Preface of the special issue on "Energy, related risks and cascade effects"

Knowledge of phenomena, technology and communication, are fundamental elements for the prevention and mitigation of risks. With this in mind, the "Energy, related risks and cascade effects" sessions were organised as part of Theme 2 "Seismic characterisation of the territory", in the frame of the 2018 and 2019 conferences of the Gruppo Nazionale di Geofisica della Terra Solida (GNGTS).

The main purpose of these sessions was to contribute to the improvement of knowledge on the research and exploitation of energy resources in order to promote sustainable management and greater security of communities. The sessions were also aimed at analysing the Na-Tech risks induced by earthquakes, which can trigger very serious accidents, such as fires, explosions and dispersion of hazardous substances.

Many examples of studies and actions to evaluate and help prevent the effects related to subsidence and induced seismicity were presented. This special issue of the Bollettino di Geofisica Teorica ed Applicata is the twenty-first volume collecting a group of selected papers presented during the sessions of the GNGTS annual national conferences.

The volume starts with the article by Carannante *et al*. (2021) "Detection and location analysis of the Minerbio integrated seismic network (Bologna, northern Italy)" on the seismic monitoring project at the pilot site of the gas storage concession Minerbio Stoccaggio (Bologna), according to the guidelines for the monitoring of microseismic activity, ground deformations and reservoir pore pressure, published in 2014 by the Italian Ministry of Economic Development. In this work, an overview of the detection analysis, performed by the team of the Italian Institute of Geophysics and Volcanology (INGV), during the experimental phase of the above-mentioned guidelines, was presented.

Some preliminary results of an experimental seismic monitoring are proposed by Braun *et al*. (2021) in the paper "On the origin of micro-earthquakes in geothermal areas (OMEGA): first results from a seismic experiment at Mt. Amiata (Italy)". In 2015, in the context of the project OMEGA, jointly carried out by the German Research Centre for Geosciences (GFZ) and the INGV, a seismic monitoring network was installed near the power plants of the Mt. Amiata geothermal area (central Italy), with the purpose of: i) monitoring the seismic activity inside the geothermal field, ii) to verify if the low local seismicity rate near Mt. Amiata reported by the INGV bulletin were either natural or due to the sparse distribution of the INGV network, and iii) to discriminate natural from possibly induced seismicity.

The paper "Seismic rehabilitation of residential buildings: an action plan for the urban centres in Val d'Agri, Italy" by Masi *et al*. (2021) describes an action plan for the seismic risk mitigation of the residential building stock of 18 villages located in a highly seismic area located in the SW of the Basilicata region (southern Italy), along the valley of the Agri River. This area has a strategic role for Italy because about 70% of the Italian oil derives from these oilfields. Large quantities of oil have been extracted since the 1990s, thus, on one hand, causing increasing attention to earthquakes possibly induced or triggered by the oil extraction process and, on the other hand, generating considerable wealth from royalties. These sums of money could be used for an extensive strengthening program able to reduce the impact of future earthquakes. The plan was applied to the village of Viggiano. Starting from the available building-by-building inventory of the typological characteristics, the seismic vulnerability of the whole building stock is studied and the expected losses deriving from an earthquake scenario are determined. Some directions for

an action plan, essentially based on reducing the seismic vulnerability of buildings, are proposed in terms of needed costs and implementation timetables.

The paper by Severi *et al*. (2021) "Oil and gas activities in Emilia-Romagna Region (Italy): land deformation and territory protection" is devoted to monitoring ground movements. The Emilia-Romagna is the third region in Italy for methane exploitation and hosts five gas storage reservoirs (see Carannante *et al*., 2021). The Emilia-Romagna plain is naturally subject to subsidence, by compaction of recent sediments. Subsidence can also be induced, or accelerated, by the extraction of fluids. The resulting ground movements can induce negative impacts on the stability of buildings, coastal erosion, and efficiency of the hydrographic network. This article illustrates the procedures required in the Environmental Impact Assessment (EIA) to estimate the expected subsidence and the solutions to be adopted to counter excessive subsidence rates and ensure the sustainability of gas exploitation and storage.

The paper "A review of impact of subsidence induced by gas exploitation on coastal erosion in Emilia Romagna, Italy" by Calabrese *et al*. (2021) aims at investigating the influence of gas exploitation on the beach erosion. Detailed analyses have been carried out in two critical sites: Reno and Fiumi Uniti deltas. The studies are based on the comparison between the geomorphological evolution and the different phases of the gas withdrawal, including the period when it had not yet been started.

The paper "Soil deformation analysis through fluid-dynamic modelling and DInSAR measurements: a focus on groundwater withdrawal in the Ravenna area (Italy)" by Antoncecchi *et al*. (2021) seeks to assess the deformation processes caused by groundwater withdrawal activities. The analysis was carried out with a multidisciplinary approach in a test area, located in the NW of Ravenna (northern Italy). Data for the 2000-2017 time interval were analysed. *In-situ* data, geologic and structural maps, piezometric measurements, underground water withdrawal volumes and satellite C-band SAR data, were used to jointly exploit two different techniques: 1) fluid-dynamic and geomechanical modelling and 2) Differential Synthetic Aperture Radar Interferometry (DInSAR) analysis. The results of this comparative analysis bring new evidence on the contribution of groundwater withdrawal to the total subsidence affecting the area during the considered time interval.

This special issue closes with a discussion on domino and cascading effects due to triggering hazards. Considering secondary or concomitant events and the complexity of the territorial systems involved can be fundamental for defining risk scenarios. This approach increases the difficulties but allows us to have a more complete view on the effects of dangerous events, not only in the areas directly affected, but also in sometimes unexpected times and spaces. To this end, the paper "Domino and cascading effects in complex events and territorial contexts" by Boni *et al*. (2021) proposes a framework representing the logic sequence of the effects (direct, secondary, etc.) due to different types of hazards (single or cascading, or concurrent), considering the characteristics of the territory, in terms of systemic vulnerabilities, response capacity and interdependencies among the involved sectors. This framework was applied to two real cases occurring during the seismic sequence 2016-2017 in central Italy (landslides triggered by the earthquakes and the snowstorm and the power outages).

In conclusion of this short overview, it is worth underlining that for the sustainable development of underground energy resources it appears essential to analyse the potential risks and effects with a holistic approach. This requires a rigorous awareness and knowledge of the hazards and consequent effects at hand with the involvement of all main stakeholders.

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