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Alessandro Maria Michetti, Daniela Pantosti, Eutizio Vittori

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The Mw 5, 2013 Matese earthquake epicentral area (southern Italy): new data on the earthquake ground effects and active tectonics framework

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Abstract: *The Matese ridge area (southern Apennines) is located in one of the most seismically active sectors in Italy. On 29th December 2013, it was affected by a Mw=5 earthquake. In the Matese area, we are carrying out a study aimed at identifying and characterizing active faults at the surface through the integration of geomorphological, structural and soil gas data, and at outlining the ground effects of the 2013 earthquake. The new data indicate that the active fault system is more complex than previously assessed. In addition, our estimation of the epicentral intensity of the 2013 earthquake according to the ESI scale (Michetti et al., 2007) indicates that earthquakes of relatively low energy may trigger noticeable environmental hazards.*

Key words: *Active faults, seismically induced ground effects, geomorphology, soil gas, southern Apennines.*

INTRODUCTION

The Matese area (southern Apennines), which falls in one of the most seismically active sectors of Italy, has recorded in historical times a number of earthquakes with a magnitude of around 7 (e.g., Esposito et al., 1987; Gasperini et al., 1999; Galli & Galadini, 2003; Fracassi and Valensise, 2007; Serva et al., 2007; Locati et al., 2011; Rovida et al., 2011; Fig. 1) and frequent moderate earthquakes. From December 2013 to January 2014, the Matese ridge area was affected by a seismic sequence. The main event, which occurred on December 29th 2013, was characterised by a moderate magnitude (17:08 UTC, Mw 5.0, according to ISIDE; http://iside.rm.ingv.it) and caused damage corresponding to a maximum intensity of VII MCS in the Piedimonte Matese and Faicchio villages (Convertito et al., 2014). The earthquake, the epicentre of which has been localized in the southeastern part of the Matese ridge, at a hypocentral depth of 12 km (Fig. 2; D'Amico et al., 2014; Milano, 2014), was also felt in the towns of Isernia, Caserta, Benevento, Napoli, Avellino and Salerno (location in Fig. 1).

In the 2013 earthquake epicentral area, and in the surrounding Matese ridge - Alife alluvial plain area, we are carrying out a study aimed at outlining the active tectonic framework by identifying and characterizing active faults at the surface based on the integration of geomorphological, structural and soil gas data. The field surveys and the collection of reports and information from local people have also allowed recognition of several ground effects that may have been directly related to the 2013 earthquake.

The ~2000 m high Matese ridge is located in the Campania-Molise sector of the southern Apennines. The southern Apennines is a NE-directed fold and thrust belt that formed from the Miocene to Quaternary.

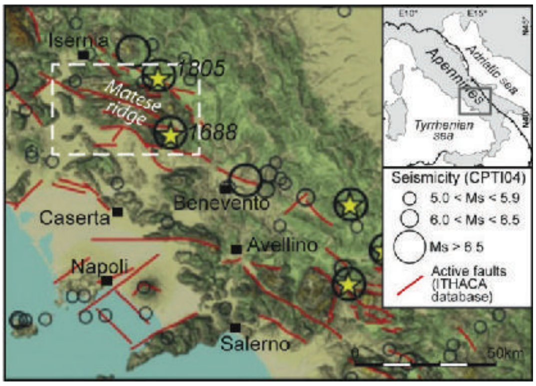

Figure 1: Historical earthquakes (Ms>5.0) in the southern Apennines according to CPTI (2004). The withe box indicates location of map in Fig. 3. (After Serva et al., 2007 modified).

Ceasing of thrusting occurred in the early part of the Middle Pleistocene, and was followed by the onset of a new tectonic regime with NE-SW oriented maximum extension (e.g., Cello et al., 1982; Cinque et al., 1993; Montone et al., 1999; Patacca et al., 2008). The structures related to this regime include extensional faults that dissect the thrust belt (e.g., Cello et al. 1982; Ascione et al., 2013). Based on fault-plane solutions, normal faults also control seismicity in the mountain belt, which is affected by low to moderate events punctuated by strong earthquakes, mostly following the chain axis and originating on NW-SE trending faults (e.g., DISS Working Group, 2010).

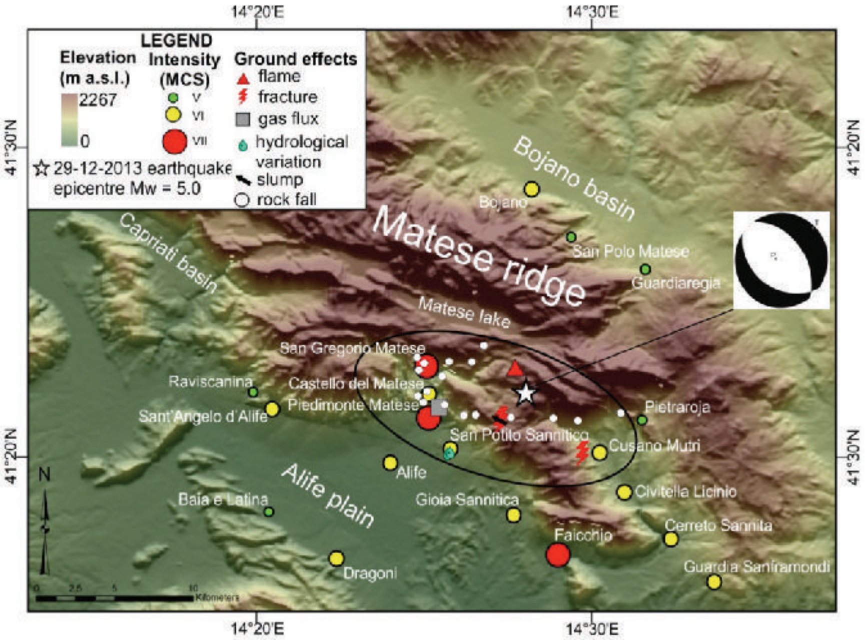

Figure 2: Epicentre location (http://iside.rm.ingv.it) of the M=5, December 29th 2013 Matese earthquake, MCS intensity recorded in the main villages of the Matese area (from Convertito et al., 2014) and main ground effects associated with the earthquake.

In the Matese area, tectonic units of the fold and thrust belt are composed of Mesozoic-Tertiary successions overlain by Neogene foredeep basin deposits. From top to bottom, these units consist of carbonate successions (Apennine Platform, outcropping in the Matese ridge), pelagic basin successions (Molise-Sannio Basin, outcropping to the N and E of the ridge), and the buried Apulian platform carbonates (Mazzoli et al., 2000). The thrust pile is dissected by NW-SE and E-W trending high-angle faults reactivated by the Middle Pleistocene to Present extensional regime (Mazzoli et al., 2000, and references therein). The main Quaternary extensional faults bound the Matese ridge towards the NE and SW, with the latter ones lowering the top of the carbonates below the sea level in the Alife alluvial basin (Corniello & Russo, 1990). Late Quaternary activity of mainly NW-SE, WNW-ESE and E-W trending faults in the Matese ridge and adjoining alluvial basins has also been recognised (Cinque et al., 2000; Galli & Naso, 2009).

In the Matese area, strong historical earthquakes with a high level of damage (I>X MCS) occurred in 1456, 1688 and 1805 (Fig. 1). The December 1456 earthquakes were probably the most powerful in Italy, with different epicentral areas spanning from the Abruzzo to the Campania regions (Figliuolo, 1988), Imax=XI MCS, M=7.2 (Rovida et al., 2011). The M=7, I=XI MCS June 5th 1688 earthquake hit the southeastern area of the Matese ridge causing the destruction of Cerreto Sannita and Civitella Licinio and heavy damage in 130 localities in the districts of Benevento, Avellino and Caserta. About 10,000 casualties have been estimated (Serva, 1985; Rovida et al., 2011). In 14 localities, including Cerreto Sannita and the town of Benevento, seismically induced effects mainly consisted of slope movements, however ground cracks and hydrological variations were also observed (Porfido et al., 2007; Serva et al., 2007). On July 26th, 1805, a destructive earthquake with a maximum intensity of I=XI MCS and an estimated magnitude of 6.7 (Fig. 1; Esposito et al., 1987) hit the Molise Region and part of Campania. This earthquake damaged over 200 localities and claimed more than 5,000 lives. Based on the review of historical documents, and consistent with geological investigations (Guerrieri et al., 2000; Michetti et al., 2000b; Porfido et al., 2002), a large number of effects on the natural environment were identified in 50 municipalities located both in the near and far field areas. Primary effects such as surface faulting, and secondary effects including hydrological anomalies, ground cracks, slope movements, ground settlements were recorded (Porfido et al., 2002; Porfido et al., 2007; Serva et al., 2007). Along the Campania coast tsunami waves were observed (Mallet, 1852-1854; Baratta, 1901), classified with Intensity 2 in the Euro-Mediterranean Tsunami Catalogue (Maramai et al., 2014).

In the last few decades, the Matese area has been affected by low-magnitude background seismicity characterised by both sparse earthquakes and seismic sequences (Milano et al., 2005; Chiarabba et al., 2011). The M=5 earthquake which struck the Matese area on December 29th 2013 was characterised by a normal faulting focal mechanism and a NE oriented T axis (http://cnt.rm.ingv.it/tdmt.html), consistent with moment tensor solutions for 31 small to moderate events of the entire December 2013-January 2014 seismic sequence (e.g., D'Amico et al., 2014).

DISCUSSION

The study we have carried out has allowed the detection of a dense net of faults showing geomorphological-stratigraphical evidence of late Quaternary activity in the Matese area. Such evidence, coupled with the analysis of longitudinal profiles of more than 40 streams, has also provided information on the spatial distribution of large-scale vertical motions.

Faults showing evidence of activity in the late Quaternary include few major structures with WNW-ESE and NW-SE trends and lengths around 10 km. These occur at the boundary of subsiding alluvial basins, e.g., the Capriati basin (e.g., Cinque et al., 2000; Galli & Naso, 2009), the Alife plain and the Matese Lake. In addition, several strands, characterised by mainly N-S and E-W trends, relatively small offsets and a small size (few km long) are identified within both major topographic highs and lows. Such minor structures probably represent the response to local variations in the regional stress field (Ascione et al., 2014). In the southeastern part of the Matese ridge, recent vertical motions are suggested by the presence, in the top surface, of small-size dammed basins and by features of the active/relic fluvial network (wind gaps, water gaps).

Important information on the features of the southern Matese active fault system has been obtained through the detection of anomalous emissions of several gas species (CO_2, CH_4, Rn and He) along fault strands in the western part of the study area (Fig. 3; Ascione et al., 2014). Such emissions, pointing to strong gas leakage along active fault strands, suggest that the southern Matese active fault system is composed of a complex fracture network linking surface faults to deeply rooted structures.

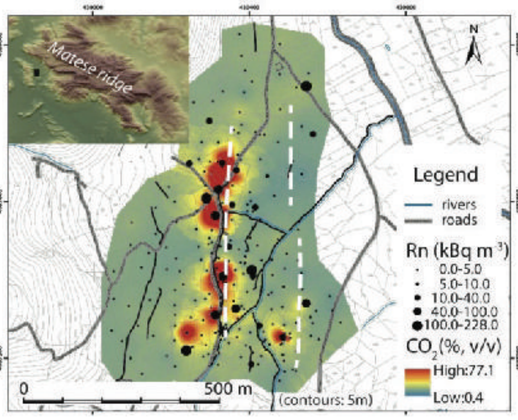

Figure 3: Soil gas (CO_2 and Rn) emission detected in the Colle Sponeta area (location in inset map). The main soil gas anomalies are aligned along active fault traces (dashed white lines).

The December 29th 2013 earthquake has induced a series of ground effects, which include small size landslides (mostly rock falls) and hydrological variations. Several rock falls have affected the roadcuts in the area between Piedimonte Matese and San Gregorio Matese. In the latter site, damages to the aqueduct have also been reported. Associated with the seismic sequence, variations in the spring discharge, and an increase in the turbidity of spring water at one of the major springs have also been recorded (Fig. 2). Local people described the occurrence of a flame in an area very close to the instrumental earthquake epicentre (Fig. 2) at the very beginning of the main shock. This localised effect, commonly observed during earthquakes (Oddone, 1915), is frequent in those areas in which strong gas (methane and/or hydrogen) emissions are detected (Ascione et al., 2014). Following this phenomenon, a further soil gas investigation in the epicentre area is presently being carried out. A coseismic scarp up to around 40 cm high, around 50 m long, striking N120 and facing NE (Fig. 4) has been identified in the Matese ridge top surface, at a distance of about 2.5 km to the SW of the earthquake epicentre (Fig. 2). The scarp follows a WNW-ESE trending fault damming a small size, internally drained basin. In particular, it affects the northeastern slope of a subdued carbonate ridge, which bounds the basin to the SW. Such a scenario allows hypothesising that the scarp results from coseismic fault reactivation. However, further investigations are being carried out with the aim of assessing whether such scarp represents a primary or secondary earthquake effect. In fact, taking into account the scarp features (height and length) and those of the 2013 earthquake (magnitude and hypocentral depth), an origin of the scarp as local effect (e.g., compaction of fault breccia) cannot be ruled out.

Figure 4: The around 40cm high, N120 trending, NE-facing coesismic scarp in the Piano d'Amore area (Matese ridge).

The spatial distribution of the ground effects (which cover an area of around 90 km^2; Fig. 2) allows for the estimation of the epicentral intensity according to the ESI Scale (Michetti et al., 2007). The resulting evaluation is I_0 = VIII ESI, a value exceeding by one degree the former MCS scale intensity evaluation by Convertito et al. (2014).

The new data on the 2013 earthquake ground effects, and on the spatial distribution, geometry and gas-bearing properties of active faults provide information crucial to the assessment and mitigation of seismic hazards in the Matese area. Our data point to the occurrence, in the Matese area, of a deformation pattern at the surface more complex than previously assessed. In addition, the M=5, 29th December 2013 earthquake ground effects indicate that earthquakes of relatively low energy and intensity barely exceeding the damage threshold of man made structures, may trigger noticeable environmental hazards. Such information provides a more complete perspective on an earthquake scenario, which should be seriously considered in the framework of both seismic hazard prevention and mitigation, and, on a local scale, civil planning.

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