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Multi-origin of soft-sediment deformation structures and seismites

The fallacy of interpreting SSDS with different types of breccias as seismites amid the multifarious origins of earthquakes: Implications

G. Shanmugam

Department of Earth and Environmental Sciences, The University of Texas at Arlington, Arlington, TX 76019, USA

Abstract At present, there are no criteria to distinguish soft-sediment deformation structures (SSDS) formed by earthquakes from SSDS formed by the other 20 triggering mechanisms (see a companion paper in Vol. 5, No. 4 of this journal by Shanmugam, 2016). Even if one believes that earthquakes are the true triggering mechanism of SSDS in a given case, the story is still incomplete. This is because earthquakes (seismic shocks) are induced by a variety of causes: 1) global tectonics and associated faults (*i.e.*, mid-ocean ridges, trenches, and transform faults); 2) meteorite-impact events; 3) volcanic eruptions; 4) post-glacial uplift; 5) tsunami impact; 6) cyclonic impact; 7) landslides (mass-transport deposits); 8) tidal activity; 9) sea-level rise; 10) erosion; and 11) fluid pumping. These different causes are important for developing SSDS.

Breccias are an important group of SSDS. Although there are many types of breccias classified on the basis of their origin, five types are discussed here (fault, volcanic, meteorite impact, sedimentary-depositional, sedimentary-collapse). Although different breccia types may resemble each other, distinguishing one type (*e.g.*, meteorite breccias) from the other types (*e.g.*, fault, volcanic, and sedimentary breccias) has important implications. 1) Meteorite breccias are characterized by shock features (*e.g.*, planar deformation features in mineral grains, planar fractures, high-pressure polymorphs, shock melts, *etc*.), whereas sedimentary-depositional breccias (*e.g.*, debrites) do not. 2) Meteorite breccias imply a confined sediment distribution in the vicinity of craters, whereas sedimentary-depositional breccias imply an unconfined sediment distribution, variable sediment transport, and variable sediment provenance. 3) Meteorite, volcanic, and fault breccias are invariably subjected to diagenesis and hydrothermal mineralization with altered reservoir quality, whereas sedimentary-depositional breccias exhibit primary (unaltered) reservoir quality. And finally, 4) sedimentary-collapse breccias are associated with economic mineralization (*e.g.*, uranium ore), whereas sedimentary-depositional breccias are associated with petroleum reservoirs. Based on this important group of SSDS with breccias, the current practice of interpreting all SSDS as “seismites” is inappropriate. Ending this practice is necessary for enhancing conceptual clarity and for advancing this research domain.

E-mail address: shanshanmugam@aol.com.

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1. Introduction

This article is a companion to my earlier paper "*The seismite problem*" (Shanmugam, 2016). The purpose of the original paper was to explain that there are no objective criteria to recognize earthquakes as a unique triggering mechanism (among 20 others) of soft-sediment deformation structures (SSDS) (Fig. 1). Even if one recognizes earthquakes as the mechanism that contributed to the origin of SSDS, the geological story is still incomplete. This is because earthquakes are generated by a multitude of causes. Selected examples are:

1) Global tectonics (Kearey *et al.*, 2009; Ruff, 1996).
2) Meteorite-impact events (Collins *et al.*, 2005).
3) Volcanic eruptions (Moran *et al.*, 2008).
4) Post-glacial uplift (Fjeldskaar *et al.*, 2000).
5) Tsunami impact (Tappin *et al.*, 2001).
6) Cyclonic impact (Meng *et al.*, 2013).
7) Landslides (Mass-transport deposits) (Pankow *et al.*, 2014).
8) Tidal activity (Barruol *et al.*, 2013).
9) Sea-level rise (Brothers *et al.*, 2013).
10) Erosion (Steer *et al.*, 2014).
11) Fluid pumping (Zhang *et al.*, 2013).

Given these alternatives, simply naming a deposit as "seismites" without identifying the root cause of seismic shock responsible for the deformation is incomplete in understanding the geological origin of SSDS. An analogy in the field of clinical diagnosis would be like a doctor of medicine diagnosing a

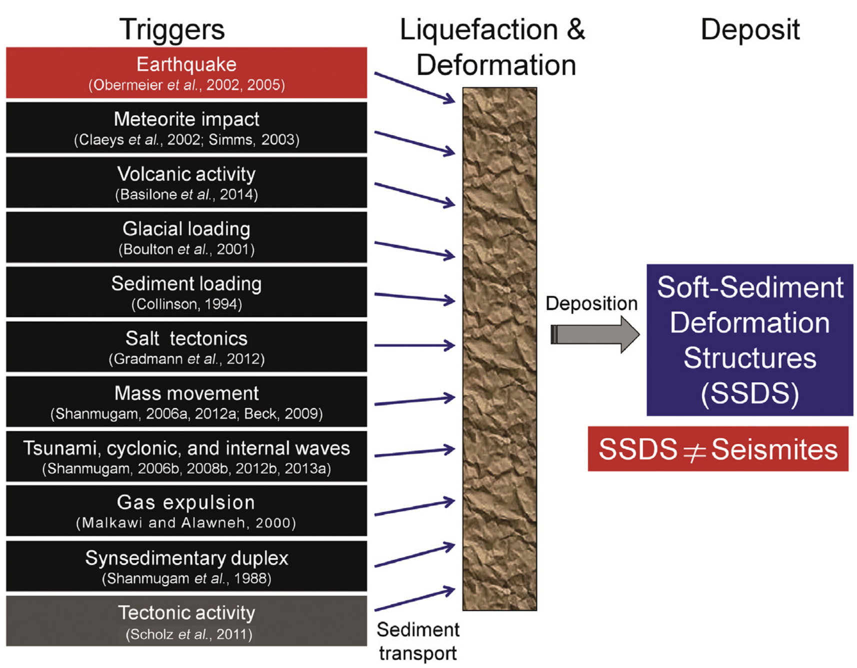

Fig. 1 Selected types of triggers, state of liquefaction, and soft-sediment deformation structures (SSDS). There are 21 triggers and they are all directly or indirectly responsible for sediment transport, deposition, and liquefaction. In reflecting published literature, earthquakes and tectonic activity are listed as two different types. However, earthquakes and volcanism are an integral component of global tectonics (Kearey *et al.*, 2009). Note that both tectonic and non-tectonic triggers go through liquefaction in developing SSDS. Also note that earthquake is one of many triggers that can develop SSDS. SSDS are not seismites. Thin blue arrows: One or more sediment transport processes with or without flow transformations (Fisher, 1983). Thick gray arrow: Final deposition. See Shanmugam (2006a, 2006b, 2008a, 2008b, 2012a, 2013b, 2015, 2016) for discussion of examples of triggers shown here (Basilone et al., 2014, Beck, 2009, Boulton et al.,2001, Gradmann et al., 2012, Malkawi and Alawneh, 2000, Obermeier et al., 2002, Scholz et al., 2011, Shanmugam, 2012b, Shanmugam, 2013a, Shanmugam et al., 1988, Simms, 2003). Figure from Shanmugam (2016).

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