Geophysical Research Abstracts
Vol. 17, EGU2015-14590, 2015
EGU General Assembly 2015

Contrasting styles of large-scale displacement of unconsolidated sand: examples from the early Jurassic Navajo Sandstone on the Colorado Plateau, USA

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Large-scale soft-sediment deformation features in the Navajo Sandstone have been a topic of interest for nearly 40 years, ever since they were first explored as a criterion for discriminating between marine and continental processes in the depositional environment. For much of this time, evidence for large-scale sediment displacements was commonly attributed to processes of mass wasting. That is, gravity-driven movements of surficial sand. These slope failures were attributed to the inherent susceptibility of dune sand responding to environmental triggers such as earthquakes, floods, impacts, and the differential loading associated with dune topography. During the last decade, a new wave of research is focusing on the event significance of deformation features in more detail, revealing a broad diversity of large-scale deformation morphologies. This research has led to a better appreciation of subsurface dynamics in the early Jurassic deformation events recorded in the Navajo Sandstone, including the important role of intrastratal sediment flow.

This report documents two illustrative examples of large-scale sediment displacements represented in extensive outcrops of the Navajo Sandstone along the Utah/Arizona border. Architectural relationships in these outcrops provide definitive constraints that enable the recognition of a large-scale sediment outflow, at one location, and an equally large-scale subsurface flow at the other. At both sites, evidence for associated processes of liquefaction appear at depths of at least 40 m below the original depositional surface, which is nearly an order of magnitude greater than has commonly been reported from modern settings. The surficial, mass flow feature displays attributes that are consistent with much smaller-scale sediment eruptions (sand volcanoes) that are often documented from modern earthquake zones, including the development of hydraulic pressure from localized, subsurface liquefaction and the subsequent escape of fluidized sand toward the unconfined conditions of the surface. The origin of the forces that produced the lateral, subsurface movement of a large body of sand at the other site is not readily apparent. The various constraints on modeling the generation of the lateral force required to produce the observed displacement are considered here, along with photodocumentation of key outcrop relationships.