1821

Geol. Jb.	D 92	503 — 516	3 Fig.	1 Tab.	Hannover 1990

Trace Element and Isotopic (Sr, Nd) Geochemistry of Volcanic Rocks from the Lau Basin

XAVIER BOESPFLUG, LAURE DOSSO, HENRI BOUGAULT & JEAN-LOUIS JORON

back-arc basins, mid-ocean ridges, basalts, andesites, major element analyses, rare earths, trace element analyses, Sr-87/Sr-86, Nd-143/Nd-144, subduction zones, sea-floor spreading

South West Pacific, Lau Basin

Abstract: Rock samples have been dredged during SO-35 and SEAPSO IV cruises (1984 and 1985) from different spreading ridges in the Lau Basin, south-western Pacific. They were analyzed for major and trace elements and isotopic ratios (Sr, Nd). Northern Lau Basin samples show N-MORB type characteristics, both in major and trace elements, whereas southern Lau Basin ones are differentiated and show significant Ta-Nb negative anomalies in their extended REE patterns, which is characteristic of subduction zones. Isotopic ratios (Sr, Nd) are quite heterogeneous and intermediate between MORB and island arc values. The northern Lau Basin Ridge has geochemical characteristics suggestive of medio-oceanic type spreading, whereas the southern Lau Basin Ridge (Valu Fa Ridge) with its geochemical characteristics influenced by subducted slab material, could either be a nascent island arc or correspond to an initial stage of back-arc opening.

A comparison of the Lau Basin results with those from the North Fiji Basin and the Okinawa Trough shows geochemical trends that reflect the evolution from a rifting stage (island arc characteristics) to a mature stage (MORB characteristics) of back-arc basins.

[Geochemie der Spurenelemente und der Isotope (Sr, Nd) von vulkanischen Gesteinen aus dem Lau-Becken]

Kurzfassung: Während der SO-35- und SEAPSO IV-Kampagnen (1984 und 1985) wurden Gesteinsproben von verschiedenen Spreading-Rücken im Lau-Becken (Südwest-Pazifik) gedredscht. An ihnen wurden die Haupt- und Spurenelemente sowie die Isotopenverhältnisse für Sr und Nd bestimmt. Die Proben aus dem nördlichen Lau-Becken zeigen N-MORB-Charakter in der Verteilung sowohl der Haupt- als auch der Spurenelemente. Die Proben aus dem südlichen Lau-Becken dagegen sind differenziert und zeigen in ihrem erweiterten Seltene-Erden-Verteilungsmuster deutliche negative Ta-Nb-Anomalien, die typisch für Subduktionszonen sind. Die Isotopenverhältnisse für Sr und Nd sind sehr heterogen und liegen zwischen MORB- und Inselbogen-Werten. Der nördliche Lau Basin Ridge zeigt geochemische Eigenschaften, die für mittelozeanisches Spreading sprechen; der südliche Lau Basin Ridge (Valu-Fa-Rücken) dagegen mit seinen durch subduziertes Material beeinflußten geochemischen Eigenschaften könnte entweder ein neu entstehender Inselbogen sein oder er könnte das Anfangsstadium eines Back-Arc (Spreading) repräsentieren.

Ein Vergleich der Lau-Becken-Ergebnisse mit denen vom Nord-Fidschi-Becken und dem Okinawa-Trog zeigt geochemische Trends, die die Entwicklung vom Riftstadium (Inselbogen-Charakter) zum reifen Stadium (MORB-Charakter) eines Back-Arc-Beckens widerspiegeln.

Authors' addresses: Dr. L. DOSSO, X. BOESPFLUG, G. D. R. Génèse et évolution des domaines océaniques, IFREMER — Centre de Brest, B. P. 70 — 29263 Plouzané, France. Dr. H. BOUGAULT, IFREMER-Centre de Brest, B. P. 70 — 29263 Plouzané, France. Dr. J.-L. JORON, Groupe des Sciences de la Terre, Laboratoire Pierre Sue, Centre d'Etude Nucléaire de Saclay, B. P. 2 — 91191 Gif-sur-Yvette, France.

Contents

1 Introduction

Rock samples have been collected during SO-35 and SEAPSO IV cruises (VON STACKELBERG et al. 1985, FOUCHER et al. 1988) in the Lau Basin, a back-arc basin located behind the Tonga Trench and Tonga Ridge in the south-western Pacific (Fig. 1). They were dredged in different parts of the basin, on ridges and seamounts. Several studies have been undertaken on geochemical features of Lau Basin lavas; HAWKINS (1976) described MORB-like samples, while GILL (1976) found basalts whose characteristics are intermediate between ocean floor and island arc tholeiites; HAWKINS & MELCHIOR (1985) identified two groups in Lau Basin basalts: one resembles primitive N-MORB, the other is intermediate between Mid Ocean Ridge Basalts (MORB) and arc lavas; JENNER et al. (1987) described isotopic features and concluded to mixing processes between MORB, Island Arc Volcanics (IAV) and sediments.

In this paper we present major, trace element and isotopic data from the northern and the southern parts of the basin. Comparing these two areas and information given by major and trace elements and isotopic ratios, we try to give some complementary information on relationships between the composition of rocks and the structure of Lau Basin. Isotopic ratios and trace elements are used to trace both sources and subduction characteristics (especially Ta-Nb anomalies). We also compare our results with data from two other back-arc basins: we try to relate basalt compositions to tectonic settings and maturity of back-arc basins (SAUNDERS & TARNEY 1984).

2 Geological Setting

The Lau Basin is a back-arc basin presently opening behind the Tonga subduction zone. Its opening has to be put in relation with the convergence of Pacific, Indo-Australian and Eurasian plates (Fig. 1). It lies between Lau and Tonga ridges and has a triangular shape about 450 km wide near 18° S and 190 km wide near 26° S (HAWKINS & MELCHIOR 1985). KARIG (1971) first described the Lau Basin as being an extensional active basin. After different authors, its opening initiated 5 Ma (KARIG 1971), 3.5 Ma (WEISSEL 1977), or 2.5 Ma ago (MALAHOFF et al. 1982) by spreading of many diffuse short ridges (HAWKINS & MELCHIOR 1985). From north to south, the present day spreading axis is defined by several ridge segments. The structure of Lau Basin is complex. A NNE trending ridge segment has been identified during SO-35 cruise around 176° W and near 18° 40′ S (northern SO-35 dredges on Fig. 1), about 250 km westward of Tonga arc, 400 km from the Tonga trench (Fig. 1) and about 300 km above the Benioff zone (ISACKS & BARAZANGI 1977). A spreading rate of about 6 cm/yr was estimated VON STACKELBERG et al. 1985).

Samples collected in the northern part of Lau Basin include pillow basalts (with fresh glassy rinds): 2KD2, 8KD1, 9KD1, 9KD2 and 10KD2 have been dredged in the middle or on the flanks of the "Northern Lau Basin Ridge" (NLR on Fig. 1) (VON STACKELBERG et al. 1985); older samples (13KD1 and 13KD2) have been dredged from the eastern part of the ridge. One sample (DR1), a vacuolar andesite with glassy crust, has been dredged during SEAPSO IV cruise in the middle-east part of Lau Basin, on a discovered NNE trending morphological ridge near 19° S (MER).

South of 20° 50′ S, a linear volcanic ridge, also trending NNE, lies on the east side of the basin; it has been discovered during the RV LEE cruise (1982), 40 km westward of the volcanic arc, 200 km from the Tonga Trench, and about 150 km above the Benioff zone (JENNER et al. 1987) and has been named the Valu Fa Ridge (VFR). It spreads with a rate of

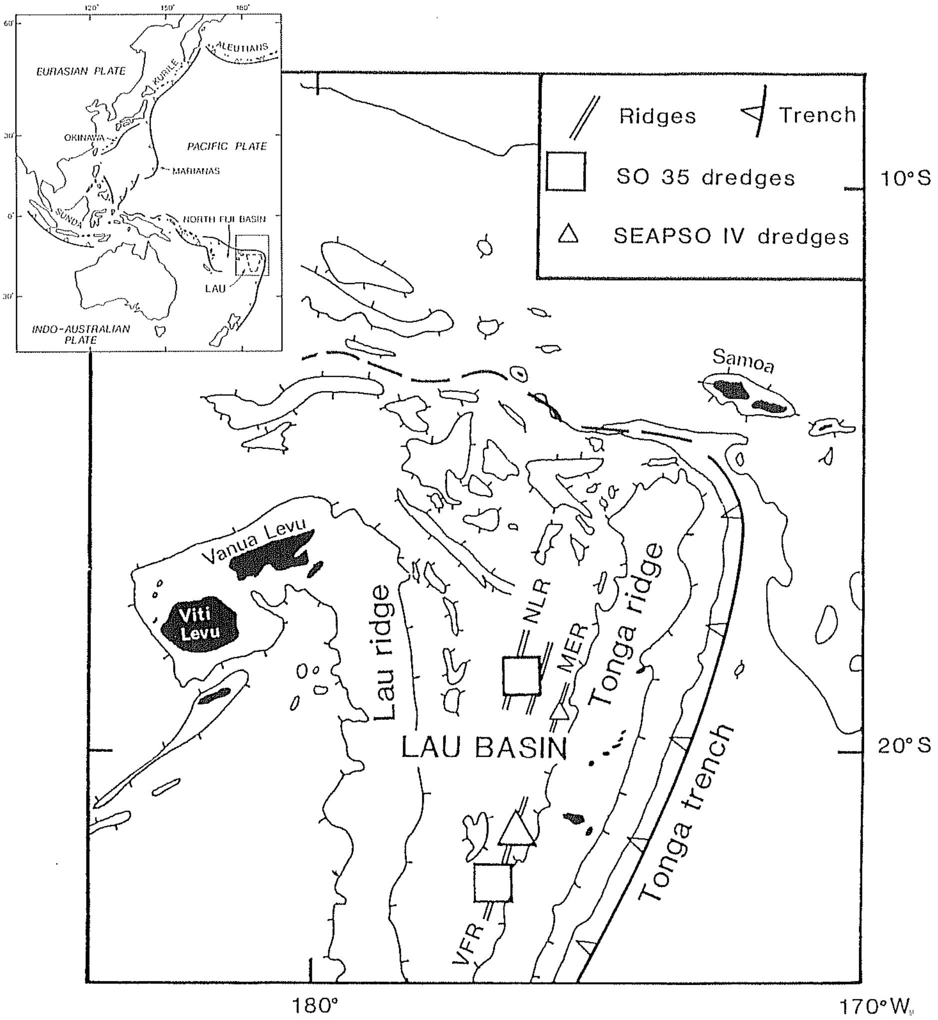

Fig. 1: Location of samples dredged during SO-35 and SEAPSO IV cruises. Map modified from AUZENDE et al. (1988); NLR = Northern Lau Basin Ridge; VFR = Valu Fa Ridge; MER = Middle East Ridge.

7 cm/yr (MORTON & SLEEP 1985). MORTON & SLEEP (1985) described a magmatic chamber which is about 2 or 3 km wide beneath the Valu Fa Ridge near 22° 30′ S. Valu Fa Ridge was proposed to be a main active spreading axis (MORTON & SLEEP 1985). However RUELLAN et al. (1990) suggest that Valu Fa Ridge might be a trans-tensional structure, connected to the retreat of the Tonga Arc, while the main spreading axis might be to the west of it. We conclude, both from the description of the Lau Basin (several axial structures) and from interpretations, that this back-arc is opening through more complex processes than that related to typical oceanic spreading centers.

Unaltered sheet flows and older rocks have been dredged during SO-35 cruise 73KD1, 83KD1, 94KD, 127KD on the active spreading ridge (Valu Fa Ridge); 67KD3 and 121KD3 on seamounts western of the Valu Fa Ridge; 128KD2 on a seamount eastern of the Valu Fa Ridge (VON STACKELBERG, personal communication). DR2 from the north extent of Valu Fa Ridge contains vacuolar aphyric pillow andesites; DR3, eastern of Valu Fa Ridge, contains quite fresh andesites from the west side from a seamount 300 m high; DR3-1C has 2 mm thick Fe-Mn crust; DR4 was sampled from a graben on the north extent of Valu Fa Ridge, about 8 miles north of DR2 and contains sub-aphyric andesites.

3 Analytical Techniques

All samples were crushed in an agate mortar. Concentration of major elements were determined by X-ray spectrometry using the glass disk heavy absorber method (flux: $Li_2B_4O_7$, La_2O_3) with exception of Na_2O concentrations that were obtained from a disk without La_2O_3. Trace element XRF measurements were made on pellets according to the procedure described by BOUGAULT et al. (1977) and ETOUBLEAU et al. (1985). Trace element neutron activation analysis used was pure instrumental epithermal neutron activation according to the procedure described by JAFFREZIC et al. (1977).

Separation of Sr and Nd were performed using standard ion exchange chromatography techniques according to the procedure of RICHARD et al. (1976). Isotopic ratios measurements were made in Brest using a new Finnigan MAT 261 variable 5-collector mass spectrometer. For Sr isotopes, the value of the NBS 987 standard during the time period of the analysis was 0.710239 ± 12 (2 sigma of the mean) (11 values) the values were all corrected for mass fractionation using $^{86}Sr/^{88}Sr = 0.1194$; blanks were about 0.5 ng. For Nd isotopes the value of the La Jolla standard during the time period of the analysis was 0.511848 ± 5 (2 sigma of the mean) (10 values). The values were all corrected for mass fractionation using $^{146}Nd/^{144}Nd = 0.7219$; blanks were about 0.5 ng. BCR1 analysis has given values of $^{87}Sr/^{86}Sr = 0.705025 \pm 24$ and $^{143}Nd/^{144}Nd = 0.512624 \pm 20$ (maximum deviation from the mean of 3 values). We analyzed some duplicates on leached powder samples with HCl 0.1 N for 10 minutes in an ultrasonic bath; the results confirmed that seawater contamination is negligible (Table 1).

4 Results

Major and trace element data are reported in Table 1. Geographically, we can divide samples in two groups: in the northern part of Lau Basin (around 18° 50′ S) 7 samples have been analyzed. They have a composition close to that of MORB's with low K_2O and SiO_2 of about 50 %. Samples 13KD are somewhat higher in SiO_2. The composition of 13KD2 seems to reflect differentiation processes.

In the southern Lau Basin (Valu Fa Ridge and around) 11 samples dredged around 22° S have been analyzed. They either display characteristics intermediate between MORB and arc andesites or tend to andesitic composition (SiO_2 up to 58 %) (Table 1-B).

Trace element data are summarized in an extended Corryell Masuda plot (Fig. 2). Two groups are distinguished: the first one is of N-MORB type, depleted in light rare earths (2KD2, 9KD2, 10KD2, 13KD2); the second group (67KD3, 73KD1, 83KD1, 94KD, 121KD3, 127KD, 128KD2, DR3-1C) shows flat to slightly enriched patterns with negative Nb-Ta anomalies. These anomalies are known to be associated with subduction zone environments (JORON & TREVIL, 1977, BRIQUEU et al. 1984).

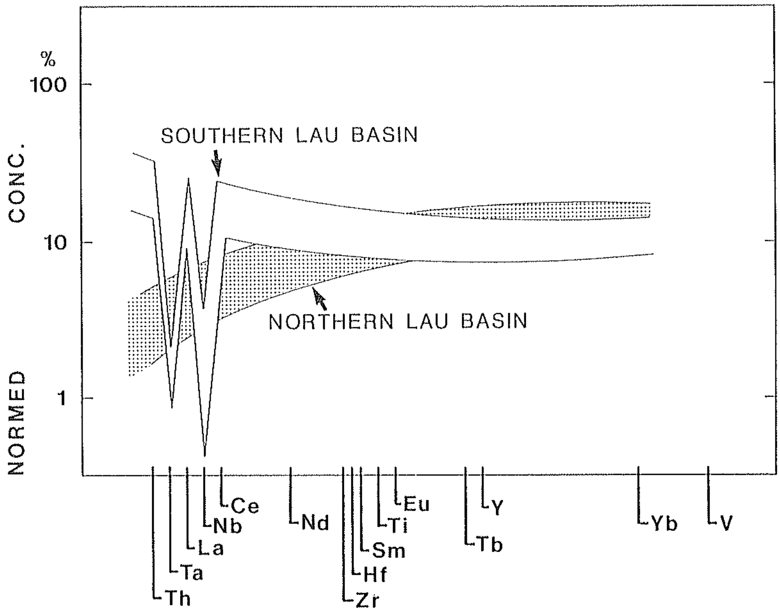

Fig. 2: Extended Coryell-Masuda plot for Lau Basin samples analysed in this study. Depleted patterns represent northern Lau Basin samples; enriched patterns represent southern Lau Basin samples.

Samples analysed for Sr and Nd isotopic ratios fall within the mantle array (Fig. 3) The isotopic values are quite heterogeneous with $^{87}Sr/^{86}Sr$ varying from 0.703209 to 0.703563 and $^{143}Nd/^{144}Nd$ from 0.513004 to 0.513143. The Lau Basin fields of values overlap the radiogenic part of MORB field as well as fields for Pacific island arcs such as the Aleutians arc, Kurile arc and basin, Mariana arc and Fiji islands. Isotopic data can also be divided in the two groups defined above: northern Lau Basin samples plot within the MORB field and seem to be correlated in a way similar to the mantle array (Fig. 3), while southern Lau Basin samples are slightly more radiogenic in Sr and have correlatively less radiogenic Nd compositions.

Our northern Lau Basin data are consistent with those of VOLPE et al. (1986) who reported isotopic composition (Sr-Nd) of glasses from the same area (17° S — 19° S). Values reported by JENNER et al. (1987) for Valu Fa Ridge and Ata Island, are included in the field shown by the new data for the southern group.

This data seem to confirm the existence of two groups of samples, and thus point out the existence of two mantle sources, each source being heterogeneous. For the northern part of Lau Basin the isotopic data are of enriched MORB type, and the field of Sr-Nd data is elongated in the same direction as observed in oceanic basalt (Fig. 3). This suggests that the northern Lau Basin source is not significantly contaminated by the subducted hydrothermally altered plate, which is consistent with the position of the Ridge well above the Benioff zone (300 km) and the large distance from the Ridge to the arc location (250 km). These samples display typical MORB characteristics in major, and trace elements

Table 1: Major and trace elements and isotope data of Lau Basin samples.

Major and trace elements concentrations have been measured in the geochemistry laboratory at IFREMER, Brest, by X-ray fluorescence (XRF) (CAMBON & ETOUBLEAU), at P. Sue laboratory, CEN, Saclay, by instrumental neutron activation (NAA) (JORON) and by isotopic dilution (ID). Isotopic ratios (Sr, Nd) have been measured at GIS "Océanologie et Géodynamique" Brest, on a new 5 collector (4 variable) FINNIGAN-MAT 261 mass spectrometer (BOESPFLUG & DOSSO). Sr is corrected for mass fractionation using $^{86}Sr/^{88}Sr = 0.1194$. Nd is corrected for mass fractionation using $^{146}Nd/^{144}Nd = 0.7219$. ε_{Nd} values are calculated with respect to a Bulk Earth value of 0.51264. Sr analyses marked with * have been done on powder leached in 0.1 M HCl. ^are samples dredged exactly on the axis; ^^dredged from Middle East Ridge (MER).

A: northern Lau Basin samples; B: southern Lau Basin samples.

A

Sample	2KD2^	8KD1^	9KD1^	9KD2^	10KD2^	13KD1	13KD2
lat.(S)	18°35′	18°41′	18°41′	18°41′	18°41′	18°39′	18°39′
lon.(W)	176°24′	176°29′	176°27′	176°27′	176°22′	176°03′	176°03′
SiO_2	50.01	49.96	49.96	49.95	48.56	52.66	52.21
Al_2O_3	13.99	13.94	14.55	14.44	15.72	15.00	14.27
Fe_2O_3	12.42	12.54	11.55	11.54	11.28	10.46	12.98
MnO	0.20	0.20	0.19	0.19	0.18	0.17	0.25
MgO	7.25	7.40	7.42	7.60	8.79	7.60	5.42
CaO	12.01	11.99	12.68	12.68	12.37	12.42	9.73
Na_2O	1.88	1.87	1.86	1.79	1.40	0.72	1.64
K_2O	0.15	0.09	0.07	0.06	0.07	0.20	0.38
TiO_2	1.35	1.29	1.18	1.20	1.12	0.58	1.09
P_2O_5	0.10	0.09	0.12	0.09	0.07	0.07	0.15
Total	99.36	99.37	99.58	99.54	99.56	99.88	98.12
LoI 110 °C	0.19	0.07	0.07	0.05	0.12	0.16	0.41
LoI 1050 °C	-0.24	-0.51	-0.51	-0.79	-0.34	0.32	0.61
Cs(NAA)	0.02	—	—	0.01	0.01	0.07	0.11
Ba(NAA)	18.3	—	—	—	—	13.0	61.2
Rb(ID)	1.54	1.01	0.70	0.75	0.60	2.78	—
Sr(ID)	88.9	89.6	86.1	87.2	101.2	115.3	—
U(NAA)	0.10	—	—	—	0.13	0.20	0.05
Th(NAA)	0.142	0.128	0.087	0.073	0.072	0.133	0.298
Ta(NAA)	0.146	0.097	0.092	0.075	0.068	0.042	0.083
La(NAA)	2.19	1.76	2.23	1.5	0.85	1.51	2.82
Nb(XRF)	3.2	2.7	2.4	2.4	1.2	0.9	2.0
Ce(NAA)	6.2	7.0	3.9	n.d	4.2	4.5	7.2
Nd(ID)	7.84	7.52	6.54	6.68	6.39	3.61	—
Zr(XRF)	76	74	64	59	63	34	49
Hf(NAA)	2.11	1.81	1.84	1.50	1.63	0.65	1.44
Sm(ID)	3.0	2.85	2.57	2.63	2.50	1.26	—
Ti(XRF)	8100	7740	7080	7200	6720	3480	6540
Eu(NAA)	1.19	1.13	1.03	0.86	1.01	0.42	0.92
Tb(NAA)	0.751	0.701	0.637	0.599	0.616	0.290	0.552
Y(XRF)	35.5	32.5	31.8	31.4	29.3	17.8	27.0
Yb(NAA)	3.3	4.1	2.6	3.4	2.8	2.4	3.4
Sc(NAA)	44.2	44.0	43.4	39.9	40.6	39.4	38.3
Cr(NAA)	248	99	217	210	309	73	64
Co(NAA)	44.3	45.4	43.4	39.7	46.6	39.3	39.9
Ni(NAA)	78	65	69	67	140	59	45
$^{86}Sr/^{87}Sr$	.703439±11	.703232±11*	.703213±12* .703197±11*	.703214±13 .703188±14*	.703343±10	.703330±13	
$^{143}Nd/^{144}Nd$	.513063±05 .513067±06	.513073±09	.513103±05	.513143±09	.513077±15	.513024±13 .513036±20	
ε_{Nd}	+8.25 +8.33	+8.52	+9.03	+9.81	+8.52	+7.49 +7.72	

B

Sample	67KD3	73KD1^	83KD1^	94KD^	121KD3	127KD^
lat.(S)	22°10′	22°12′	22°15′	22°24′	22°07′	22°15′
lon.(W)	176°41′	176°36′	176°37′	176°46′	177°01′	176°37′
SiO_2	50.81	55.11	56.29	58.36	57.46	56.21
Al_2O_3	15.63	15.10	14.90	14.86	15.43	14.90
Fe_2O_3	10.62	11.19	11.83	10.64	10.44	11.88
MnO	0.18	0.20	0.20	0.20	0.15	0.20
MgO	7.49	4.20	3.48	2.69	2.97	3.51
CaO	13.00	8.85	7.85	6.83	7.86	7.74
Na_2O	1.03	2.82	2.92	3.25	3.32	2.84
K_2O	0.22	0.42	0.47	0.62	0.76	0.47
TiO_2	0.61	1.19	1.48	1.38	1.23	1.52
P_2O_5	0.06	0.17	0.22	0.30	0.20	0.22
Total	99.65	99.25	99.64	99.13	99.82	99.49
LoI 110 °C	0.34	0.30	0.20	0.25	0.33	0.18
LoI 1050 °C	0.09	0.58	0.51	1.31	1.41	0.30
Cs(NAA)	0.10	0.14	0.18	0.22	0.12	0.18
Ba(NAA)	56.0	83	98	116	145	113
Rb(ID)	3.30	6.41	7.18	9.22	8.54	7.48
Sr(ID)	161.6	164.9	172	183.2	269.5	172.3
U(NAA)	0.07	0.17	0.13	0.19	0.39	0.23
Th(NAA)	0.180	0.392	0.424	0.487	0.879	0.455
Ta(NAA)	0.021	0.071	0.079	0.094	0.082	0.084
La(NAA)	1.25	3.66	3.78	5.04	6.71	4.45
Nb(XRF)	0.8	1.9	1.1	1.6	2.1	2.0
Ce(NAA)	4.6	13.0	13.0	12.3	13.9	13.7
Nd(ID)	4.24	10.35	10.49	13.01	13.93	11.26
Zr(XRF)	24	82	76	90	81	84
Hf(NAA)	0.77	2.35	2.24	2.59	2.44	2.44
Sm(ID)	1.51	3.44	3.64	4.25	3.96	3.75
Ti(XRF)	3660	7140	8880	8280	7380	9120
Eu(NAA)	0.57	1.28	1.28	1.60	1.46	1.50
Tb(NAA)	0.330	0.769	0.783	0.936	0.751	0.839
Y(XRF)	17.9	34.2	35.3	38.7	32.0	35.1
Yb(NAA)	2.3	4.5	4.6	3.8	2.9	5.4
Sc(NAA)	40.3	30.8	29.4	26.1	27.0	29.7
Cr(NAA)	35	—	—	—	—	38
Co(NAA)	42.2	29.8	25.5	16.3	23.8	25.9
Ni(NAA)	45	19	5.5	1.4	2.5	6.5
$^{87}Sr/^{86}Sr$	.703331±16	.703355±12	.703340±10	.703331±07	.703584±08	.703321±18
	.703337±13				.703563±06*	
$^{143}Nd/^{144}Nd$	.513063±20	.513053±07	.513061±07	.513061±08	.513056±16	.513074±07
	.513054±18			.513061±07	.513065±08	
ε_{Nd}	+8.25	+8.06	+8.21	+8.21	+8.11	+8.47
	+8.08			+8.21	+8.29	

Sample	128KD2	DR1-1A^^	DR2-1C^	DR3-1C	DR4-1C^
lat.(S)	22°17′	19°18′	21°26′	21°23′	21°19′
lon.(W)	176°34′	175°26′	176°23′	176°16′	176°20′
SiO_2	52.57	53.30	53.50	51.10	53.20
Al_2O_3	14.44	16.80	14.78	16.19	15.04
Fe_2O_3	10.09	10.40	13.35	10.00	11.96
MnO	0.17	0.16	0.20	0.16	0.19
MgO	7.52	5.79	4.58	7.46	5.40
CaO	12.04	11.60	9.15	12.97	10.07
Na_2O	1.06	1.10	2.38	1.70	2.40
K_2O	0.71	0.29	0.40	0.32	0.34
TiO_2	0.57	0.58	1.47	0.60	1.30
P_2O_5	0.16	0.07	0.17	0.08	0.16
Total	99.33	100.09	99.98	100.58	100.06
LoI 110	0.08	0.55	0.14	0.17	0.19
LoI 1050	0.13	1.06	0.33	0.33	0.27
Cs(NAA)	0.28	0.12	0.13	0.14	0.12
Ba(NAA)	143	46.8	56	65.4	62
Rb(ID)	13.6	3.4	6.2	5.2	5.1
Sr(ID)	237.2	146.5	143.4	164.9	133.7
U(NAA)	0.24	0.05	0.09	0.06	0.15
Th(NAA)	0.519	0.139	0.258	0.168	0.207
Ta(NAA)	0.033	0.027	0.073	0.020	0.089
La(NAA)	4.40	1.59	3.60	1.34	3.22
Nb(XRF)	0.3	2.0	1.6	0.4	1.6
Ce(NAA)	8.2	n.d	9.6	3.4	9.3
Nd(ID)	7.32	3.77	8.87	4.36	8.45
Zr(XRF)	37	36	71	35	74
Hf(NAA)	1.05	0.76	2.10	0.77	2.00
Sm(ID)	2.04	1.28	3.02	1.54	2.87
Ti(XRF)	3420	3480	8820	3600	7800
Eu(NAA)	0.70	0.44	1.21	0.64	1.22
Tb(NAA)	0.351	0.296	0.707	0.321	0.678
Y(XRF)	16.7	16.8	34.0	17.4	31.9
Yb(NAA)	2.1	n.d	3.0	1.5	2.9
Sc(NAA)	36.7	37.7	33.4	36.5	35.2
Cr(NAA)	237	15	—	127	6
Co(NAA)	41.8	34.0	37.6	39.8	37.9
Ni(NAA)	51	35	13	70	23
$^{87}Sr/^{86}Sr$	.703404±10	.703471±11	.703209±12 .703216±12	0.703377±10	0.703286±09
$^{143}Nd/^{144}Nd$	.513012±16 .513021±08	.513004±04	.513030±06	.513063±10	.513028±05
ε_{Nd}	+7.26 +7.43	+7.10	+7.61	+8.25	+7.57

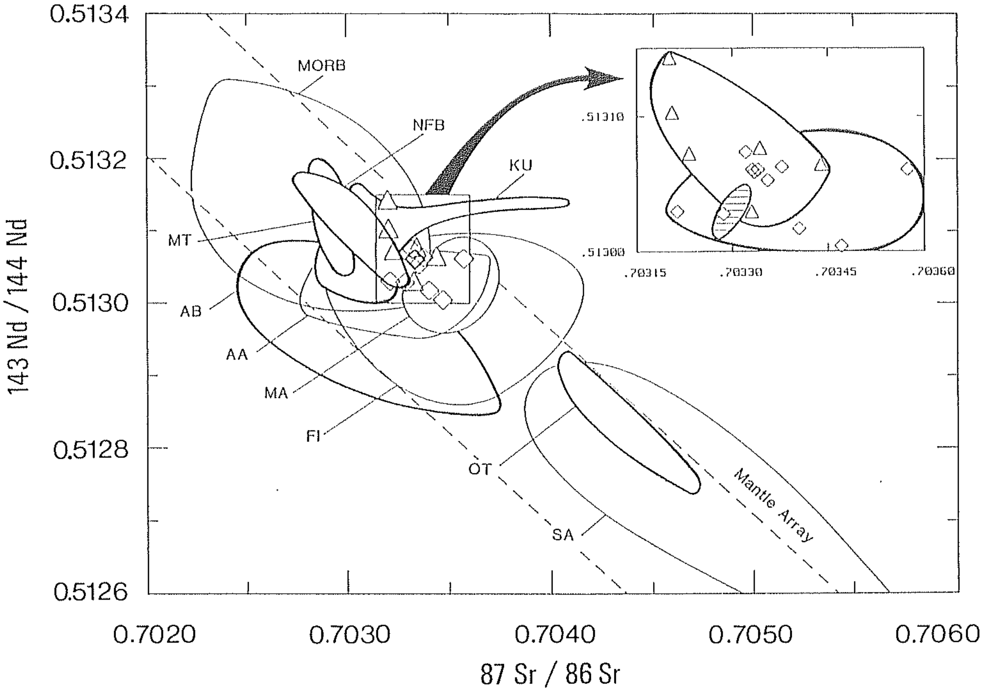

Fig. 3: Sr-Nd isotopic variation in Lau Basin samples with fields for other back arc basins (thick line fields) and island arcs (thin line fields). MORB (O'Nions et al. 1977; White & Hoffmann 1982; Cohen & O'Nions 1982; Ito et al. 1987; White et al. 1987); NFB = North Fiji Basin (Brest, unpublished data), KU = Kurile Arc and Basin (Zhuravlev et al. 1987), MT = Mariana Trough (Volpe et al. 1987), AB = Aleutian Basin (Menzies & Murthy 1980; von Drach et al. 1986), AA = Aleutian Arc (McCulloch & Perfit 1981, White & Patchett 1984; von Drach et al. 1986) MA = Mariana Arc (Dixon & Stern 1983; Stern & Bibee 1984; White & Patchett 1984), FI = Fiji Islands (Gill 1984), OT = Okinawa Trough (Brest, unpublished data), SA = Sunda Arc (Whitford et al. 1981; Varne & Foden 1986). In the upper diagram we represent Lau Basin field: triangles are northern Lau Basin; diamonds are southern Lau Basin (VFR) and one is from Middle East Ridge (MER), and striped area is VFR, from Jenner et al. 1987. Dashed line Mantle Array is after Volpe et al. 1987.

and isotopic ratios. Similar data are given on Fig. 3 for the North Fiji Basin (unpublished data) and Mariana Trough (Volpe et al. 1987); the Sr-Nd inverse correlation observed precludes involvement of seawater saturated volcanic sediments in the genesis of these basalts, such as noted for Mariana Trough basalts (Volpe et al. 1987). We suggest that the northern Lau Basin ridge could be the main axis of the Lau Basin.

Southern Lau Basin samples were generated from mantle sources presenting more radiogenic Sr values, such as commonly found in island arcs where isotopic data are often shifted from the mantle array towards Sr radiogenic values. This is in particular well illustrated by Mariana Arc and Fiji Islands data (White & Patchett 1984, Gill 1984 respectively) which have more radiogenic Sr values than their associated back-arc basin, i. e. Mariana Trough (Volpe et al. 1987) and North Fiji Basin (Brest, unpublished data). Southern Lau Basin samples also display arc characteristics in their trace element pattern

(Nb-Ta negative anomalies, Fig. 2). Such a result is consistent with the proximity of Valu Fa Ridge to the Tonga arc (40 km) and the Benioff zone (150 km); it tends to support the interpretation by FOUCHER et al. (1988) upon which Valu Fa Ridge may have formed as the result of migration to the back-arc domain of the volcanic front of the arc system. We can also suggest from chemistry that it is a back-arc opening with still the influence of subducted material.

We compare our results with other unpublished data from two other back-arc basins (North Fiji Basin — south-western Pacific and Okinawa Trough — western Pacific). Fresh basalts have been dredged in the North Fiji Basin along its spreading axis; they are N-MORB type basalts both from REE patterns and isotopic features (Fig. 3). Samples from the Okinawa Trough show arc-like features both for magmaphile elements (negative Nb-Ta anomalies) and for isotopic features (Fig. 3).

Geophysical data suggest that North Fiji Basin started opening 10 Ma ago (MALAHOFF et al. 1982), Lau Basin, 2.5 Ma ago (MALAHOFF et al. 1982) and Okinawa Trough, 1.9 Ma ago (KIMURA 1985). As SAUNDERS & TARNEY (1984) already showed that it is possible to relate the geochemistry and the geological environment evolution, we find that isotopic ratios and extended REE patterns reflect back-arc basin evolution. When opening initiates, geochemical features are similar to those of island arcs. As spreading continues in the back-arc basin, it becomes more and more like a typical oceanic basin, and the influence of the subducted zone becomes weaker: both isotopic ratios and trace elements of back-arc basin basalts tend to MORB characteristics. This is in good agreement with the idea of TAYLOR & KARNER (1983) who suggested that back-arc basin spreading centers may be initiated close to the arc and above a shallow subducted slab (Lau Basin and Okinawa Trough), and with time migrate away from the arc and no longer overlie a Benioff zone (North Fiji Basin); this would explain the correlation between evolution stages and geochemical features of back-arc basins.

5 Summary

The Lau Basin has heterogeneous geochemical features for which combined trace element and isotopic data give very coherent information: 1 — Northern Lau Basin samples have depleted extended rare earth patterns typical of MORB samples and have Sr and Nd isotopic values which are close to those observed on E-type MORB. 2 — Southern Lau Basin samples have slight to enriched rare earth elements patterns with Ta-Nb negative anomalies such as commonly observed in subduction zone environments. Their Sr and Nd isotopic values are closer to values obtained on island arc samples. They suggest mid-oceanic type spreading in the northern part of the Lau Basin, whereas Valu Fa Ridge, in the southern part of the basin, is more influenced by the subducted plate and could be a nascent island arc or correspond to an initial stage of back-arc opening.

6 References

AUZENDE, J. M., EISSEN J. P., LAFOY Y., GENTE, P. & CHARLOU, J. L. (1988): Seafloor spreading in the North Fiji Basin (Southwest Pacific). — Tectonophysics, **146**: 317—351.

BRIQUEU, L., BOUGAULT, H. & JORON, J.-L. (1984): Quantification of Nb, Ta, Ti and V anomalies in magmas associated with subduction zones: petrogenetic implications. — Earth and planet. Sci. Letters, **68**; : 297—308.

—, Cambon, P. & Toulhouat, H. (1977): X-Ray spectrometric analysis of trace elements in rocks: correction for instrumental interference. — X-Ray spectrom. **6:** 66—72.

Cohen, R. S. & O'Nions, R. K. (1982): The lead, neodymium and strontium isotopic structure of ocean ridge basalts. — J. Petrol. **23,** 3: 299—324.

Dixon, T. H. & Stern, R. J. (1983): Petrology, chemistry, and isotopic composition of submarine volcanoes in the southern Mariana arc. — Bull. geol. Soc. Amer., **94:** 1159—1172.

Drach, V. von, Marsh, B. D. & Wasserburg, G. J. (1986): Nd and Sr isotopes in the Aleutians: multicomponent parenthood of island-arc magmas. — Contr. Mineral. and Petrol., **92:** 13—34.

Etoubleau, J., Bougault, H., Rideout, M., Brannon, J. & Weaver, B. (1985): Trace element analysis by X-Ray fluorescence spectrometry on board an oceanographic vessel. — In: H. Bougault, S. C. Cande et al.: Init. Rep. DSDP, **82:** 35—43.

Foucher, J. P., Dupont, J., Bouysse, P., Charlou, J. L., Davagnier, M., Eissen, J. P., Fouquet, Y., Gueneley, S., Harmegnies, F., Lafoy, Y., Lapouille, A., Maze, J. P., Morton, J., Ondreas, H., Ruellan, E. & Sibuet, J. C. (1988): La ride volcanique de Valu Fa dans le bassin de Lau méridional (sud-ouest Pacifique). — C. R. Acad. Sci. Paris, **307:** 609—616.

Gill, J. B. (1976): Composition and age of Lau Basin and Ridge volcanic rocks: implications for evolution of an interarc basin and remnant arc. — Bull. geol. Soc. Amer., **87:** 1384—1395.

— (1984): Sr-Pb-Nd isotopic evidence that both MORB and OIB sources contribute to oceanic island arc magmas in Fiji. — Earth and planet. Sci. Letters, **68:** 443—458.

Hawkins, J. W. (1976): Petrology and geochemistry of basaltic rocks of the Lau Basin. — Earth and planet. Sci. Letters, **28:** 283—297.

— & Melchior, J. T. (1985): Petrology of Mariana Trough and Lau Basin basalts. — J. geophys. Res., **90,** B13: 11431—11468.

Isacks, B. L. & Barazangi, M. (1977): Geometry of Benioff zones: lateral segmentation and downwards bending of the subducted lithosphere. — In: M. Talwani & W. C. Pitman (Eds.): Island arcs, deep sea trenches and back-arc basin. — Amer. geophysic. Union, Washington, D. C., Maurice Ewing Series, **1:** 99—114.

Ito, E., White, W. M. & Gopel, C. (1987): The O, Sr, Nd and Pb isotope geochemistry of MORB. — Chem. Geol., **62:** 157—176.

Jaffrezic, H., Joron, J. L. & Treuil, M. (1977): Trace element determination in rock powders: a study of the precision of a given analytical procedure-instrumental neutron activation. — J. Radioanalytical Chemistry, **39:** 185—188.

Jenner, G. A., Cawood, P. A., Rautenschlein, M. & White, W. M. (1987): Composition of back-arc basin volcanisms, ValuFa Ridge, Lau Basin: evidence for a slab derived component in their mantle source. — In: S. D. Weaver & R. W. Johnson (Eds.): Tectonic Controls on Magma Genesis. — J. Volcanol. Geotherm. Res., **32:** 209—222.

Joron, J. L. & Treuil, M. (1977): Utilisation des propriétés des éléments fortement hygromagmaphiles pour l'étude de la composition chimique et de l'hetérogénéité du manteau. — Bull. Soc. Géol. de France, **XIX, 6:** 1197—1205.

Karig, D. E. (1971): Origin and development of marginal basins in the western Pacific. — J. geophys. Res., **76:** 2542—2561.

Kimura, M. (1985): Back-arc rifting in the Okinawa Trough. — Marine and Petroleum Geol., **2:** 222—240.

McCulloch, M. T. & Perfit, M. R. (1981): ^{143}Nd/^{144}Nd, ^{87}Sr/^{86}Sr and trace element constraints on the petrogenesis of Aleutian island arc magmas. — Earth and planet. Sci. Letters, **56:** 167—179.

MALAHOFF, A., HAMMOND, S. R., NAUGHTON, J. J., KEELING, D. L. & RICHMOND, R. N. (1982): Geophysical evidence for post-Miocene rotation of the island of Viti Levu, and its relationship to the tectonic development of the North Fiji Basin. — Earth and planet. Sci. Letters, **57**: 398—414.

MENZIES, M. & MURTHY, V. R. (1980): Nd and Sr isotope geochemistry of hydrous mantle nodules and their host alkali basalts: implications for local heterogeneities in metasomatically veined mantle. — Earth and planet. Sci. Letters, **46**: 323—334.

MORTON, J. L. & SLEEP, N. H. (1985): Seismic reflections from a Lau Basin magma chamber. — In: D. W. SCHOLL & T. L. VALLIER (Eds.): Geology and offshore Resources of Pacific island arcs — Tonga region. — Amer. Assoc. Petrol. Geologists, Tulsa, Circum Pacific Council for Energy and Mineral Resources, Earth Science Series, **2**: 441—453.

O'NIONS, R. K., HAMILTON, P. J. & EVENSEN, N. M. (1977): Variations in ^{143}Nd/^{144}Nd and ^{87}Sr/^{86}Sr ratios in oceanic basalts. — Earth and planet. Sci. Letters, **34**: 13—22.

RICHARD, P., SHIMIZU, N. & ALLEGRE, C. J. (1976): ^{143}Nd/^{146}Nd, a natural tracer: an application to oceanic basalts. — Earth and planet. Sci. Letters, **31**: 269—278.

RUELLAN, E., LAFOY, Y., AUZENDE, J. M., FOUCHER, J. P. & DUPONT, J. (1990): Oblique spreading in the southern part of the Lau back-arc basin (S.W. Pacific). — In: BALLANCE, P. F., HERZER, R. H. & STEVENSON, A. J. (Eds.): Contribution to the marine and on-land geology and resources of the Tonga-Lau-Fiji region. — [In press]

SAUNDERS, A. D. & TARNEY, J. (1984): Geochemical characteristics of basaltic volcanism within back-arc basins. — In: KOKELAAR, B. P. & HOWELLS, M. F. (Eds.): Marginal basin geology volcanic and associated sedimentary and tectonic processes in modern and ancient marginal basins. — Blackwell sci. Publ.: 59—76.

STACKELBERG, U. VON and the SHIPBOARD SCIENTIFIC PARTY (1985): Hydrothermal sulfide deposits in back-arc spreading centers in the Southwest Pacific. — BGR Circular, **2**: 14 p.

STERN, R. J. & BIBEE, L. D. (1984): Esmeralda Bank: Geochemistry of an active submarine volcano in the Mariana island arc. — Contr. to Mineral. and Petrol. **86**: 159—169.

TAYLOR, B. & KARNER, G. D. (1983): On the evolution of marginal basins. — Rev. Geophys. and Space Physics, **21**, 8: 1727—1741.

VARNE, R. & FODEN, J. D. (1986): Geochemical and isotopic systematics of eastern Sunda arc volcanics: implications for mantle sources and mantle mixing processes. — In: WEZEL, F. C. (Eds.): The origin of arc developments in geotectonics, **21**: 567 p., (Elsevier).

VOLPE, A. M., HAWKINS, J. W. & MACDOUGALL, J. D. (1986): Basaltic and andesitic glasses from the Lau Basin: chemical and isotopic compositions. — EOS, **67**, 44: 1253.

—, MACDOUGALL, J. D. & HAWKINS, J. W. (1987): Mariana trough basalts (MTB): trace element and Sr-Nd isotopic evidence for mixing between MORB-like and arc-like melts. — Earth and planet. Sci. Letters, **82**: 241—254.

WEISSEL, J. K. (1977): Evolution of the Lau Basin by the growth of small plates. — In: M. TALWANI & W. C. PITMAN (Eds.): Island arcs, deep sea trenches and back-arc basin. — Amer. geophysic. Union, Washington, D. C., Maurice Ewing Series, **1**: 99—114.

WHITE, W. M. & HOFFMAN, A. W. (1982): Sr and Nd isotope geochemistry of oceanic basalts and mantle evolution. — Nature, **296**: 821—825.

WHITE, W. M., HOFFMAN, A. W. & PUCHELT, H. (1987): Isotope Geochemistry of Pacific Mid-Ocean Ridge Basalt. — J. geophys. Res., **92**, B6: 4881—4893.

—, & PATCHETT, J. (1984): Hf-Nd-Sr isotopes and incompatible element abundances in island arcs: implications for magma origins and crust-mantle evolution. — Earth and planet. Sci. Letters, **67**: 167—185.

WHITFORD, D. J., WHITE, W. M. & JEZEK, P. A. (1981): Neodymium isotpic composition of quaternary island arc lavas from Indonesia. —Geochimica cosmochimica Acta, **45**: 989—995.

ZHURAVLEV, D. Z., TSVETKOV, A. A., ZHURAVLEV, A. Z., GLADKOV, N. G. & CHERNYSHEV, I. V. (1987): ^{143}Nd/^{144}Nd and ^{87}Sr/^{86}Sr ratios in recent magmatic rocks of the Kurile island arc. — Chemical Geology (Isotope Geoscience Section), **66**: 227—243.