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Shear zone liquefaction in mass transport deposit emplacement: A multi-scale integration of seismic reflection and outcrop data

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ABSTRACT

We present the integrated outcrop-geophysical study of two mass transport complexes, the exhumed Specchio unit in the Northern Apennines of Italy and the Holocene Poverty unit in the Hikurangi margin of New Zealand. The combination of micro- to meso-scale structural, stratigraphic and sedimentologic analyses carried on continuous three-dimensional outcrops, with large-scale structural and morphologic data deriving from seismic/acoustic imaging of the present-day continental margins, allow important considerations on submarine landslide processes and mechanisms through the broader (up-scaled and down-scaled) understanding of the mass transport-related structural associations. We compare the discontinuous high-amplitude, reverse-polarity reflectors observed within the Poverty with the syn-sedimentary, ductile shear zones found within the Specchio mass transport complex. The seismic signature of such structures suggests localized fluid overpressure along detachment/thrust zones due to shearing and loading of undrained, water-saturated, fine-grained material, developed along with the slide mass movement. The outcrop expression of these structures is tentatively attributed to m- to tens of m-thick shear zones comprising large amounts of sedimentary matrix which separate and accommodate the differential movements of the internal slide components (e.g. slide blocks, olistoliths). The sedimentary matrix is an unsorted, lithologically mixed medium characterized by a scale-invariant "block-in-matrix" fabric (i.e. brecciated, mud-supported), that injects, sustain and surrounds discrete slide elements (from particles to blocks) and interpreted as a hyper-concentrated (liquefied/fluidized) suspension of water and scattered sediments developed in fluid overpressure conditions. We highlight the fundamental role of shearing-related liquefaction as one of the main factors controlling slide mobility through the "lubrication" of the internal and basal friction forces. The analysis of such features can therefore provide important information for the characterization of mass transport deposits developed from potentially catastrophic, long run-out mass transport events, and consequently, to better understand their possible socio-economic impact in terms of tsunamigenic potential.

1. Introduction

The recent achievements in marine geology on seafloor and sub-seafloor mapping allow important consideration on recent to modern submarine landslides, giving general clues on their overall morphology and areal extent (Canals et al., 2004; Frey-Martinez et al., 2006; Gee et al., 2007; Bull et al., 2009). One of the main challenges arising from these studies revolves around the characterization of the complex internal anatomy of such deposits, and thus, the correct understanding of the genetic mechanisms and processes, which is crucial for offshore hydrocarbon exploration, and geohazard assessment and mitigation (see Hampton et al., 1996; Mosher et al., 2009; Kawamura et al., 2012).

Most of the internal structures of a slide body are developed at the meso-scale (meters to ten of meters), and therefore hardly recognizable through geophysical methods being well below the standard seismic resolution. Moreover, the high internal heterogeneities and the combined occurrence of materials with different degrees of consolidation contribute to complicate the seismic signal, resulting in acoustic artifacts and transparent zones. On the other hand, at the outcrop scale, these internal structures can be observed and described in detail (Lucente and Pini, 2003; Callot et al., 2008a, 200b; Ogata et al., 2012a), and, depending on the quality and the continuity of the exposures, such analyses could be up-scaled to fit to the seismic field of observation. In this framework we believe that a systematic comparison with fossil mass transport deposits cropping out in orogenic belts (i.e. sedimentary

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