GEOGACETA, 20 (4), 1996

Backarc evolution from rifting to mature spreading: The Bransfileld and North Fiji Basins (NW Antarctica and SW Pacific)

E. Gracia (*), M. Canals (*), Y. Lagabrielle (**) and J.M. Auzende (***)

*UA Geociencies Marines CSIC-UB, GRQ Geociencies Marines, Dpt. Geologia Dinamica, Geofisica y Paleontologia, Univ. Barcelona, 08028 Barcelona.
**CNRS-URA 1278 Domaines Océaniques, Univ. de Bretagne Occidentale, 6 Av. Le Gorgeu, BP 452, 29275 Brest, France.
***DRO/GM IFREMER, now at: Dpt. Géologie-Géophysique, Centre ORSTOM, BP A5, Nouméa, Nouvelle Calédonie.

ABSTRACT

Five areas, the Eastern and Central Bransfield Basins off the Antarctic Peninsula, and the Tripartite, Central Spreading and South Pandora Ridges of the North Fiji Basin, have been studied using swath-bathymetry and geophysical data. The sites can be classified in terms of backarc basin evolution, from less evolved stages dominated by rifting and incipient spreading (Bransfield Basin), to the maturest stages characterized by organized backarc seafloor spreading, like the North Fiji Basin ridges.

RESUMEN

Las Cuencas Central y Oriental de Bransfield (NO Peninsula Antartica) y las Dorsales Tripartita, Central y Sur-Pandora de la Cuenca Nor-Fidjiana (Pacifico SO) han sido estudiadas a partir de datos de batimetria de multihaz y metodos geofísicos. Dichas áreas pueden clasificarse en estadios evolutivos de tras-arco, desde estadios incipientes y de pre-expansión como la Cuenca de Bransfield , hasta los estadios maduros de expansión oceánica organizada, como las dorsales de la Cuenca Nor-Fidjiana.

Key words: *Swath-bathymetry, magnetics, backarc basin, rifting, seafloor spreading, Antarctica, southwest Pacific.*

Geogaceta, 20 (4) (1996), 826-829
ISSN: 0213683X

Introduction

The last ten years have seen fundamental changes in the understanding of tectonics, volcanism, hydrothermalism and sedimentation in backarc basins. This new thinking has been stimulated in part by the availability of new surveying instruments, such as high resolution swath-mapping systems, satellite altimetry, geophysical methods and submersible exploration. Two active backarc basins, the Bransfield (NW Antarctica) and the North Fiji Basins (SW Pacific), have been studied in detail using the same conventional methods and that constitutes the basis for comparison between them. The Bransfield Basin (Fig. 1a) is a narrow and elongated ensialic basin located between the Antarctic Peninsula and the South Shetland Islands, at the southwestern edge of the Scotia Arc. The age of the basin is still controversial, ranging between the 26-22 Ma suggested by Birkenmajer (1992) and the 4 Ma by Barker (1982).The Bransfield Basin is composed of three small basins separated respectively by Deception and Bridgeman Islands. Two of the basins, the Central and Eastern Bransfield Basins (Fig. 1a), were surveyed by the GEBRA 93 cruise during which swath-bathymetry, seismic reflection and magnetic profiles were acquired (Canals *et al.*, 1994).

The North Fiji Basin (Fig. 1b) is a mature basin (12 Ma) located between two active subduction zones of opposite polarity: the New Hebrides and the Tonga-Kermadec trenches (Auzende *et al.*, 1988). Several extensional features and spreading centres have been identified within the basin. Three of these features have been studied in detail: the Tripartite, the Central Spreading and the South Pandora Ridges (Fig. 1b). In this paper, we discuss the backarc evolution of the Bransfield and North Fiji Basins. Backarc rifting and incipient stages of seafloor spreading are both well illustrated in the Bransfield Basins (Fig. 2a). In contrast, well developed backarc seafloor spreading is characteristic of the North Fiji Basin spreading centres (Fig. 2b).

The Bransfield Basin: Backarc rifting and incipient seafloor spreading

The Eastern Bransfield Basin

Morphologically, the 150 km long and 42 km wide Eastern Bransfield Basin (Fig. 3) is characterised by four rhombic troughs with axial depths of 2150 to 2750 m. The troughs (T1 to T4) are arranged en echelon showing a zig-zag pattern in plan view and trending slightly oblique to their margins (Gracia *et al.*, 1996a). Left-lateral strike-slip motion may occur along the Eastern Bransfield Basin (Fig. 3) as suggested by the shape of the structures, the proximity of the sinistral South Scotia Ridge (Fig. 1), and the presence of transtensional focal mechanisms north of the basin. Numerous small volcanic cones, 50 to 125 m high and 1 to 3 km^2 of basal area, are scattered at the southwestern part of the basin. They show a disorganized distribution, and only one neovolcanic ridge (G) is identified. This diffuse volcanism together with the rift graben morphology, and by analogy with other known rifting backarc basins, indicate that the Eastern

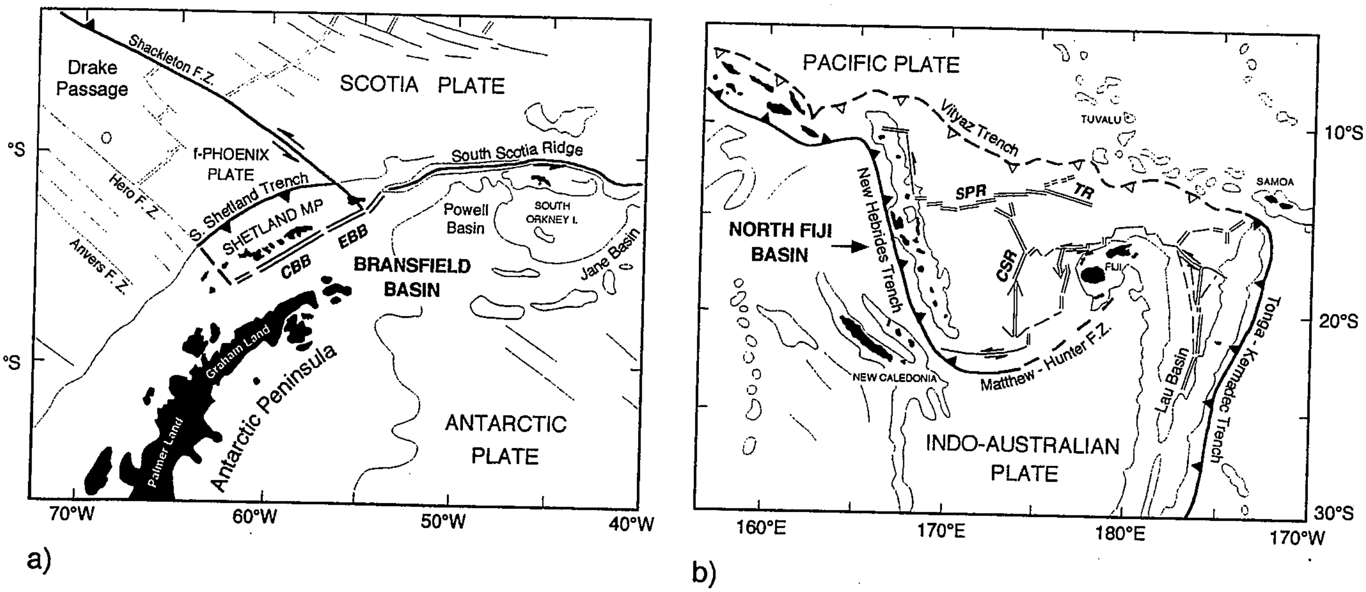

Fig. 1. a) Present-day plate tectonic of the Bransfield and b) the North Fiji Basins. Black aligned triangles: active subduction zones. White aligned triangles: fossil subduction zones. Thick double lines: active spreading centres. CBB: Central Bransfield Basin, EBB: Eastern Bransfield Basin, MP: Microplate. CSR: Central Spreading Ridge, SPR: South Pandora Ridge, TR: Tripartite Ridge. The maps are not at the same scale.

Basin may be in a pre-spreading rifting stage, that is, backarc rifting prior to tnte spreading.

The Central Bransfield Basin

The morphology of the 230 km long, 60 km wide and 1950 m deep Central Bransfield Basin (Fig. 3) is dominated by six large volcanic edifices (A to F) aligned with the basin axis that protrude from the highly sedimented seafloor (Gracia *et al.*, 1996a; Canals and Gracia, this issue). The seamounts present circular, semi-circular and elongated morphologies, and they are larger, 100 to 600 m high, and up to 150 km^2 of basal area, and less numerous than on the Eastern Basin. The trend of the structures (N55-60) and the linear arrangement and shape of the large edifices suggest that a NW-SE extension may be taking place in this basin (Fig. 3). Magnetic anomalies are difficult to identify, although a positive alignment, the Bransfield Rift Anomaly (BRA), correlates well with the submarine volcanoes of the Central Bransfield Basin. If we tentatively interpret the BRA as the Anomaly 1, the maximum age of spreading in the basin would be 0.71 Ma and the resulting maximum full rate 0.83 mm/yr, much less than the values suggested by Roach *et al.* (1978), González-Ferrán (1991) and others. The concentration of extensional faulting along the young (c 0.3 Ma) axial MORB-type volcanoes (Keller *et al.*, 1991) may be interpreted as the result of incipient seafloor spreading through the continental crust of the Central Bransfield Basin.

The North Fiji Basin: Young to mature seafloor spreading

The three areas studied at the north and central parts of the North Fiji Basin (Fig. 1b) are representative of different degrees of maturity, in terms of organized backarc seafloor spreading (Fig.2).

The Tripartite Ridge

The N110 trending and 290 km long Tripartite Ridge (Fig. 4) is located at the eastern end of the South Pandora Ridge (Fig. 1b), in one of the less explored areas of the basin. It is formed by three large axial seamounts alternating along-axis with deep troughs (Fig. 4). Magnetic Anomaly 1 is clearly identified showing that the Tripartite Ridge is a young spreading centre formed at least 0.71 Ma ago. The structural and magnetic patterns along the Tripartite Ridge indicate a V-shaped structure narrowing towards the southeast. This suggests an axial propagation of the Tripartite Ridge within the preexisting lithosphere of the basin (Fig. 4). From the magnetic anomalies, an ultra-slow full spreading rate has been calculated which decreases from 8.5 mm/yr to 0 mm/yr. A main NNE-SSW extensional trend is suggested for the Tripartite Ridge.

The Central Spreading Ridge

This is the best known of all the spreading centres identified in the basin, and has been intensively explored during the French-Japanese STARMER project (Auzende and Urabe, 1994). The Central Spreading Ridge is 80.0 km long and 50-60 km wide, and is segmented into three first order segments: N160, N15 and N-S (Fig. 5). The axial morphology changes from a succession of long en echelon grabens, similar to that of the Mid-Atlantic Ridge, along the N160 segment to a central flat and rectangular high, like in the East Pacific Rise along the N-S segment (Gracia *et al.*, 1996b). The Central Spreading Ridge is 3.5 Ma old, as magnetic Anomalies I to 2A have been clearly identified (Huchon *et al.*, 1994). The full spreading rate is intermediate and decreases northwards from 82 to 52 mm/yr (Fig. 5). A main E-W extensional trend is considered for the N-S and N15 segments, changing to NE-SW for the N160 segment.

The South Pandora Ridge

Relatively old crust is present in the northern part of the North Fiji Basin, at the mature 510 km long South Pandora Ridge (Fig. 4). The area was surveyed by the NOFI cruise during which swath-bathymetry, geophysical and geological data were acquired (Lagabrielle *et al.*, 1995). It is composed by two first-order segments (N75 and E-W) and characterised by an extremely contrasted morphology, changing from deep grabens to axial seamounts. Oceanic spreading processes have been occurring almost continuously for at least 7 Ma along the South Pandora Ridge, as revealed by the identification of Anomalies 1 lo 3A. The magnetic anomalies identified suggest a full spreading rate of 16 mm/yr (Fig. 4), which classifies the South Pandora Ridge as an ultra-slow spreading centre. At a regional scale, this mature spreading system shows a relatively stable geometry, as revealed by the well-organized E-W parallel pattern of magnetic lineations suggesting a N-S extension (Fig. 4).

Discussion and conclusions

The Bransfield Basin is formed by rifting of the Antarctic Peninsula parallel to the South Shetland Trench. It seems that most of the extension occurring on the Bransfield Basin involves a combination of rifting of the preexisting thinned continental crust, injection of intrusions and volcanism. Seafloor spreading, as extension accommodated primarily by accretion of new backarc crust, may occur only discontinuously along the Central Bransfield Basin. By other part, the Tripartite, Central Spreading and the South Pandora Ridges are both active centres where new oceanic crust is created through organised seafloor spreading. In summary, the five areas studied have been classified in terms of backarc evolutive stages. The Central and Eastern Bransfield Basin illustrate the incipient and pre-spreading rifting stages respectively (Fig. 2a), whereas the ridges studied in the North Fiji Basin are representative of well organized seafloor spreading (Fig. 2b), from young, Tripartite (< 1 Ma), to mature, Central Spreading (3 Ma) and South Pandora Ridges (7 Ma). The present-day opening in the Bransfield Baisn seems to be related to the rollback of the subduction hinge at the South Shetland Trench (Lawver *et al.*, 1995), whereas it does not seem to be related to any subduction in the North Fiji Basin, as suggested by geochemical and structural data (e.g. Sinton *et al.*, 1993). The current opening in the North Fiji Basin may be linked to a regional thermal anomaly, suggesting high mantle convection that induces rapid crustal production, together with the transcurrent motion between the Pacific and Indo-Australian Plates. The study of backarc rifting areas, like the Eastern Bransfield Basin, shows that initial rifting of the arc may pre-determine the future segmentation of the basin. The constant distance between each eruptive centre observed in incipient and young spreading areas, like the Central Bransfield Basin and Tripartite Ridge respectively, suggests a regular spacing of the upwellings forming linear proto-segments.

Moreover, the study of mature backarc systems as the Central Spreading and South Pandora Ridges in the North Fiji Basin, shows that the fundamental accretionary processes are similar in backarc and mid- ocean ridges.

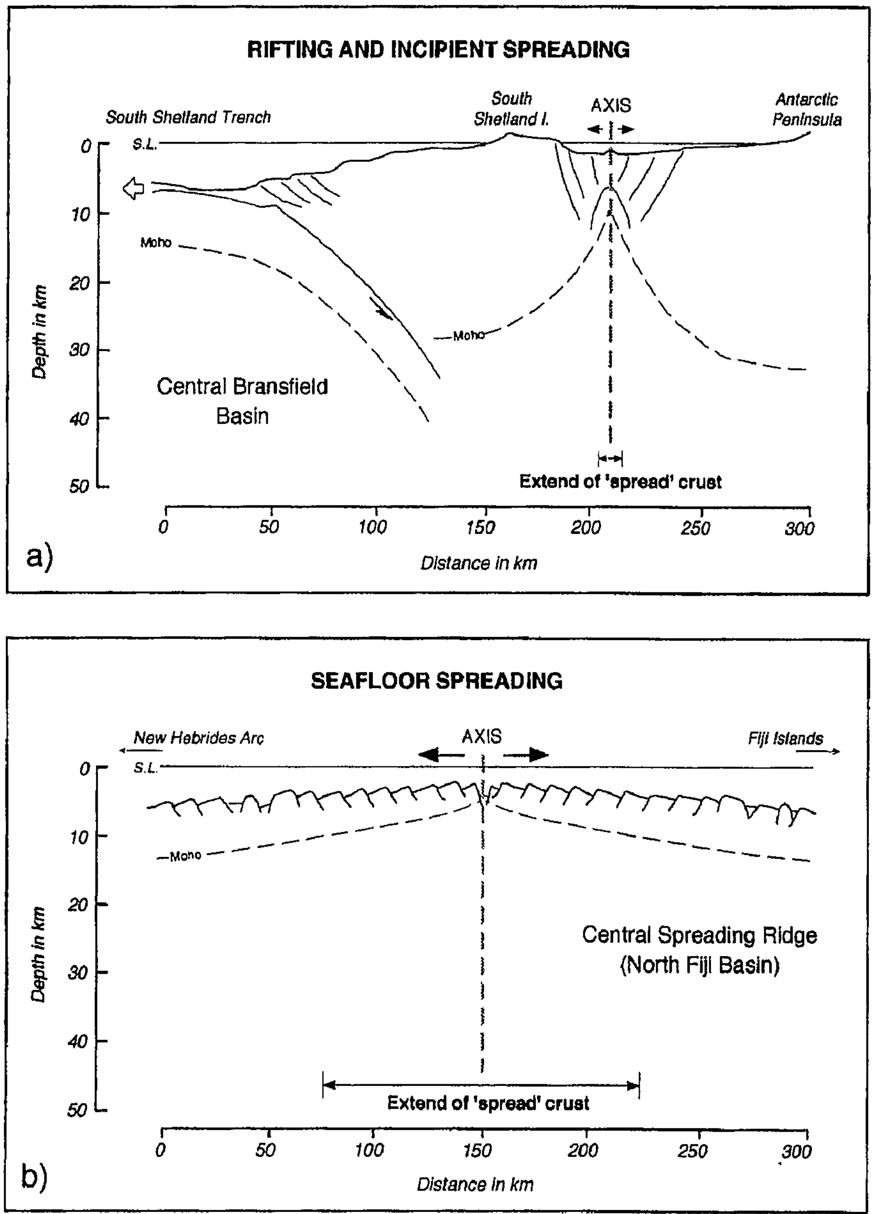

Fig. 2. Comparison of models for how backarc extension is accomplished for a) the Central Bransfield Basin and b) the Central Spreading Ridge (North Fiji Basin). Note the different estimates for the width of the crust formed by seafloor spreading ('spread' crust) in the Central Spreading Ridge (150 km) and in the Central Bransfield Basin (less than 10 km). Open arrow: trench rollback.

Acknowledgements

We would like to thank the captains, crew members and scientific team who assisted in the collection of the data during the STARMER, GEBRA and NOFI cruises. This work was supported by the project ANT-93-1008-C03-01. E. Gracia benefited from a fellowship FPU AP 91- 46338255 from the Ministerio de Educación y Ciencia. The GRQ «Geociencies Marines» at the University of Barcelona has been supported by «Generalitat de Catalunya» grant GRQ94/95-1026.

References

Auzende, J.M., Urabe, T (1994). Mar. Geol, 116, 1-3.

Auzende, J.M., Eissen, J.P., Lafoy, Y., Gente, P., Charlou, J.L. (1988). Tectonophysics, 146, 317-351.

Barker, P.F. (1982). Geol. Soc. London J., 139, 787-801.

Birkenmajer, K. (1992). En: Yoshida, Y., *et al.* eds., Terra Scientific Publ. Co., Tokyo, 405-410.

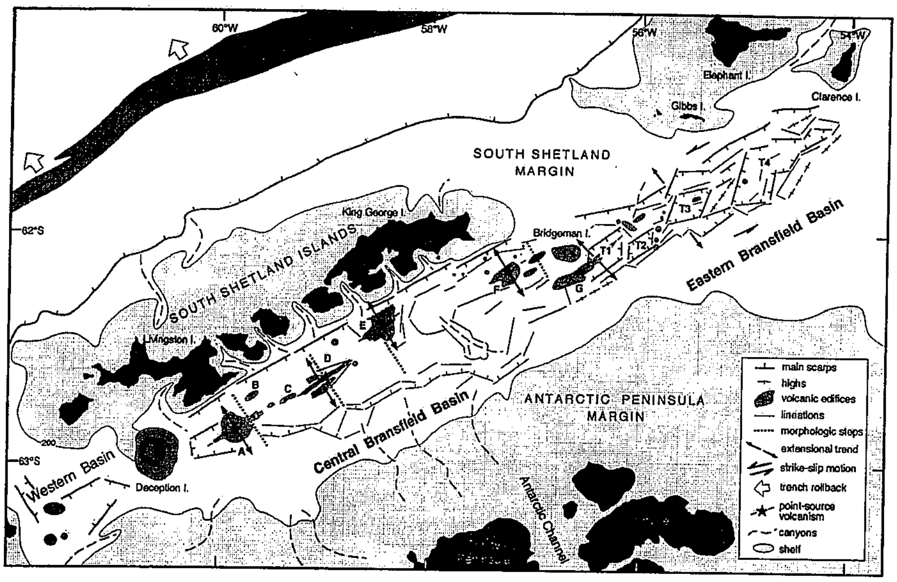

Fig. 3. Geodynamic sketch of the Central and Eastern Bransfield Basins. A to G: submarine volcanic edifices. T1 to T4: troughs along the Eastern Basin.

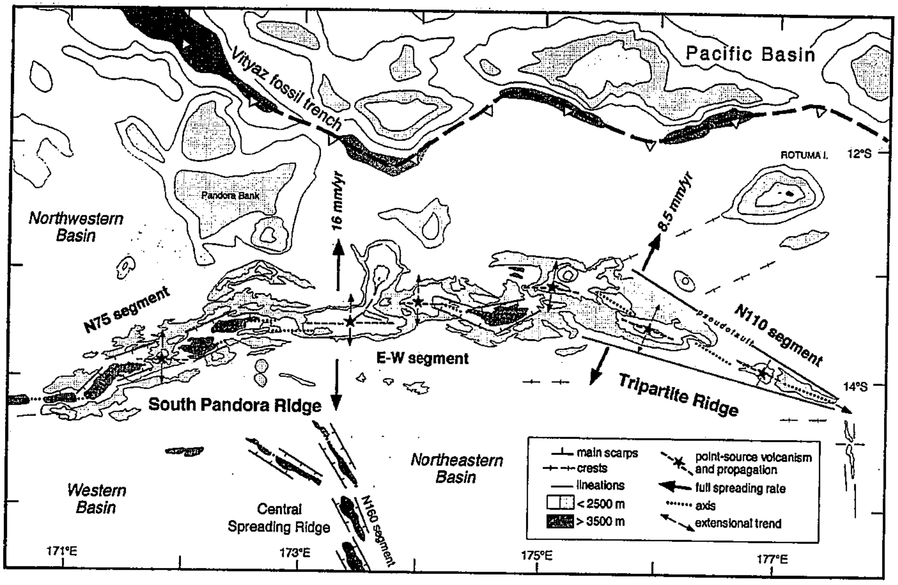

Fig. 4. Geodynamic sketch of the South Pandora and Tripartite Ridges (North Fiji Basin) and junction with the Central Spreading Ridge. Spreading rates are from magnetic anomalies.

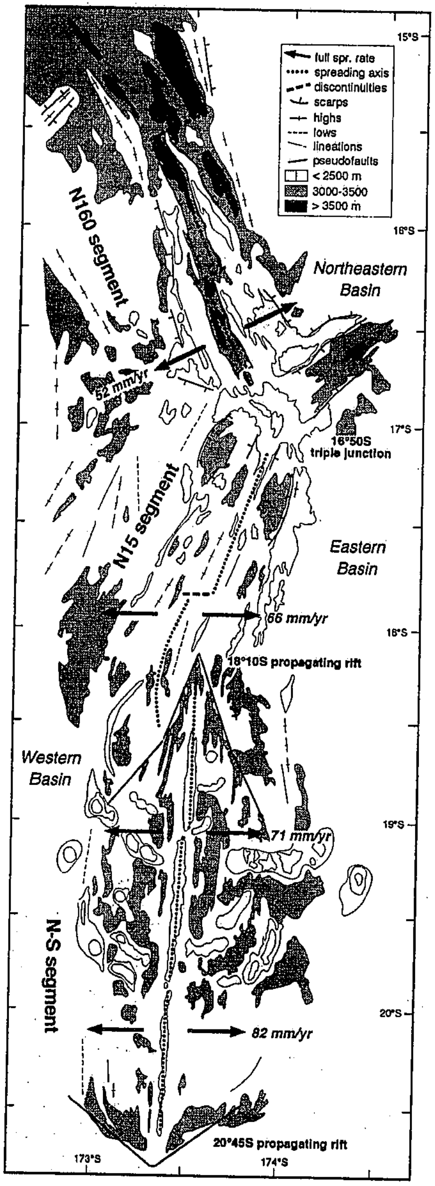

Fig. 5. Geodynamic sketch of the Central Spreading Ridge (North Fiji Basin). Spreading rates are from magnetic anomalies. young spreading areas, like the Central Bransfield Basin and Tripartite Ridge respectively, suggests a regular spacing

Canals, M. and Gracia, E. (this issue). Geogaceta.

Canals, M., Acosta, J., Baraza, J., *et al.* (1994). Geogaceta, 16, 132-135.

González-Ferrán, O. (1991). En: Thomson, R.A., *et al.*, eds., Cambridge University Press, 505-509.

Grácia, E., Canals, M., Farrán, M., *et al.* (1996a). Mar. Geophys. Res., 18 (1-3).

Grácia, E., Tisseau, C., Maua, M., *et al.* (1996b). Mar. Geophys. Res., 18, (1-3).

Huchon, P., Gracia, E., Ruellan, E., *et al.* (1994). Mar. Geol., 116, 69-89.

Lagabrielle, Y., Ruellan, E., Tanahashi, M., *et al.* (1995), InterRIDGE News, 4 (1), 29-36.

Lawver, L.A., Keller, R.A., Fisk, M.R., Strelin, J., (1995). En: Taylor, B. ed., Plenum Publ. Corp., New York, 315-342.

Keller, R.A., Fislk, M.R., White, W.M.,

Birkenmajer, K., (1991). Earth Planet. Sci. Lett., 111, 287- 303.

Roach, PJ. (1978). J. Res. Astron. Soc., 53, 165.

Sinton, J.M., Price, R.C., Johnson, K.M., Staudigel, H., Zindler, A. (1993). En: Kroenke, L.W., Eade, J.V. eds., Circum-Pacific Council for Energy and Mineral Resources, Ser. 15, Springer-Verlag, New York, 119-135.