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Reconciling large seismogenic and shallow normal faults in the Messina Straits: the analogue modeling perspective

L. Bonini (1), D. Di Bucci (2), S. Seno (1), G. Toscani (1), and G. Valensise (3)

(1) Dipartimento Scienze della Terra, Università di Pavia, Pavia, Italy, (lorenzo.bonini@dst.unipv.it), (2) Dipartimento della Protezione Civile, Rome, Italy, (3) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy

The elevation changes, the seismographic recordings and the damage distribution associated with the disastrous 28 December 1908, Messina Straits, Southern Italy earthquake (Mw 7.1) have been used jointly by seismologists to derive a robust model of the seismogenic source. It consists of a 40 km-long, 30°SE-dipping normal fault extending between 3 and 12 km depth over the entire length of the Messina Straits and consistent with the recent morphotectonic setting. In the same area several investigators describe several shallow, high-angle normal faults, dipping both to the NW and to the SE. These faults are located both on- and off-shore, affect recent deposits and in most cases reach the topographic surface. They have sometimes been invoked to constrain models of the seismogenic source alternative to that involving slip on a single, major blind fault, but they are generally not compatible with the instrumental data available for the 1908 earthquake. We used analogue models to verify whether the field evidence for smaller high-angle normal faults can be reconciled with the presence of a deeper, larger, low-angle normal fault such as that believed to be responsible for the 1908 earthquake. We carried out a set of analogue models that reproduce in 3D a normal fault with a dip of 30°. The models are at 1:100,000 scale. We then activated a 40 cm-long fault, corresponding to the 1908 earthquake source, using a sandbox large enough to allow also deformation at the fault lateral tips to be recorded and analyzed. The internal friction of the sand used in the analogue models was 34°. A 2 cm-thick layer of glass microbeads (internal friction: 24°) marked the surface of the master fault. We carried out four experiments with extension of 0.5, 2.0, 3.5 and 5.5 cm, respectively. All models showed the activation of the entire surface of the master fault. Many high angle, synthetic and antithetic normal faults nucleated and developed in its hanging wall, often organized in one or, less frequently, two graben systems. In a plan view, the faults that developed at the hanging wall of the master fault are parallel to it, whereas at the lateral tips the newly formed faults deflect from the strike of the master fault and rotate of about 30° toward the hanging wall. All synthetic and antithetic high angle normal faults are directly linked to the low angle master fault and all nucleated during the very early stages of deformation (e.g., 0.5 cm extension). The results of the analogue modelling suggest a more detailed and complex hypothesis to unravel the long-term deformation associated with the source of the 1908 earthquake. The models show that shallow minor faults, each characterized by slip rates smaller or much smaller than those associated with the master fault, not only are perfectly compatible with it but are an expected outcome of its long-term activity. The high angle normal faults surveyed and mapped by many investigators in the Messina Straits could hence be considered as a surface expression of a long-term activity of the large SE-dipping normal fault that generated the 1908 earthquake.