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Research paper

Free gas accumulations in basal shear zones of mass-transport deposits (Pearl River Mouth Basin, South China Sea): An important geohazard on continental slope basins

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A B S T R A C T

Free gas is an important trigger of instability on continental slopes, and resulting mass-wasting strata can potentially form competent seals to hydrocarbon accumulations. This work uses two high-quality 3D seismic volumes to investigate fluid accumulations at the base of mass-transport deposits in the Pearl River Mouth Basin, South China Sea. In parallel, IODP/ODP borehole data are used to document the petrophysical character of mass-transport deposits formed in similar continental-slope environments to the South China Sea. The interpreted data show gas accumulations as comprising enhanced seismic reflections that are discordant, or vertically stacked, below mass-transport deposits with chaotic seismic facies. Gas was accumulated in basal shear zones of mass-transport deposits in response to differences in capillary pressure and porosity. Free gas in Zone A covers an area of at least 18 km^2. In Zone B, the free gas is sub-circular in plan view and covers an area of 30.58 km^2 for a volume of sediment approaching 1.5 km^3. This work is important as it shows that vertical migration of gas is not significant in mass-transport deposits from the Pearl River Mouth Basin, but up-dip migration along their basal shear zones is suggested in multiple locations. As a result, free gas can pinch-out laterally to extend 1–2 km beyond these same basal shear zones. As a corollary, we show that free gas accumulations below mass-transport deposits comprise an important geohazard and should be taken into account when drilling continental-slope successions in both the South China Sea and continental margins recording important mass wasting. Strata charged with free gas form weak layers, hinting at a novel trigger of retrogressive slope failures on continental slopes worldwide.

1. Introduction

Mass-transport deposits (MTDs) can shape both passive and active continental margins, transporting large volumes of sediment to continental-slope basins (e.g. Haflidason et al., 2004; Alves and Cartwright, 2009; Alves, 2010; Soares et al., 2012). They are of recognised importance as local geohazards when drilling (e.g. Varnes, 1978; Locat and Lee, 2002; Krastel et al., 2006; Masson et al., 2006; Lo Iacono et al., 2012), originate when downslope-directed forces exceed resisting forces on a continental slope (e.g. Hampton et al., 1996; Masson et al., 2006; Dugan, 2012). Multiple factors such as high sedimentation rates (e.g., Dalla Valle et al., 2013; Noda et al., 2013), methane hydrate dissociation (e.g., Laberg and Vorren, 2000; Maslin et al., 2005), release of free gas (e.g., Bünz et al., 2005; Best et al., 2003; Dugan and Flemings, 2000), tectonic activity (e.g., Hance, 2003; Chadwick et al., 2012; Laberg et al., 2014), and slope oversteepening (e.g., Strozyk et al., 2010; Ikari et al., 2011) comprise important triggers for the generation of MTDs. In parallel, submarine creep zones act as a precursor of large-scale slope failure (Li et al., 2016a,b).

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Failed strata are transported downslope along a basal shear zone of variable thickness and lithology when submarine slope instabilities occur (Alves and Lourenco, 2010). As a result, three distinct domains are identified within MTDs based on their deformation styles (Martinsen, 1994; Lastras et al., 2002; Bull et al., 2009). They are: a) a headwall domain characterised by extensional deformation, including headwall scarps, extensional ridges and blocks; b) a translational domain comprising the main translated body of the MTD (including sidewall scarps, strike-slip deformation, ramps and flats, grooves and striations, blocks, slump folds, longitudinal shears and secondary flow fabrics), and c) a toe domain dominated by compressional deformation, including pressure ridges, small-scale folds and thrusts (Prior et al., 1984; Bull et al., 2009). Outcrop data from SE Crete has shown that glide planes of submarine landslides comprise a deformation zone in which strata is deformed, sheared and fractures to enhance porosity and fluid migration (e.g. Alves and Lourenco, 2010). Importantly, large volumes of fluids can be focused in vertical and horizontal surfaces within, or immediately below displaced blocks and MTDs, with these same blocks marking the sudden release of overburden pressure near the seafloor (Sultan et al., 2004; Alves, 2015). Notwithstanding this work, the roles of MTDs on fluid migration after their emplacement have seldom been addressed in the published literature.

In the Pearl River Mouth Basin, small-scale MTDs are observed on a canyon-incised continental slope (e.g. Dickinson et al., 2012; Gong et al., 2013; He et al., 2014; Li et al., 2016a,b). Here, large-scale MTDs are grouped together to form the Baiyun Submarine Slide Complex (BSSC), and cover an area of more than 10,000 km^2. They are imaged on multibeam bathymetry and 2D/3D seismic data on the continental slope off the Pearl River Mouth Basin (Sun et al., 2008; Li et al., 2014; Wang et al., 2014; Sun et al., 2017). The BSSC is composed of, at least, three vertically stacked MTDs, which were respectively emplaced at 0.19 Ma, 0.50 Ma and 1.59 Ma before

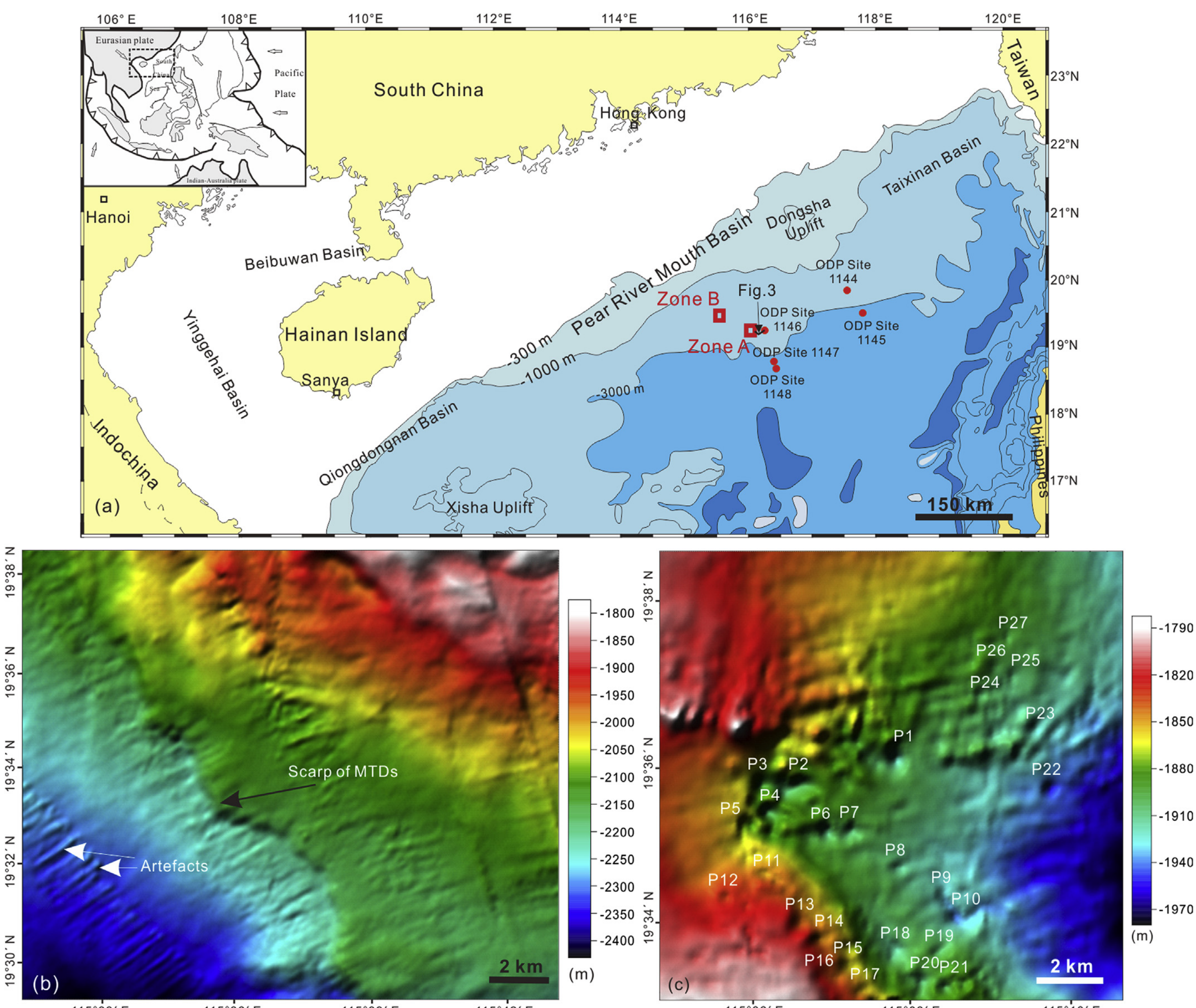

Fig. 1. (a) Geological setting and location of sedimentary basins in the northern South China Sea. Inset (top left): regional setting. The two study areas (highlighted by the red squares) are located within the Pearl River Mouth Basin (modified from Sun et al., 2012). ODP sites 1144–1148 are labeled; (b) Seabed morphology of Zone A. The MTD scarp is identified; (c) Seabed morphology of Zone B. Pockmarks (P) are observed and numbered. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)