



Faunal Assemblages on the Pacific-Antarctic Ridge near the Foundation Seamount Chain (37°30' S, 110°30' W)

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Introduction

The Pacific-Antarctic Ridge (PAR) is a fast spreading centre (10 cm year⁻¹ full rate) that trends north-south through the SE Pacific Ocean (Lonsdale, 1994). The northernmost part of the PAR is adjacent to the inferred present-day position of the Foundation mantle plume, a “hotspot” that has generated the 1400 km-long Foundation Seamount Chain (Devey et al., 1997). Consequently, there is a significant interaction between the spreading ridge and the upwelling mantle plume (Maia et al., 2000, 2001). This interaction may be responsible for an unusual suite of silicic lavas (andesite-dacite) that have been erupted along the northern PAR, the anomalously shallow depth of the PAR crest (~2.2 km), and the widespread occurrence of hydrothermal activity (Hékinian et al., 1997, 1999).

Both the *F/S Sonne* and the *N/O l'Atalante* undertook reconnaissance studies of the northern PAR near the Foundation seamounts during 1995 and 1997, respectively (Devey et al., 1997; Hékinian et al., 1999). The *F/S Sonne* re-visited the PAR from 37°35' to 41°45'S in mid-2001, primarily to determine the extent of the silicic lavas and hydrothermal activity (Stoffers et al., 2002). Faunal assemblages associated with hydrothermal venting were investigated within two working areas on the PAR crest; area “A” from 37°35'-37°50'S and subdivided into northern and southern parts, and area “B” near 39°25'S (Fig. 1).

Methods

The faunal assemblages were investigated using two instruments. A TV-controlled grab (GTVA) allowed precise sampling under visual guidance. The grab weighs 3.2 tonnes, and has two excavator shovels that cover an area of 2 m² with a maximum penetration depth of 0.7 m. Primarily

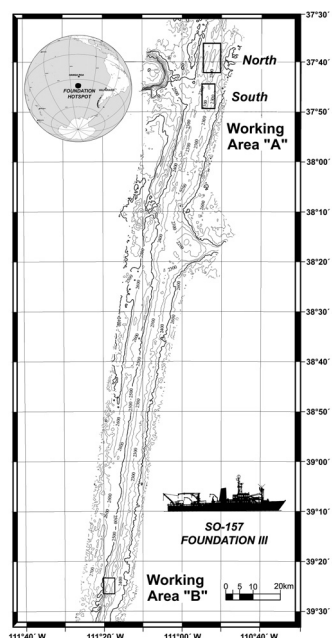


Figure 1. Working areas for biological investigations during the *Sonne* cruise SO-157, Foundation III.

sessile, semi-sessile, and slow moving taxa (e.g., *Neolepas* cf. *rapanui*, *Bathymodiolus* cf. *thermophilus*) were recovered and identified using the TV-grab.

Large-scale mapping of the faunal assemblages was completed using the Ocean Floor Observation System (OFOS). The OFOS sled houses several cameras in a 2 x 1.5 x 1.5 m frame. A video camera provided full-time monitoring, and a PHOTOSEA 5000 35 mm camera took

still photographs on operator command. This camera was fitted with a 28 mm wide-angle water correcting lens, and could be focused on a minimum distance of 0.6 m at an aperture of $f = 3.5-22$. Two laser beams aimed slightly forward in parallel give a true scale of 20 cm on the images. They are visible in the upper part of each slide as two red dots. Additionally, a third laser beam is fixed to form a line with the other beams when the camera lenses are 3 m above the seafloor.

During the four surveys, the OFOS sled was allowed to drift at 20 cm sec^{-1} ($= 12 \text{ m minute}^{-1}$) over long swaths of the seafloor. Video recordings and visual observations were made on board, while the conductivity, temperature, and water depth were recorded on-line from a CTD attached to the OFOS. The abundance of taxa within biologically active localities was classified as follows: "subdominant" = 1-5 observations minute^{-1} , "dominant" = 5-10 observations minute^{-1} , and "eudominant" >10 observations minute^{-1} . Faunal distribution patterns were then analysed using the time-scaled visual observations documented by the video recordings and synchronized with the CTD measurements.

Results

A total of 15 biologically active localities were identified within the two working areas. The time-frequency analyses of taxa showed an obvious variation of taxa dominance, allowing each active locality to be subdivided into central and peripheral sectors (Table 1). For working area "A", the central sector coincided with recorded temperature anomalies. For working area "B", where no temperature anomalies were recorded, we have used the time-scaled counts of gorgonians, galatheid and lithodid crabs to define the central sector. The observed dimensions of the biologically active localities ranged from 30 to 65 m in diameter. The central sectors were of similar diameter in both working areas (10-15 m), whereas the peripheral sectors varied from 25 to 50 m wide.

Working area "A"

Nine biologically active localities were found in the northern part of area "A", and six of these were associated with temperature anomalies (ΔT : $+0.1-0.20^\circ\text{C}$). However, no evidence of active venting was observed (e.g., cloudy bottom water). At least four generations of lavas were evident, and the youngest glassy pillows, lobate and ropy flows were not observed on parallel camera tracks during the 1995 and 1997 surveys (Devey et al., 1997; Hékinian et al., 1999). No bacterial mats were observed in the central sector of these active localities. Bythograeid and galatheid crabs were generally eudominant. The faunal assemblage of the peripheral sectors featured eudominant comatulid crinoids followed by dominant-eudominant rhodalids and anguillid fish. Macrourid fish (rat-tails) were dominant.

In the southern part we found two biologically active localities, in one we mapped a hydrothermal faunal assemblage, which measured $30 \text{ m} \times 30 \text{ m}$. This assemblage was developed near an active vent associated with cloudy bottom water (ΔT : $+0.25^\circ\text{C}$). Active and fossil sulphide deposits, encircled by deep fissures, characterized the seafloor together with young glassy lava. Eudominant taxa in the central sector surrounding the active vent were

Table 1. General distribution patterns of the dominant taxa within biological active localities. Based on time scale observations faunal distribution patterns of the two working areas differ significantly, and allowed generally to distinguish between peripheral and central subareas. "+" = subdominant, observations 1-5 [individuals / minute]; "+ +" = dominant, observations 5-10 [individuals minute]; "+ + +" = eudominant, observations >10 [individuals minute].

Taxa	Periphery			Central		
	Working Area A		B	Working Area A		B
	north	south		north	south	
macrourid fish	++	++	+++	+	+	+
anguillid fish	++	+++	+	+	+	+
<i>Hyocirantus</i> sp.	++	++	+++			
comatulid crinoids	+++	+++	+			
Brisingidae	+	+	+++			
Paraclinopoda	+	++	+++			
stalked sponges						
(type Caulophacidae)	+	+	+++			
plate sponges	+	+	+++			
Actinians		+	+++			++
Rhodalids	++	+++	+			
calcificated gorgonians						+++
bythograeid crabs	+	+	+	+++	+++	++
galatheid crabs		++	+			+++
(type: Shinkaiinae)						
<i>Munidopsis</i> sp.	+	+	+	+++	+++	++
lithodid crabs (type <i>Paralomis</i>)						+++
<i>Neolepas</i> cf. <i>rapanui</i>					+++	
<i>Bathymodiolus</i> cf. <i>thermophilus</i>					+++	
vesicomyid clams (only shells)					+++	
chaetopterid tubes worms					+++	
Limpets (<i>Lepetodrilus</i> sp.)					+++	

Bathymodiolus cf. *thermophilus* and *Neolepas* cf. *rapanui*, occurring in pockets between basalt blocks. Shells of dead vesicomyid clams (up to 20 cm in length) were observed near these *Bathymodiolus* aggregates (Fig. 2). Opened specimens of *Bathymodiolus* showed only moderately hypertrophic gills. Neither of the two bivalve genera were seen in the other biologically active localities (Table 1). Chaetopterid tube worms and limpets of the genus *Lepetodrilus* were dominant-eudominant. The faunal assemblage of the peripheral sector was comparable to that at the northern area "A" localities.

Working area "B"

Four biologically active localities were identified in this area, but there were no temperature anomalies. Most of the seafloor consisted of old sedimented pillow lavas, although two generations of lava outcropped in the higher northern part of the area. There, fresh ropy lavas and sheet flows were characterized by strongly elongated flow-aligned vesicles which were often lined with small pyrite-cubanite crystals and released H_2S when cut (Stoffers et al., 2002).

Actinians (*Actinostola* sp.) were widespread at all active localities and mostly eudominant. Crustaceans were eudominant in the northern localities, dominant in two gorgonian patches further south, and more crustacean taxa were recorded relative to localities in working area "A". In addition to dominant bythograeid crabs and squat lobsters (*Munidopsis* sp.), species of galatheid (similar to

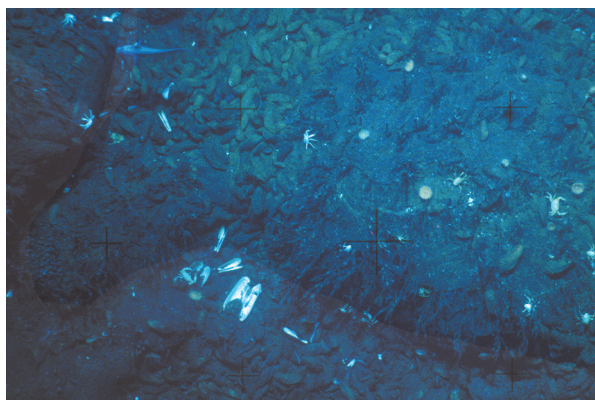


Figure 2. Aggregations of *Bathymodiolus* cf. *thermophilus* attended with *Neolepas* cf. *rapanui*, chaetopterid tube worms, dead vesicomyid clams, bythograeid crabs, actinians (Actinostolidae) and macrourid fish (working area "A" south, vicinity of an active vent, water depth 2210 m).

Shinkaiinae) and lithodid (probably *Paralomis* sp.) decapods were eudominant. Most of the eudominant gorgonians in the two gorgonian patches were dead and strongly calcified (Table 1).

The peripheral sectors of the four biologically active localities featured macrourid fish, filter feeders including asterid starfish (Brisingidae), pelagic holothurians (Paraclinopoda), and stalked sponges (Caulophacidae). Large plate sponges up to 30 cm in diameter were found predominantly on fresh lava. Stalked crinoids of *Hyocriantus* sp. were eudominant, and significantly more were recorded than within working area "A" (Table 1).

Discussion

The OFOS observations and TV-grab sampling of the PAR hydrothermal communities in working area "A" reveal many similarities with the communities documented at various sites on the East Pacific Rise (EPR) between 21°N and 30°S (Francheteau & Ballard, 1983; Renard et al., 1985; Fustec et al., 1987; Marchig et al., 1988; Lutz, 1991; Holler, 1993). For example, the near-vent occurrence of *Bathymodiolus* cf. *thermophilus* assemblages living in pockets between basalt blocks and accompanied by large numbers of dead vesicomyid clams. However, our PAR faunal assemblages are characterized by the dominance of filter-feeders such as comatulid crinoids, stalked crinoids of *Hyocriantus* sp., Paraclinopoda, Rhodalids, and sponges resting on fresh lava. A flow of particulate matter providing nutrition to the hydrothermal communities is strongly suggested by the abundance of filter-feeders at the PAR. We suspect this particulate flow is linked to recent geological events in area "A", namely the eruption of fresh lavas observed during our mid-2001 cruise but not reported during the 1995 and 1997 surveys (Devey et al., 1997; Hékinian et al., 1999).

The destruction and replacement of megafaunal communities on short time-scales following submarine eruptions has been documented at other spreading centres (Hayman et al., 1991; Lutz et al., 1994; Desbruyères & Segonzac, 1997). Typically, there is an intensive

development of bacterial mats around diffuse hydrothermal vents after the eruption, and these mats are eaten by bythograeid crabs within the first six months (Desbruyères & Segonzac, 1997). This is similar to our observations on the PAR, where bythograeid crabs were widespread on the young lavas but bacterial mats were not identified. An age somewhat in excess of 6 months, but less than 4 years (1997 survey), is inferred for the youngest lavas in area "A".

Diffuse venting is likely to dwindle to low levels in the months following an eruption, leading to further changes in the faunal assemblage. Bythograeid crabs were frequently seen and associated with *Hyocriantus* sp. in area "A", and were also found in the vicinity of the strongly calcified gorgonians in working area "B". These gorgonians are obvious indicators of a dying community (Grasshoff & Zibrowius, 1983). Both *Hyocriantus* and the gorgonians were anchored on older lavas surrounded by the fresh pillows and lava tubes. Although the young lavas contain sulphides lining their vesicles, it is unlikely that high concentrations of H_2S are at present released into the water column. This may also explain why the gill filaments of *Bathymodiolus* cf. *thermophilus* were only moderately hypertrophic: the available H_2S concentration is now too low for chemoautotrophic bacteria.

Other evidence for a recent decrease in hydrothermal venting includes the displacement of an older vesicomyid assemblage by *Bathymodiolus* in the southern part of area "A". The same temporal change in the faunal community has been reported elsewhere on the EPR (e.g., Lutz, 1991). Decreasing vesicomyid clam populations have been attributed to a decline in hydrothermal venting, as the ability of these clams to filter-feed is limited (Hessler & Smithey, 1983; Childress & Fisher, 1992).

Chaetopterid tube worms were eudominant in our hydrothermal faunal assemblages on the PAR, whereas they have not been reported on the EPR (e.g., Tunnicliffe, 1991; van Dover, 2000). Chaetopterid polychaeta are also filter-feeders, and we suspect their presence reflects a previously unrecognized temporal variation in the food chain developed at localities with declining hydrothermal activity. Their feeding and living strategy is well-adapted to a combination of weak hydrothermal activity and high particle flow, as the tube protects the worm against dissolved H_2S and enables it to reach deep into the particle flow (e.g., Childress & Fisher, 1992).

The dominant-eudominant occurrence of the limpet *Lepetodrilus* sp. further supports the notion of weak hydrothermal activity and is indicative of dissolved H_2S (Hessler & Smithey, 1983). No specimens of *Riftia pachyptila* Jones, 1981 were identified by us at either 37°35'S or 39°25'S on the PAR, which contrasts with their documented presence at 17°S and 20°S on the EPR (Guinot & Segonzac, 1997; Juniper et al., 1990; Marchig et al., 1988). The absence of *Riftia pachyptila* is in accord with the collapsed vesicomyid assemblage, but does not preclude its presence in the past.

Conclusions

Faunal assemblages along the northern PAR are dominated by filter-feeders, which are especially prevalent in the older

communities of working area "B" where the hydrothermal flux is less. Our observations demonstrate the impressive temporal and spatial variations of these hydrothermally influenced faunal assemblages, and also faunal replacement strategies that reflect the changing magnitude of hydrothermal activity. Two replacement strategies can be seen on the northern PAR:

In the immediate aftermath of an eruption, the old megafauna is destroyed and/or replaced by new biota. A young hydrothermal-based community displaces the old filter feeding assemblage.

Diffuse hydrothermal venting diminishes with time and leads to a natural ageing cycle in which, for example, vesicomyid clam assemblages are replaced by *Bathymodiolus*. A symbiosis-dominated community now progressively shifts to a filter feeding assemblage.

One of the outstanding remaining problems is to document the time scales of these faunal changes and their relationship to geological processes. The northern PAR represents an ideal laboratory for such studies, as eruptions and associated changes in the magnitude of the hydrothermal flux occur on short time-scales. Furthermore, different hydrothermal sites along the PAR are at present at different stages of these cycles.

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