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Newly incepted faulting or extensional reactivation of a large thrust ramp? Understanding the source of the 30 October 2016, Mw 6.5 Norcia earthquake (Central Italy)

Gianluca Valensise (1), Lorenzo Bonini (2), Francesco Emanuele Maesano (1), Roberto Basili (1), Valentina Cannelli (1), Umberto Fracassi (1), Daniele Melini (1), Gabriele Tarabusi (1), Mara Monica Tiberti (1), and Paola Vannoli (1)

(1) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy (gianluca.valensise@ingv.it), (2) Dipartimento di Matematica e Geoscienze, Università di Trieste, Italy

The 30 October 2016, Mw 6.5 Norcia earthquake is the largest shock of the 2016-2017, Central Italy earthquake sequence. The focal mechanisms, the deformation detected by InSAR and GPS observations and the observed surface ruptures all suggest that the sequence was generated by a set of normal faults striking parallel to the Apennines crest and dipping to the west. In this work we investigate a major open issue concerning the origin of the 2016-2017 sequence: is the ongoing extension of the crestal portion of the Apennines accommodated by large, relatively youthful normal faults cutting through the existing fabric, or rather by a negative inversion of former regional thrust faults, or perhaps by a combination of these two end-members?

The epicentral area of the 30 October 2016 shock falls entirely above the Sibillini thrust, a large and thoroughly investigated tectonic structure. Prior to the current extensional regime the central Apennines experienced at least two major tectonic phases: Mesozoic extension, leading to the creation of several structural highs and lows, and Neogene-Quaternary contraction, leading to the buildup of the Apennines. The present-day seismogenic faults are hence overprinting highly diverse and strongly deformed rocks of widely different age, plus a number of large, fossil tectonic structures, all of which may act selectively, ultimately controlling the geometry and modes of ongoing extension.

In this work we first use good quality InSAR observations, complemented by seismological, GPS and geological observations, to derive accurate geometrical parameters for the deeper, seismogenic portion of the fault. The analysis of the InSAR data indicated a best-fitting fault dip of 37°.

We then used published geological maps to generate a set of geological models and sections, extending the analysis down to the base of the seismogenic fault whenever possible. Each model implies a different nature and evolution for the source of the 2016-2017 earthquakes. Unfortunately the tectonic evolution of the Apennines is still highly debated; there exist several competing models, whose major difference rests in the role assigned to the Mesozoic extensional phase. In the literature these models are often referred to as belonging to two major categories: thin-skinned and thick-skinned.

We then introduced in each model the geometry of the seismogenic fault obtained from InSAR observations. In a thin-skinned tectonics perspective the seismogenic fault would be a low-angle fault that developed entirely during the Quaternary, whereas in a thick-skinned perspective the seismogenic fault would be a portion of a large thrust-ramp reactivated during the current extensional phase.

Our results - and specifically the limited dip of the fault - favor the second hypothesis, namely that the 30 October earthquake was caused by negative inversion of a thrust-ramp. This finding has crucial implications for seismogenic processes across the central Apennines, as it implies that a similar mechanisms may apply to other portions of the Sibillini thrust north of Norcia and to other large thrusts that exist in the region.