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NAUTILE SUBMARINE OBSERVATIONS OF THE PRESENT-DAY ACTIVITY AT THE SUPERFAST EAST PACIFIC RISE (1993 NAUDUR CRUISE)

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A large segment of the East Pacific Rise (EPR) extending from the Garrett Fracture Zone at 13°S to the Eastern Microplate at 23°S shows a spreading rate varying from 141 to 162 mm/year (PERRAM et al., 1993), one of the fastest even measured. Minor segmentation at different scales occurs between 13°S and 23°S of the EPR, resulting in irregularly spaced offsets that take the form of propagating rifts, overlapping spreading centres and minor deviations in axial linearity (devals). Discontinuities are mostly left-stepping as results of asymmetric spreading, which is about two times faster for the western flank than for the easten one. Consequently, Pacific Plate lithosphere is being transferred to the Nazca Plate.

To understand the effects of superfast spreading rate on magmatic, tectonic and hydrothermal processes in mid-ocean ridge systems, the axial zone of the EPR between 17°S and 19°S has been explored in December 1993 with the Nautile submersible of IFREMER.

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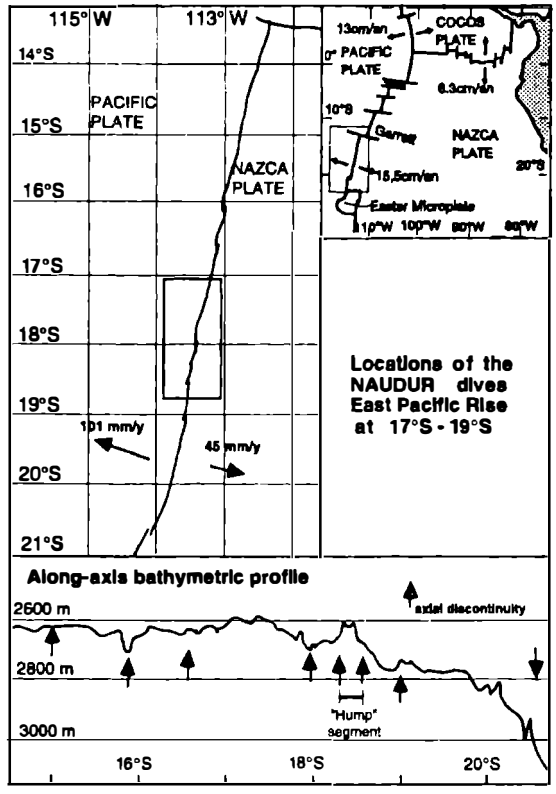

Figure 1: Location map of the Nautile dives.

During the NAUDUR (NAUtile Dorsale Ultra-Rapide) cruise, 23 dives have been completed along and across the axis in the regions centered around 17°10'S and 17°25'S, characterized by an axial dome culminating at less than -2600 m, and in the "Hump" zone (17°56'S - 18°45'S) where the axial domain consists of three segments 25 to 40 km long separated by overlapping spreading centres (Fig. 1). During the dives, samples of rocks, sulphide deposits, waters, hydrothermal fluids and animals were collected, and gravity measurements were made (AUZENDE et al., 1994a, 1994b; FOUQUET et al., 1994; GEISTDOERFER et al., 1994).

Before the NAUDUR cruise, both the regions at 17°10'S, 17°25'S and the Hump zone have been surveyed extensively with Seabeam and Seamark I, and rock samples have been recovered by dredging (SINTON et al., 1991) and submersible operations with the Cyana (RENARD et al., 1985). At 17°22'S, multichannel seismic surveys have allowed to recognize a very shallow seismic reflector, regarded as the top of the magma chamber (DETRICK et al., 1993).

Observed structures

All types of structural evolution have been observed along the explored segments, from shallow axial dome only by few meters wide and deep fissures up to a deeper axial zone widely open and showing a well developped, several hundred meters wide and hundred meters deep graben.

At 17°10'S the axial dome culminating at less than -2600 m and devoid of summital tectonic graben shows a present-day active accretion located in a narrow N10° trending fissure, 30 to 50 meters deep, few meters to less than one hundred meters wide or distributed into two fissures with the same size. Two main types of lavas have been observed; pillows and tubes on the flanks of the ridge and more fluid, draped or lobated lavas at the axis. In the very axial part of the dome, the fissures cut through the most recent lobate flows.

The 17°25'S region is morphologically similar to the previous area, with an axial dome also culminating at less than 2600 m. Two main domains were recognized: the first one corresponds to the bathymetrically defined top of the axial dome occupied by fresh lobated and draped lava flows and characterised by shimmering waters directly expelled from the top of the lava lakes or from the pillars. The second domain is 50 - 100 m deeper with an axial graben 50 to 100 m-wide and 20 - 50 m-deep. In this area the lobated lava altern with pillows and the hydrothermalism is more evolved with chimneys, sulphide deposits and fauna colonisation.

The northernmost Hump segment (17°56'S to 18°22'S) is characterised by a wide graben, up to 800 m in width, whose walls culminate at -2650 m, including a secondary axial graben with a maximum depth of 80 m, bounded by two steps. The bottom of the central valley shows intense fissuring with open fissures some meters wide which bound small locally tilted horsts. The observed volcanic formations include chaotic, brecciated, draped lavas on the outer flanks of the axial graben, thick pillow lavas at the inner edge of the graben and collapsed lava lakes with up to 10 - 15 m high relict pillars and associated pillows in the central graben.

The Hump segment between 18°22'S and 18°34'S exhibits a complex morphology. A median graben, 200 to 500 m wide displays two asymmetrical walls. In the northern part of the area the present-day accretion is located in a 500 m-wide, about 100 m-deep infilled by lobated lava flows. To the south, around 18°30'S, the 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 pillowed horsts. A uniform sedimentary cover, a few millimeters thick, is observed throughout the entire domain.

Near 18°37'S spreading is distributed on two segments separated by an "overlap basin" two kilometers wide, almost entirely composed of constructional lavas, separating the median and the southern Hump segments.

The median Hump segment shows an axial region characterized by horst and graben structure. At 18°36.15'S there is a marked boundary between the tectonized region to the north and constructional pillow terrain to the south.

The southern Hump segment shows a series of sheet flows and lobate lavas that appear to have been erupted from the eastern axis. The volcanological conditions for these flows are a little uncertain but the evidence suggests that they represent very high discharge rate lava flows that have viscous outer surfaces and very fluid interiors that can locally drain out into smooth channels. The summit region of this segment consists of a very young, expansive sheet flow.

At 18°45'S, one dive carried out a cross-section of the present-day active axis to an abandoned ridge (CORMIER & MACDONALD, 1994), lying approximately 2 km to the east. The present ridge axis is more than 2700 deep, about 1.4 km wide with a neovolcanic zone only 750 m wide characterised by fresh lobated flows. The depression between the two ridges is nearly flat and underlain in the western part by lobated and sheet flows. The abandonned ridge shows a shear wall of truncated pillows and flows on the western flank, and is highly sedimented at its top.

Evidence for recent volcanism

One of the major result of the NAUDUR cruise was the diversity of the manifestations of recent volcanism. Evidence for recent volcanism in the area include: lava flows completely devoid of sediment, fresh lava surrounding recently extinct hydrothermal chimneys, uncolonised, fresh lava covering animal communities, lava flows colonised only with bacteria and worms, and warm to hot water shimmering directly off the lava.

Observations on sediment distribution on top of the lavas suggest that eruptions have occurred in the region within the last decade or so. Also estimates of the time for colonisation by animal communities and their disappearance from hydrothermal sites once become inactive suggest eruption within the last few months to years.

Furthermore, the revisiting of the site near 17°25'S surveyed with a Cyana dive in 1984 (RENARD et al., 1985) clearly evidenced substantial volcanic activity to have occurred in this area in the last ten years.

Finally several examples of unsedimented lava still containing heat were observed. For example, near 18°34'S a temperature of about 150 °C was measured in warm water shimmering off the entire surface of a lava flow, not yet colonised by vent animals, and a temperature anomaly of approximately 2.50 °C, 2 - 3 m above the flow surface was measured. Near 18°37'S shimmering water also was observed emerging from the surface of a young sheet flow, densely colonised by vent animals and presumably somewhat older than the former one.

In conclusion, there is abundant evidence for very recent volcanism along the axis between 17° - 19°S. The youngest activity is located between 17°09'S -

17°27'S, near 18°34'S and 18°37'S. Whether or not any of the young lava was active at the time of NAUDUR cruise is presently unclear. Nevertheless if our observations are typical for the area, eruption frequency on the order of every few years may be characteristic for this superfast spreading ridge.

Hydrothermalism

The NAUDUR dives allowed to discover 69 hydrothermal sites that can be grouped into 14 hydrothermal fields, located in four geographical areas centred on 17°10'S, 17°25'S, 18°15'S, and 18°37'S.

At 17°10'S and 17°25'S three types of hydrothermal discharge are distinguished:

a) large areas of diffuse discharge without sessil animals, located at the bottom the collapsed lava lakes and at the surface of the most lava flows, characterized by shimmering waters between 25 °C and 50 °C;
b) diffuse discharge with sessil animals and active chimneys associated with older, but still recent lava, away from the axial collapsed lava lakes,
c) dead chimneys probably representing the oldest hydrothermal episode of the area.

In the 18°22 segment 20 hydrothermal sites were discovered along 20 km of the eastern wall and two active black smokers (up to 310 °C) were seen. This zone is lacking of diffuse discharge and animals around the vents and includes abundant dead silicic chimneys.

The 18°37'S segment shows a strong contrast between the hydrothermal discharge in the northern and the southern part. In the southern segment the discharge is similar to the type a) described for the 17°25'S sites. At the northern part, intense hydrothermal activity is concentrated along the eastern wall of the graben. 16 sites were seen along a 2 km long survey showing distinct hydrothermal episodes. An older one is represented by big spires (up to 20 m high) of sulphides growing on sulphidic mounds; chimneys are often tilted towards the graben and outcrops of the stockwork were seen under the sulphide deposits. A younger activity is represented by shimmering water (up to 55 °C) through the talus along the faults, without associated hydrothermal chimneys and fixed animals. Finally, young active chimneys (fluids up to 310 °C) colonised by worms, growing on the talus and very close to the graben wall were also observed.

Conclusions

The five explored segments clearly illustrate the evolution of the accretion processes and related phenomena at an ultra-fast spreading ridge. One of the major observation is the close relationships between the detailed morphologic characteristics of the spreading axis and the stage of evolution of magmatic and tectonic activities: the well pronounced axial domes are, in each of the case,

associated with present-day or very recent lava flows covering all the older structures. The deepening of the axial dome is correlated with the beginning of predominant tectonic activity and the apparition of an axial graben.

These changes of morphology and activity styles are very rapid in time and space and define a kilometric segmentation due to magmatic emissions at year scale.

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