Proc. NIPR Symp. Antarct. Geosci., **8**, 49-64, 1995

GEOCHEMICAL CHARACTERISTICS OF MAFIC DIKE ROCKS FROM THE SØR RONDANE MOUNTAINS, EAST ANTARCTICA

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Abstract: Mafic dike rocks (lamprophyre and dolerite) which have been metamorphosed up to amphibolite facies grade intruded Neoproterozoic metamorphic terrains of the Sør Rondane Mountains. Major and trace element abundance and Sr and Nd isotopic compositions were determined on the mafic dike rocks. The lamprophyre are characterized by extremely high K_2O, P_2O_5, Rb, Ba, Sr, Zr, and light rare earth elements which have minette or lamproite affinity. The geochemical characteristics of lamprophyre and dolerite suggest that these mafic rocks were derived from partial melting of a re-enriched mantle source by mixing of remnant subduction-related materials in the Pan-African orogenic time and a metasomatically enriched mantle. It seems likely that these mafic magmatic activities were related to post orogenic igneous activity in a continental collision zone linked to the Pan-African orogeny.

1. Introduction

During a geological survey by the Japanese Antarctic Research Expedition (JARE) programs (JARE-20, -21, -25, -26, -31, and -32), mafic metamorphosed dikes, lamprophyre and dolerite have been found from Neoproterozoic to Cambrian metamorphic terrains of the Yamato Mountains and Sør Rondane Mountains in eastern Queen Maud Land. The lamprophyre from the Yamato Mountains are minette or lamproite affinity (ARIMA and SHIRAISHI, 1993). The mafic dike rocks including the lamprophyre and dolerite in the Sør Rondane Mountains, however, are not well investigated and understood in terms of the genetical relationship among the dike suites. We here describe geochemical characteristics of these mafic dike rocks which cast light on these questions, and discuss the tectonic significance of their modes of occurrence.

2. Geological Setting

The Sør Rondane Mountains consist mainly of Proterozoic metamorphic rocks (1000–1100 Ma) and various plutonic rocks (950–500 Ma) (KOJIMA and SHIRAISHI, 1986; ISHIZUKA and KOJIMA, 1987; SAKIYAMA *et al*., 1988; SHIRAISHI and KAGAMI, 1989; TAKAHASHI *et al*., 1990; SHIRAISHI *et al*., 1991; ASAMI *et al*., 1992; GREW *et al*., 1992; OSANAI *et al*., 1992;

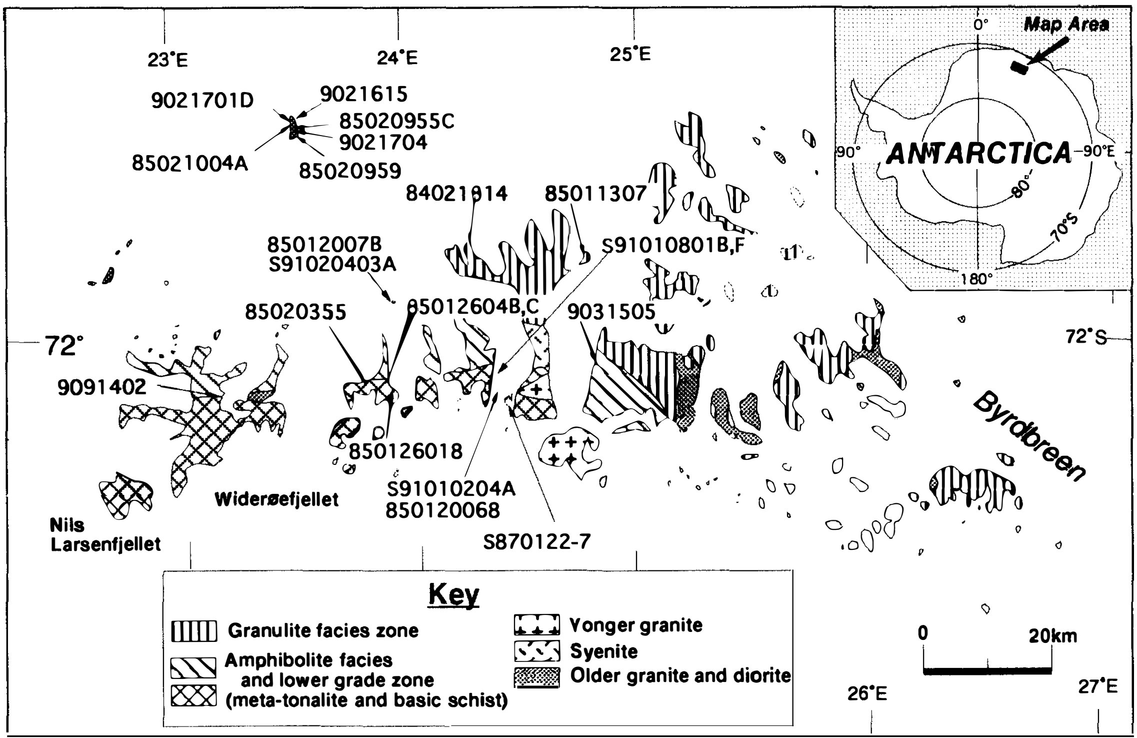

Fig. 1. Sample localities of mafic dike rocks and simplified geological map in the western and central parts of the Sør Rondane Mountains.

SHIRAISHI and KAGAMI, 1992; TAINOSHO *et al.*, 1992) (Fig. 1).

Mafic dike rocks (lamprophyre and dolerite) intrude the Proterozoic metamorphic rocks, but are cut in places by the younger veins of Paleozoic granite and pegmatite (SHIRAISHI *et al.*, 1988). Mafic dikes with various ages and compositions have been reported from eastern Queen Maud Land, including the Lützow-Holm Complex, Yamato-Belgica Complex, Sør Rondane Mountains, and Schirmacher Hills (SHIRAISHI *et al.*, 1988; ARIMA and SHIRAISHI, 1993). The radiogenic ages (K-Ar and Ar-Ar methods) of the youngest mafic dike rocks from Queen Maud Land indicate 434–536 Ma (KOJIMA and SHIRAISHI, 1986; TAKIGAMI *et al.*, 1987; TAKIGAMI and FUNAKI, 1991; ARIMA and SHIRAISHI, 1993). These activities have been thought to be a manifestation of an initial stage of the continental rift system and occurred a few tens of millions of years after the ~500 Ma major orogenic event (Pan-African orogeny) (SHIRAISHI *et al.*, 1988; ARIMA and SHIRAISHI, 1993).

3. Samples and Analytical Methods

Sample localities of mafic dike rocks in the Sør Rondane Mountains are shown in Fig. 1. Lamprophyres exhibit a well-recrystallized grano-lepidoblastic texture, and apparently the igneous texture is not preserved. The rocks consist dominantly of greenish brown biotite and alkali-feldspar which commonly show microcline texture with or without bluish green amphibole, epidote, muscovite, and quartz. Accessory minerals are apatite, sphene, orthite, hematite, and opaque minerals.

Dolerites are re-crystallized in various grades. They generally show a sub-ophitic dolerite texture and are composed of igneous pyroxene and plagioclase, and of metamorphic biotite with or without greenish to bluish green hornblende. Ilmenite, apatite, sphene, orthite, and pyrite are common as accessory minerals. Some dolerites are well-recrystallized and corroded plagioclase laths are not well preserved. Completely recrystallized rocks are hornblende-biotite schist without pyroxenes.

Major elements were analyzed by ICP. Abundances of Nb, Rb and Pb were determined by XRF, and REEs were analyzed by INAA. The other trace elements were analyzed by ICP. The measurements of Sr and Nd isotope ratios were performed with a double Re-Ta filament mode, using on MAT 261 with five Faraday collectors at the Institute for Study of the Earth's Interior, Okayama University. The experimental procedures followed the method of KAGAMI *et al.* (1987, 1989). The average $^{87}Sr/^{86}Sr$ ratios for NBS 987 during the period of this study was $0.710222 \pm 11 (2\sigma)$ (for $n=3$). The measured $^{143}Nd/^{144}Nd$ ratios were normalized to $^{146}Nd/^{144}Nd=0.7219$ and adjusted to a $^{143}Nd/^{144}Nd$ ratio for BCR-1=0.512640. $^{143}Nd/^{144}Nd$ ratios of BCR-1 during this study gave an average (for $n=4$) 0.512604 ± 12 (2σ).

4. Major and Trace Element Geochemistry

Major and trace element abundances of the mafic dike rocks are given in Tables 1 and 2. High-grade (amphibolite to granulite facies) metamorphism of mafic rocks commonly results in significant depletion in large-ion lithophile elements (LILE), but causes no effect on high-field strength elements (HFS) such as Nb, Zr, and Y (SHERATON, 1984). The mafic dike rocks from the studied area exhibit high concentrations of LILE and HFS (Tables 1 and 2) and most of the rocks show similar normalized patterns of elemental abundance (Figs. 2 and 3). These features suggest that the chemical characteristics of magmatic processes are well preserved and that modification during metamorphism is insignificant, as mentioned by ARIMA and SHIRAISHI (1993).

Lamprophyres show variable SiO_2 content (45.6–60.7 wt%) and high K_2O (3.5–8.5 wt%), P_2O_5 (0.4–2.1 wt%), and incompatible elements (Ba=893–9049 ppm, Rb=123–415 ppm, Sr=167–3154 ppm, and Zr=108–675 ppm). In the characterization diagram by ROCK (1987), all the rock data are plotted in the fields of calc-alkaline lamprophyre and lamproite (Fig. 4). In the diagram of BERGMAN (1987), the rocks are plotted in the fields of lamproite and lamprophyre (Fig. 5). Although it is not clear as to whether the high potassium rocks are classified as "lamproite" or "calc-alkaline lamprophyre" (*i.e.* minette which is classified by MITCHELL and BERGMAN, 1991), we use the term, "lamprophyre" hereafter. These geochemical characteristics of the "lamprophyre" are similar to those of the high potassium dike rocks in the Yamato Mountains ~300 km eastward from the present region in Antarctica (ARIMA and SHIRAISHI, 1993).

Incompatible-element concentrations are normalized to the estimated primitive mantle abundances (SUN and McDONOUGH, 1989) and compiled in Fig. 2. The "lamprophyre" shows pronounced negative anomalies of Nb-Ta and Ti which are commonly observed in subduction related rocks, lamproite and calc-alkaline lamprophyre (MITCHELL and BERGMAN, 1991; ROCK, 1991).

Dolerites (SiO_2=49.8–54.4 wt%) are characterized by relatively high contents of K_2O (2.0–3.0 wt%), TiO_2 (2.5–3.6 wt%), P_2O_5 (0.9–1.6 wt%), Ba (1206–2354 ppm), Sr (883–1434

Table 1. Major elements abundances (wt%) of mafic dike rocks from Sør Rondane Mountains.

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
Lamprophyre												
S91010801F	45.54	1.08	11.03	10.81	0.18	9.40	7.22	0.60	5.65	1.34	5.21	98.17
S91010801B	48.27	2.88	11.93	16.82	0.22	4.23	7.82	0.01	4.20	0.30	1.80	98.48
85012007B	50.72	1.59	13.02	8.16	0.14	5.00	7.33	0.71	8.54	2.05	0.40	97.66
85012601B	53.00	1.25	12.66	7.49	0.13	5.07	5.79	3.97	3.54	1.55	3.24	97.69
S870122-7	54.54	1.41	12.40	7.25	0.14	5.33	5.60	0.98	7.42	1.59	1.20	97.86
9091402	56.71	1.07	13.70	9.94	0.18	2.89	3.24	2.31	5.64	0.26	2.99	98.93
9031505	60.68	1.33	13.24	5.06	0.10	3.62	3.28	1.73	7.13	1.07	0.64	97.88
Dolerite												
S91020403A	49.67	3.17	13.54	11.15	0.15	5.36	7.54	3.38	2.30	1.07	0.85	98.18
85011307	49.75	3.13	13.51	11.51	0.17	5.42	7.41	3.35	2.51	1.09	0.84	98.69
84021814	50.30	3.18	13.53	11.26	0.14	5.66	7.74	3.49	2.13	1.00	0.40	98.83
9021701D	50.61	3.33	13.78	11.75	0.15	3.50	6.56	3.28	2.61	1.49	1.70	98.76
85012604B	51.10	2.68	14.29	10.74	0.15	5.77	7.41	3.34	2.03	0.91	0.97	99.39
S91010204A	51.14	3.64	13.16	12.95	0.16	3.67	6.57	3.06	2.26	1.60	0.20	98.40
85020955C	51.44	3.56	13.79	12.24	0.15	3.94	6.67	3.19	2.20	1.48	0.40	99.04
85021004A	52.05	3.18	14.09	10.97	0.13	4.24	6.57	3.01	2.80	1.29	0.58	98.91
9021704	52.29	3.32	13.77	11.82	0.14	3.89	6.39	3.24	2.46	1.49	0.38	99.22
85012006B	52.30	3.58	13.32	12.95	0.16	3.69	6.47	3.08	2.44	1.53	0.40	99.92
85020959	52.59	3.17	13.61	11.03	0.14	3.62	6.17	2.97	3.04	1.31	0.44	98.09
85020355	53.64	3.61	13.08	13.18	0.16	2.79	6.31	3.01	2.47	1.57	1.19	101.01
85012604C	54.17	2.50	14.06	10.02	0.13	4.86	6.20	3.45	2.46	0.87	0.99	99.71
9021615	54.38	3.62	13.15	11.84	0.14	2.92	6.08	3.21	2.39	1.70	0.40	99.83

*Total iron as Fe_2O_3.

Table 2. Trace element abundances (ppm) of mafic dike rocks from Sør Rondane Mountains.

Sample No.	Y	Zr	Nb	V	Cr	Co	Ni	Zn	Rb	Sr	Ba	Pb	U	Hf	Th	Ta	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
Lamprophyre																								
S91010801F	26	138	15	137	605	31.6	90	138	177	167	2677	<5	1.8	4.2	8.1	0.6	58.1	126	60	10.8	2.72	1.2	1.91	0.26
S91010801B	60	182	6	404	469	41.7	52	147	123	372	893	7	0.8	5.1	1.3	<0.3	11.1	33	26	6.71	2.09	1.4	6.08	0.92
85012007B	56	675	20	116	94	20.8	42	129	345	3154	9049	15	7.6	16.7	10.8	1.1	83.5	178	92	18.1	5.31	2.3	3.22	0.42
85012601B	32	108	19	97	192	27.5	89	78	284	1277	6018	9	4.1	13.7	13.4	0.8	48.3	112	62	11.1	3.26	1.5	2.39	0.32
S870112-7	35	125	17	113	194	25.7	127	125	211	1926	7413	101	3.5	14.9	13.5	0.6	62.0	125	63	13.6	3.49	1.4	2.14	0.31
9091402	49	281	22	89	675	19.2	56	206	385	169	1755	11	4.9	4.5	4.3	2.4	37.6	82	43	9.51	1.84	1.5	5.3	0.79
9031505	21	724	21	68	343	16.6	118	128	415	1127	2888	19	7.4	19.2	13.9	0.8	37.7	78	43	7.59	2.01	0.7	1.32	0.22
Dolerite																								
S91020403A	34	273	30	125	220	35.1	221	127	43	1417	1867	9	0.7	5.7	2.3	1.5	57.1	136	76	13.7	4.13	1.4	2.22	0.31
85011307	34	275	26	125	263	37.7	348	137	44	1388	1857	7	0.7	5.8	2.3	1.5	56.3	131	72	13.5	4.04	1.4	2.21	0.31
8402184	32	260	27	131	206	37.1	181	127	41	1434	1837	8	0.4	5.9	2.1	1.5	54.8	131	73	13.4	4.02	1.5	2.21	0.29
9021701D	55	450	37	98	111	23.8	66	167	32	1140	2330	11	1	10.2	3.2	1.5	106	232	129	21.2	5.09	2.2	3.33	0.46
85012604B	34	246	25	131	327	31.7	123	114	41	1007	1206	6	0.8	5.2	3.5	<0.3	43.9	104	64	11.5	3.02	1.0	2.23	0.34
S91010204A	57	551	37	109	235	26.7	89	194	55	932	2177	15	1.0	12.5	4.0	1.3	107	231	134	22.0	5.12	2.0	3.40	0.49
85020955C	45	314	32	107	121	25.5	38	150	38	1196	2011	8	1.2	7.3	2.1	1.9	67.1	157	90	16.6	4.53	1.7	2.75	0.37
85021004A	44	298	25	113	110	25.3	57	142	117	1018	1606	13	11.8	6.3	3.1	1.4	60.9	139	83	14.8	4.14	1.6	2.87	0.42
9021704	39	340	27	105	99.7	24.3	38	149	45	1179	2291	12	1.6	7.0	26	1.4	60.7	139	78	14.8	4.07	1.5	2.39	0.32
85012006B	57	487	33	107	186	25.1	48	183	54	934	2237	18	1.1	12.6	4.0	1.5	109	233	125	21.4	5.29	2.4	3.33	0.45
85020959	47	284	30	98	70.8	21.8	33	143	112	995	1643	16	6.1	6.7	4.8	1.4	62.8	147	85	15.8	4.20	1.9	3.17	0.41
85020355	53	772	34	85	119	21.3	16	200	42	1156	2347	15	1.0	15.6	3.4	1.3	91.4	201	114	20.6	5.24	2.0	3.09	0.43
85012604C	36	276	24	113	269	27.9	147	125	72	883	1218	8	2.5	5.9	8.1	1.5	50.0	113	66	11.5	2.82	1.3	2.38	0.38
9021615	46	388	34	103	133	21.7	22	185	53	1025	2354	17	1.4	10.0	3.1	1.3	91.4	203	117	19.6	4.77	1.9	2.78	0.41

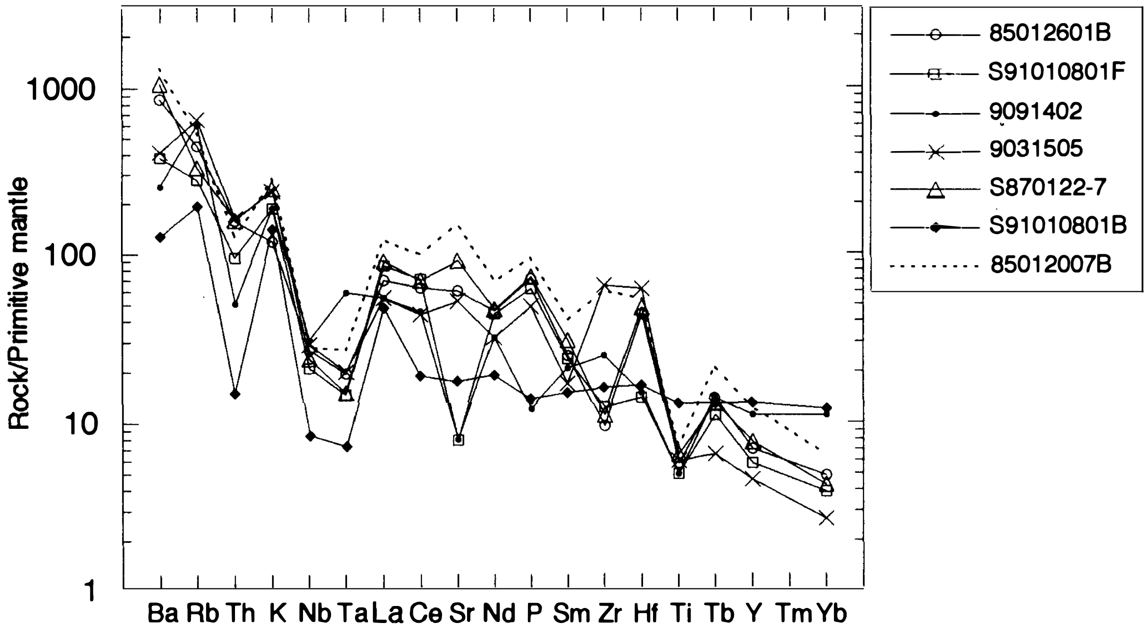

Fig. 2. Mantle-normalized trace element variation diagram (spiderdiagram) for the metamorphosed high potassium dike rocks ("lamprophyre") from the Sør Rondane Mountains. The data are normalized to estimated primitive mantle abundances by SUN *and* MCDONOUGH *(1989).*

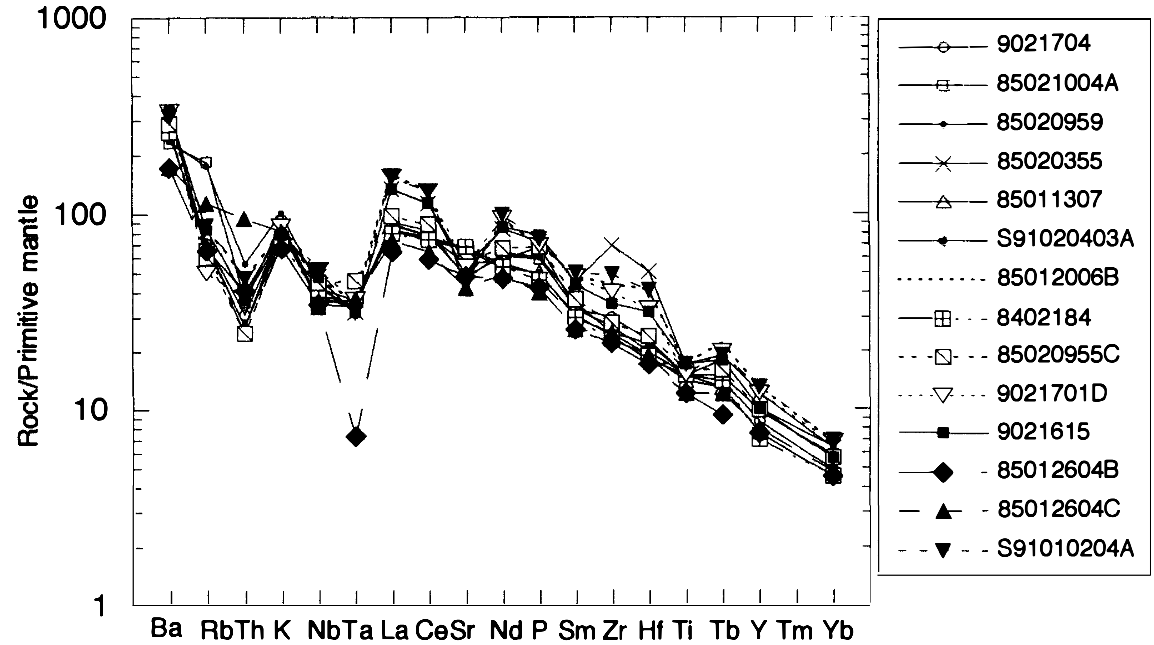

Fig. 3. Mantle-normalized trace element variation diagram (spiderdiagram) for the metamorphosed dolerites from the Sør Rondane Mountains. The data are normalized to estimated primitive mantle abundances by SUN *and* MCDONOUGH *(1989).*

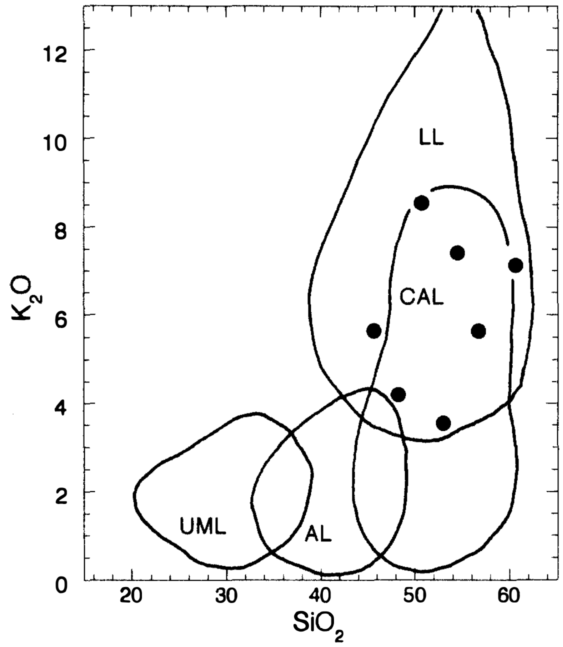

Fig. 4. Discrimination diagram of ultrapotassic mafic and ultramafic igneous rocks into LL (lamproite), CAL (calc-alkaline lamprophyre), AL (alkaline lamprophyre) and UML (ultramafic lamprophyre) on the basis of wt% K_2O versus SiO_2 (after ROCK*, 1987). Solid circles: metamorphosed high potassium dike rocks ("lamprophyre") from the Sør Rondane Mountains.*

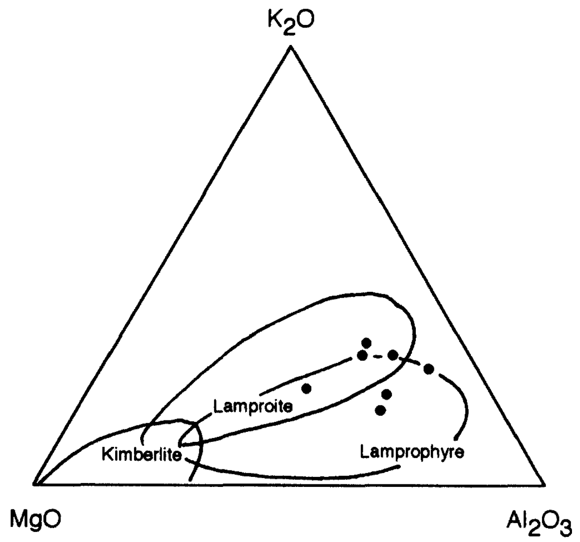

Fig. 5. Discrimination diagram of lamproite, lamprophyre and kimberlite on the basis of wt% K_2O, MgO and Al_2O_3 (after BERGMAN*, 1987). Solid circles: metamorphosed high potassium dike rocks ("lamprophyre") from the Sør Rondane Mountains.*

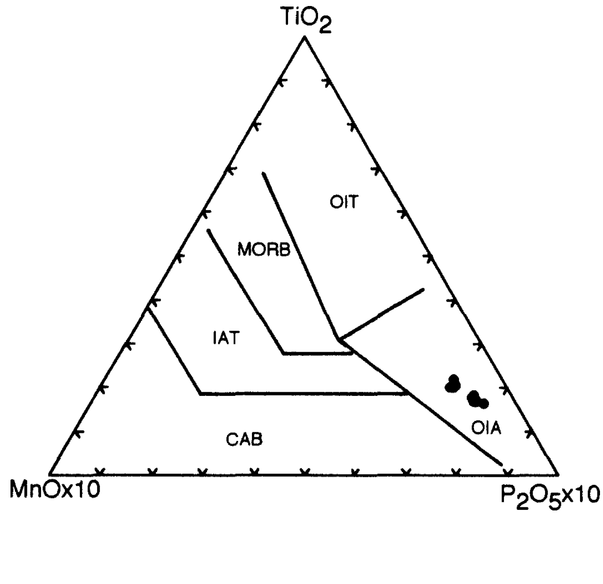

Fig. 6. The metamorphosed dolerites from the Sør Rondane Mountains in the TiO_2-MnO-P_2O_5 tectonomagmatic discrimination diagram for OIT (oceanic island tholeiite), OIA (oceanic island alkalic), MORB (mid-ocean ridge basalt), IAT (island arc tholeiite) and CAB (island arc calc-alkaline basalt) of MULLEN *(1983).*

ppm) and Zr (273–772 ppm). For characterization of the chemical composition, the dolerites are plotted on some standard discrimination diagrams of MULLEN (1983), MESCHEDE (1986) and IKEDA (1990) (Figs. 6–8). Most of the samples plot within the field

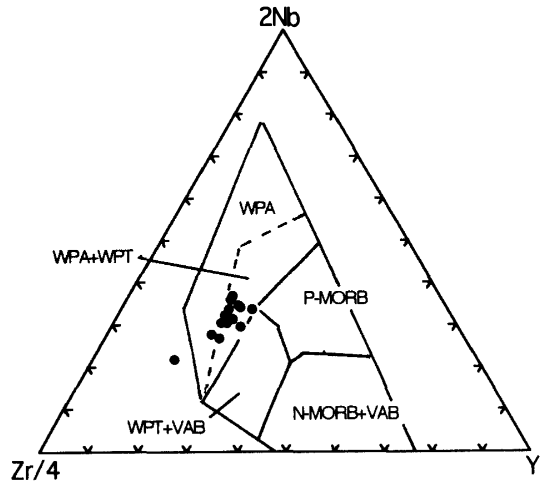

Fig. 7. The metamorphosed dolerites from the Sør Rondane Mountains in the 2Nb-Zr/4-Y tectonomagmatic discrimination diagram for WPA (within-plate alkalic), WPT (within-plate tholeiite), VAB (volcanic arc basalt), P-MORB (plume MORB) and N-MORB (normal MORB) of MESCHEDE *(1986).*

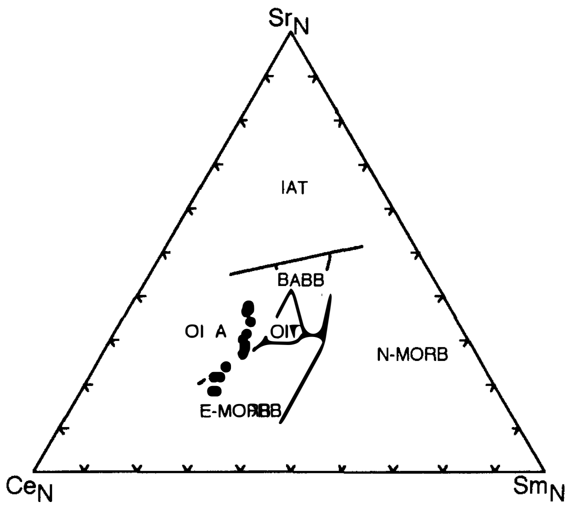

Fig. 8. The metamorphosed dolerites from the Sør Rondane Mountains in the Sr_N-Ce_N-Sm_N tectonomagmatic discrimination diagram for IAT (island arc tholeiite), BABB (back-arc basin basalt), N-MORB (normal MORB), E-MORB (enriched MORB), OIT (ocean island tholeiite) and OIA (ocean island alkalic) of IKEDA *(1990). The subscript N means concentrations are normalized to primordial mantle composition (Ce = 1.9 ppm, Sm = 0.385 ppm and Sr = 23 ppm).*

of within-plate type alkaline rocks. However, the mantle-normalized trace element patterns of the dolerites show Nb-Ta depression, which is common to the island-arc rocks (Fig. 3).

5. Isotope Geochemistry

The isotope data of the mafic dike rocks are listed in Tables 3 and 4 and compiled in $^{143}Nd/^{144}Nd$ *vs.* $^{87}Sr/^{86}Sr$ diagram of Fig. 9 with the data published for various lam proite suites and compositionally related rock groups after BERGMAN (1987) and HAWKESWORTH *et al.* (1990). The initial Sr and Nd isotopic compositions are calculated assuming 480 Ma (average K-Ar age) for the age of mafic dike rocks from the Sør Rondane Mountains (KOJIMA and SHIRAISHI, 1986; TAKIGAMI *et al.*, 1987; TAKIGAMI and FUNAKI, 1991) because Rb-Sr and Sm-Nd isotopic data are not available. The mafic dike rocks, lamprophyre and dolerite, have similar initial Nd and Sr isotopic compositions, and the enriched isotopic compositions compared to mid-oceanic ridge basalt (MORB) and ocean

Table 3. Rb-Sr isotope data of mafic dike rocks from Sør Rondane Mountains.

Sample No.	Sr (ppm)	Rb (ppm)	$^{87}Rb/^{86}Sr$	$(^{87}Sr/^{86}Sr \pm 2\sigma)_p$	$(^{87}Sr/^{86}Sr)_{480Ma}$
Lamprophyre					
S91010801B	372	123	0.9570	0.711791±9	0.705268
S870112-7	1926	211	0.3169	0.706932±13	0.704772
9091402	169	385	6.622	0.755763±12	0.710627
9031505	1127	415	1.066	0.711987±13	0.704721
Dolerite					
85012604B	1007	41	0.1178	0.705735±11	0.704932
S91010204A	932	55	0.1707	0.706367±11	0.705204
85012604C	883	72	0.2359	0.706466±13	0.704858
9021615	1025	53	0.1496	0.706399±11	0.705379

Table 4. Sm-Nd isotope data of mafic dike rocks from Sør Rondane Mountains.

Sample No.	Nd(ppm)	Sm(ppm)	$^{147}Sm/^{144}Nd$	$(^{143}Nd/^{144}Nd \pm 2\sigma)_p$	$(^{143}Nd/^{144}Nd)_{480Ma}$
Lamprophyre					
S91010801B	26	6.71	0.1560	0.512804±12	0.512314
S870122-7	63	13.6	0.1305	0.512341±10	0.511931
9091402	43	9.51	0.1337	0.512443±13	0.512023
9031505	43	7.59	0.1067	0.512348±9	0.512013
Dolerite					
85012604B	64	11.5	0.1086	0.512329±14	0.511988
S91010204A	134	22.0	0.0992	0.512259±11	0.511948
85012604C	66	11.5	0.1053	0.512319±13	0.511988
9021615	117	19.6	0.1013	0.512300±13	0.511982

island basalt (OIB) (Fig. 9). These isotopic features are generally interpreted to mean that their source regions have long histories with higher Rb/Sr and Nd/Sm ratios than those of bulk Earth, and are derived from metasomatized mantle sources (McCulloch *et al.*, 1983; Vollmer and Norry, 1983; Fraser *et al.*, 1985; Nelson *et al.*, 1986; Bergman, 1987; Wilson, 1989). Lamproite Nd-Sr isotopic data fall along two distinct trends: one is Smoky Butte (SB) and Leucite Hills (LH) suites and another is Gaussberg (GSB), Murcia and Almeria Province, Spain (MAP) and Fitzroy Basin, Western Australia (WKB) rock suites (Bergman, 1987) (Fig. 9). Most of the mafic dike rocks plot close to the SB-LH suites indicating slightly radiogenic $^{87}Sr/^{86}Sr$ ratios with extremely non-radiogenic $^{143}Nd/^{144}Nd$ ratios (Fig. 9).

6. Discussion and Conclusions

6.1. *Tectonic significances*

High potassium rocks such as lamproite suites occur in a wide variety of tectonic settings, including the continental rift zone, oceanic islands, island arcs, active continental margins and continental collision zones (Rock, 1987; Foley *et al.*, 1987). Foley *et al.* (1987) subdivided the lamproite suite rocks into four groups based on their major element chemistry. Each group tends to occur in a distinct tectonic setting: continental region

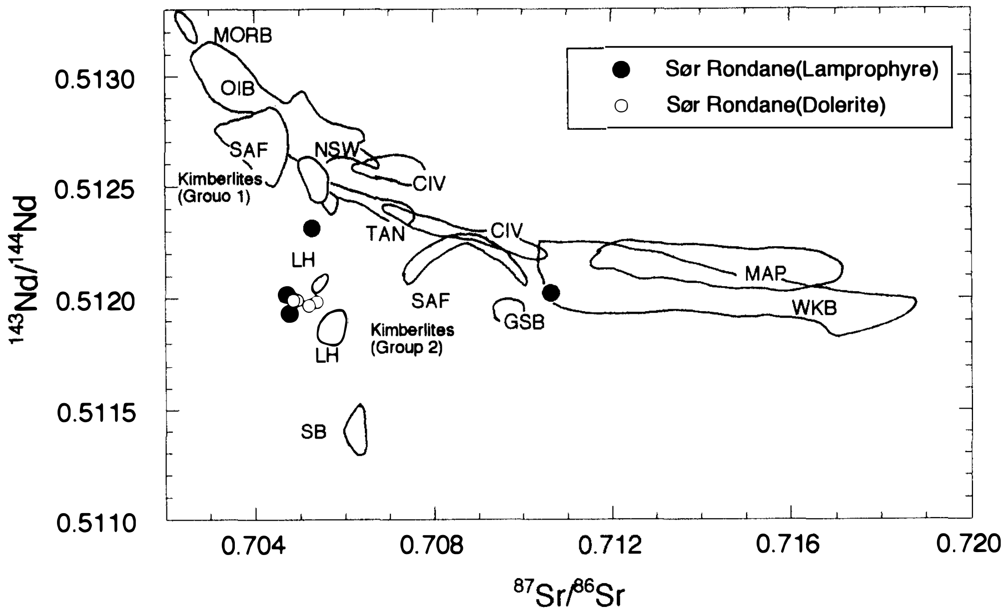

Fig. 9. $^{143}Nd/^{144}Nd$ *versus* $^{87}Sr/^{86}Sr$ *ratios for the metamorphosed high potassium rocks ("lamprophyre") and dolerites from the Sør Rondane Mountains which are normalized to 480 Ma and various lamproite suite and compositionally related rocks (compiled from* BERGMAN, *1987;* HAWKESWORTH *et al., 1990). MORB: mid-ocean ridge basalt, OIB: ocean island basalt, SAF: South African kimberlites (Group 1 and 2), CIV: continental interior volcanics , NSW: Lake Cargelligo area, New South Wales, TAN: Birunga & Toro-Ankole, Uganda, GSB: Gaussberg, Antarctica, MAP: Murcia & Almeria Province, Spain, WKB: Fitzroy Basin Western Australia, LH: Leucite Hills, Wyoming and SB: Smoky Butte, Montana.*

(Group I), continental rift system (Group II), island arc (Group III), and transitional zone between Groups I and III (Group IV). In his discrimination diagram, the data of the lamprophyre from the Sør Rondane Mountains and the Yamato Mountains are plotted in the Group IV (Fig. 10). Mantle-normalized trace element patterns for the lamprophyre from the Sør Rondane Mountains (Fig. 2) are similar to those of the Group III (FOLEY *et al.*, 1987). MÜLLER *et al.* (1992) proposed geochemical discrimination diagrams for potassic volcanic rocks (SiO_2=41.4–62.1 wt%, K_2O=0.4–8.4 wt%, $0.14<K_2O/Na_2O<8.9$) with five different tectonic settings: continental arc, postcollisional arc, initial oceanic arc, late oceanic arc, and within-plate. In order to determine the tectonic setting of the investigated mafic dike rocks, they were plotted on the discrimination diagrams following a flow-chart scheme for separating unknown samples of potassic volcanic rocks into the five tectonic settings of MÜLLER *et al.* (1992). The mafic dike rocks from the Sør Rondane and Yamato Mountains plot in the fields of within-plate and island arc close to the within-plate field (Figs. 11–13). The island arc environment for some mafic dike rocks from the Sør Rondane Mountains are consistent with the negative Nb, Ta and Ti spikes of the rocks (Figs. 2 and 3). Thus, the geological and geochemical data suggest that the mafic dike rock magmas formed in a continental within-plate tectonic setting by mixing of subduction-related materials and a metasomatically enriched mantle source. A similar model has also been applied to the origin of the ~500 Ma post-tectonic mela-syenite in

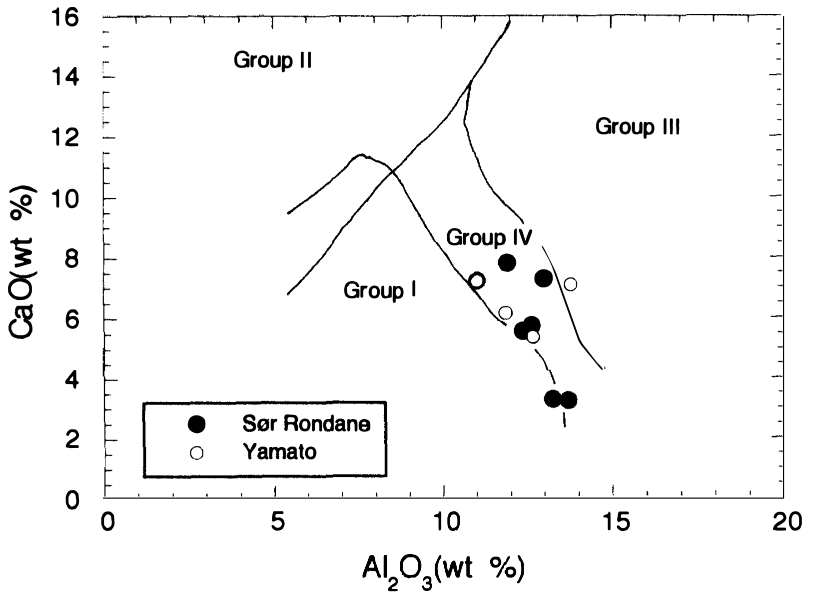

Fig. 10. Discrimination diagram for ultrapotassic igneous rocks into Groups I, II, III and IV on the basis of wt% CaO versus Al_2O_3 (after FOLEY *et al., 1987) and high potassium rocks ("lamprophyre") from the Sør Rondane (this report) and Yamato (*ARIMA *and* SHIRAISHI*, 1993).*

East Antarctica (ZHAO *et al.*, 1995).

The mafic dike rocks from eastern Queen Maud Land were emplaced about a few tens million years after the ~500 Ma Pan-African orogeny (SHIRAISHI *et al.*, 1992, 1994). As discussed in ARIMA and SHIRAISHI (1993), the mafic dike rocks in eastern Queen Maud Land

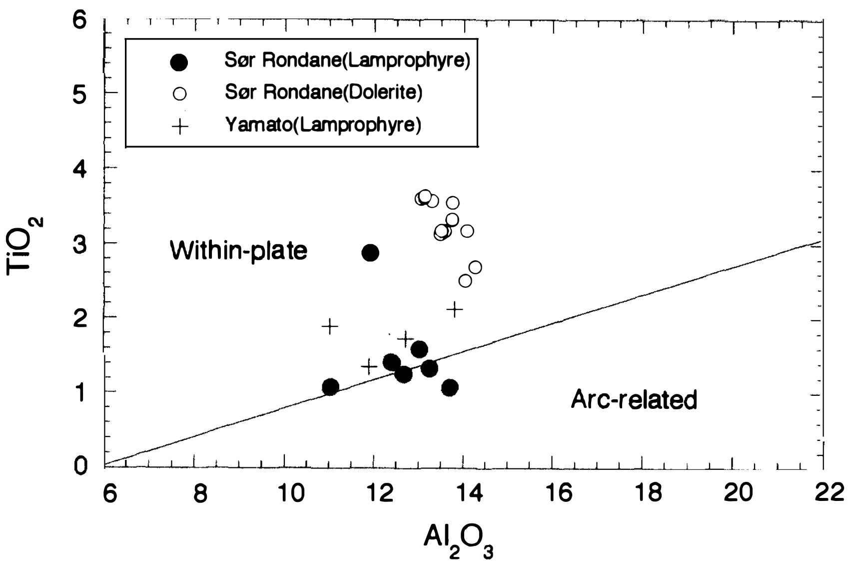

*Fig. 11. The metamorphosed high potassium rocks ("lamprophyre") and dolerites from the Sør Rondane (this report) and Yamato (*ARIMA *and* SHIRAISHI*, 1993) in the TiO_2 versus Al_2O_3 discrimination diagram for pottassic volcanic rocks (after* MÜLLER *et al., 1992).*

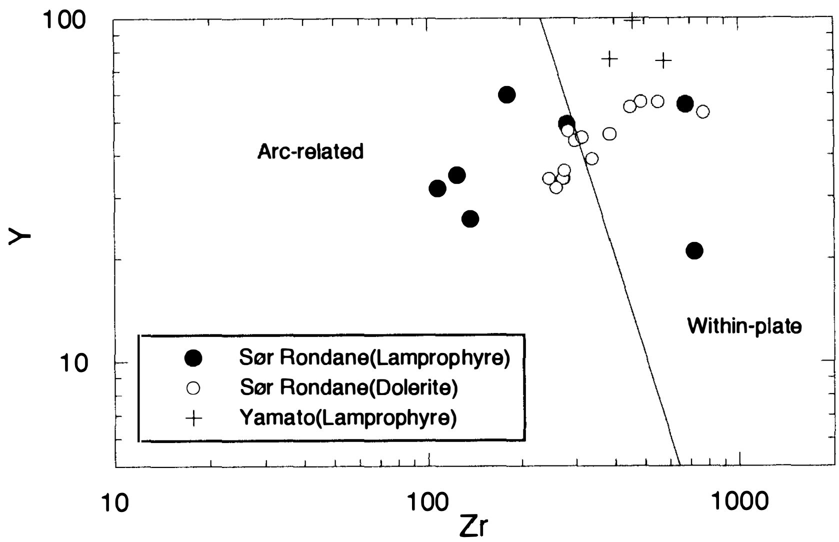

Fig. 12. The metamorphosed high potassium rocks ("lamprophyre") and dolerites from the Sør Rondane (this report) and Yamato (ARIMA and SHIRAISHI, 1993) in the Y versus Zr discrimination diagram for pottassic volcanic rocks (after MÜLLER et al., 1992).

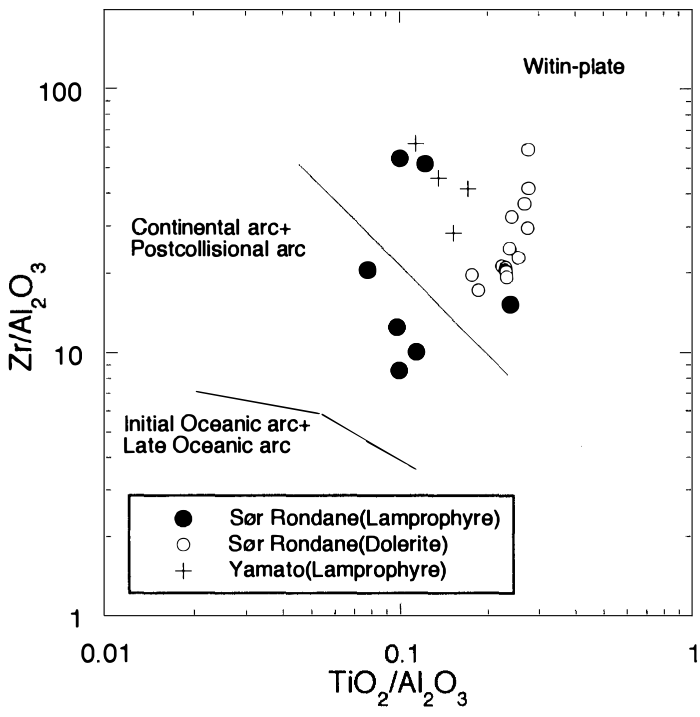

Fig. 13. The metamorphosed high potassium rocks ("lamprophyre") and dolerites from the Sør Rondane (this report) and Yamato (ARIMA and SHIRAISHI, 1993) in the Zr/Al_2O_3 versus TiO_2/Al_2O_3 discrimination diagram for pottassic volcanic rocks (after MÜLLER et al., 1992).

are best interpreted as a manifestation of post orogenic igneous activity linked to the Pan-African orogeny. SHIRAISHI *et al.* (1992, 1994) interpreted this to mean that the orogeny was associated with overthickening of the lithosphere by collision of east and west Gondwana. By analogy, the mafic dike rocks from the Sør Rondane Mountains were likely formed in the continental collision zone, and the subduction-related materials of magma sources may have come from the lithosphere at the orogenic time.

6.2. Petrogenetic relationship among the mafic dike rocks

The Nd-Sr isotopic data of Fig. 9 suggest that the mafic dike rocks, lamprophyre and dolerite, from the Sør Rondane Mountains were derived from similar metasomatically enriched mantle sources. In the magma process identification diagram (ALLEGRE and MINSTER, 1978) with reference to the mafic dike rocks from the Yamato Mountains of ARIMA and SHIRAISHI (1993), the lamprophyre and dolerite follow a partial melting trend with plotted rows of relatively steep slope. The geochemical features suggest that these rocks are derived from a common enriched mantle source with almost the same degree of partial melting (Fig. 14). Following the partial melting, a fractional crystallization with the position of the horizontal data points probably occurred (Fig. 14). The advanced fractional crystallization process may have concentrated incompatible elements such as P, Rb, Ba, Ce, La, Zr, Sr, and Zr. These geochemical characteristics suggest that both the lamprophyre and dolerite from the Sør Rondane Mountains originated from similar mantle segments.

Acknowledgments

We are grateful to Mr. S. OHNO for making thin sections for this study. Some samples

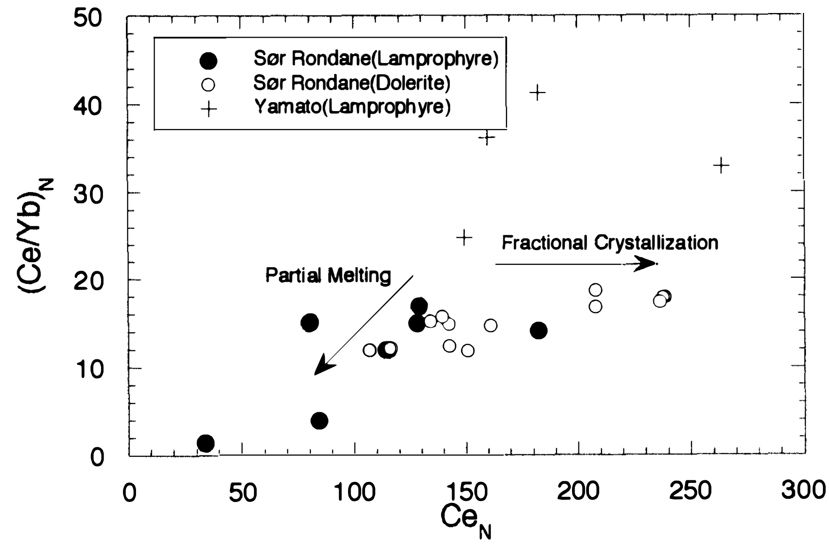

Fig. 14. The metamorphosed high potassium rocks ("lamprophyre") and dolerites from the Sør Rondane (this report) and Yamato (ARIMA and SHIRAISHI, 1993) in the $(Ce/Yb)_N$ versus Ce_N magma process identification diagram (after ALLEGRE and MINSTER, 1978). The subscript N means concentrations are normalized to Leedey chondrite values (Ce = 0.976 ppm, Yb = 0.249 ppm) of MASUDA et al. (1973).

were collected by S. KOJIMA of JARE-26. A part of this work was supported by a Grant in Aid for Scientific Research of the Ministry of Education, Japan to K.S. (No. 06640591).

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(Received February 24, 1995; Revised manuscript received May 12, 1995)