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The Italian Group for Solid Earth Geophysics

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ABSTRACT The structure of the Italian Group for Solid Earth Geophysics is described together with the main activities that the Group has developed over the years.

Key words: Gruppo Nazionale Geofisica Terra Solida, history.

1. Introduction

Solid Earth Geophysics is the branch of sciences and technologies that studies phenomena associated with the physical characteristics of the solid part of the Earth (Slejko, 2001). The knowledge of such phenomena derives from measurements carried out mostly on the land and sea surface of our planet, but also at various heights with aircraft or satellites and below the surface through perforations. From these measures, the geophysicist not only tries to derive information on the phenomena, but also the knowledge of the geometry and physical parameters of the various bodies constituting the Earth. From measures repeated over time (time-lapse geophysics) and from the identification of effects that the occurred phenomena have left, scientists try to hypothesise on the evolution of the phenomena in the past and, therefore, to project this evolution into the future. An essential component to understand these phenomena is their mathematical and physical modelling that allows us to theoretically reproduce the effects of the hypothesised causes of the phenomena and, therefore, to verify the hypotheses made and the compatibility of theories with the physical reality given by the measurements.

The complexity of the Earth's constitution and its evolution over time implies that all the phenomenologies that can be measured and which constitute different branches of geophysics are taken into consideration. These include seismology, that studies the phenomena of the generation of earthquakes and seismic wave propagation, gravimetry and magnetometry, that analyse, respectively, the gravimetric and magnetic terrestrial fields, geothermics, that measures the propagation of heat from inside the Earth, geodesy, that focuses on the shape of the Earth and its variations over time, geoelectromagnetism, that studies the propagation of electric currents and electromagnetic fields. Another important branch of Solid Earth Geophysics is Applied Geophysics, which exploits the above phenomenologies to achieve technological and economic objectives such as the search for minerals and energy sources, the identification of geological bodies or cultural heritage, the search for water, etc. In the distant past, each of these branches of geophysics had an almost completely independent development with rare collaborations or integrations aimed at specific objectives, also limited in time.

Geophysics is the most powerful way to acquire information on the Earth's crust from depths greater than a few metres to tens of kilometres, up to the Earth's core. The research methods

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are based on the objectives to be investigated, and the results obtainable are more reliable when the outcomes from different methods are integrated. Some of these, such as seismic methods, constitute the constraints on which to calibrate other methods. It can be said, for example, that everything that is known quantitatively on a regional scale of the Earth's crust in Italy is derived from the integration of research into deep refraction and reflection seismics, seismology, gravimetry, and magnetometry.

The problem is important also with reference to the genesis and transformation of the deep fluids and to the study of the rheological state of the crust, whose contribution to the tectonic evolution and to the crustal and subcrustal changes is increasingly recognised and studied, even for practical purposes.

Recently, the knowledge of the natural risks and strategies for their reduction have reached paramount importance and, for this aspect, the contribution of geophysics plays a fundamental role.

2. The Italian Group for Solid Earth Geophysics

The Italian Group for Solid Earth Geophysics (GNGTS) was established by the joint initiative of the Committees for Physical Sciences and Geological Sciences of the Italian National Research Council (CNR), with a decree of the CNR president (D.P. CNR no. 5514) dated 22 June 1978, absorbing the Commission for Mining and Applied Geophysics and the Group for Large Seismic Profiles (operating since 1956, under the auspices of the European Seismological Commission). The task of the Group was "promoting, carrying out, and coordinating research in the field of the geophysics of the Solid Earth, in harmony with the general plans and directives of CNR". From the beginning, GNGTS has accomplished the founding tasks by coordinating the geophysical activities of the various institutions, and promoting wide-ranging international and national initiatives. After the termination (1 January 1978) of the Italian Geodetic Commission, geodesy and related sciences were also part of GNGTS.

The main purpose of GNGTS was to bring together and enable researchers to interact, not only from the various branches of Geophysics and other disciplines of Geosciences, but also belonging to the different schools that developed in Italy, to make known and compare updated methodologies and techniques, to promote research, seminars and conferences where the various facts and information could be compared and integrated. The Group also allowed the individual researcher to acquire knowledge of the whole context of geophysical science in Italy and, consequently, for young researchers to become known and evaluated by the Italian geophysical community even before confronting the international audience.

The limited funding given to GNGTS by the Italian Ministry of Education, University and Research and by CNR did not allow the Group itself to develop and conduct major research projects involving a large number of researchers. Nevertheless, some significant results were achieved. The Group's endowment funds [50-70 million Italian lira a year (between 25,000 and 35,000 Euro today)] allowed specific seminars and coordination meetings to be held, where also large projects were designed, later evolving autonomously, as well as making the internal bodies work. The funds allocated by CNR for research allowed GNGTS to stay alive and develop a series of research topics not included in the themes financed by large national projects and to create new lines of research that were later developed independently. Among the financed research topics,

it is worth mentioning some monitoring activities and the development of small theoretical and applied projects often proposed by young scientists. Moreover, the annual national conference was organised which is still the meeting point for all Italian geophysical scientists.

One of the main topics that GNGTS pursued was the study of the Earth's crust, studies already organised and funded within CNR prior to the creation of the Group as individual and international projects, but to which the Group gave particular attention, coordination and stimulus. The crustal and sub-crustal knowledge acquired with deep geophysical surveys offered significant scientific and practical contributions, for example for the exploitation of geo-resources and the defence against earthquakes and volcanic eruptions. The new algorithms developed, in fact, allowed studying the intermediate and deep crust (geometric parameters of the Earth's crust and laws of velocity propagation of the seismic waves in the crustal strata) through the joint analysis of the seismic reflection and refraction data, seismology, geodesy, gravimetry, magnetometry, petrophysics, and heat flow.

On 31 December 2000, GNGTS terminated as an organ of CNR and its activity has continued only in organising the annual conference, thanks to funding by the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS).

3. Structure and role of GNGTS

As a CNR body, GNGTS was structured in sections whose themes summarised the various topics mentioned above. The six sections were: Mining and Environmental Geophysics, Crustal Geophysics, Geodesy and Gravimetry, Seismic Prospecting, Geothermal Resources and Seismology.

The section "Mining and Environmental Geophysics" co-ordinated the research applied to the investigation of the most superficial part of the Earth's crust (from the first metres to the first thousand metres, excluding research for hydrocarbons) and of particular artefacts. This section, therefore, included topics suitable to solve problems on a small scale (research of cultural heritage or superficial bodies, assessments of the state of artefacts, pollutants, etc.), medium-scale (research and characterisation of geological bodies related to geological-technical problems, e.g. landslides, foundations, dams, etc.), and large scale (research of water, mineral resources, etc.). In this context, all the innovative and traditional geophysical methodologies were taken into consideration, studying the improvement of theories and techniques of acquisition, processing, and interpretation, as well as checking their possibilities and limits of application.

The section "Crustal Geophysics" carried out geophysical research aimed at i) defining the structures of the Earth's crust (from 0 to 30-50 km depth) and the upper mantle, ii) characterising deep structures in terms of geometries and physical parameters, and iii) interpreting geophysical data in the framework of different structural-geodynamic domains. In particular, in this section the contributions of researchers converged in the sectors of: 1) design, planning and undertaking of new experiments aimed at prospecting the Earth's crust; 2) development of new techniques for processing crustal geophysical data; 3) reliability analysis of the results of the processing and geophysical modelling; 4) joint interpretation of the results and information deriving from the geophysical models with geological information and data, aimed at improving the knowledge of the structural and geodynamic structure of the lithosphere for the investigated areas.

The "Geodesy and Gravimetry" section undertook research aimed at studying the shape of the Earth and the physical phenomena that are behind it, the physical parameters characterising the rotation motion and its implications on the structure and dynamics of the Earth, the deformation of the terrestrial surface and the plate movement implications on the geodynamic phenomena that determine them. To achieve the scientific objectives required by modern geodesy, the section stimulated a close integration and interaction between technology (i.e. development of tools and techniques of acquisition) and theory (development of algorithms for interpretation and inversion of data). The section was also involved in the multiple applications of geodesy, in particular regarding the control of the territory with spatial geodetic techniques.

The section "Seismic Prospecting" developed new methods of time lapse seismics, aimed at identifying changes in petrophysical parameters over time, improved methodologies that make use of the drilling bit as a source of energy, and carried out research on seismic modelling in anisotropic and inelastic media, on new techniques of numerical signal elaboration, aimed at increasing the quality of seismic images obtainable from prospecting in the sea and on land, and on innovative techniques of reflection-refraction tomography, able to jointly consider the contribution of different seismic experiments to various geometry. All these research topics, many of which were financed by international private companies and EU research programmes, were, and still are, widely used in the search for energy sources, for environmental protection, and for the exploration of the Earth's crust. Regarding this last aspect, we should note the fundamental contribution to the Deep Crust project (Crosta Profonda, CROP), in the design, acquisition, processing and interpretation of deep seismic reflection profiles over the entire Italian peninsula, the surrounding seas, and, in collaboration with analogous foreign experiments, across the Alps.

The section "Geothermal Resources" coordinated research on the thermal state of the lithosphere in Italy in its various aspects: 1) measurements of the thermal parameters of the rocks; 2) heat flow measurements; 3) interpretation of the heat flow in relation to the lithospheric geodynamics; 4) influence of the temperature on the rheology of the rocks and on the attenuation of the seismic waves; 5) thermal field produced by magmatic intrusions and energy implications.

The establishment of the national seismic network of the Istituto Nazionale di Geofisica (currently Istituto Nazionale di Geofisica e Vulcanologia, INGV) and the installation of numerous local seismic networks in areas of particular interest allowed formidable advances in the knowledge of the Earth's crust and the upper mantle within the activities of the section "Seismology". Studies of specific earthquake sequences, better when correlated with tectonic studies, and tomographic analyses, contributed significantly to a better definition and characterisation of the seismogenic zones used in the seismic hazard assessment aimed at seismic risk reduction.

Although GNGTS was a stable body of CNR, it did not have any employees, but all the researchers of the universities, public and private research institutes who were interested in solid Earth physics were involved, extending this cultural area to cover the relevant skills referring to geology and environment in a broad sense. From this viewpoint, it constituted the common home of Italian researchers working in different institutions. In summary, the Group promoted projects and disseminated research results in the field of Earth sciences at a national and international level.

The GNGTS activity was coordinated by its Scientific Council (Table 1), who took all decisions about research financing and section activity, as well as the organisation of conferences and seminars (Fig. 1).

Fig. 1 - Carlo Morelli, GNGTS president from 1981 to his death (2007) and Iginio Marson, GNGTS director from 1996 to 1997, in 2003.

After its unofficial life from 2001 to 2017, in 2018 it was decided to officially formalise GNGTS through a joint venture among the main Italian institutions operating in the field of geophysics. A Scientific Technical Committee was established, made up of representatives from the following six institutions: OGS, Department of Civil Protection (DPC), CNR, INGV, Interuniversity Consortium RELUIS Seismic Engineering, and Italian Section EAGE-SEG (Table 2). The representative of the OGS is, by statute, the President of the Committee.

Table 1 - The past structure of the GNGTS Scientific Council.

Years	Director	President	Members
1981 - 1995	M. Bernabini	C. Morelli	E. Accerboni, L. Alfano, G. Amadei, E. Armando, E. Boschi, A. Bottari, E. Brizzolari, M. Caputo, R. Cristofolini, C. Eva, A. Fabbri, G. Ferrara, I. Finetti, M. Fornaseri, G. Lechi, G. Luongo, F. Mongelli, A. Norinelli, A. Patella, G. Orlando, L. Taffi, R. Trudu, L. Villari, M. Zadro
1996 - 1997	I. Marson	C. Morelli	L. Alfano, E. Armando, F. Bella, E. Bonatti, E. Boschi, A. Bottari, G. Cavarretta, C. Cesi, L. Civetta, R. Cristofolini, C. Eva, P. Favali, G. Ferrara, I. Finetti, C. Lippa, F.P. Massaro, F. Mongelli, A. Patella, V. Petrini, R. Santacroce, D. Slejko, P. Squarci, L. Surace, M. Zadro
1998 - 2017	D. Slejko	C. Morelli*	M. Bernabini, G. Biella, P. Cosentino, R. de Franco, G. De Natale, I. Marson, A. Mazzotti, F. Mongelli, G. Neri, G. Ranieri

* till 2007, when he died.

Table 2 - The GNGTS Scientific Technical Committee: present structure of the Group.

President	Members
A. Rebez	C. Chiarabba, D. Di Bucci, G. Florio, A. Masi, P. Messina

4. The main projects developed by GNGTS

GNGTS was responsible for the realisation of important geophysical projects for the exploration of the lithosphere (terrestrial crust and upper mantle) in Italy and in Europe in the 1970s and 1980s. Among the most important ones, it is worth mentioning the Great Crustal Seismic Profiles (Fig. 2), which saw the participation of almost all the Italian universities and research institutions and the European Geotraverse (EGT), in the context of the European Science Foundation (ESF), whose southern segment (Alps-Tunisia), entrusted to Italy, was set up with the use of two CNR ships and over 200 mobile seismic stations.

The Great Crustal Seismic Profiles were predominantly carried out by refraction seismics (Deep Seismic Sounding, DSS), and, later with the technological advancement, they were all digitised and reprocessed. They have, thus, contributed significantly to a first regional knowledge of the geometry and characteristics of the Earth's crust (velocity laws of seismic waves, discontinuity of the layers) and are still the basis for any deep interpretation (including the calibration for reflection seismics surveys).

The CROP project was also developed within the GNGTS during the years 1986-1999 (Fig. 3). This project, aimed at exploring the Earth's crust through the technique of reflection seismics, was promoted by the CNR with a feasibility study (1982-1984) in adherence to

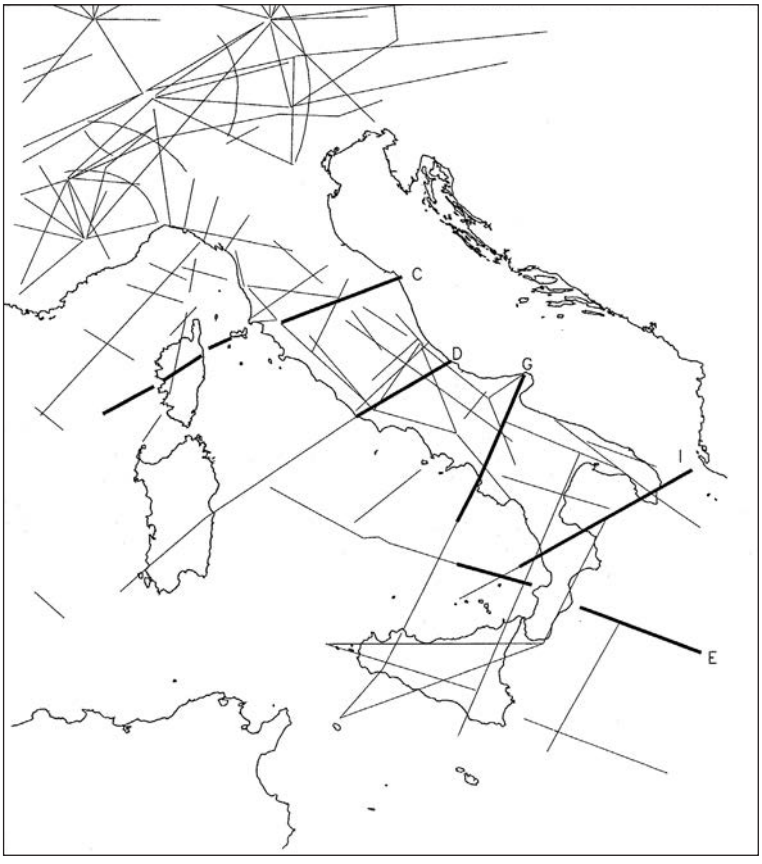

Fig. 2 - Location map of the Great Crustal Seismic Profiles.

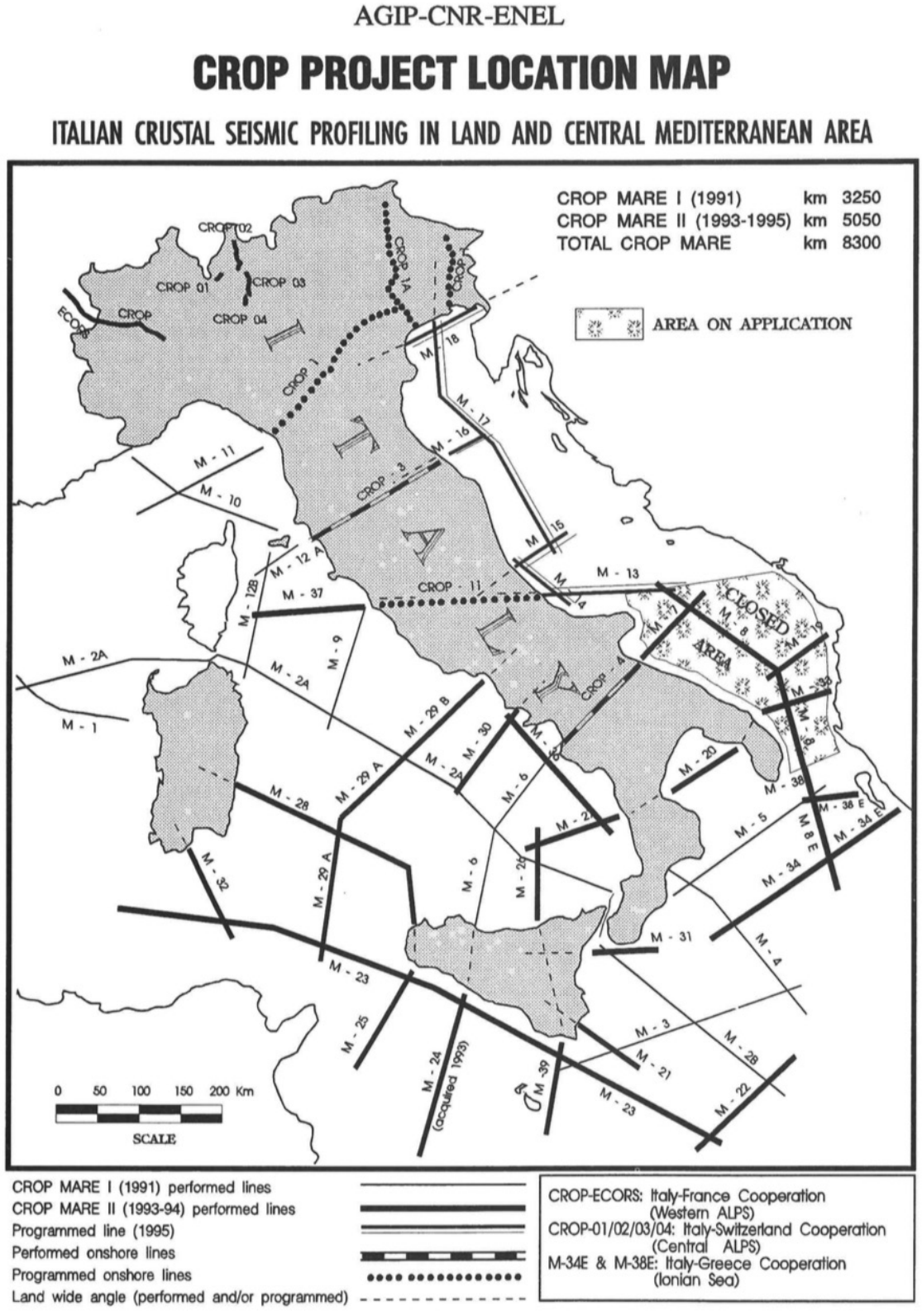

Fig. 3 - Location map of the CROP lines (from Finetti, 1994a).

other international projects (French ECORS, German DEKORP). CROP activities started in collaboration with the corresponding French and Swiss projects ECORS and NRP20, exploring the Italian part of two transects across the western and central Alps. Since 1986, CROP became a more extensive autonomous project that involved not only the CNR and several universities but also some Italian industrial partners, such as the main oil company (ENI) and the main company for electricity (ENEL). CROP explored several terrestrial and marine transepts (Fig. 3) such as: CROP-Central Alps, CROP-03 in the northern Apennines, CROP-04 in the southern Apennines, the transept CROP-11 in the central Apennines, and CROP-01a in the eastern Alps. These experiments contributed greatly to the knowledge of the structures of the entire crust with considerable impact on the understanding of some important seismogenic structures of the Italian area. The CROP project extended the crustal exploration also at sea, acquiring a total 9,000 km of seismic lines obtained by deep vertical reflection seismics also integrated by the acquisitions in land-sea configuration for the exploration of coastal margin areas (Finetti, 1994a, 1994b, 2005).

GNGTS planned and completed the project "Map of geothermal flow in Italy and adjacent seas", which was later integrated into the international project "Geothermal Atlas of Europe" (Hurtig *et al*., 1992) and also sponsored the Italian participation in the project EUROPROBE of the European Science Foundation, for the exploration of the lithosphere in Europe.

Another important product achieved by GNGTS with related institutes and private companies, for the sole purpose of scientific research, is represented by the different databases obtained in the frame of different projects:

1) gravimetric and aeromagnetic stations with a 3-km grid onshore or on the continental shelf, stored at the Servizio Geologico Italiano, and stations along profiles with increasing spacing with distance from the coast, held at OGS;
2) NVR deep reflection seismic profiles; atlas of the CROP profiles, published in the frame of the CROP-CNR program; digitised profiles in the Mediterranean Sea, available at OGS;
3) digitised wide-angle deep refraction seismic profiles, available at CNR's Istituto di Ricerca sul Rischio Sismico (currently Istituto per la Dinamica dei Processi Ambientali) in Milan;
4) heat flow measurements, available at the CNR's Istituto Internazionale per le Ricerche Geotermiche (now Istituto di Geoscienze e Georisorse) in Pisa.

After this brief description, it may safely be stated there are few nations that can boast a similar wealth of data, even if allocating much larger funds for research than Italy.

5. The annual national congress

GNGTS gathers together almost all (more than 500) researchers in the field of solid Earth geophysics. During the annual conferences organised by the GNGTS, scientists show the main results obtained during the last year and they also benefit from the opportunity to present and discuss ongoing research and proposals for new projects. This role is important in terms of dissemination of the results for young researchers for many of which the GNGTS conference constitutes not only participation at a scientific conference but the first real experience to grasp the multidisciplinary aspect of research in the field of geophysics and, often, to show, for the first time, their work to a scientific audience.

Fig. 4 - The main hall at the CNR headquarter in Rome during the 26th GNGTS conference.

Starting in 1981, GNGTS has organised its conference yearly, with the sole exception of 1982, at the CNR headquarter in Rome until 2007 (Fig. 4) and later in different locations (see Table 3). Admission to the conference (free of charge) has been substantial since the first year, with more than 200 members, and the number has grown over time to stabilise, then, between 300 and 500 participants. Fig. 5 shows the number of participants at the conference over the years: notable for

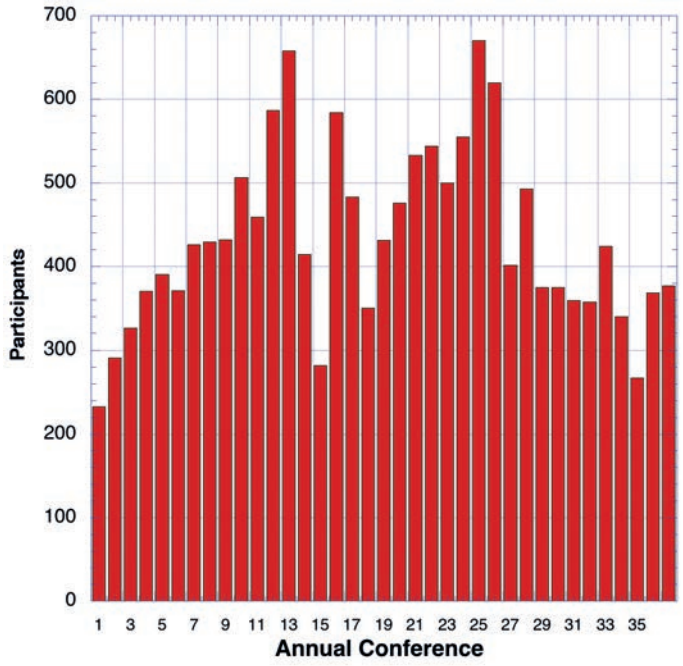

Fig. 5 - Number of participants at the GNGTS conferences.

Table 3 - Locations of the annual GNGTS national conferences.

Conference	Year(s)	Location	Organising institution
1-26	1981 - 2007	Rome	La Sapienza University, Rome
27-28	2008-2009	Trieste	OGS, Trieste
29	2010	Prato	Istituto Geofisico Toscano, Prato
30	2011	Trieste	OGS, Trieste
31	2012	Potenza	Basilicata University, Potenza
32	2013	Trieste	OGS, Trieste
33	2014	Bologna	Emilia Romagna Region, Bologna
34	2015	Trieste	OGS, Trieste
35	2016	Lecce	CNR, Lecce
36	2017	Trieste	OGS, Trieste
37	2018	Bologna	Emilia Romagna Region, Bologna

Fig. 6 - 36th GNGTS conference at the Maritime Station in Trieste: a) the palace; b) the main hall.

Fig. 7 - 35th GNGTS conference in Lecce: a) one of the halls; b) the poster session and instrument exhibition.

the very large audiences were the 13th (1994, year of the Northridge earthquake), 25th (2006, silver anniversary of GNGTS) and 26th (2007) conferences, when there were more than 600 attending and the smaller participation at the 15th (1996) and 35th (2016) conferences, with less than 300 participants. The location of the conference surely plays an important role: Rome and Bologna are easily reachable from everywhere in Italy, but this is not so for Trieste (large participation only the first time in 2008, when it was an agreeable novelty, Fig. 6) and especially for Lecce (35th conference, Fig. 7).

During the national conferences, special sessions were also often held, especially dedicated to specific earthquakes that occurred during the year and, on some particular topics, often of multidisciplinary interest. These multidisciplinary sessions saw the active participation of many researchers from various sectors of Earth sciences, with a beneficial exchange of information, knowledge and points of view, as well as ideas for subsequent successful collaborations and integrations. Even in some "normal" sessions, the presence of non-geophysical researchers is usual, such as geologists, engineers, and, more rarely, sociologists.

The results presented during the conference were collected in printed volumes of proceedings from the first conference until the 15th (in 1996) and from the 31st (in 2012) to the 34th (in 2015) and in CD-Roms from the 16th (in 1997) to the 23rd (in 2004).

A volume of abstracts, transformed to extended abstracts from the 17th conference in 1998 to the 30th in 2011, then at the 35th in 2016 and the 36th in 2017, was always distributed during the conference, with the exception of the years 2012 to 2015, when the proceedings volume was issued.

Fig. 8 illustrates and summarises the type of communications presented during the various conferences and the number of related notes then published in the proceedings. We can see that starting from the 3rd conference the number of presentations exceeded 100 to then level off between 150 and 250 except for the 23rd (year 2004), 25th (2006), and 28th (2009) conferences when they exceeded that number. Conversely, the 18th conference (year 1999) was characterised by a low number of presented papers (only 109).

While initially almost all communications found their way into an article written for the proceedings, over time a certain disaffection has developed and the results of many communications

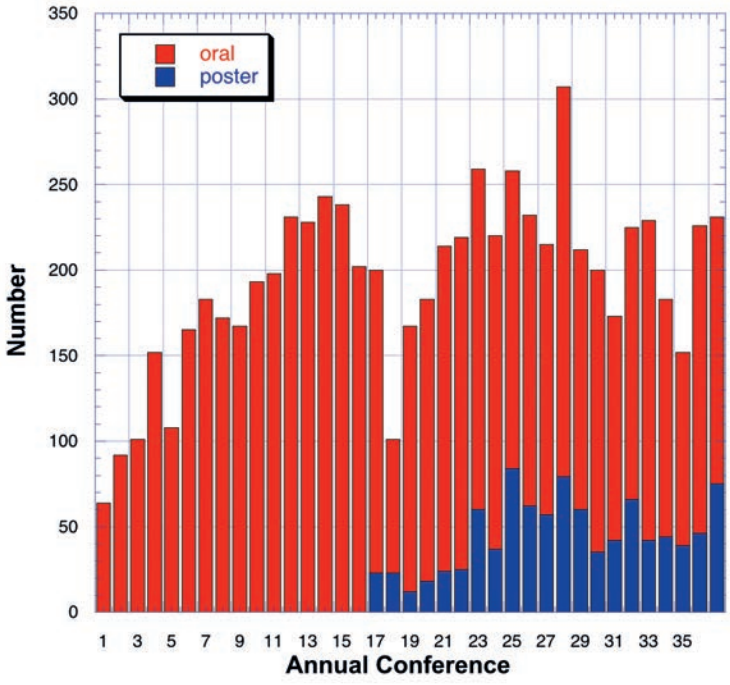

Fig. 8 - Number of papers with full text or abstract published in the GNGTS proceedings or abstract volume.

were not presented in the form of full papers for the proceedings. For this reason, starting from 2005, it was thought to eliminate the proceedings and to print a volume (on a memory stick from 2014 to 2017) of extended abstracts, with figures and bibliography, to be distributed during the conference. This initiative, replacing the volume of the proceedings published and distributed one year after the related conference, offered immediate availability of a significant trace of what was presented during the conference regardless of the final destination of the articles that would gather together the results of the various studies. The idea of the volume of the proceedings, collecting the full papers of the conference, was resumed from 2012 to 2015 with satisfactory agreement but not much enthusiasm by the scientific community. It was, therefore, decided in 2016 to produce the more practicable volume of the extended abstracts once again.

Since 1998, it was decided to offer the researchers the possibility to show their study as a poster presentation instead of only an oral presentation. Fig. 9 shows the number of oral and poster presentations that were made in the different conferences. Generally speaking, it can be seen that a large number of posters is related to the years when numerous oral presentations were scheduled too, but the oral presentation was in general the preferred choice. In some cases, the poster option of a few papers was decided by the convenors of the sessions for organisational reasons.

Selected papers from the different sessions of the conference were published in special issues of the international scientific journal "Bollettino di Geofisica Teorica ed Applicata" (BGTA) of thematic or multidisciplinary topics (see Table 4 for a complete list).

During the conference, the general convention meeting is held, where specific topics of general interest for the geophysical community are discussed and new activities are presented.

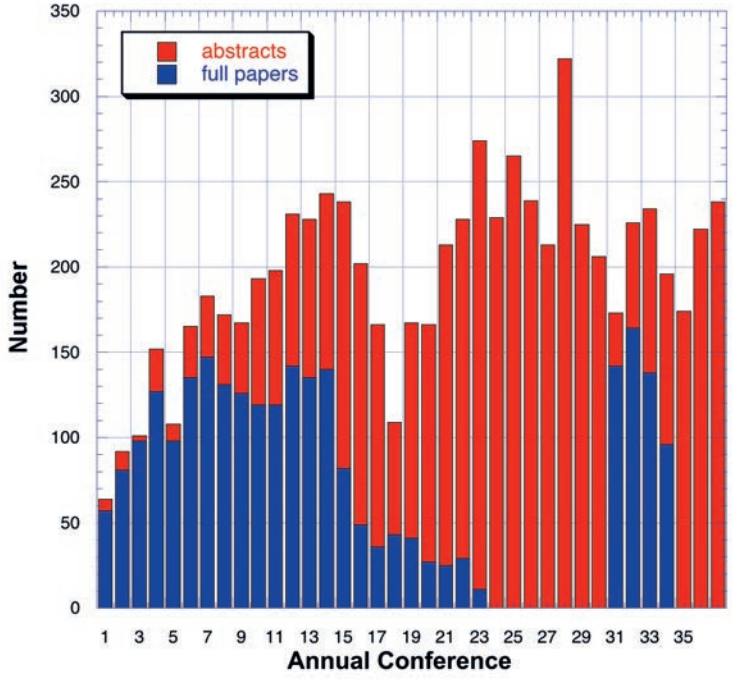

Fig. 9 - Number of oral and poster presentations at the GNGTS conferences.

Table 4 - The special issues of BGTA dedicated to selected papers from the GNGTS conferences.

Conference-year	Editor(s) (year)	Title	BGTA vol./issue
19-2000	Slejko (2002a)	Advances in Solid Earth geophysics	43/1-2
20-2001	Slejko (2002b)	More about Solid Earth Geophysics	43/3-4
21-2002	Marcellini *et al.* (2004)	More about regional and local seismic hazard in Italy	45/4
22-2003	Slejko and Rebez (2005)	A step forward in Solid Earth Geophysics	46/2-3
23-2004	Slejko and Rebez (2006)	New insights into Solid Earth Geophysics	47/1-2
24-2005	Slejko (2007)	Solid Earth Geophysics: a bit of this and a bit of that	48/2
25-2006	Slejko (2008)	Carlo Morelli's mission and passion: Geophysics	49/2
26-2007	Slejko (2009)	Pieces of Geophysics	50/2
27-2008	Slejko (2010)	Novelties in Geophysics	51/2-3
28-2009	Albarello and Slejko (2011a)	Geophysical research in Italy	52/2
28-2009	Amato *et al.* (2011)	The 2009 L'Aquila earthquake: geophysical insights from the 28th GNGTS Congress	52/3
28-2009	Albarello and Slejko (2011b)	Geophysics for prospecting, monitoring, and hazard assessment	52/4
28-2009	Albarello and Meletti (2012)	Earthquake forecasting and hazard assessment	53/1
29-2010	Cardarelli and Slejko (2012)	A little bit of Geophysics	53/3
29-2010	Rossi and Slejko (2012)	The Earth, its phenomena, and some related methods	53/4
30-2011	Grimaz and Slejko (2014)	Geophysics and critical facilities	55/1
35-2016	Persico and Slejko (2017)	Recent multi-topic geophysical investigations	58/4
36-2017	Dolce and Martelli (2019)	Science, technology and communication to support seismic prevention	60/2
37-2020	Rossi and Slejko (2020)	Geophysical solutiones in environmental and natural hazard fields	61/1

The Licio Cernobori Association for Geophysics (AGLC), established on 30 October 2000 in remembrance of Licio Cernobori, a geophysicist who died prematurely, aims at promoting geophysical studies, and above all the scientific training and the development of young researchers. This objective was initially pursued through the awarding of a study prize at the University of Trieste, also open to undergraduates/graduates in applied geophysics of other universities or scientific structures involved in joint projects with the University of Trieste. Since 2010, the AGLC has followed the tradition of assigning the prize to young speakers at the annual GNGTS congress, and the winners are announced and awarded during the general convention meeting. Since 2012, three prizes have been awarded to young researchers working in three main themes of GNGTS: Geodynamics, Seismic characterisation, and Applied Geophysics. Since 2016 the Italian Section EAGE-SEG contributes, by funding one of the prizes.

6. Conclusions

The positive aims of the original GNGTS have unfortunately been lost over time, largely because it has overlooked the role of designing and financing research. Nevertheless, the high number of participants at the annual conference testifies that the Group is still considered the most important meeting point for the Italian geophysical community also because it keeps the researchers in contact via its website (www.gngts.it), where information about the ongoing geophysical activities is published.

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