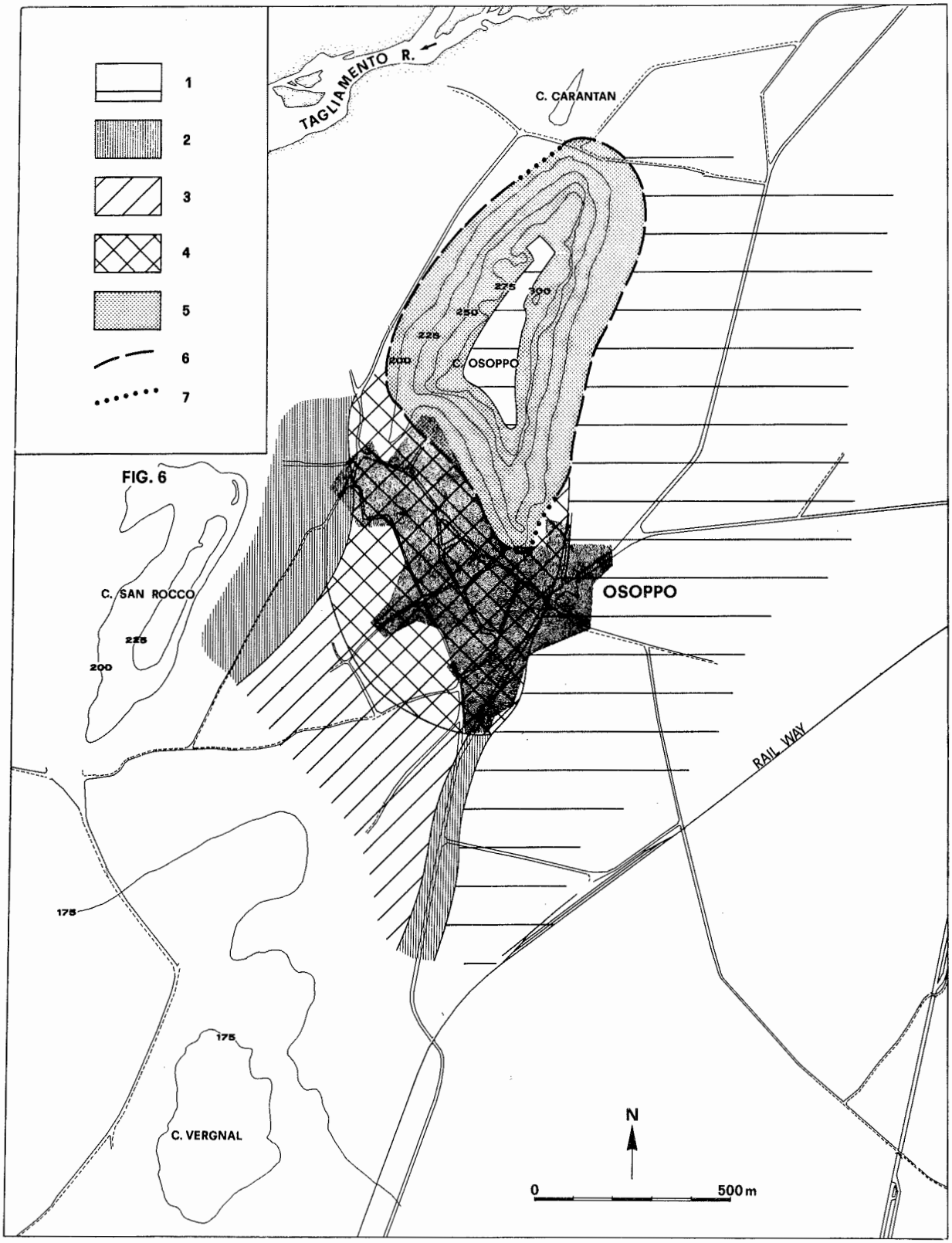
To each of these categories (which have been given the combination of positive or negative factors which characterize the area indicated), a different degree of suitability has been given. More precisely in the case of Osoppo:

- Category A defines suitable zones. It is to be borne in mind that to utilize them the normal geological-technical research provided for by the law must be carried out.
- Category B defines less suitable zones, compared to Category A, and it was not possible, due to the type of survey, to assure with precision in a few cases the lithology of the subsoil and the depth of the water table. In short , Category B covers those areas which at least in part could be included either in the first category or the following one.
- Category C defines zones which, due to the complexity of the problems which arose during research and due to the uncertain situation under the geological-technical point of view, need systematic initial research which must be carried out before the planning of eventual programmes by the "Piano Regolatore Generale". As mentioned this is indispensable, because the existing geological picture has shown the need for deeper research and the exact definition

of the problems which have arisen. Within Category C, Category C1 has been introduced due to the precarious geological and hydrological situation found there.

- Category D defines zones which under the existing geostatic situation are very unfavourable, especially in this case, due to the danger of impending landslides.

In conclusion of what has been written above, it must be pointed out once again with exstreme unambiguous clarity, that what has been proposed for land utilization will not necessarily be the definite subdivision. This is only a very approximate indication at a time of emergency with the only aim being to indicate, through basic geological criteria, the degree of land utilization, in order to supply in time, proposed authorities with a first concrete means, in order to choose the first measures for reconstruction. Furthermore it must be emphasised, that the criteria adopted are aimed above all at forming opinions, as homogeneous as possible, on the earthquake zone. Despite this, it is implicit that at a local level a degree of suitability relative to the zona is brought to light, in order to define better zones for the beginnings of reconstruction.


1
2
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7
TAGLIAMENTO R.
C. CARANTAN
275
300
250
225
210
C. OSOPPO
FIG. 6
C. SAN ROCCO
225
200
OSOPPO
RAIL WAY
175
175
C. VERGNAL
N
0
500 m

Legend of Fig.6 Map of land utilization

1) Category A, 2) Category B,

3) Category C, 4) Category C1,

5) Category D, 6) safety bound,

7) defensive works.

BOLLETTINO DI GEOFISICA TEORICA ED APPLICATA

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