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by ***J. C. Van Wagoner, D.C.J.D. Hoyal, T. Sun*** *and* ***N.L. Adair***

Energy Dissipation: Origin of Structure and Organization in Siliciclastic Sedimentary Systems

Siliciclastic strata are nested bundles of sedimentary bodies classified and named according to depositional environment, geometry, and scale. Our analysis of 482 sedimentary bodies formed by unidirectional, fully turbulent flows, ranging in length scales from <10 cm to thousands of kilometers, from most depositional environments, reveals that the shapes of these bodies are statistically similar, scale invariant, and independent of depositional environment. This similarity suggests that these bodies were deposited by a common global physics. We postulate that this fundamental physics is non-equilibrium thermodynamics, in particular, energy dissipation and dissipative structures.

We believe that all sedimentary bodies, from current ripples to submarine fans, are dissipative structures

Geologically significant flows are far-from-equilibrium open systems with large energy gradients. The Second Law of Thermodynamics requires that these gradients be minimized. Far-from-equilibrium flows do this through the formation of dissipative structures. The primary dissipative structure in flows in all environments of deposition is the jet/plume pair linked through a hydraulic jump. Such flow structure is self-similar and scale invariant, from the scale of the entire flow down to the viscous sublayer. For this reason, the bodies produced by this type of decelerating flow are also scale invariant.

The jet/plume pair dissipates kinetic energy though entrainment in the jet portion of the flow causing flow deceleration. In the process, deposition occurs if the flow is carrying particles. As the resulting sedimentary body grows and interacts with the flow, it also becomes a dissipative structure. We believe that all sedimentary bodies, from current ripples to submarine fans, are dissipative structures. That is, a sedimentary body is the framework to optimally deliver kinetic energy through channels or flow pathways to new dissipation sites where jets are active. As a result of deposition and consequent vertical growth of the sedimentary body, flows are superelevated by being locally forced up and over the deposit. This creates the energy dissipation paradox: in the process of dissipating kinetic energy, potential energy is created. Potential energy gradients are minimized by another dissipative mechanism, avulsion.

This evolution of sedimentary bodies from the initial jet deposits to complex avulsive bodies such as deltas and submarine fans follows a specific pathway from jet deposit nonavulsive or leaf deposit avulsive or tree deposit. We call this the energy dissipation pathway. It is the scale invariant pathway along which all sedimentary bodies evolve. We believe that current ripples, bars in rivers, deltas, and submarine fans all form and evolve along this pathway. If correct, this hypothesis of energy dissipation and the energy dissipation pathway provides a new, unifying context for the analysis and interpretation of sedimentary systems.

Biographical Sketch

Mr. Van Wagoner obtained his PhD from Rice University in Houston, Texas, in 1977. He is currently senior research advisor to the reservoir geometry and Continuity Division at ExxonMobil Upstream Research Company. Teaching responsibilities have included instructor on Advanced Clastic Facies and Sequence Stratigraphy, and Overview of Sequence Stratigraphy schools. Before 1999 his responsibilities included conducting nonmarine sequence stratigraphy, performing research application work, leading field trips, writing papers for company and outside publication, and giving talks on sequence stratigraphy.