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Distribution of mega fauna on sulfide edifices on the Eastern Lau Spreading Center and Valu Fa Ridge

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ABSTRACT

Hydrothermal vent sulfide edifices contain some of the most extreme thermal and chemical conditions in which animals are able to live. As a result, sulfide edifices in the East Pacific Rise, Juan de Fuca Ridge, and Mid Atlantic Ridge vent systems often contain distinct faunal assemblages. In this study, we used high-resolution imagery and *in-situ* physico-chemical measurements within the context of a Geographic Information System (GIS) to examine community structure and niche differentiation of dominant fauna on sulfide edifices in the Eastern Lau Spreading Center (ELSC) and Valu Fa Ridge (VFR) in the Western Pacific Ocean. Our results show that ELSC and VFR sulfide edifices host two distinct types of communities. One type, that covers the majority of sulfide edifice faces, is overall very similar to nearby lava communities and biomass is dominated by the same chemoautotrophic symbiont-containing molluscs that dominate lava communities, namely the provannid gastropods *Alviniconcha* spp. and *Ifremeria nautilei* and the mytilid bivalve *Bathymodiolus brevior*. The spatial distribution of the dominant molluscs is often a variation of the pattern of concentric rings observed on lavas, with *Alviniconcha* spp. at the tops of edifices where exposure to vent flow is the highest, and *I. nautilei* and *B. brevior* below. Our physico-chemical measurements indicate that because of rapid dispersion of vent fluid, habitable area for symbiont-containing fauna is quite limited on sulfide edifices, and the realized niches of the mollusc groups are narrower on sulfide edifices than on lavas. We suggest that competition plays an important role in determining the realized distributions of the mollusc groups on edifices. The other habitat, present in small patches of presumably hot, new anhydrite, is avoided by the dominant symbiont-containing molluscs and inhabited by crabs, shrimp and polynoids that are likely more heat tolerant. The ratio of sulfide concentration to temperature anomaly of vent fluids was significantly different between sulfide edifice sites and lava sites in the southern vent fields but not in the northern vent fields. We suggest that this is due to increased sulfide consumption by a large microbial consortium associated with the more friable andesitic lava substrates in the south.

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1. Introduction

The Lau Back-arc Basin is situated in the Western Pacific between the nations of Fiji and the Kingdom of Tonga. Two regions of the Lau Basin, the Eastern Lau Spreading Center (ELSC, from ~19°S to ~21°S) and the Valu Fa Ridge (VFR, from ~21°S to 23°S), are located between a remnant arc (Lau Ridge) and an active volcanic arc (Tofua Volcanic Arc), west of the Tonga-Kermadec Trench (Fig. 1). These regions have been the focus of integrated biological and geological studies because crustal chemistry, spreading rates, lithospheric thickness and mantle properties all vary from north to south along the spreading center (Baker et al., 2006; Ferrini et al., 2008; Martinez et al., 2006; Pearce et al., 1994; Taylor et al., 1996, Tivey et al., 2012). Moving north to south along the ELSC and VFR (hereafter ELSC/VFR), distance from the active volcanic arc decreases from about 110 km to within 40 km (Ferrini et al., 2008; Martinez et al., 2006). Hydrothermal plume incidence decreases from north to south (Baker et al., 2006; Ferrini et al., 2008; Martinez et al., 2006), as do spreading rates, from about 97 mm/yr in the

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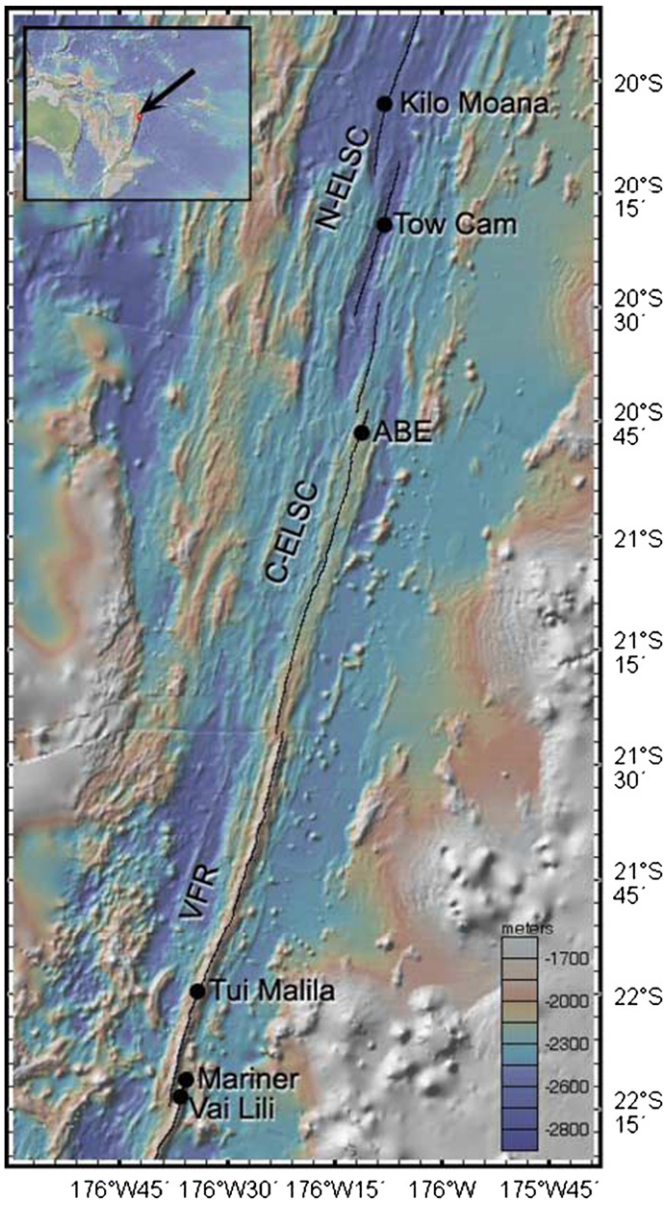

Fig. 1. Map of the vent fields of the Eastern Lau Spreading Center and Valu Fa Ridge (courtesy Ferrini et al., Variable morphologic expression of volcanic, tectonic, and hydrothermalprocesses at six hydrothermal vent fields in the Lau back-arc basin. Geochemistry Geophysics Geosystems 9 (7), 2008. Copyright (2008) American Geophysical Union. Reproduced with permission of American Geophysical Union).

north to 39 mm/yr in the south (Ferrini et al., 2008). Crustal thickness follows the opposite trend, with thin lithospheric crusts present in the north that nearly double in thickness to the south (Martinez et al., 2006). The crustal morphology also changes quite dramatically, with the northern sites being characterized by deep, flat axial basins and containing more faulting and fissuring than the southern sites, which are characterized by shallow, peaked ridges (Ferrini et al., 2008; Martinez et al., 2006).

Differences in the physical properties of lavas have been suggested to contribute to differences in the diffuse flow communities between northern and southern sites (Podowski et al., 2010). The northern sites of the ELSC are characterized by lobate pillow lavas of tholeiitic basalt, similar to mid-ocean ridge basalts (Fouquet et al., 1991a). The southern sites, however, have more complex and varied lavas, with a mixture of pillows and andesites (Ferrini et al., 2008; Fouquet et al., 1991a; Martinez et al., 2006). The andesitic lavas of the south are more porous, crumbly and have higher silica content than the pillow basalts of the north (Ferrini et al., 2008; Pearce et al., 1994). The proximity to the subducting slab and the presence of an axial magma chamber (only under southern sites) lead to a much higher gas content in the magma. This is thought to be responsible for making the lavas in the south more brecciated and vesicular (Fouquet et al., 1991a,b; Martinez et al., 2006; Pearce et al., 1994). North-to-south differences in chemistry and acidity of venting fluids are also attributed to the distance from the subducting slab and the presence/absence of the magma chamber (Baker et al., 2006; Gartman et al., 2011; Luther et al., 2012; Martinez et al., 2006; Mottl et al., 2011). The along-strike changes in the geochemistry of the lavas and hydrothermal fluid on the ELSC and VFR provide an excellent natural laboratory to investigate the interactions between the animal communities and the rock substrate and fluid chemistry.

A number of researchers have studied hydrothermal vents through still and video imagery as well as within the context of a Geographical Information System (Copley et al., 1997, 1999, 2007; Cuvelier et al., 2011; Fabri et al., 2011; Podowski et al., 2009, 2010; Sarrazin and Juniper, 1999; Tsurumi, 1998). Deep-sea vents are extremely difficult to access and these methods represent an uninvasive and relatively quick way in which these systems can be studied. Podowski et al. (2009, 2010) and Kim and Hammerstrom (2012) used these methods to examine the hydrothermal vent communities on lavas of the ELSC/VFR within the context of the geological and thermo-chemical gradients present in this region. However, the communities present on hydrothermal vent sulfide edifices in the Western Pacific region have not been well studied and have been characterized variously as dominated by one species of gastropod (Both et al., 1986; Stein et al., 1988), consisting of 'diverse assemblages' (Tufar, 1989), and 'abiotic' (Desbruyères et al., 1994). Our goal was to characterize these sulfide edifice communities, compare them to the communities found on the surrounding lavas, and to explore the roles of abiotic factors and biological interactions in shaping them. Abiotic factors can influence the structure of hydrothermal vent communities because distributions of symbiont-containing fauna are strongly correlated with hydrothermal conditions, as are the distributions of other vent fauna, albeit often at very different scales (Govenar, 2010). Gradients in vent fluid temperature and chemistry are quite steep on sulfide edifice structures where temperatures can change by over 100 °C within just a few centimeters (Harmsen et al., 1997; Jannasch, 1995; Takai et al., 2008; Tivey and McDuff, 1990). Additionally, biological interactions have been shown to shape hydrothermal vent communities (Lenihan et al., 2008; Micheli et al., 2002), including those on sulfide edifice structures (Levesque et al., 2003). Here, we used spatially explicit *in situ* physico-chemical measurements paired with high-resolution photo mosaics of Lau Basin sulfide edifices to address how both biotic and abiotic factors affect community structure as well as refine our understanding of the physiological ecology of the dominant fauna associated with diffuse hydrothermal flow on sulfides and lavas in the Lau Basin.

2. Methods and materials

2.1. Imaging and mosaicking

We collected photographic and physico-chemical data from eight sulfide edifices (sulfide edifice assessment sites) from the four main vent fields along the ELSC/VFR axis: Kilo Moana (KM), Tow Cam (TC), and ABE on the ELSC and Tu'i Malila (TM) on the VFR (Table 1 and Fig. 1). All data collection was conducted in September

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