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The geosciences perspective on seismic response assessment and application to risk mitigation - Guest Editorial

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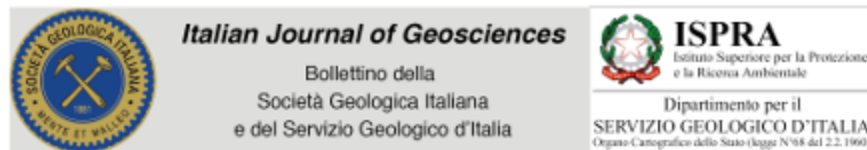
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Special Issue on *Italian Journal of Geosciences*

TITLE

The geosciences perspective on seismic response assessment and application to risk mitigation

Vignaroli G.^{1,2,*}, Di Giulio G.³, Esposito C.⁴, Moscatelli M.², Pagliaroli A.⁵

- 1 - Dipartimento di Scienze Biologiche, Geologiche e Ambientali (BiGeA), Università degli Studi di Bologna, Bologna, Italy; gianluca.vignaroli@unibo.it
- 2 - Istituto di Geologia Ambientale e Geoingegneria (IGAG), Consiglio Nazionale delle Ricerche (CNR), Area della Ricerca di Roma 1, Montelibretti, Italy; massimiliano.moscatelli@igag.cnr.it
- 3 - Istituto Nazionale di Geofisica e Vulcanologia, sede di L'Aquila, Italy; giuseppe.digiulio@ingv.it
- 4 - Dipartimento di Scienze della Terra, Sapienza, Università di Roma, Rome, Italy; carlo.esposito@uniroma1.it
- 5 - Dipartimento di Ingegneria e Geologia, Università degli Studi "G. d'Annunzio" Chieti – Pescara, Pescara, Italy; alessandro.pagliaroli@unich.it

*** Corresponding author:**

Gianluca Vignaroli
Dipartimento di Scienze Biologiche, Geologiche e Naturali
Alma Mater Studiorum, Università di Bologna
Via Zamboni, 67
40126, Bologna (Italy)
gianluca.vignaroli@unibo.it

GUEST EDITORIAL

1. Introduction

Earthquake effects cause dramatic social damage in terms of deaths, injuries and homeless, as well as economic losses when they impact human activities and infrastructures. During the last four decades, the number of people living in areas potentially exposed to earthquakes has almost doubled, as about 2.7 billion people presently reside in seismically active regions. In the period 2001-2020, earthquakes (and tsunamis) were responsible for an average (per year) of 38,000 killed people, more than 6.2 million affected people, and economic losses of about 35 billion US\$ (CRED's Emergency Events Database, 2021; <https://www.cred.be/publications>). Not only the most destructive events (e.g., Sumatra 2004, Haiti 2010, Fukushima 2011), but also minor worldwide distributed earthquakes (about 15,000 per year events with magnitude between 7.0 and 4.0) are continuously revealing the essential role of prevention activities devoted to the assessment, management, and mitigation of seismic risk in urban settlements. This is the case of Italy, one of the Mediterranean regions more prone to seismic activity where even earthquakes of moderate magnitude produced dramatic scenarios of devastated villages and loss of lives. The last earthquakes in northern-central Italy (the 2009 Mw=6.1 L'Aquila event, the 2012 ML=5.9. Emilia event, the 2016-2017 up to Mw 6.5 Amatrice-Norcia sequence) severely damaged many residential and strategic infrastructures, and hundreds of people died after the collapses of structures and unreinforced masonry buildings. For these seismic sequences, several technical and scientific activities were carried out in the emergency and post-emergency phases (i) to collect information related the nature and the source of the seismic event (e.g., Lavecchia et al., 2012; Chiaraluce et al., 2017; Wilkinson et al., 2017; Pezzo et al., 2018), (ii) to identify the extent and evaluation of local site effects in comparison to the building damage pattern (e.g., Tertulliani et al., 2012; Douglas et al., 2015), and (iii) to support reconstruction in the damaged settlements (e.g., Moscatelli et al., 2020; Vessia et al., 2021).

We learnt from these emergency and post-emergency activities that a strategy for seismic hazard assessment and risk mitigation requires the combination of multidisciplinary and multiscale approaches to manage heterogeneous datasets and procedures, which would provide limited knowledge and ambiguous results if taken separately.

A geosciences perspective should aim to overcome these difficulties by integrating specific case histories and methodological approaches to properly investigate the seismogenic process and the site response. Geological, geotechnical, and geophysical data collected during field activities contribute to the formulation of a reliable conceptual model of the subsoil, with a representation of the geological features and the physical and mechanical behaviour of the geomaterials. Based on field data and model results, geoscientists are required (i) to evaluate the ground shaking level at a target site including the soil amplification phenomena due to local geological conditions (Donati et al., 1998; Calderoni et al. 2010; Sarris et al., 2010; Leyton et al., 2013; Fabbrocino et al., 2015; Papadopoulos et al., 2017; Giallini et al., 2020), (ii) to provide map of active faults and their traces at the surface or imaging buried structures (e.g., Ben-Zion et al., 2003; Galli et al., 2014; Tarabusi and Caputo, 2017; Villani et al., 2018), (iii) to assess the liquefaction susceptibility in saturated sandy soils (Wotherspoon et al., 2012; Papathanassiou et al., 2015; Lai et al., 2019), and (iv) to investigate the phenomena related to slope instabilities (Jibson 2007; Terrier et al., 2014; Nowicki et al., 2014; Allstadt et al., 2018; Martino et al., 2020).

A geosciences perspective provides the required link between regional-to-local-scale applications and normative/guidelines devoted to the seismic response assessment and risk mitigation, taking advantage of the upgraded competencies in Earth Science disciplines, and connected with the development of new and improved technological instruments for environmental monitoring and laboratory and in-situ testing.

2. In this Special Issue

This Special Issue would aim to bring together research in seismic response assessment and risk mitigation by strengthening the interaction between different geosciences skills and expertise. The thirteen contributions in this Special Issue cover approaches and strategies for the assessment of the subsoil model and seismic response in complex geological settings. These contributions address the evaluation of critical geodiversities at different scales of observation, from regional-scale urbanised areas to site-specific case histories, through the application of multidisciplinary approaches combining the geosciences concepts with other disciplines involved in natural and anthropic risk assessment. Then, several applications will be presented through the discussion of the seismic microzonation procedures, the methodologies for seismic risk and post-event resilience assessment, the current normative on building codes, the retrospective analysis of activities carried out for post-earthquake reconstruction.

Anelli et al. present a framework to map urban limit conditions for different earthquake scenarios according to the expected percentage of residents in usable buildings as a proxy to measure resilience. The proposed framework is applied to all municipalities in five regions of southern Italy and the results are discussed to understand the consequences of housing functionality losses from a resilience perspective understood as the capacity of an urban system to respond to seismic events and recover from them.

Aristizabal et al. present a comprehensive review paper that covers different approaches for conducting site specific probabilistic seismic hazard assessment estimates. Although the analysis of the authors is restricted to a well-characterised site (Euroseistest-Greece), the paper illustrates the various approaches for conducting site specific analyses including site effects at different levels, and its conclusions may be of global importance towards a realistic seismic hazard assessment.

Bonasera et al. present the results of a study for the identification of the fault responsible for the Tortona earthquake in 1828 (northern Italy). The distinctive feature of the study is the multi-disciplinary approach: archive investigations used to retrieve information on co-seismic effects, together with the analysis of geological, geomorphological and geophysical data, and the review of macroseismic data and earthquake relocations allowed the authors to estimate the location of the fault system causative of the reference seismic event.

Cesarano et al. illustrate a standardised procedure to reclassify geological maps at different scales (namely national, regional and sub-regional), with the aim to tune new scientifically robust procedures capable of optimizing existing available data and returning information useful for risk prevention. The procedure is designed to exploit existing geothematic data sources and provide information relevant for engineering-geological applications, such as mapping areas prone to stratigraphic seismic amplification effects up to assessing the related amplification factor. The potential of such a procedure is illustrated in terms of results obtained at the sub-regional scale in an area of southern Italy in the frame of a project managed by the Italian National Department of Civil Protection.

Falcone et al., based on the case study of the “San Benedetto” school in Norcia (Italy), suggest a procedure to evaluate retrofitting costs over large areas (e.g., regional scale) based on site- and building- specific data. The procedure is essentially based on building fragility curves obtain via recorded data on the building itself (i.e., experimental modal parameters obtained from ambient vibration analysis) and the local seismic site response estimated by means of numerical one-dimensional site response analyses or by means of the simplified technical code approach.

Famà et al. present an inter-disciplinary approach to define the input motion for the seismic analysis of masonry buildings. In particular, the authors show the results of a case study where the seismic

input at the sites of construction of three modern unreinforced masonry buildings caused by the Emilia May 29, 2012 M6.0 earthquake was recreated following three different methods involving natural, artificial, and deconvolved accelerograms. The differences in the results are compared highlighting the intrinsic limitations of the three different approaches.

Mancini et al. provide with a detailed study of seismic microzonation (Grade 3) of the northern and western volcanic setting of the Ischia Island (Italy), where a $M_w=3.9$ seismic event caused diffuse damage pattern and two killed people. The authors document how the structural-stratigraphic settings and the topographic features were responsible for the distribution of the amplification effects. The case study of Ischia Island would provide a reference background for seismic microzonation studies in other complex volcano-tectonic settings that host urbanised areas.

Nocentini et al. deal with the topic of hazards related to the co-seismic collapse of underground cavities. The first part, based on the systematic collection of existing data, is dedicated to a large-scale analysis of the Italian national territory to explore the relationships between seismicity, geological setting and the occurrence of co-seismic sinkholes. Subsequently, a procedure aimed at assessing the related susceptibility at the urban scale (typical of seismic microzonation) is proposed, with specific reference to the Italian regulations but which may have a broader impact on territorial planning. The proposal consists of a stepwise screening procedure that, by applying increasingly accurate (and "data demanding") approaches, starts from the identification of areas of attention on a qualitative basis and can lead to the estimation of the safety factor for the co-seismic collapse of individual cavities.

Riccio et al. analyse earthquake weak ground motions and ambient noise measurements to investigate local site effects in the Val d'Agri basin (southern Italy), one of the areas of highest seismic hazard in Italy where the presence of widespread residential buildings with high seismic vulnerability, a water reservoir, and infrastructures related to hydrocarbon exploitation contribute to increasing the local seismic risk. The results of this study evidence the role played by i) the basin edge effects and ii) the lateral heterogeneities of filling deposits on the observed ground motion amplifications.

Riga et al. investigate the effects of the method applied for modelling site conditions and site amplification in urban risk assessment using as test site Thessaloniki, Greece. In particular, the authors compare seismic hazard and risk results obtained using two different approaches for site conditions/site amplification modelling. Four seismic hazard models are obtained by the authors and the risk assessment is presented in terms of expected damages and economic losses for 475-year return period.

Salvatore et al. investigate the potential of liquefaction in gravelly soils with a multidisciplinary approach which combines in-situ tests, laboratory geotechnical analysis and geological studies. The paper is focused on a case history in Central Italy (Sulmona) but includes a short section on state-of-art on worldwide liquefaction of gravelly soils. The authors illustrate how borehole log with standard geotechnical laboratory information and geological studies are fundamental to achieve a reliable assessment of the liquefaction hazard.

Spacagna et al. propose a methodological approach to define maps in terms of liquefaction susceptibility at two different geographical scales (i.e., regional and sub-regional scale). The Calabria region in Southern Italy, characterised by a relatively high level of seismicity and liquefaction occurrences recorded during the numerous historical earthquakes, has been selected as test area. At the sub-regional scale, the quantitative assessment of the liquefaction predisposition is expressed by a new index (namely the Territorial Liquefaction Predisposing Index, TLPI) producing maps in which the uncertainties are also highlighted giving essential information to address the location of further investigations for a higher analysis level of detail.

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Testa et al. (2021) present the first application of the probabilistic fault displacement hazard analysis in Italy. The Authors carefully assess the displacement of the Anghiari – Città di Castello Fault (northern Apennines) with the aim to explore the hazards for infrastructures and buildings located near active and capable faults. Displacement hazard maps for the Anghiari – Città di Castello Fault are compared with the “Attention Zone for Active and Capable Fault” requested by the Italian guidelines for seismic microzonation.

3. Conclusions

The thirteen papers collected in this Special Issue address the evaluation of critical geodiversities in seismically active regions at different scales of observation, from regional-scale urbanised areas to site-specific case histories, sometimes with a specific focus on providing useful tools and methods to efficiently transfer scientific knowledge to institutional stakeholders. This Special Issue stresses the importance of geoscience-based multidisciplinary approaches and, as final goal, would promote a strong connection between researchers, professional individuals, and authorities involved in urban planning, land use management, emergency planning, seismic design, and post-earthquake reconstruction.

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