



Scale-invariance of sediment patterns - the fingerprint of fundamental drivers (Jean Baptiste Lamarck Medal Lecture)

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In contrast to the realms of magmatism and metamorphism, most depositional processes can be observed directly at the earth's surface. Observation of sediment patterns advanced significantly with the advent of remote sensing and 3D reflection seismics. Remote sensing is particularly relevant for the present topic because it documents mainly Holocene sediments - the best objects to link depositional processes to products.

Classic examples of scale-invariant geometry are channel-fan systems, i.e. river-delta and canyon-fan complexes. The underlying control in both instances is the energy-dispersion of a channeled stream of water that discharges in a body of still water. The resulting fan-shaped sediment accumulations are scale-invariant over 7 orders of magnitude in linear size. The Mesozoic-Cenozoic record shows comparable trends and patterns.

Further examples of depositional scale-invariance include foresets of non-cohesive sediments and braided-channel deposits.

Reefs and carbonate platforms offer an example of scale-invariance related to biotic growth. Shallow-water carbonate platforms rimmed by reefs or reef-rimmed atolls with deep lagoons are characteristic morphologies of tropical carbonate deposits. The structure has been compared to a bucket where stiff reef rims hold a pile of loose sediment. Remote sensing data from the Maldives, Chagos and Laccadive archipelagos of the Indian Ocean show that bucket structures are the dominant depositional pattern from meter-size reefs to archipelagos of hundreds of kilometers in diameter, i.e. over more than 4 orders of magnitude in linear size. Over 2.5 orders of magnitude, the bucket structures qualify as statistical fractals. Ecologic and hydrodynamic studies on modern reefs suggest that the bucket structure is a form of biotic self-organization: The edge position in a reef is favored over the center position because bottom shear is higher and the diffusive boundary layer between reef and water thinner. Thus, the reef edge has easier access to nutrients. Moreover, the edge is less likely to be buried by sediment. The bucket structure is an ecologic response to these conditions. Buckets have been documented from all periods of the Phanerozoic and analogous structures from the late Proterozoic show that the microbial carbonate factory also built buckets.

We conclude that a voyage through scales in the sediment realm reveals islands of scale-invariance wherever a single principle dominates the sedimentation process.