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How boudinage triggers the localization of low-angle normal faults

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Initiation and subsequent growth of mid to upper crustal low-angle normal faults is commonly explained by unusual low fault friction caused by either high fluid pressure, weak fault-zone materials probably formed by reaction softening, movement along pre-existing anisotropies and/or aseismic deformation mechanisms. Interestingly, low-angle normal fault localize within a broad range of different host rocks and obviously not a single process but several processes, which probably interact, may lead to the formation of faults with shallow dip angles. Here we report a complex chemo-mechanical feedback process, which facilitated the formation of a crustal scale low-angle normal fault in the Cyclades.

On the island of Serifos in the Western Cyclades (Greece) a brittle/ductile low-angle normal fault localized within a dolomite/calcite marble mylonite with numerous centimeter-thick mylonitic quartz layers. The quartz layers have been fractured perpendicular to the layering and record moderate synthetic rotation of the individual blocky boudin segments with generally low aspect ratios into the shear direction. Intuitively, the shear strain recorded by this domino type boudinage is only low, conflicting with the fact that the low-angle normal fault is supposed to juxtapose different tectonic units with an offset of several tens of kilometers. Closer inspection of the boudinage reveals that a reaction front developed between the dolomite/calcite marble and the quartz mylonite consisting of fluid assisted and mainly stress-induced breakdown of dolomite and nucleation of talc and secondary generation calcite. Locally further fluid activity triggered also tremolite formation. During synthetic rotation the boudins get totally coated by a continuous talc/cc-rich layer, which developed into low-angle sc and scc'-type shear zones.

Comparison of the domino boudinage with mechanical finite element modeling reveals that as long as the sides of the boudins slide antithetically against each other the individual objects rotate much slower than an isolated rigid particle as predicted by analytical solutions. In case of separation of the neighbouring boudins, the rotation rate accelerates.

In conclusion, the fluid assisted reaction of host marble and quartz layer and the developing feedback between this chemical reaction and the boudinage may lead to shear zones which can accommodate high shear strain facilitating the evolution of crustal scale low-angle normal faults.