GROUND DEFORMATION AND SOURCE GEOMETRY OF THE 30 OCTOBER 2016 MW 6.5 NORCIA EARTHQUAKE (CENTRAL ITALY) INVESTIGATED THROUGH SEISMOLOGICAL DATA, DINSAR MEASUREMENTS AND NUMERICAL MODELLING

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We investigate the M_w 6.5 Norcia (Central Italy) earthquake by exploiting seismological data, DInSAR measurements and a numerical modelling approach. In particular, we first retrieve the vertical component (uplift and subsidence) of the displacements affecting the hangingwall and the footwall blocks of the seismogenic faults identified, at depth, through the hypocentres distribution analysis. The Norcia earthquake activated the SW-dipping Mount Vettore fault system, characterized by extensional/transtensional kinematics and dissecting the heterogeneous clayey/marly to carbonatic sedimentary succession of the Umbria-Marche Apennines (Barchi *et al*., 2012); the Mount Vettore fault system is ~18 km long and consists of a series of SW-dipping faults (34–75°; Galadini and Galli, 2003). Moreover, the uplifted footwall block is not significantly affected by seismicity, whereas the uplifted area in the hangingwall block is bounded by a well-developed cluster of seismicity nearby the town of Norcia. In order to constrain the geometry and location of the tectonic structures involved during the Norcia earthquake, we take into account the relocated hypocentres (Chiaraluce *et al.,* 2017) with $0.1 \leq M_w \leq 6.5$ that occurred between 24 August and 29 November 2016, recorded by the INGV seismometric network. Specifically, once projected the relocated hypocentres onto sections, we highlight three different geological structures: (i) a SW-dipping alignment parallel to the main fault system, characterized by principal faults striking N150°– 160° and dipping 45°–55°; (ii) an E-dipping low-angle normal fault cutting through the upper crust; the relocated earthquakes highlight a flat structure which is located at most between about 8 and 10 km of depth and can also reach greater depths (down to about 12 km). This low-angle structure is the lower bound of the whole normal fault system, which is confined within the first 8 km of the upper crust, and coincides also with the lower limit of seismicity, the decollement surface; (iii) ENE-dipping structures that are antithetic to the main fault.

In this context, we focus on the analysis of the vertical displacements retrieved from DInSAR measurements. In particular, we use two interferometric pairs acquired by the ALOS-2 system: the first one was acquired along the ascending orbits on 24 August and 2 November 2016, respectively (Tab. 1); the second one was acquired along the descending orbits on 31 August and 9 November 2016 (Tab. 1), respectively. By combining the radar line-of-sight (LOS) displacements retrieved from these interferometric pairs, we compute the Vertical and the E-W displacement maps of the coseismic ground deformations, respectively. In particular, the vertical displacements are subsequently used for our rock volumes analysis. The retrieved map displays four main patterns: (i) a major subsidence reaching its maximum value of about 98 cm near the epicentral zones nearby the town of Norcia; (ii) three smaller uplift zones, one lobe that affects the hangingwall block (reaching maximum values of about 14 cm), a second one that affects the footwall block (reaching maximum values of about 10 cm) and an elongated easternmost deformation pattern (nearly parallel to the main Apennines structures).

Tab. 1 - Coseismic interferometric pair exploited for the DInSAR analysis. ALOS-2 data pairs involving both the 26 October Visso and the 30 October Norcia events.

Sensor	InSAR pair	Orbit	Wavelenght (cm)	Perpendicular baseline (m)	Track	Look angle (deg)
ALOS-2	24082016-02112016	ASC	24.2	99	197	36.6
ALOS-2	31082016-09112016	DESC	24.2	59	92	32.8
ALOS-2	24082016-06092017	ASC	24.2	99	197	36.6
ALOS-2	31082016-24052017	DESC	24.2	59	92	32.8

To better discriminate which are the actual zones affected by ground deformation, we use two other interferometric pairs acquired by the ALOS-2 satellite. Specifically, one pair was acquired along the ascending orbits on 24 August 2016 and 6 September 2017, respectively; the second pair was acquired along the descending orbits on 31 August 2016 and 24 May 2017, respectively (Tab. 1). The analysis of this second data pair allows us to show that the elongated easternmost deformation pattern located in the footwall block is not clearly visible anymore; accordingly, we hypothesize that it is probably generated by atmospheric phase artefacts correlated with the topography of the area. Therefore, we consider that the ground surface affected by deformation phenomena are relevant to the central subsided area and the two adjacent uplifted lobes.

Starting from these evidence, we compute the rock volumes affected by uplift and subsidence phenomena, highlighting that those involved by the retrieved subsidence are characterized by significantly higher deformation values than those affected by uplift (about 14 times). In order to provide a possible interpretation of this volumetric asymmetry we extend our analysis by applying a 2D numerical modelling approach based on the finite element method, implemented in a structural-mechanic framework and exploiting the available geological and seismological data and comparing the results with the ground deformation measurements retrieved from the multi-orbit ALOS-2 DInSAR analysis. In this case, we consider two different scenarios, the first one based on a single SW-dipping fault, the latter on a main SW-dipping fault and an antithetic zone. In this context, the model characterized by the occurrence of an antithetic zone presents the retrieved best fit coseismic surface deformation pattern. The results of our 2D modelling highlight that the presence of an antithetic zone is necessary to reach the best fit between measured and simulated coseismic surface deformations. This scenario allows us to justify the occurrence of subsidence and uplift phenomena caused by the M_w 6.5 Norcia earthquake as the result of combination of pure double couple mechanism along the main fault and gravitational accommodation of the involved rock volumes.

References

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