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OBLIQUE SPREADING IN THE SOUTHERN PART OF THE LAU BACK-ARC BASIN (SW PACIFIC)

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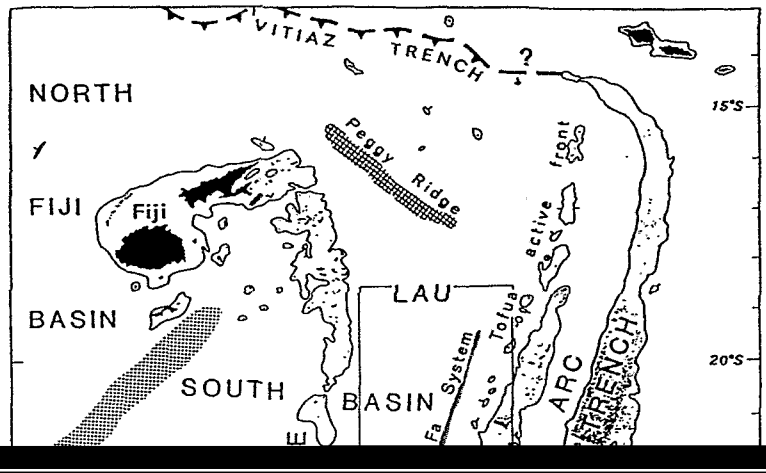
ABSTRACT

The Lau Basin is an actively spreading back-arc basin in the S.W. Pacific area. It is located at the convergent Pacific/Indo-Australian plate boundary, between the Tonga arc and the Lau Ridge. Geological and geophysical investigations were conducted during the R/V *Jean Charcot* SEAPSO 4 (January 1986) and PAPNOUM (April 1987) cruises, to study oceanic spreading and hydrothermal processes in the Lau back-arc basin. Multibeam bathymetric, magnetic, gravimetric and single-channel seismic reflection profiles were recorded in the southern part of the basin between 19°S and 23°S, and particularly on the Valu Fa Ridge. Geological sampling by dredging was also carried out. The Valu Fa Ridge, which is one of the most prominent features of the area, extends over a length of more than 200 km, from 22°40'S to 20°50'S. North of 21°30'S, a secondary volcanic chain, previously described as far as 20°30'S, can be traced northwards to 19°05'S in an en-echelon relay position behind the Tofua active volcanic arc. Altered



Thomas Washington cruise (USA), in 1985 and 1986 the R/V *Sonne* cruises (Germany), in 1986 and 1987 the R/V *Jean Charcot* cruises (France) and in 1988 the R/V *Charles Darwin* cruises (Great Britain). These cruises were performed with all the modern tools of oceanology, especially with multibeam echo sounder, single and multichannel seismic reflection, long range side-scan sonar (GLORIA) and different means of rock and water sampling.

We present here essentially the data from the two R/V *Jean Charcot* cruises (Figure 2): SEAPSO 4 and PAPNOUM

A second segment of Valu Fa Ridge, located between 21°15'S and 21°40'S (Figures 2, 3 and 4), was mapped during the SEAPSO 4 and PAPNOUM cruises (Foucher and others, 1988). Within the mapped area the ridge strikes N 15° and is about 7-10 km wide and 200-500 m high. A sharp transition in the axial morphology occurs near 21°26'S. The ridge crest has a dome shape and is at a quite constant depth of 1900 m south of the transition zone (between 21°26'S and 21°40'S). To the north, its topography is more subdued (2000-2100 m) and there is a 100 m deep axial valley. On a broader scale, bathymetric and geophysical data gathered during the SEAPSO 4 and PAPNOUM cruises indicate that Valu Fa Ridge extends northward to 20°50'S. North of 20°50'S, the ridge disappears under the sedimentary cover, and a secondary volcanic chain, traced from 21°30'S to 19°05'S in an en echelon position, occupies the axis of the sedimentary trough between the Valu Fa Ridge and the Tofua volcanic arc. The en echelon relay transition zone characterized by the presence of both ridges is 55 km long and 24 km wide.

So, the Valu Fa Ridge appears to be only a part of a large tectonic system, which is 450 km long and composed of several ridges in en echelon relay position. We call this tectonic system the Valu Fa System, which is composed of the Valu Fa Ridge and the secondary volcanic chain. Striking N 15°, it extends from 22°45'S to 19°05'S and is very linear and straight. Initial observations show that the Valu Fa System, firstly, is parallel to the Tofua active volcanic chain and also to the main trend of the Tonga arc in this area, and secondly, seems not to be cut by major transverse faults.

Fresh looking glassy andesites were dredged along the Valu Fa Ridge crest while tholeiitic basalts were sampled on a seamount of the secondary volcanic chain (Foucher and others, 1988). A methane anomaly (20 nl/l) found near the sea bottom at the axis of Valu Fa Ridge suggests hydrothermal activity.

The Axial Ridge System of the Lau Basin

The second major structural feature exhibited by Figures 3 and 4 is a system, striking grossly N-S, found in the axial part of the southern Lau Basin, west of the Valu Fa System. This new structural trend is characterized by a succession of N-S elongated horsts and grabens covered by a thin sedimentary layer.

The transverse seismic section in Figure 5, located near 21°S, illustrates the general structure of the southern Lau Basin observed on all the available seismic lines. On the western end of the profile, is a ridge characterized by

This axial ridge without any sedimentary cover is well defined topographically. It can be followed easily from line to line and extends from 18°50'S to 21°40'S. It shows a striking topography (Figure 5) and includes several overlapping segments similar to those described on the East Pacific Rise (Macdonald and others, 1984). Numerous N 60°–trending faults crosscut the N-S oceanic crust structural trends, then dissect each axial ridge segment into offset portions. The N 60° faulting is concentrated in two main areas, around 20°15'S and 22°S.

This ridge also shows a magnetic symmetry and seems to correspond to the location of a spreading axis creating the N-S magnetic lineations identified by Weissel (1977) and Larue and others (1982) in this southern part of the Lau Basin.

North of 18°S we have too little data to locate an active spreading axis. However, a N 20° ridge surveyed by the R/V *Sonne* (Stackelberg and others, 1985) could be the prolongation of the N-S spreading axis we described. Moreover, one hydrocast taken on the axial ridge (PAPATUA IV and V cruises, 1986) revealed large methane and manganese anomalies (H. Craig, pers. comm.) suggesting that this ridge like the Valu Fa one is the setting of active hydrothermalism.

The same N-S horsts and grabens are observed in the elongated basin located between the Valu Fa System and the Tofua arc as are observed west of the Valu Fa system. Similarly, Figures 3 and 4 also display N 60° transverse faults in this area. According to these observations, the Valu Fa System appears to obliquely cut the N-S structural trends of the central part of the Lau Basin, and to be a younger tectonic feature of the basin than the N-S structures.

In addition to the main structural features described above on the seismic profile of Figure 5, one should note:

- A relatively thick sedimentary layer (about 300 ms TWT, = 300 m) can be seen in the small basin located between the Tofua volcanic arc and the Valu Fa System. The basement in this area is affected by normal faulting and shows horst and graben topography.
- Valu Fa Ridge has very thin or no sedimentary cover. The ridge is here 10 km wide and appears as a 500 m high dome flanked by normal faults.
- A relatively thin sedimentary layer, which does not exceed 200 m can be seen in the large basin located west of Valu Fa Ridge. The horsts and grabens are very well expressed in the basement topography here.

DISCUSSION

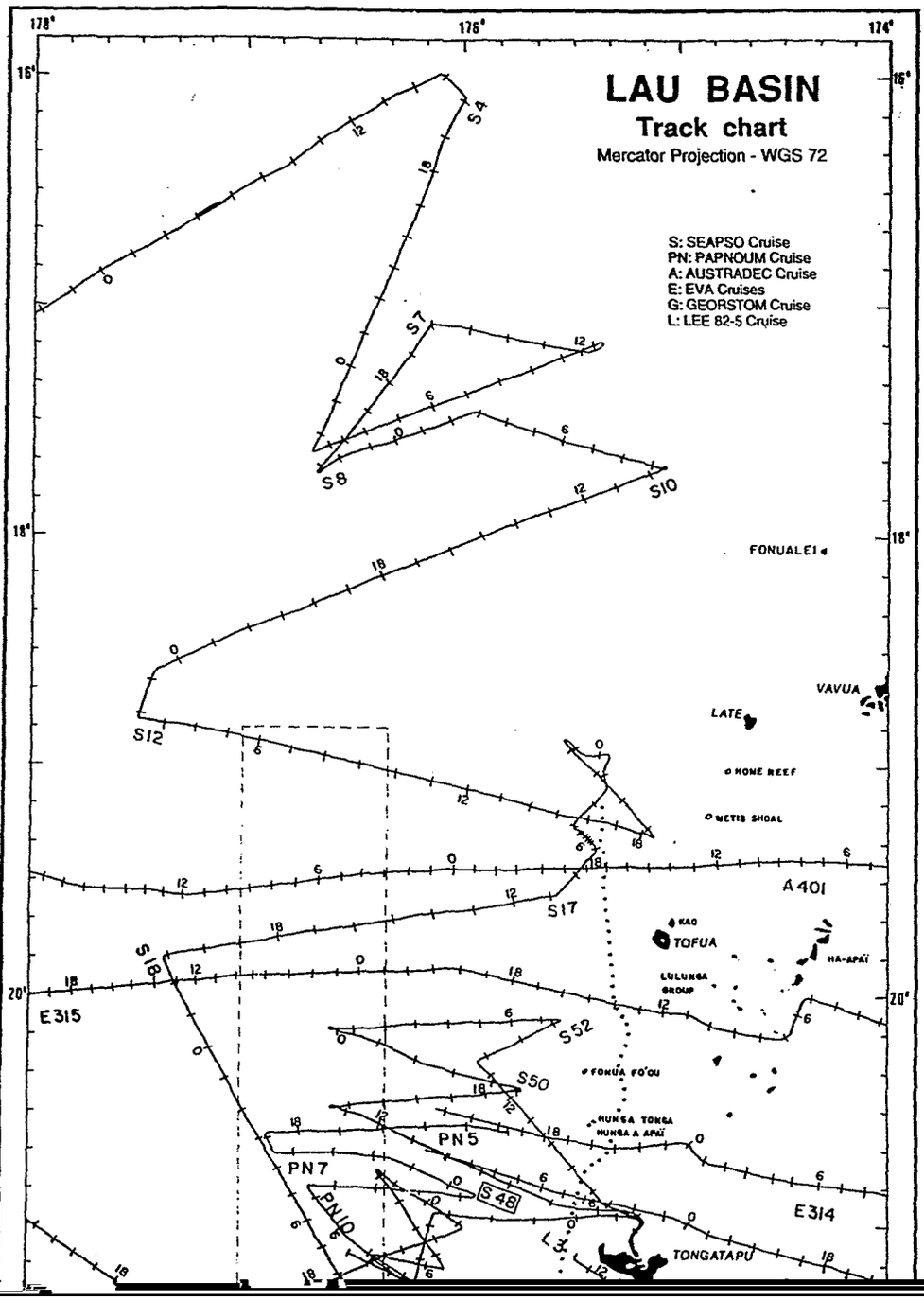


Figure 2. Location map of the cruises in the Lau Basin used for this work. SEAPSO 4 (S) and PAPNOUM (PN) tracks have Seabeam, seismic reflection and magnetic data. AUSTRADEC

Oblique Spreading in the Southern part of the Lau Back-Arc Basin (SW Pacific)

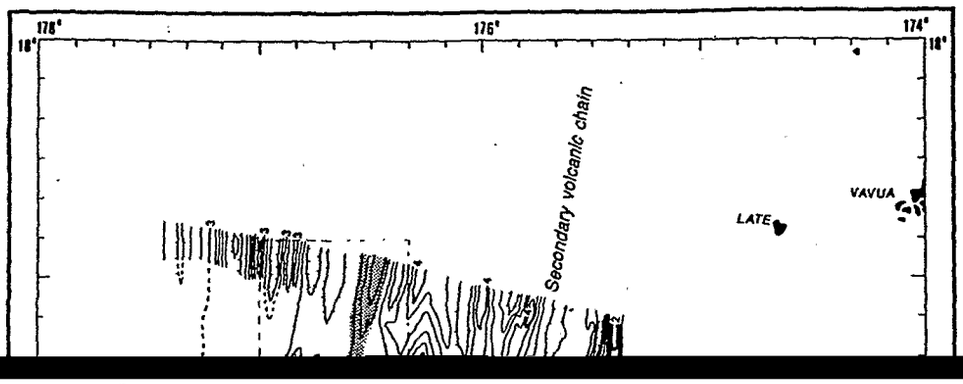


Figure 4. Structural map of the southern part of the Lau Basin. 1: normal faults manifested by scarps; 2: interpreted strike slip and transform faults; 3: ridge crests; 4: lows; 5: axial spreading area of the Lau Basin. The dashed heavy lines are inferred faults. The dashed rectangle indicates the area where the spreading ridge of Lau Basin is located.

ized by a great linearity and appears to be a more recent feature crosscutting an earlier N-S grain of the oceanic back-arc crust and its N 60° fractures. The apparent right lateral offset of N 60° faults observed on either side of the Valu Fa System supports this interpretation. At the beginning and during the first stages of oceanic opening of the Lau Basin, the geometric incompatibility would not have been so important and we can speculate that the right-lateral strike-slip movement was diffused within the arc and back-arc domains. Nevertheless, the horst and graben structure and the uplift of the Valu Fa System are not satisfactorily explained by strike-slip movement alone.

First, the horst and graben structure points to some approximately E-W component of stress. A possible interpretation of this extensional deformation would be in terms of an E-W to ENE-WSW regional extensional stress field induced in the vicinity of the Tonga arc by the subduction process itself. This extensional stress field could be also accentuated by velocity differences due to the obliquity between the directions of Pacific plate subduction and Lau Basin opening.

Secondly, this extensional deformation must have been sufficiently large to allow for the formation of a shallow magma chamber of considerable width under the ridge (Morton and Sleep, 1985). We postulate that thermal expansion associated with this extension and magmatism has induced the uplift of the whole Valu Fa System.

The parallelism between the Valu Fa System, the Tofua volcanic arc and the Tonga structural arc also suggests that these features are closely related, a relationship supported by the andesites and dacites dredged on Valu Fa Ridge. The Valu Fa System, interpreted here as

CONCLUSION

To sum up, the axial topographic ridge, near 176°30'W, in the southern Lau Basin, has several characteristics making it the main spreading center active in this part of the basin. The Valu Fa System, on the other hand, can be interpreted as a right-lateral transtensional faulting boundary where the relative motion of the Tonga arc with respect to the axial back-arc basin has been absorbed in the recent past by a mainly right-lateral strike-slip movement. This new interpretation allows us to explain most of the observations on the whole southern Lau Basin and on the Valu Fa System, such as the lack of transform structures crossing the Valu Fa ridge, the mainly arc type volcanism, the shallow magma chamber and the asymmetry of the sediment thickness on either side of the ridge.

ACKNOWLEDGMENTS

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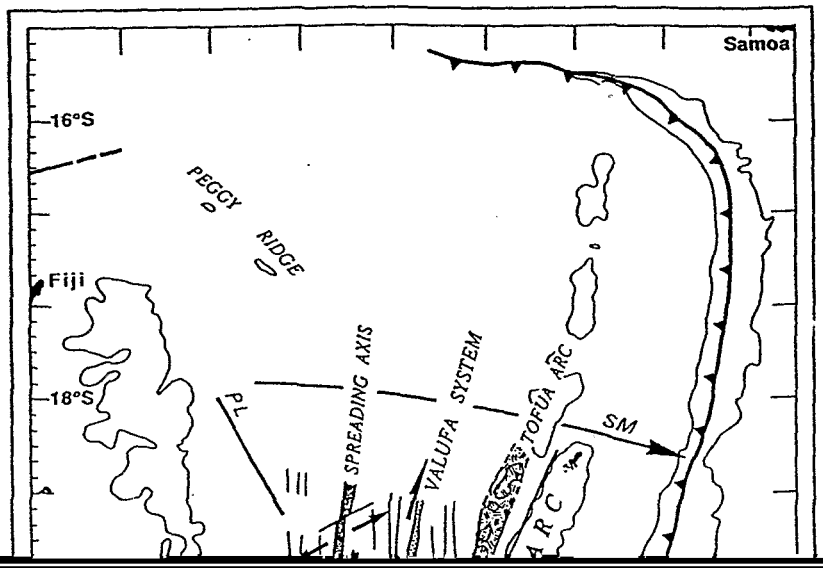

Figure 6. Interpretative tectonic sketch

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