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Geometry and displacement profiles along juvenile normal faults in fine-grained carbonates

Catherine Homberg (1), Johann Schnyder (1), and Véronique Léonardi (2)

(1) Université Pierre et Marie Curie, ISTeP- UMR UPMC-CNRS 7193, Case 129, 4 place Jussieu, 75252 Paris Cedex 05, France., (2) UMR Hydrosciences Montpellier, Université Montpellier 2, Place Eugène Bataillon, 34095 Montpellier Cedex 5, France.

We present data on meso-scale normal faults which likely developed before complete compaction of the sediments. These data are used to discuss the geometrical characteristics and the growth processes of faults in weakly lithified and thus very soft rocks. The investigated faults cut the Late Jurassic or Early Cretaceous sequences of the Vocontien through, a sub-bassin of the Mesozoic south-eastern French basin which developed in relation with the opening of the western Tethys. These hosting rocks are well stratified sequences consisting today of a succession of decimetre-thick micritic and homogeneous limestone beds, sometimes separated by thin marly intervals. Micro-conglomeratic beds with infra-millimetric to centimetric lithoclasts also exist. The normal faults were observed on vertical cross-sections and we measured the strike and dip of the fault plane on several sampling points, as well as the slip vector when visible. The upper and lower limits of each bed constitute good markers which we used to establish how the displacement varies along each fault. At several places, the deformation includes both offset by fault slip as well as by folding which we interpret as extensional fault-propagation folding. In order to discuss the deformation mode, we measured both the offsets very close to the fault plane and those a few decimetres or more away from it. These data correspond to the strain achieved respectively by faulting and by both faulting and folding and are referred below as the near-field and far-field displacements. Where the fault is composed of overlapping segments, we also calculated the cumulative displacement profile by summing displacements on each individual segment.

The studied normal faults have maximal displacement ranging from 3 cm to 50 cm and their exposed lengths vary from 1 m to more than 3 m. Generally, only part of the faults is visible but for all but one faults, at least one tip is exposed. Their mean strike is NNW-SSE and WNW-ESE in the Jurassic and Early Cretaceous sequences respectively and no significant variation in their direction are observed. On the other hand, changes in dip are common on most faults and this over a short distance. They do not correspond to a fault refraction as the function of the lithology as observed in lithified multilayer systems. The variation of the fault dip occurs within a single bed so that the fault shows a curved segment with sometimes reverse dips at the top and bottom of the bed. Analysis of near-field displacement profiles indicate that these sinuous faults generally show high tip gradients up to 1 and also local gradients up to 0.3. These values are very much higher than those commonly determined in carbonatic sequences. For reference, a few other faults showing straight segments were analysed and they are characterized by mean gradient close to 0.04. A positive relation thus exists between the fault geometry and the local or tip gradients. Comparison of the near-field and far-field displacement profiles indicate that variation in displacement achieved by faulting and folding may occur in a similar but also opposite way along the fault. The contribution of folding to the total strain is variable but can be very significant and account for 50% of the deformation. Together with the high gradient, these data show a very reduced propagation of the fault as the strain accrued.