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Observations of Present-Day Activity at Super-Fast Spreading : Volcanic, Hydrothermal and Tectonic Studies of the EPR 17-19°S

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In December 1993, during the NAUDUR cruise, we conducted a series of dives using the French submersible *Nautile* (Fig. 1). The purpose of these dives was to explore the East Pacific Rise (EPR) axis between 17°S and 19°S where the spreading rate is nearly the fastest presently active (141 to 162 mm/y) (Rea, 1977; Naar and Hey, 1989; DeMets et al., 1990; Perram et al., 1993; Cormier and Macdonald, 1994). The area between 17° and 19°S has been extensively surveyed since 1982 with Seabeam and SeaMARC II by French, German and American institutions (Renard et al., 1985; Bäcker et al., 1985; Macdonald et al., 1988; Perram et al., 1993; Scheirer et al., 1993; Cormier and Macdonald, 1994). The ridge axis in this region varies from a shallow axial dome less than 2600 m deep to an axial graben a few hundred meters wide and a few tens meters deep cutting the top of the dome. A very shallow (less than 1 km deep) seismic reflector interpreted as the top of the magma chamber has been identified by multichannel seismic surveys (Detrick et al., 1993) near 17°22'S. In 1984 the submersible *Cyana* carried out 8 dives between 17°30' and 21°30'S (Renard et al., 1985; Bäcker et al., 1985; Gente, 1987) and discovered fossil hydrothermal deposits in collapsed lava lakes.

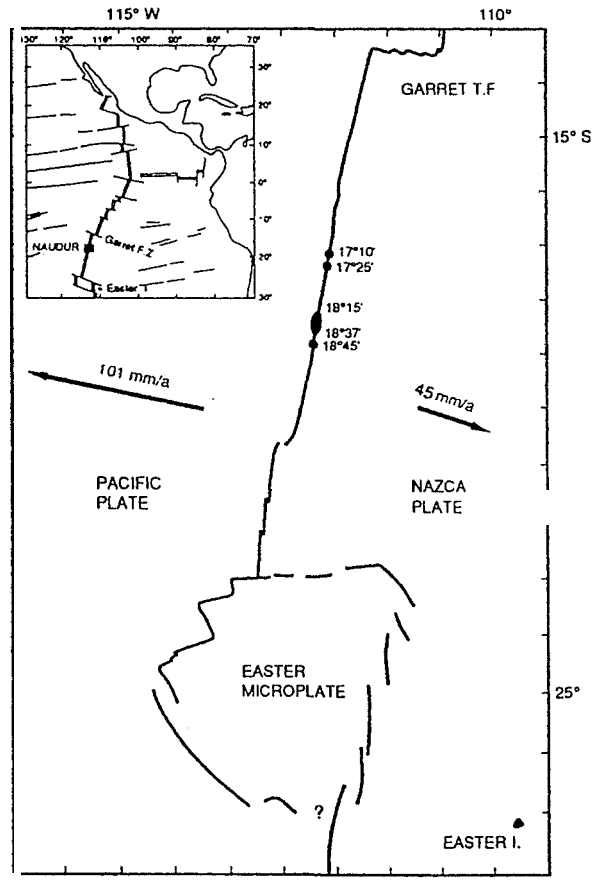

Figure 1. Location map of the NAUDUR cruise dives. Sketch of the EPR after Cormier and Macdonald (1994).

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Objectives and Results of the NAUDUR cruise

The objectives of the NAUDUR cruise were to carry out geological explorations along different segments of the EPR located between 17° and 19°S in order to study the interaction between magmatic, tectonic and hydrothermal processes at a very fast spreading mid-ocean ridge axis (Auzende et al., in press). Twenty three dives were successfully completed along and across the axis in five different regions centered around 17°10'S, 17°25'S, 18°15'S, 18°25'S and 18°45'S (Fig. 1). These regions are characterized by a range of axis morphologies varying from an axial volcanic dome covered by very recent lava, to significantly more tectonized axes. Although various manifestations of hydrothermal activity are present on all the explored segments, the style of this activity appears to vary with axis morphology and how recently the area has been volcanically active.

The spreading ridge in the 17°10'S zone is a dome culminating at 2600 m depth and devoid of summital tectonic graben. Two main types of lavas have been observed; pillows and tubes on the flanks of the ridge and more fluid, sheet-like draped or lobated lavas at the axis. The pillows and tubes are capped by a very thin sedimentary cover, but the fluid lavas are extremely fresh and lack any sedimentary dust. Locally, very fresh lobate lavas have been observed partially covering clams and serpulid colonies (Fig. 2) and inactive sulfide mounds and chimneys. In the very axial part of the dome, one or two parallel fissures cut through the most recent lobate flows. Active and fossil vents were observed and sampled on the edge of the axial fissure. They consist of groups of small vents of shimmering water and associated colonies of clams, serpulids, vestimentifers, etc. Living colonies of clams and serpulids were present on now extinct vents that were thus probably active very recently.

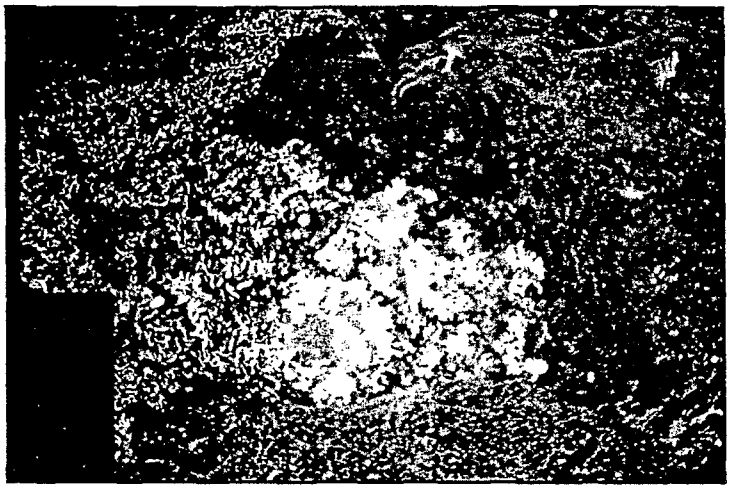

Figure 2. Photograph of present-day lava flow overlying previous flows colonized by serpulid worms (17°10'S area)

The 17°25'S region shows morphological characteristics very similar to those of the previous area, with an axial dome also culminating at 2600 m. This region was explored during *Cyana* dives in 1984 (Renard et al., 1985). At that time, the magmatic activity was concentrated only along an axial alignment of narrow collapsed lava lakes, and hydrothermal activity was not important. The six dives carried out in this region during the NAUDUR cruise lead us to conclude that important changes in morphology as a result of magmatic and hydrothermal activity have occurred since 1984.

To the north of the zone explored in 1984, the axis has a quite uniform character, with lavas alternating from pillow flows to lobated lava flows. Very recent fissures, a few tens of centimeters to a few meters wide, truncate these flows. A discontinuous collapsed lava lake, with 6-12 m high pillars is present locally at the ridge axis; it is floored either by debris from the very recently collapsed roof or locally by sheet flows that clearly post-date the collapse debris. To the south, extremely fresh lavas have been observed on the almost flat, top surface of the ridge, which is not at all tectonized. The lavas include pillowed and lobated flows characterized by a black, very glassy surface with yellowish bacterial-like vellum. They are completely devoid of sediments and do not show fixed faunas.

Hydrothermal vents are common in the axial domain (Fouquet et al., in press). They include diffusion of shimmering water from many areas of the most recent lava surfaces and high temperature venting (black smokers, 250-340°C) in older regions (Fig. 3). Pillars of the recently collapsed lava lake clearly serve as conduits for venting of shimmering water. Temperature anomalies were recorded by the *Nautile* in the region of the summital lava lake. Such anomalies could be related either to the diffuse venting of hot water or to the occurrence of still hot, cooling lavas. Animal colonies are abundant and show a large variety of species (Geistdoerfer, et al., in press).

The segment immediately north of 18°22'S, is characterized by a wide graben bounded by two ridges culminating at 2650 m. From dive results, the graben appears to have a maximum width of 800 m. It may include a secondary axial graben with a maximum depth of 80 m, bounded by two steps. The main boundary faults of the graben have a total vertical offset of 30-40 m. The bottom of the central valley shows

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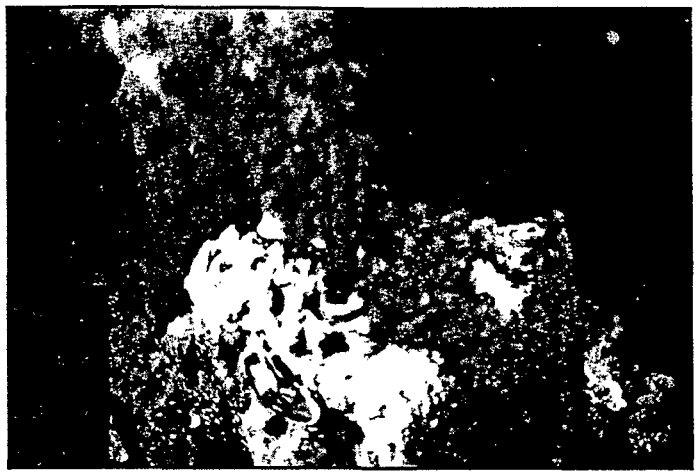

Figure 3. Active hydrothermal site with black smokers at 17°25'S. The measured temperature of the water is 318°C.

intense fissuring. Open fissures, some meters wide, are extremely common. Some of them separate small horsts that are only a few meters wide and 10 meters high. These very fragile features are locally tilted. The observed volcanic formations include chaotic, brecciated, draped lavas outside of the axial graben, thick pillow lava formations at the edge of the graben and collapsed lava lakes with up to 10-15 m high relict pillars and associated pillows in the central graben.

Numerous fossil and active hydrothermal sites (Fouquet et al., in press) were observed along all the dives and in all parts of the graben. They include large sulfide chimneys, black and white smokers and low-temperature fossil chimneys composed of silica and iron-hydroxides. They are most common along the the eastern secondary graben to the south and in the axial region in the northern part of the diving area.

The central zone of the "Hump" between 18°22'S and 18°34'S exhibits a more complex morphology. A median graben, 200 to 500 m wide is bounded by two asymmetrical ridges. The eastern ridge culminates at 2600 m and the western ridge at 2700 m. Six dives were conducted along this segment. Our observations indicate that intense tectonic activity is affecting the entire median graben as shown by the occurrence of numerous open fissures, up to 10 m wide, which separate pillow ridges. A uniform sedimentary cover, some millimeters thick, is observed througout the entire domain. This segment is characterized by important hydrothermal activity which appears to be concentrated primarly along a narrow ridge of pillow debris close to the eastern wall of the graben. More than 15 individual sites have been discovered and sampled. They mainly are black smokers (340°C) set on active, white mounds venting hot shimmering water (up to 150°C).

Further to the south, between 18°34'S and 18°37'S, the axis of this segment consists of a 50 m deep and 200 m wide summital graben, bounded by two vertical, symmetrical walls in which poorly tectonized, lobate lavas, lava lakes and massive lavas have been emplaced. Extremely recent flows are present in this region, which were observed covering older lava flows and recent talus. Hot water is emerging from the entire surface of the lavas. The temperature of the water 2-3 m above the lava surface is about 2.5°C above the ambient water temperature for this region. No hydrothermal deposits were observed in the immediate vicinity of this recent lava.

Two dives were carried out on the southern segment of the "Hump". One near the northern end of the southern segment found extremely young sheet flows with shimmering water emerging directly off of lava surfaces extensively colonized by a wide variety of animals. At 18°45'S, a dive carried out a cross-section of the present-day active axis characterized by fresh lobated flows up to the eastern abandoned ridge (Cormier and Macdonald, 1994) showing pillows covered by a uniform sedimentary film.

Conclusions

All the ridge segments explored during the NAUDUR cruise show recent activity related to the fast rate of opening in the area. At 17°10'S, 17°25'S and near 18°34'S, extremely fresh volcanics in the axial domain must be the products of very recent eruptions. In many places, black, shiny lobated lavas overlie older flows and dead or living animal colonies consisting of clams, cirripeds or serpulids. The fresh lavas are associated with shimmering waters being expelled between the lava lobes and by recently foundered pillars. In these domains new animal colonies have not yet become established; the only observed living animals are crabs and fishes. Similarly, the hydrothermal circulation is not yet well-organized, and there are no black smokers or hydrothermal deposits. The observed hydrothermal sites, with characteristics close to the 9°50'N zone (Haymon et al., 1993) are located out of the present-day axis on older faults and fissures.

The two segments north of 18°22'S are chacterized by extensive tectonism with an axial graben, 200 to 800 m wide, that is intensively fractured and fissured. In these areas, evidence for recent volcanism is absent and localized to the 20 to 30 m-wide, 20 to 40 m-deep axial fissure. Intense fracturing and

fissuring has allowed hydrothermal circulation to become well-developed with numerous hydrothermal sites (black smokers with sulfide deposits) aligned along the walls of the axial graben.

During the NAUDUR cruise, 70 hydrothermal sites (active and fossil) were explored and sampled. Most of them are unusual with sulfide chimneys prolongated by thin smokers covered by anhydrite. Animal colonization is, for the most part, very primitve with animal species mainly restricted to crabs and fishes, a result that we interpret to indicate the overall youth and/or short life span of individual vents in the area.♦

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marking its docking mooring, turn toward it, and dock.

In June 1994, we plan to take ABE to join the *Atlantis II* in San Diego, again in conjunction with a series of *Alvin* engineering dives. We hope to demonstrate ABE's capabilities to conduct repeated dockings, follow tracklines within the *Alvin* transponder net, and capture images at specified locations. We may also have an opportunity to attempt more ambitious missions in early September in conjunction with another *Alvin* engineering dive series.

The first real science mission will occur in mid-1995, when ABE will conduct a complete magnetometer survey over a lava flow, known to have erupted in July 1993 along the CoAxial Segment of the Juan de Fuca Ridge. A previous survey conducted from the *Alvin* indicated the presence of a notch-like magnetic low at the center of the new flow, which has been interpreted to be related to the thermal demagnetization of the underlying feeder dike (Tivey and Johnson, 1994). The survey with ABE, which will fly at an altitude of 20m above the bottom and will cover an area of 1km by 300m with about 20m spacing between tracklines, is designed to investigate how this anomaly changes with time, thereby providing constraints on the cooling and structure of the lava flow.♦

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