Insights into the Transformation of Mud to Mudstone from Ocean Drilling Results

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ABSTRACT

The mud to mudstone transition has been continuously cored at hundreds of sites in various tectonic settings across the world's oceans thanks to almost sixty years of ocean drilling program expeditions (DSDP, ODP, IODP). Shipboard scientists documented these transitions with visual core descriptions, physical properties measurements, pore-water geochemistry, and lithological classifications usually determined through smear slide analysis. Associated data sets usually include bulk mineralogy (XRD), electric logs, and age constraints from biostratigraphy and magnetostratigraphy.

Typically, the mud/mudstone transition is gradual, but depending on the lithofacies variability and stratigraphic continuity it can be abrupt. Where fine and coarse interbeds are present, lithification can be variable within a core interval with the "stone" term applied to one lithology before another, for example, early cementation of sandstone interbeds within mud, or alternatively, stiffer mudstones between unconsolidated sand beds. The transition from mud to mudstone is usually a major topic of discussion among shipboard scientists because this change is often noted as a subunit or unit boundary, equivalent to a member or formation boundary designation on land. The mud/mudstone transition often results in the need to change coring technology, e.g., from hydraulic piston core to extended core barrel at the point that coring creates biscuits of "stone" between a deformed gravy of mud or sand. Mud lithification occurs in response to burial compaction and cementation. In general, dissolution of unstable phases such as biogenic aragonite, biogenic opal, or volcanic glass, leads to the formation of authigenic phases such as carbonate, clay minerals, zeolites, or quartz . These dissolution and precipitation phenomena are readily discernible using smear slide and higher-resolution SEM techniques.

The impact of this transition can be seen in outcrops of deformed Quaternary to Pliocene marine sediments associated with active margin settings. We have looked in detail at one such area in the uplifted Hikurangi forearc region ofthe North Island, New Zealand. Here, outcrops of young marine fine- grained units are often referred to as mudstones, yet their "hardness" may be a product of subaerial exposure and desiccation. We have seen this point illustrated shipboard where scrapings off a drill core that was still soft/pliable and infused with formation fluids would dry to form hard "rocks." When weathered, such young mudstone outcrops essentially "melt" or easily disaggregate into their mud components when placed in water, only producing sand or gravel fragments where diagenetically modified. The modification usually involves dissolution of unstable constituents and precipitation of authigenic phases, in this New Zealand case, carbonate. In contrast, older shale units that are sufficiently lithified via compaction and diagenesis produce abundant rock fragments. Degree of lithification is also expressed in the degree of durability of the mudstone fragments as they undergo stream transport.

Data from ocean drilling provides key information in the chemical and mechanical processes that need to be modeled for prediction of bulk rock properties in oil and gas shales.