Thematic set:
Polygenetic mélanges

JGS
Journal of the Geological Society

Published Online First

https://doi.org/10.1144/jgs2019-020

Mid-Eocene giant slope failure (sedimentary mélanges) in the Ligurian accretionary wedge (NW Italy) and relationships with tectonics, global climate change and the dissociation of gas hydrates

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Abstract: Upper Lutetian–Bartonian sedimentary mélanges, corresponding to ancient mud-rich submarine mass transport deposits, are widely distributed over an area *c.* 300 km long and tens of kilometres wide along the exhumed outer part of the External Ligurian accretionary wedge in the Northern Apennines. The occurrence of methane-derived carbonate concretions (septarians) in a specific tectonostratigraphic position below these sedimentary mélanges allows us to document the relationships among a significant period of regional-scale slope failure, climate change (the Early and Mid-Eocene Optimum stages), the dissociation of gas hydrates and accretionary tectonics during the Ligurian Tectonic Phase (early–mid-Lutetian). The distribution of septarians at the core of thrust-related anticlines suggests that the dissociation of gas hydrates was triggered by accretionary tectonics rather than climate change. The different ages of slope failure emplacement and the formation of the septarians support the view that the dissociation of gas hydrates was not the most important trigger for slope failure. The latter occurred during a tectonic quiescence stage associated with a regressive depositional trend, and probably minor residual tectonic pulses, which followed the Ligurian Tectonic Phase, favouring the dynamic re-equilibrium of the External Ligurian accretionary wedge. Our findings provide useful information for a better understanding of the factors controlling giant slope failure events in modern accretionary settings, where they may cause tsunamis.

Received 14 February 2019; **revised** 23 May 2019; **accepted** 28 June 2019

The downslope emplacement of medium- (10–1000 km^2) to giant- (≥1000 km^2) sized heterogeneous, mud-rich mass transport deposits (MTDs) is documented to play a significant part in controlling and maintaining the dynamic equilibrium of the outer wedge of modern subduction–accretionary complexes (e.g. von Huene *et al.* 2004; Remitti *et al.* 2011; Festa *et al.* 2015*b*, 2018; Artoni *et al.* 2019). In these settings, slope failure can be triggered or favoured by several concomitant and/or interlinked factors, such as shaking by earthquakes (e.g. Brothers *et al.* 2013), the subduction of asperities (e.g. seamounts or ridges; see Ruh 2016), a warming climate and rising sea-levels (e.g. Urgeles & Camerlenghi 2013) and the dissociation of gas hydrates (e.g. Maslin *et al.* 1998; Brown *et al.* 2006). However, the relationships between mass transport processes and these different factors are still a matter of debate and contrasting interpretations. For example, observations that the frequency of submarine landslides seems to increase during periods of sea-level rise, lowstand or rapid subsidence (e.g. Paull *et al.* 1996; Piper *et al.* 2003; Lee *et al.* 2010) suggest that variations in sea-level might potentially be more important triggers than the dissociation of gas hydrates (Urgeles & Camerlenghi 2013). This is supported by evidence that the headwalls of many giant submarine MTDs appear to be located in water depths (between *c.* 1000 and 1300 m; see Huhnerbach *et al.* 2004) that are too deep for triggering by the dissociation of gas hydrates, at least under present day conditions (Grozic 2010; Talling *et al.* 2014). However, reconstruction of the stability field for the dissociation of gas hydrates in the past is a complex task and depends on the pressure and temperature as well as the temperature of the seawater at the sea bottom and the geothermal gradient (e.g. Tréhu *et al.* 2006). Other observations indicate that the occurrence of submarine slope failure events is either weakly (or not) linked to global changes in sea-level and the dissociation of gas hydrates in open continental slope settings (e.g. Urlaub *et al.* 2013; Talling *et al.* 2014). Because of their geohazard potential (e.g. tsunamis and damage to the infrastructure of the seabed), it is important to better understand and constrain the relationships among submarine slope failure and active tectonics, climate change, the dissociation of gas hydrates and variations in sea-level.

Mid-Eocene mud-rich submarine MTDs, corresponding to sedimentary mélanges (olistostromes), are widely distributed along the exhumed outer part of the External Ligurian accretionary wedge (ELAW) in the Northern Apennines of Italy over an area *c.* 300 km long and tens of kilometres wide. They mark a significant period of regional-scale instability at the end of the Ligurian Tectonic Phase (early–mid-Lutetian). The time interval between the earlier part of this tectonic phase and the regional-scale emplacement of these sedimentary mélanges encompasses the Early (EECO; *c.* 53–52 to 50 Ma) and Mid- (MECO; *c.* 40 Ma) Eocene Climatic Optimum, two global warming events which temporally interrupted the long-term Cenozoic cooling trend (e.g. Shackleton & Boersma 1981; Miller *et al.* 1987; Bohaty & Zachos 2003; Boscolo Galazzo *et al.* 2014). These events were characterized by a perturbation in the global carbon cycle (Payros *et al.* 2015) and a negative carbon isotope excursion, for which methane hydrate dissociation has been argued to be the cause (Dickens *et al.* 1995), among other hypotheses (e.g. Higgins & Schrag 2006; DeConto *et al.* 2012).