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Submarine volcanic mounds in the Pearl River Mouth Basin, northern South China Sea

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ABSTRACT

A number of enigmatic, km-scale mound structures have been discovered in the Baiyun Sag of the Pearl River Mouth Basin using high-resolution 2D and 3D seismic data combined with multi-beam bathymetry. Based on detailed seismic characterization, we interpret these as sill-fed volcanic mounds. Associated structures include igneous sills, trans-tensional faults, lava flows and compactional drape folds. The igneous intrusions and associated mounds were emplaced in the late Early Miocene (c. 18.5 Ma or shortly thereafter), constrained by the onlap relationship between the mounds and their overburden. The volcanic mounds are preferentially developed above or adjacent to basement highs, indicating a structural control on the igneous plumbing system. We propose that the fractures and tectonic faults above the raised basement follow pre-existing zones of weakness and may have acted as feeding conduits for the magmatic material. The discovery of the Early Miocene igneous province has important implications for the understanding of the evolution of the Pearl River Mouth Basin and for regional hydrocarbon prospectivity.

1. Introduction

Submarine volcanic mounds are widespread above active spreading centers in oceanic settings such as the Juan de Fuca Ridge and the Mid Atlantic Ridge (c.f. Embley and Chadwick, 1994; Smith et al., 1995), and recently observed in several sedimentary basins such as Faroe-Shetland Basin along the Atlantic margin and the Great Australian Bight (c.f. Hodges et al., 1999; Davies et al., 2002; Schofield and Totterdell, 2008; Jackson, 2012; Magee et al., 2013). They have received increasing attention over the last decade due to the wider appreciation of their importance for global climate change and understanding basin-scale process including fluid flow and diagenesis, as well as predicting the distribution of hydrocarbons in sedimentary basins (Svensen et al., 2004; Cartwright et al., 2007; Rohrman, 2007; Sun et al., 2014). Volcanic mounds often occur above igneous sill complexes and are thus often interpreted as sill-fed volcanic cones. The timing of mounds can be estimated using radiometric methods. However, in the absence of radiometrically-dated rock samples, seismic stratigraphic relationships can be used to constrain the timing of sill emplacement, based on the seismic interpretation of the relationship between overlying strata and the stratigraphic context of the mounds (Smallwood and Maresh, 2002; Trude et al., 2003; Svensen et al., 2004; Hansen and Cartwright, 2006).

Several previous studies have mentioned the possibility that large-scale igneous intrusions may exist in the study area (Zou et al., 1995; Wang et al., 2002; Sun et al., 2005) and this is confirmed by Sun et al. (2014) using high-resolution 3D seismic data. The OBS data which is acquired in 1993 also suggested that Neogene magmatic rocks formed after the cessation of sea floor spreading (Yan et al., 2006). However, key questions concerning the true morphology, age and tectonic controls for the volcanic and intrusive rocks in the study area have been unresolved due to poor seismic coverage and paucity of actual rock samples.

Submarine volcanic mounds and the related igneous sills and other related structures imaged by our high-resolution 3D seismic data have not previously been documented in the study area and surrounding areas of the northern South China Sea. The new 3D and 2D seismic data and multi-beam bathymetry have thus allowed these structures to be documented in detail for the first time. We discuss the age and the tectonic drivers for magmatic activity and preservation of these submarine mounds. We conclude by proposing a model placing the igneous structures in a tectono-stratigraphic context. Our study has improved the overall understanding of igneous activities in the northern South China Sea area and provided new information for the evolution of the

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Pearl River Mouth Basin with implications for future petroleum exploration of the area.

2. Geological setting

As the largest and deepest marginal sea in the western Pacific Ocean, the South China Sea (SCS) is separated from Indochina by a transform zone and from the South China Block by an extensional zone and is bounded by a subduction zone adjacent to the Philippine arc and a compressional zone in Malaysia and Indonesia (Fig. 1; Taylor and Hayes, 1983; Li et al., 2008). It had drifted to its present position in the mid Miocene after seafloor spreading (Taylor and Hayes, 1983).

A series of Cenozoic rift basins formed along its northern margin, including the Qiongdongnan Basin, the Pearl River Mouth Basin (PRMB), the Yinggehai Basin, the Taixinan Basin and the Beibuwan Basin (Fig. 1; Lin and Zhang, 1997). These basins formed in response to Paleocene–Oligocene rifting and Neogene–Quaternary post-rift subsidence (Ru and Pigott, 1986; Huang et al., 2003). The sedimentary environment changed from alluvial and lacustrine in the early stage, to shallow marine facies, and finally turned to open marine in the late stage, which are coincident with the two tectonic evolutionary stages, respectively (Zhu et al., 2009).

The study area is located in the southeast part of Baiyun Sag in the PRMB, covering an area of ca. 2500 km^2 (Fig. 1). The present water depth of the study area is 1100 to 2500 m (Fig. 1). Regional unconformities represent five major tectonic events, the 1st Zhuqiong Event, the 2nd Zhuqiong Event, the Nanhai Event, the 23.8 Ma Tectonic Event and the Dongsha Event (Li, 1994; Pang et al., 2007; Dong et al., 2008;

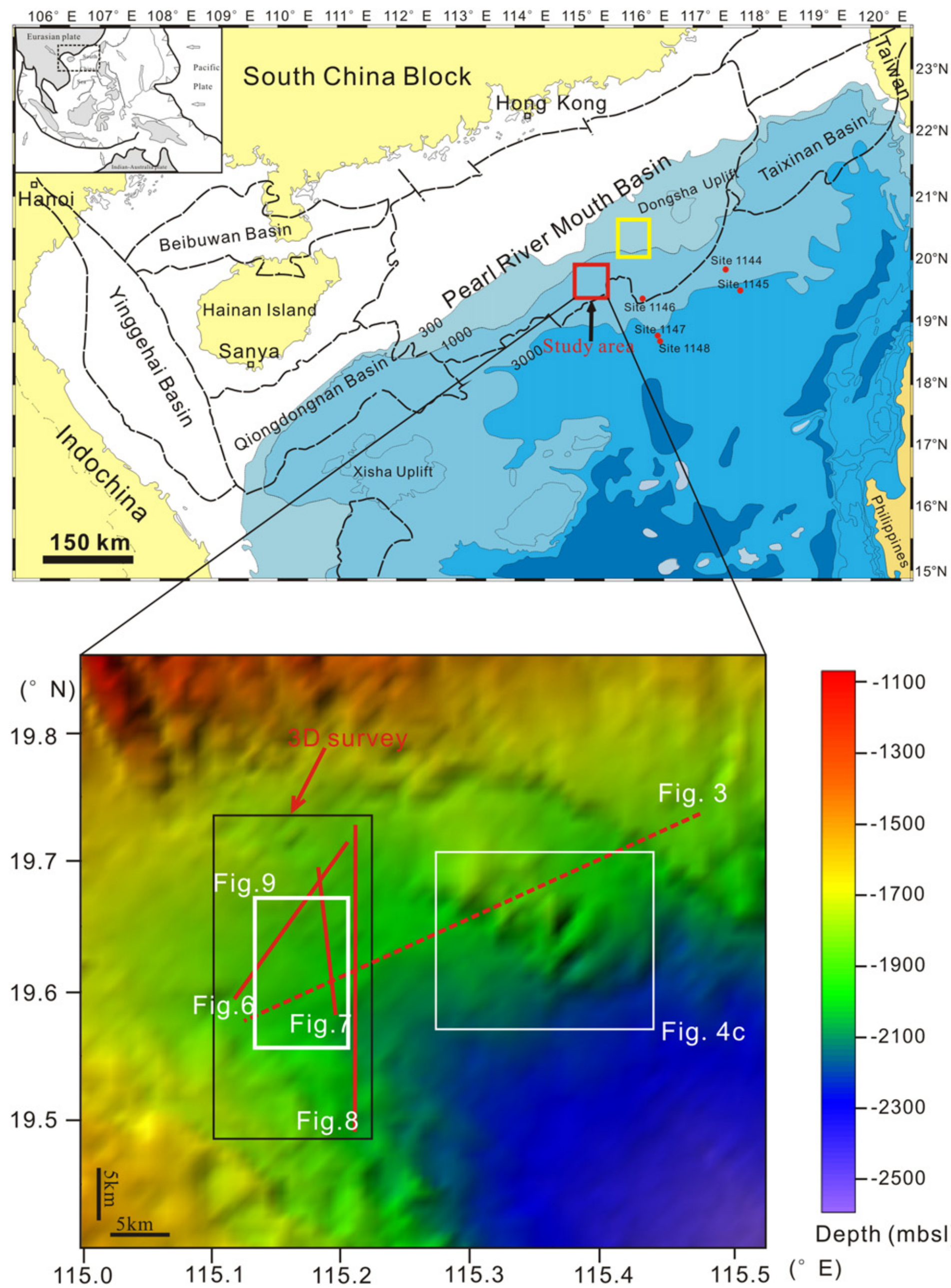

Fig. 1. (A) The location of the study area and sedimentary basins in the northern South China Sea. Inset (top left): regional geological setting (after Sun et al., 2012). The yellow rectangle shows the location of Sun et al.'s (2014) study area; (B) Multi-beam bathymetry image of the study area showing water depth and the details of the seismic surveys used in this study. The 3D seismic survey is outlined by the black rectangle. The red dotted line and red solid lines indicate the locations of 2D seismic line and 3D seismic lines, respectively. The right white outline shows the location of a 3D visualization section. mbsl, meters below sea-level.