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Sealing capacity of clays in multilayer systems: a field study of fracture-fluid flow relationships (Blue Clay formation, Maltese Islands)

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Draining properties of tectonic structures are a key parameter in various projects in geological host-rocks (CO2 storage, hydrocarbons trapping, radioactive waste deep disposals...). In the context of research and development programs relative to deep disposal of radioactive waste, clayey formations are studied in several countries as potential host rocks. The present paper deals with the "sealing capacity" of clay layers by reducing tectonic fracturing and fluid flows from more brittle rocks, in an outcropping formation shearing similarities to these potential host rocks.

The 70 m thick Blue Clay formation (Maltese Islands) outcrops between two limestone formations of Oligocene-Miocene age affected by slight extensional tectonics. The space relationships between fractures and palaeo-fluids are expressed by an oxidation phenomenon where the fluids passed. Joints and small faults in limestones (displacement < 5 m) seem to dampen rapidly within the Blue Clays. Large faults (displacement > 50 m), which cross both limestone and clay layers, show smearing structures and behave as a barrier for the palaeo-fluids. To the contrary, in the case of intermediate faults, the deformation zone widens in the clays and the fault plane is replaced by a large set of joints. These joints are filled with gypsum veins up to 5 cm thick and surrounded by oxidation patterns.

Fluid inclusions and isotope studies were performed on the gypsum infill in the fractures and in the rock matrix of the Blue Clay formation to state the origin and age of the fluid circulation. The large number of primary single-phased inclusions indicates that the fluid was at low temperature (< 50°C). Scarce bi-phased primary inclusions indicate an average salinity between 6 to 8%. The 87Sr/86Sr ratios of the gypsum in the Blue Clay formation correspond to the ratio of the Messinian seawater. We thus propose that the gypsum infill in the fractures results from the dissolution of Messinian evaporites (nowadays disappeared), and that the oxidizing fluids percolated downward through the Blue Clays via intermediate, subseismic faults. This post-Messinian fluid flow may be related with the Plio-Quaternary slight tectonic reactivation phase during rift shoulder uplift and subsequent relative sea-level fall.

These observations indicate that although these intermediate fault throws are moderate, they have penetrated into clays, and significant palaeo-fluid flows have occurred through open fractures in this clayey formation.