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Mechanostratigraphy and fracture facies in Lower Cretaceous carbonates of Provence (SE-France)

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We aim to quantify the mechanical and petrophysical properties of carbonates depending on their sedimentological facies and geodynamic history.

In Provence, the Mesozoic basin developed from Triassic to Late Maastrichtian times in a differential subsidence setting, before polyphase tectonic inversion (Pyrenean and Alpine phases) locally uplifted the buried carbonates. In order to better understand the mechanostratigraphy and fracturing relationships, we analysed the tectonic and burial history of carbonates in seven specific outcrops in the Provence Basin (SE-France) in relation to their fracture facies. These sites were explicitly chosen in poorly deformed areas where strain partitioning and localization effects are not expected to affect fracturing. We targeted four Urgonian-type carbonates of Barremian age (Lower Cretaceous), one older carbonate of Tithonian age and two younger carbonates of Campanian and Late Maastrichtian age. The investigated outcrops are sampled over an area of ∼60km x ∼60km.

For each location, we characterize the fracture geometry and chronology from field measurements (∼1500 measurements). The sequence of fracture development is compared to the burial/uplift history deduced from subsidence curves and regional structural analysis (burial ranges from 300 to >1000m). The carbonate facies are based on macroscopic observations in the field and on 80 laboratory samples. Seven type-facies from mudstone to floatstone are defined.

In each sampling site, the fractures are clustered into two sets of mutually intersecting and perpendicular joints which strike either N030-N120 or N080-N170. This indicates that a unique brittle event affected the carbonates whatever their age. The subsidence curves allow Time-Depth windows for fracture development to be drawn. The sequence of fracture development compared to subsidence curves indicates that most fractures occur during the early and fast burial stage, whatever the age of the rock. This implies that carbonates have early brittle properties and thus have undergone early diagenesis. The comparison between old and deeply buried rocks (Tithonian, Barremian) with young and shallow buried rocks (Maastrichtian) showed that the occurrence and number of burial stylolites are not controlled by the burial depth like Maastrichtian lacustrine carbonates which contain numerous stylolites. The occurrence of stylolites is therefore controlled by the initial facies (porosity) and early diagenesis.

Although no clear mechanical stratigraphy is observed in the studied outcrops, they exhibit specific fracture facies. In particular, the fracture frequency is inversely proportional to the layer thickness and depends on the carbonate facies. Mudstone-wackstone dominated carbonates show smaller fracture density than grainstone dominated carbonates. However, the densely fractured facies (tension gashes and burial stylolites) occur in tight carbonates while porous facies are less fractured. As fractures develop during early burial, we conclude that the porosity in Urgonian carbonates of Provence is acquired in the early stages of burial and diagenesis.