



Low angle normal faults record pure extension during the opening of the Lower Permian Orobic Basin, Southern Alps

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Incredibly well preserved low-angle normal faults (LANFs) outcrop along the watershed of the central Southern Alps, Italy, in the highest part of the Brembana Valley. LANF systems are related to the opening of the Lower Permian Orobic Basin and, due to their unfavorable orientation with respect to the Alpine shortening, they still preserve most of their original features consisting of cataclastic layers associated with abundant tourmalinites and other ore deposits. These faults, exhuming the Carboniferous Variscan metamorphic basement during the deposition of the upper portion of the Laghi Gemelli Group, interacted with ENE-WSW high-angle normal faults resulting in asymmetric half-grabens that dominated the Lower Permian depositional systems. Most of the high-angle north dipping normal faults were partially inverted during the first stages of the Alpine compression along the Orobic Thrust, one of the main reverse fault system of the belt, which stacked the Carboniferous metamorphic basement onto the Permian to Mesozoic sedimentary cover of the Southern Alps. In spite of the strong Alpine deformation, syn-sedimentary deformations recorded by brittle to semi-brittle mesoscopic structures, are preserved in the hangingwall of the LANF at the base of the Pizzo del Diavolo Formation. Conjugate Andersonian faults forming symmetrical horst-and-graben associated with domino-style planar faults are closely related to liquefaction and dewatering structures like ball-and-pillow, flames, and sand dikes, which suggest that deformation occurred in hydroplastic conditions during fault motions, possibly associated to seismic shaking.

Syn-depositional tectonics is also recorded by sharp lateral facies changes and abrupt thickness variations of the half-graben infilling toward the basin depocenter, which is characterized by a transition from coarse-grained conglomerates to lacustrine black shales and volcanoclastic sandstones spanning from a few tens to several hundreds of meters.

The main LANF system bounds the entire northern boundary of the Orobic basin crossing the watershed and extending to the west for tens of kilometers, where it is related to one of the most important uranium ore bodies of the Southern Alps suggesting important implications between the Permian extensional tectonics and hydrothermal mineral deposition.

Our analyses indicate that the Lower Permian tectonics was dominated by pure extensional fault systems forming half-graben structures accommodating the deposition of the thick volcanic and terrigenous layers of the Laghi Gemelli Group. The reconstructed framework, together with a growing amount of evidence from the literature, suggest alternative interpretations in terms of pure extension to the classic model of the post-Variscan tectonics which should be chiefly controlled by a dextral megashear active between Gondwana and Laurussia.