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Polyphase deformation and fluid flow in the Internal Ligurian Units, Italy

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We studied the Internal Ligurian Unit (ILU) of the Northern Apennines, Italy. Field observations, fold axes, stylolites and crenulation cleavages indicate that the first folding had a direction of NW-SE, whereas the second main folding was in the direction of NE-SW. These orientations are in accordance with previous studies attributing the first folding to a E-SE-dipping, early subduction, and the second (main) folding to the accretion of the sequence towards the NE in a W-SW-dipping subduction zone. The unfolding of conjugate veins along the second folding axes showed the rotation of the main horizontal stresses. Oldest conjugates formed during the deformation in the SE-dipping subduction zone. As the subduction polarity-flip occurred and the subduction zone migrated towards its current strike direction, NW-SE, the main horizontal stresses also rotated forming conjugates triggered by E-W, NE-SW and N-S compression. Tectonic stylolites found in the Val Lavagna Shale also reflect these compression directions. In addition to conjugates, several other vein types (e.g. bed-parallel and perpendicular, folding-related veins, blobs of mineralization) were observed in the Palombini and Val Lavagna Shale. As the veins intensity was increasing towards the Palombini-Val Lavagna boundary that is considered a fault-contact, we propose that fluid flow along the fault was responsible for the veining. Microstructural evidence, however, also suggested that diffusion from the host rock and dissolution of the veins could have contributed locally to material transport. Early veins show combinations of layer parallel and perpendicular veins and probably represent fluid overpressures. However these features are relatively local.