Mineral Diagenesis in Silt- and Clay-Rich Mudstones: Macroscopic to Microscopic Characteristics

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ABSTRACT

Significant research has been undertaken upon siliceous- and carbonate-rich organic-rich mudstones, due to their role as economic shale gas and shale oil reservoirs. However, silt- and clay-rich mudstones are the most abundant in the rock record, commonly have low organic matter contents and in many cases also act as economic shale reservoirs. However, the detailed nature of diagenesis within these rocks is poorly constrained. Diagenetic processes are likely to have a significant impact on the petrophysical and mechanical properties of mudstones. We document details of diagenetic alteration within a range of Paleozoic and Mesozoic mudstones from the USA and the UK. We highlight the reactive nature of these rocks, both with respect to carbonate and silicate minerals.

Earliest cements often comprise macroscopic carbonate concretionary horizons, capping upward-coarsening sediment packages 1- 3 m thick, interpreted to be parasequences. Carbonate cementation is interpreted to result from breaks in sediment accumulation below marine flooding surfaces and highlights the importance of macroscopic scale diagenetic carbonate mobility in these mudstones. Kaolinite is present both in uncompacted tests of organisms and as vein fills in septarian concretions. Kaolinite is interpreted to have occurred prior to significant compaction and indicates that both silica and aluminium were mobile during early diagenesis. Aluminum-mobilization may have resulted from the presence of organic acids generated during organic matter oxidation reactions, with the aluminum sourced from poorly crystalline detrital aluminum oxides and clay minerals.

Following these earliest cements, silica precipitation and dolomitisation are important in these mudstones. However the timing of these processes may be early and/or late in diagenesis. Silica cement can take the form of quartz overgrowths and microcrystalline quartz crystals. Recrystallization of biogenic silica (opal-A) and higher temperature smectite-to-illite transformation are likely important sources for quartz cements. Magnesium and ferroan dolomitisation of carbonate grains and cements is commonly observed. Both types of dolomite indicate a degree of iron and magnesium mobility beyond the earliest stages of diagenesis.

Late diagenetic partial-to-complete albite replacement of large pyrite- and kaolinite-filled bioclasts is also abundant in deeper buried mudstones. Iron-rich chlorite, often as kaolinite pseudomorphs is also present in some examples. These mineral phases highlight that microscopic-scale diagenetic mobility of silica and aluminium is important, even within mudstones lacking obvious sources of biogenic silica. The scale of these diagenetic processes varies significantly between samples and mudstone examples. This variability indicates that a thorough understanding of diagenetic processes and their controls is important in their prediction.