Lateral diagenetic patterns in the fabrics, petrophysics and geochemistry of Madison dolograinstones – evidence of self-organizing phenomena?

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Five-hundred to 1000 foot-long horizontal (1D) transects in Permian dolostones of west Texas, Mississippian dolowackestones of Wyoming (Sheep Mt), Mississippian dolograinstones (Lysite Mt., WY), and Eocene dolograinstone of Florida all exhibit similar lateral petrophysical patterns. Geostatistical analysis reveals a large near-random component (50%-60% of all porosity variance at 1-ft spacing), a dominant short-range structure measured in tens of feet, and a pronounced low magnitude, longer range cyclic pattern at scales of tens to >150 ft. The short and longer range structures combine to form lateral periodic oscillations in porosity and permeability that is superimposed on the near-random noise. Flow modeling of simulated water floods indicates that fingering, sweep-efficiency, and breakthrough time are sensitive to this lateral heterogeneity

Samples at 1-ft spacing along one 250 foot-long lateral transect in the Madison dolograinstones were examined in detail in an effort to understand the lateral petrophysical patterns. Calcite-free bulk-rock trace element compositions (Mn, Sr, Na, and Fe) and stable isotopic values (carbon and oxygen) show the same distinct lateral variability as porosity, and in some cases exhibit an even stronger dominance by the long-range cyclic effects. These dolograinstones consist of medium-crystalline dolomite rhombs with moldic and intercrystalline porosity. The spatial patterns are intrinsic to the dolomite fabric, but do not correlate to the abundance of just moldic porosity, just intercrystalline porosity, the ratio of the two, or crystal size. The variability is overprinted slightly by late quartz & calcite cement, meaning some low porosity values are due to the late cements, but the amount of late cement does not relate to lateral porosity variability or any geochemical variability. Estimated pre-cement porosity exhibits an even greater porosity range than post-cement porosity.

Possible origins are: (1) inheritance from the depositional precursor, (2) self-organizing processes during dolomitization, or (3) overprinting by later diagenesis. Of these three, inheritance is most unlikely given that dolomitization completely alters the microfabric of the precursor in geochemically open systems. Although overprinting cannot be ruled out in the Lysite example (at a minimum, recrystallization did occur as evidenced by Sr-isotopic compositions), generation of all the lateral patterns by self-organizing processes during dolomitization presents an intriguing explanation. (Self-organization being the creation of patterns in a system from non-patterned states due to feedback mechanisms between the processes affecting that system). Reaction-transport models coupled to textural evolution during lime grainstone to dolograinstone alteration indicate that lateral porosity patterns can form in dolostone beds due to feedback mechanisms involving reaction fingering, convergence and divergence of flow, textural and petrophysical heterogeneity, and hydrogen diffusion (at low flow rates).