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Geologic setting of PACManus hydrothermal area — High resolution mapping and in situ observations

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ABSTRACT

This study presents a systematic analysis and interpretation of autonomous underwater vehicle-based microbathymetry combined with remotely operated vehicle (ROV) video recordings, rock analyses and temperature measurements within the PACManus hydrothermal area located on Pual Ridge in the Bismarck Sea of eastern Manus Basin. The data obtained during research cruise Magellan-06 and So-216 provides a framework for understanding the relationship between the volcanism, tectonism and hydrothermal activity. PACManus is a submarine felsic vocanically-hosted hydrothermal area that hosts multiple vent fields located within several hundred meters of one another but with different fluid chemistries, vent temperatures and morphologies. The total area of hydrothermal activity is estimated to be 20,279 m^2. The microbathymetry maps combined with the ROV video observations allow for precise high-resolution mapping estimates of the areal extents of hydrothermal activity. We find the distribution of hydrothermal fields in the PACManus area is primarily controlled by volcanic features that include lava domes, thick and massive blocky lava flows, breccias and feeder dykes. Spatial variation in the permeability of local volcanic facies appears to control the distribution of venting within a field. We define a three-stage chronological sequence for the volcanic evolution of the PACManus based on lava flow morphology, sediment cover and lava SiO_2 concentration. In Stage-1, sparsely to moderately porphyritic dacite lavas (68–69.8 wt.% SiO_2) erupted to form domes or cryptodomes. In Stage-2, aphyric lava with slightly lower SiO_2 concentrations (67.2–67.9 wt.% SiO_2) formed jumbled and pillowed lava flows. In the most recent phase Stage-3, massive blocky lavas with 69 to 72.5 wt.% SiO_2 were erupted through multiple vents constructing a volcanic ridge identified as the PACManus neovolcanic zone. The transition between these stages may be gradual and related to progressive heating of a silicic magma following a recharge event of hot, mantle-derived melts.

1. Introduction

Hydrothermal systems at ridges dominated by felsic volcanism are not as well studied as the more widely documented hydrothermal systems of basalt-hosted mid-ocean ridge (MOR) spreading centres (e.g. de Ronde et al., 2001; German et al., 2004). Subaqueous, felsic volcanic ridges are common in immature back-arc basins with volatile-rich magmas, whose genesis is strongly influenced by processes related to nearby subduction zones (Kamenetsky et al., 2001; Martinez and Taylor, 2003; Park et al., 2009). It is well known the felsic host rock composition combined with the magmatic, volatile-enriched hydrothermal fluids play an important role in enriching economically important metals such as copper, gold and zinc in the vent deposits (e.g. Sangster, 1980; Herzig, 1999; Iizasa, 1999; Hannington et al., 2005; Mosier et al., 2009; Hannington et al., 2011). The surface expressions of submarine felsic-hosted hydrothermal systems (i.e. hydrothermal areas) are potentially important analogues for many ore-deposits found on land today. The PACManus (Papua–Australia–Canada–Manus) hydrothermal area is one of these surface expressions located on the crest of the Pual Ridge in the eastern Manus Basin, an immature back-arc basin (Fig. 1).

This study presents a systematic analysis using a Geographical Information Systems (GIS) database of autonomous underwater vehicle (AUV) based microbathymetry combined with remotely-operated vehicle (ROV) video recordings, rock analyses and temperature measurements of individual hydrothermal discharge sites for the hydrothermal fields of the PACManus hydrothermal area in the SE Manus Basin. It allows documentation of the first detailed, georeferenced mapping of the volcanic and hydrothermal structures in the PACManus hydrothermal area. Our analysis of the data has resulted in a set of comprehensive maps of the geological structures of the PACManus hydrothermal area and documents the interaction between subaqueous felsic volcanism and its influence on hydrothermal fluid discharge at the seafloor.

2. Geological setting

The Manus Basin is located in the eastern part of the Bismarck Sea, which is situated in the western Pacific Ocean northeast of the Papua

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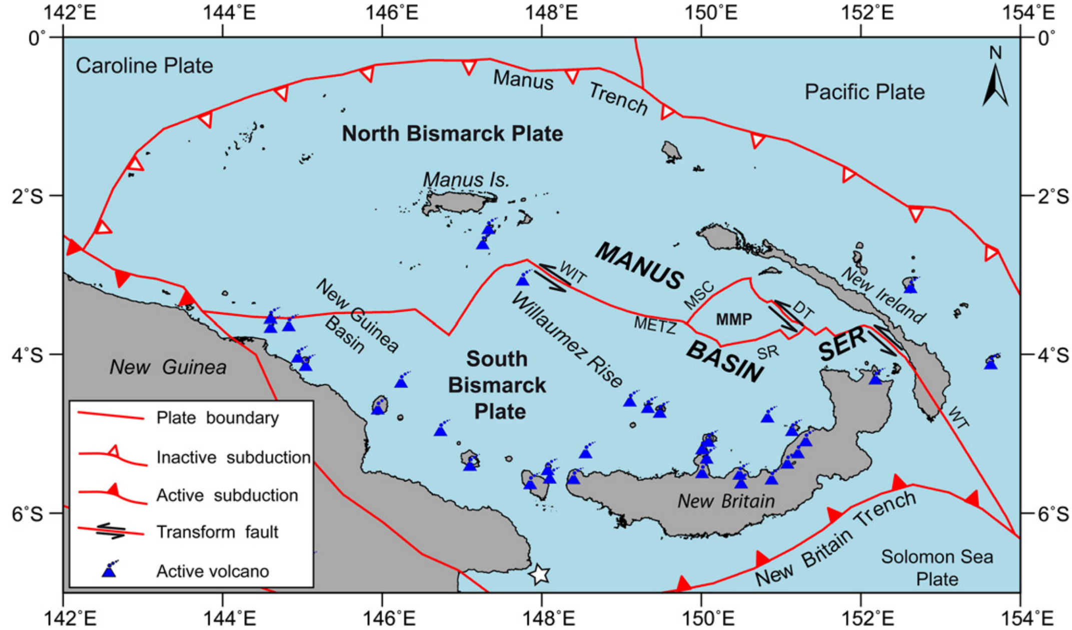

Fig. 1. Tectonics at the Manus Basin. Abbreviations: WT = Weitin Transform; DT = Djaul Transform; WIT = Willaumez Transform; METZ = Manus Extensional Transform Zone; SR = Southern Ridges; MMP = Manus Microplate; SER = Southeast Ridges; MSC = Manus Spreading Centre; Star = Absolute Pole of South Bismarck Plate Rotation; Plate boundaries from Bird (2003).

New Guinea mainland (Fig. 1). Manus Basin, with an average water depth of 2000 m, is an oblique opening back-arc basin formed by the northward subduction of the Solomon Sea Plate along the New Britain Trench (Taylor, 1979; Martinez and Taylor, 1996, 2003; Lee and Ruellan, 2006). Crustal extension in the Manus Basin is distributed between the Manus Spreading Centre (MSC), the Manus Extensional Transform Zone (METZ), the Southern Rifts (SR) and the Southeast Ridges (SER; Martinez and Taylor, 1996). The clockwise rotation (~8° Ma^{-1}) of the South Bismarck Plate around a pole at 10.2°N, 33.3°W (Star in Fig. 1) causes asymmetric spreading of the North and South Bismarck Plate (Tregoning et al., 1999). This is manifest by spreading rates of 137.5 mm a^{-1} at the SER, which are the highest spreading rates within the Bismarck Sea (Tregoning, 2002). The SER region also has bimodal, basaltic to rhyolitic volcanism (Binns and Scott, 1993), which is typical of the initial opening phase of a back-arc-basin.

The SER region is a rift zone of pre-existing island arc crust, which consists of a series of sigmoidally-shaped volcanic ridges influenced by the strike–slip movement generated by the two bordering left lateral transform faults; the Weitin Transform (WT) and the Djaul Transform (DT) (Taylor et al., 1994) (Figs. 1, 2; Supplemental Video S3). The PACManus hydrothermal area lies on the central crest of Pual Ridge, which is part of the SER. Pual ridge is ~20 km long, 1–1.5 km wide and rises 500–600 m above the surrounding seafloor (Fig. 2; Binns and Scott, 1993; Bartetzko et al., 2003; Paulick et al., 2004). The summit of Pual Ridge is capped by a 200 m by 800 m long central neovolcanic zone. The AUV ABE collected a comprehensive microbathymetry map

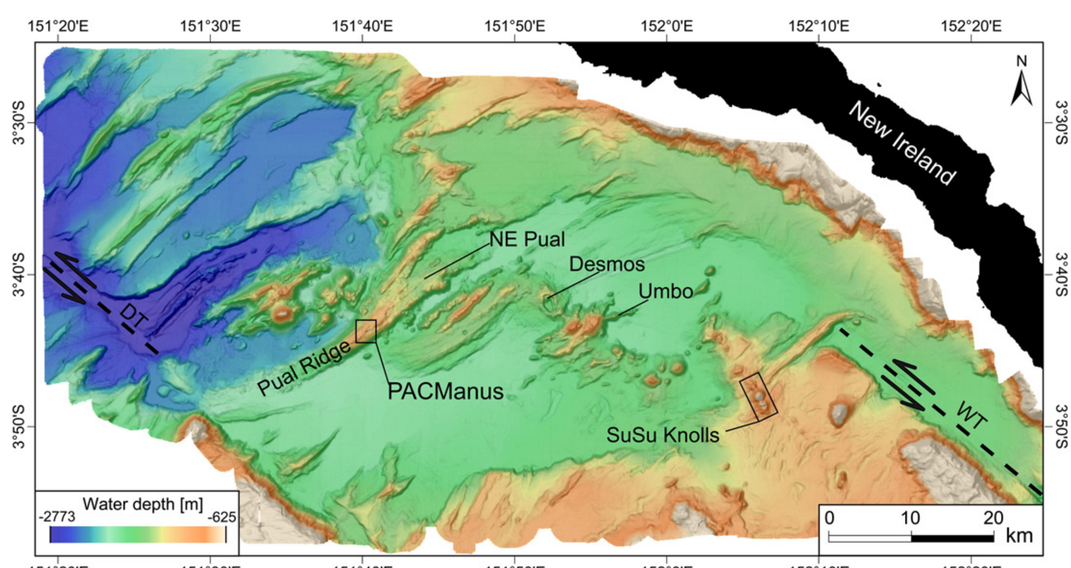

Fig. 2. Multibeam bathymetry map of South Eastern Ridges (SER) region in the Eastern Manus Basin region with known hydrothermal area. WT = Weitin Transform; DJ = Djaul Transform.
Data recorded on BAMBUS – RV Sonne 216 cruise.