

RMS-SEPM Talk, January 29th, 2013

Fuzzy Facies

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Core facies analysis is an important initial step for interpreting depositional environments and creating core-to-log comparisons for correlating and mapping strata within oil and gas fields and across prospective oil and gas basins. An accurate description of primary sedimentary structures and biogenic structures is essential for interpreting sedimentary processes and paleoenvironmental conditions. The task is easy when the core displays crystal-clear sedimentary structures and their bounding surfaces and text-book examples of biogenic structures. Published facies descriptions from Cretaceous strata in Rocky Mountain basins include the usual suspects (e.g., mud-clast conglomerates, ripple cross laminated sandstone, high angle cross stratified sandstone, hummocky cross stratified sandstone, and planar parallel laminated sandstone) that have been grouped into facies associations and facies assemblages and interpreted as alluvial plain, coastal plain, shallow marine, and deep water marine deposits. However, most core descriptions also include descriptions of sandstone that contain "faint" sedimentary structures and sandstone that is structureless and/or massive. I refer to these facies as "fuzzy facies". What is the origin of fuzzy facies? How do fuzzy facies influence interpretations of genetically related strata? Do fuzzy facies improve or degrade reservoir properties? This talk addresses the first two issues and touches on the latter issue.

Published interpretations include depositional processes, biogenic activity or diagenetic alteration. Where identifiable trace fossils are present in both marine and nonmarine sandstone facies, these structureless or faintly laminated facies are usually interpreted as intensely bioturbated sandstone. Where associated with other facies, they are interpreted as concentrated and hyperconcentrated density flow deposits, rapid sedimentation (e.g., quick beds), liquefaction, or rapid redeposition of sediment from collapsing cut banks. Possible diagenetic processes include grain replacement or grain displacement. As you can imagine, the genetic significance of fuzzy facies (i.e., sedimentary, biogenic or diagenetic process) is very important because it influences how we correlate and map the strata, and whether we can predict trends in areas with little or no data.

Over the past 10 years I have examined hundreds of cores from Cretaceous Western Interior formations that represent almost every depositional environment. They all contain fuzzy facies. In some cases, a continuum exists between crisp, clearly identifiable sedimentary structures and structureless sandstone. However, most cores are actually dominated by and characterized by fuzzy facies (i.e., fuzzy facies are the dominant facies). Using highly unsophisticated and unpatented techniques (e.g., careful observation of the core as it dries from water spray and even staring at the core as though it is a 3D stereogram), it appears that fuzzy facies are created by the pervasive interpenetration of small trace fossils or cryptic bioturbation. Cryptic

bioturbation is characterized by small, discrete, intrastratal, non-branching, subhorizontal and oblique, sinuous cylinders or tubes, similar in size, shape and/or form to *Helminthopsis*, *Phycosiphon* or small *Macaronichnus*. Individual tubes are less than 1mm to 2 mm in diameter and have a clay-rich core (fecal string) and clean rim of quartz silt or sand grains. These traces were probably formed by a small, deposit-feeding polychaete. The pervasiveness of cryptic bioturbation determines the fuzziness of the original primary sedimentary structures. Sparse cryptic bioturbation results in better preservation of primary sedimentary structures, whereas pervasive cryptic bioturbation created a homogenous fabric, obscuring original lamina-scale and, sometimes, bed-scale heterogeneities. Cryptic bioturbation or fuzzy facies occur in alluvial plain, coastal plain, shallow marine, and deep water marine deposits, which presents a challenging genetic puzzle for sedimentologists (thus, the word "cryptic" is appropriate). The occurrence of fuzzy facies in shallow marine and alluvial plain deposits suggests (1) cryptic bioturbation by different organisms with similar behavior or (2) an organism with a marine origin that followed salinity wedges up low-gradient fluvial systems during months of low water discharge. The occurrence of fuzzy facies in both shallow and deep water marine deposits suggests (1) cryptic bioturbation by different organisms with similar behavior or (2) mass transport of shelf sediments that contained millions of doomed pioneers into deep water.

In dry gas reservoirs (e.g., Williams Fork Formation in Piceance Basin), fuzzy facies has up to 3% higher porosity (microporosity) and better permeability than other sandstone facies. This is, in part, due to preservation of some primary porosity by clay coatings that protected framework grains from extensive quartz cementation.