ANNALS OF GEOPHYSICS, 59, Fast Track 5, 2016; doi: 10.4401/ag-7373

Preface

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I. INTRODUCTION

The M=6.0 earthquake that struck central Italy at 01:36 UTC (Universal Time Coordinated) on August 24, 2016, marked the beginning of a long, still-ongoing seismic sequence, which culminated in the Mw 6.5 event at 06:40 UTC on October 30, 2016, while this volume was already in preparation, and reactivated again when this preface was almost complete. This dramatic seismic sequence, which on January 18, 2017, released four additional events of M between 5.0 and 5.5 in a few hours, caused 298 casualties, hundreds of injuries, and the practically total destruction of several villages across a wide area of the central Apennines, covering the Italian Regions of Lazio, Umbria, Marche and Abruzzo. In particular, the historical village of Amatrice was completely destroyed.

This seismic sequence represents an important new case study for Earth scientists only 5 years after the Ml 5.9 destructive event in the Emilia-Romagna region in 2012 [Scognamiglio et al., 2012] and 7 years after the Mw 6.3 L'Aquila earthquake of April 6, 2009 [Chiarabba et al., 2009]. During these few years, the skill of the scientific community and its reaction to the emergencies of large destructive earthquakes have improved: the earthquake epicenter and source parameters were precisely located within a few minutes of the mainshock, while the acquisition of on-site multiparametric data started just a few hours after the onset of the seismic sequence. Seismological, geodetic, geological and geochemical data were rapidly collected and analyzed to identify the features of the seismogenic source and the geological structures responsible for these earthquakes. The level of damage, the effects on the environment and the extension of ground deformations were rapidly assessed with the ultimate goal of better understanding earthquake characteristics in order to respond to civil protection requirements. Preliminary data were shared worldwide through the internet *via* the www.ingv.it webpages, while scientific information to the media was rapid and exhaustive, also through dedicated pages (https://ingvterremoti.wordpress.com/).

Less than three months after the mainshock, the Istituto Nazionale di Geofisica e Vulcanologia (INGV) is now publishing a collection of the first scientific results in this special issue of Fast Track papers of Annals of Geophysics, vol. 59, n. 5, 2016, entirely dedicated to *The Amatrice seismic sequence: preliminary data and results*, as in the case of the 2012 Emilia earthquake [Anzidei et al., 2012].

Papers are freely available online at the web site of Annals of Geophysics (http://www.annalsofgeophysics.eu/), for the rapid distribution of these scientific results. This special issue represents an important goal for the INGV and the whole scientific community which was involved in the study of this seismic sequence.

II. ORGANIZATION AND VOLUME CONTENTS

The large amount of information is collected in 57 brief, but exhaustive, papers. Readers will find preliminary results of scientific interpretations of instrumental data and field observations. Namely, the spatial and temporal evolution of the seismic sequence, responsible faults, surface geological effects, coseismic crustal deformations, changes in geochemistry of groundwater and the considerations of seismic hazards for central Italy. Some papers introduce the reader to the geological [Falcucci et al., 2016-this issue; Bonini et al., 2016-this issue; Moro et al., 2016-this issue; Pucci et al., 2016-this issue] and historical seismological features [Castelli et al., 2016-this issue; Valensise et al., 2016-this issue] and the regional stress field [Mariucci and Montone, 2016-this issue] of the earthquake area, while others refer to the collection and analysis of instrumental data during the seismic sequence. Seismological data are shown and discussed by Ciaccio et al. [2016-this issue], Scognamiglio et al. [2016-this issue], Marzorati et al. [2016-this issue], Roselli et al. [2016-this issue], Michele et al. [2016-this issue], Lanzano et al. [2016-this issue], Marchetti et al. [2016-this issue], Pondrelli et al. [2016-this issue], Moretti et al. [2016-this issue], Massa et al. [2016-this issue], while Cheloni et al. [2016-this issue] and Avallone et al. [2016-this issue] report on static and dynamic coseismic crustal deformation observations. The analysis of remote sensing data from InSar observations is described by Romaniello et al. [2016-this issue] and Bignami et al. [2016-this issue], while geochemical data, including trends in radon concentrations at some continuous monitoring stations, are presented by Ciotoli et al. [2016-this issue] and Cannelli et al. [2016-this issue]. These studies all explore different aspects of the earthquake, providing an overview of the first interpretations and the available multiparametric data sets rapidly collected and analyzed during the seismic crisis. Finally, this issue concludes with a few contributions about the dissemination of information through popular social media communication channels [Pignone et al., 2016a-this issue; Pignone et al., 2016b-this issue; Musacchio and Piangiamore, 2016a-this issue; Musacchio et al., 2016a-this issue]. Although these papers are not strictly scientific papers, they highlight the relevance of rapid and exhaustive dissemination of the scientific information to population.

Most of the contributions presented in this issue, independent of their principal subject, show the rapid reaction of the emergency groups right after the event. Their organization was based and tuned on the experience gained during the previous seismic crises that struck the Italian peninsula during the last two or three decades. The SISMIKO team rapidly installed a set of temporary seismographic stations [Moretti et al., 2016-this issue], while the EMERGEO team [Pucci et al., 2016-this issue] and others [Aringoli et al., 2016-this issue; Livio et al., 2016-this issue] provided data on the geological and geomorphological co-seismic effects observed at the topographic surface. Measurements of the co-seismic crustal deformations are presented by the GPS team that analyzed data from the available permanent GNSS networks and installed a set of temporary geodetic stations on the existing benchmarks within a few hours of the mainshock. Macroseismic data are presented by the QUEST group [Azzaro et al., 2016-this issue], and other teams [Zanini et al., 2016-this issue; Galli et al., 2016-this issue; Hofer et al., 2016-this issue] that surveyed and mapped the damage to hundreds of buildings, using the most recent macroseismic scales. Rapid information on the extension of the area throughout which the earthquake was felt across Italy was retrieved by online questionnaires [De Rubeis et al., 2016-this issue]. Side by side with these on-site activities, are described seismological data and products, such as the location and magnitude of seismic events [Michele et al., 2016-this issue; Marchetti et al., 2016-this issue], even for earthquakes of $M<1.0$, often hidden by the waveforms of larger seismic events. The huge number of earthquakes recorded by the seismic networks during the seismic sequence required advanced management of the large amount of digital waveform data, including preliminary analysis and careful storage [Pintore et al., 2016-this issue]. The

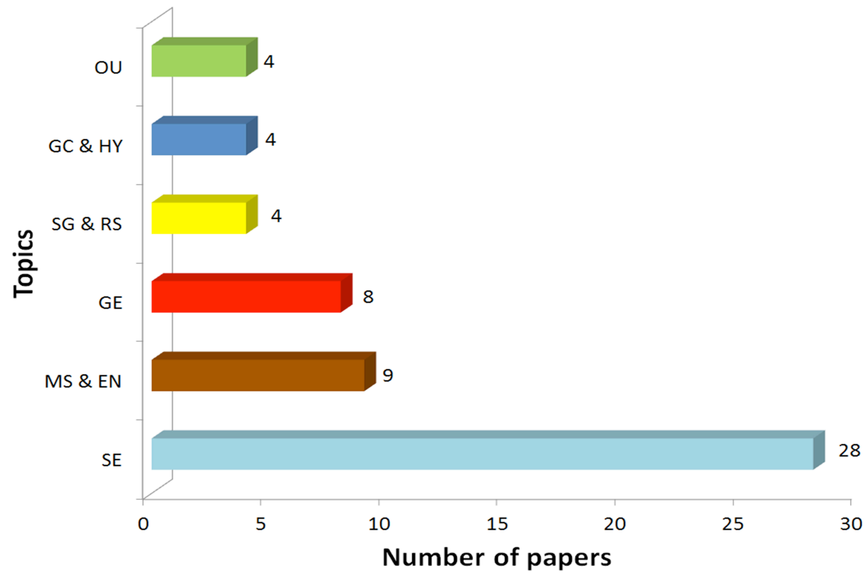

Figure 1. *Paper classification published in this volume, based on their main topics (OU, Outreach; GC & HY, Geochemistry and Hydrology; SG & RS, Space Geodesy and Remote Sensing; GE, Geology; MS & EN, Macroseismic and Environment; SE, Seismology).*

seismic moment tensors were calculated using different methods by multiple independent groups [Pondrelli et al., 2016-this issue; Scognamiglio et al., 2016-this issue], providing key information on the size of the earthquakes, the Mw moment magnitude and the focal mechanisms, to allow extended fault modelling. The latter is derived from a combination of different data sources including seismological [Magnoni and Casarotti, 2016-this issue; Saccorotti et al., 2016-this issue], geodetic [Cheloni et al., 2016-this issue; Avallone et al., 2016-this issue] and InSAR [Bignami et al., 2016-this issue]. The directivity of the earthquake propagation during the rupture is investigated by Spagnuolo et al. [2016-this issue], while Montuori et al. [2016-this issue], Meletti et al. [2016-this issue] and Murru et al. [2016-this issue] focus on the seismic hazard assessment and the b-value of the seismic sequence.

Seismological data also focus on the features of the ground shaking and related site effects. In this regard, the strong motion data presented by Cultrera et al. [2016-this issue], Massa et al. [2016-this issue], Ladina et al. [2016-this issue], Pischiutta et al. [2016-this issue], together with the shake-maps by Faenza et al. [2016-this issue], represent key information for the interpretation of structural damage experienced by buildings that responded with different modes to ground shaking depending on their features and locations [Gaudiosi et al., 2016-this issue; Masi et al., 2016-this issue; Caserta et al., 2016-this issue]. On this topic, Iervolino at al. [2016-this issue] present preliminary engineering data while de Silva et al. [2016-this issue] write on the response of shaking rigid bodies, to seismic waves.

Ground deformations, as estimated by analyzing data from the available continuous monitoring GPS stations, were elaborated by different groups, providing a consensus solution on the amount and trend of horizontal and vertical ground displacement and locating the responsible faults at depth [Cheloni et al., 2016-this issue]. High Rate geodetic data (HR-GPS), collected in the range 1-10 Hz, were also used for the seismological analysis of the co-seismic ground movements [Avallone et al., 2016-this issue]. GPS data also supported the remote sensing observations of InSAR data that provided very high resolution images of the features and extension of continuous surface deformations in relation to surface faulting, from which were estimated different models of the buried faults [Bignami et al., 2016-this issue]. The latter were also compared with the evidence of surface faulting reported by the EMERGEO team, to separate primary and secondary superficial co-seismc effects, or even gravitational motions [Albano et al., 2016-this issue; Aringoli et al., 2016-this issue; Falcucci et al., 2016-this issue; Bonini et al., 2016-this issue; Valensise et al., 2016-this issue].

Finally, some papers describe the dissemination of earthquake information. This subject has become increasingly important in the recent years due to the large impacts that earthquakes have had on the media [Musacchio and Piangiamore, 2016-this issue]. Particularly important is the role of science feeding the information system, using also the most popular social media, like Twitter or blogs (i.e. INGVTerremoti blog) [Pignone et al., 2016b-this issue], and showing unprecedented images of wave propagation [Casarotti et al., 2016-this issue] and GIS maps [Pignone et al., 2016-this issue].

III. Future perspectives

In 1980, when the Irpinia area was struck by an M 6.8 earthquake that caused 3000 deaths, 9000 injured and 100,000 homeless [Bernard and Zollo, 1989], it took several days to locate the earthquake epicenter and several months were required to understand the very first features of the earthquake. Nowadays, 36 years after this destructive and tragic event, thanks to the great development of ground geophysical networks and the advent of spatial techniques and with the experience gained from previous seismic crisis in Italy (i.e. the Umbria-Marche, 1997; Molise, 2003; L'Aquila, 2009; Emilia, 2011; and finally the 2016 central Italy seismic sequence) and elsewhere, the scientific community was prepared to face this new challenge and its actions allowed the collection of an unprecedented amount of multiparametric data. These represent the basis for new scientific advancements for the comprehension of earthquakes that will help to delineate improved monitoring strategies. In this regard, ETAS modelling [Lombardi, 2016-this issue] and probabilistic seismic hazard analysis (PSHA) [Peruzza et al., 2016-this issue], are two of the most attractive techniques for the prediction of an aftershock sequence during a seismic crisis, while spatial data from artificial satellites, namely InSAR and GPS, will improve the continuous monitoring of the movements of the Earth's surface during a seismic cycle.

Results presented in this volume are already enhancing our knowledge of the seismicity and seismic hazard of the Italian region.

Acknowledgements

The preparation of a special issue in such a short time has been a great challenge that would not have become a reality without the valuable contributions of the many reviewers who enthusiastically supported us. Their work has been of the utmost importance, and for this reason we wish to sincerely acknowledge the colleagues who worked towards this goal.

Most of studies and activities described in this volume benefit from the support of the Department of Civil Protection.

We dedicate this volume to our beloved colleagues Bruno De Simoni and Marco Mucciarelli, who both passed away in 2016.

Bruno was a Research Director of the ING and later of the INGV. His long-lasting work focused on the first realization of the modern National Seismic Network. He also directed the SISMOS project for the recovery of historical seismograms and seismographs.

Marco was Research Director at the OGS and his activity mainly focused on seismic hazard. His studies provided great improvements on the knowledge of the historical and current seismicity of Italy and surrounding regions.

We are thankful to Bruno and Marco for their valuable work, always carried out with enthusiasm and cheerfulness.

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