38. VOLCANIC ROCKS FROM DSDP LEG 29: PETROGRAPHY AND RARE-EARTH ABUNDANCES

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INTRODUCTION

In this contribution we present petrographic descriptions and rare-earth analyses of basaltic rocks obtained from four sites of DSDP Leg 29. These sites are: 278, 279 (Hole 279A), 280 (Hole 280A), and 282.

PETROGRAPHIC DESCRIPTIONS

Site 278

Three samples were examined from this site. Two samples—278-35-3, 25-35 KT and 278-35, CC(-) KT—have been analyzed for trace elements. No analysis is available for 278-35-1, 17-22 KT.

278-35-3, 25-35 KT

Feldspar-phyric basalt. 21% large phenocrysts of plagioclase zoned from mottled cores of An_{64} composition to An_{30} rims. Most phenocryst compositions are in range An_{50-55}. Phenocrysts up to 3 mm in long dimension, often occurring in glomerophyric patches up to 5 mm in size. Many phenocrysts contain irregular-shaped inclusions of devitrified dark brown glass. Vesicles are rare, usually rounded and rimmed by devitrified dark brown glass, fibrous antigorite, and filled with platy calcite. Irregular vesicles are partly to wholly filled with yellowish serpentine. Groundmass texture is intersertal with average grain size 75-100μ. Groundmass plagioclase (An_{45}) occurs as fresh laths, interstitial pyroxene occurs as fibrous to skeletal, altered grains.

278-35, CC(-) KT

Feldspar-phyric basalt. 16% large plagioclase phenocrysts. Largest phenocrysts are about 5 mm, the average about 2 mm. Phenocrysts frequently enclose irregular patches of dark brown glass. Maximum zoning in phenocrysts is An_{63} to thin rims of An_{41}. Plagioclase occurs in glomerophyric patches with phenocrysts of subhedral, colorless clinopyroxene. Also present are rare microphenocrysts of subhedral, reddish-brown spinel. Vesicles are rare, filled with brown, quenched mesostasis glass crystallized to subspherulitic intergrowths of pyroxene and titanomagnetite. Texture is intersertal, mesostasis glass is dark brown, partly recrystallized and altered. Groundmass plagioclase zoned from An_{50} to An_{44}.

278-35-1, 17-22 KT

Chilled pillow margin. Pale brown, homogeneous glass contains patchily zoned plagioclase phenocrysts up to 2 mm in size, plus small euhedra of olivine, reddish chrome-spinel, and plagioclase. A few, rounded vesicles are either empty or filled with platy calcite. Glassy zone grades into a dark brown, narrow zone of spherulitic development which in turn grades into dark brown microcrystalline basalt containing a combination of crystalline and spherulitic regions. All zones are cut by thick clacite veins rimmed by delicate quartz crystals. These are in turn cut by thin, irregular veins of pale yellow montmorillonite.

Summary

All samples are probably part of the same body. Variations are textural and reflect variable cooling rates. Chilled margin and occasional vesicles suggest that a lava flow erupted with about 20% suspended plagioclase phenocrysts. Abundant calcite veins and vesicle infillings indicate a later period of high CO_2 activity.

Site 279 (Hole 279A)

Three samples were examined. Trace element data are available for 279A-12-1, 40-46, 279A-13-2, 126-130 but no analytical data for 279A-13-1, 87-93.

279A-12-1, 40-46

Fine-grained vesicular basalt. Less than 2% plagioclase microphenocrysts (about 200 microns). 21% vesicles, average size about 1.5 mm, rounded, irregular and elliptical. Texture is intergranular, with pale brown clinopyroxene and subhedral olivine intergranular to plagioclase laths. Irregular patches of montmorillonite after mesostasis glass, which may also form a thin vesicle lining. Some vesicles partly filled with a very fine-grained intergrowth of pyroxene and elongate, skeletal ilmenite. Titanomagnetite grains form intergranular to plagioclase.

279A-13-1, 87-93

Fine grained basalt. Very rare plagioclase phenocrysts up to $500 \times 300\mu$. Less than 3% small vesicles, very rare larger, rounded vesicles. Intersertal texture. Lath-shaped plagioclase, intergranular fresh olivine, normally and sectionally zoned clinopyroxene, titanomagnetite. Mesostasis glass altered to fine-grained, montmorillonite. Average groundmass grain size, 100μ.

279A-13-2, 126-130

Coarse-grained basalt. 3% phenocrysts of tabular, zoned plagioclase, (less than 2 mm), associated with zoned, twinned clinopyroxene (less than 1 mm). Intersertal texture. Average groundmass grain size about 300μ. Groundmass composed of 52% plagioclase, 25% clinopyroxene, 2% titanomagnetite, and 20% mesostatic glass. Groundmass pyroxene normally zoned, and rarely sectorially zoned. Abundant mesostasis glass is often altered to chlorite, epidote, zeolite, with abundant brown, sheat-like patches of brown biotite.

Summary

Textural evidence equivocal as to relationship between individual samples. Decrease in vesicle concentration between 279A-12-1, 40-46 and 279A-13-1, 87-93 is striking, otherwise these samples are texturally similar and may be part of same body. Sample 279A-13-2, 126-130 is much coarser than the other samples and may either be unrelated to them, or possibly represent a more slowly cooled part of same body. Presence of abundant vesicle in 279A-12-1, 40-46 and less so in 279A-13-1, 87-93 suggests that these samples may represent flows.

Site 280 (Hole 280A)

Three samples have been examined. Trace element data are available for 280A-23-1, 88-96 KT but not for 280A-23-4, 37-41 KT or 280A-23-4, 110-118 KT.

280A-23-4, 37-41

Fine-grained basalt. Laths of zoned plagioclase form rare phenocrysts and show patchy replacement by sericite. Groundmass texture is radiate to spherulitic with large areas of epidote probably reflecting original glassy areas. Clinopyroxene, now altered, forms dendritic crystals with interstitial epidote. Occasional clots of small altered olivine grains. Rock cut by veins of platy calcite associated with fibrous antigorite and lenticular patches of serpentine.

280A-23-1, 88-96 KT

Fine-grained basalt. Partly altered, original intergranular to subophitic texture preserved in fresh patches of clinopyroxene plates enclosing small plagioclase laths. Chlorite replaces clinopyroxene, and partly replaces plagioclase. Rock cut by veins of platy calcite associated with epidote, and fibrous chlorite.

280A-23-4, 110-118 KT

Fine-grained basalt. Rare corroded fragments of plagioclase (xenocrysts) up to 1 mm long. Lath-like plagioclase phenocrysts up to 2 mm long. Phenocrystic olivine, less than 1 mm diameter, replaced by serpentine. Groundmass has intersertal texture with an average grain size of 50-100μ. Pale brown to colorless clinopyroxene intergranular to small plagioclase laths, small serpentinized olivine grains, and titanomagnetite. Scattered areas of alteration containing mainly chlorite.

Summary

Samples 280A-23-4, 37-41 and 280A-23-1, 88-96 KT are very similar. Both are essentially aphyric and are cut by calcite veins, therefore, probably part of same body. Sample 280A-23-4, 110-118 KT is different by containing more plagioclase and olivine phenocrysts and not having calcite veins. It may represent a separate body.

Site 282

Three samples were examined. Trace element data are available for 282-20-3, 45-53 KT but not for 282-18-3, 35-43 KT or 282-19-1, 126-134 KT.

282-18-3, 35-43 KT

Fine-grained basalt. 2% serpentine pseudomorphs after olivine, up to 1 mm in size (average, 300μ). Serpentine frequently contains reddish-brown grains of chrome spinel. 3-4% oxidized opaque? grains (100-500μ) with crenulate margins. Groundmass is highly altered, but original radiate-texture has been preserved. Small feldspar laths have greenish cores of sericite, and interstitial patches of epidote and chlorite.

282-20-3, 45-53 KT

Fine-grained basalt. About 5% microphenocrysts of plagioclase, average size 500μ but with rare grains up to 1.5 mm. Cores of plagioclase are replaced by chlorite and calcite. Phenocrysts associated with iddingsitized olivine pseudomorphs containing reddish-brown spinel. Groundmass texture is "sub-trachytic," with flowage alignment of small plagioclase laths. Interstitial areas to laths contain "herringbone" pyroxene nucleated on plagioclase, subsequently altered to a reddish-brown mineral. Secondary veins of platy calcite cut through the rock.

282-19-1, 126-134 KT

Fine-grained basalt. Rare pseudomorphs of antigorite-idding site intergrowths after microphenocrystal olivine. Groundmass texture is intersertal with plagioclase laths 200-300μ long associated with very fine-grained, subradiate pyroxene intergrown with titanomagnetite. Irregular areas, probably originally glass, are now altered to spherulite-like, layered intergrowths of iddingsite and serpentine?

Summary

All samples are fine grained, contain pseudomorphs after olivine, and are probably similar chemically. Texture of 282-20-3, 45-53 KT is distinctive. The large amount of oxidized opaque? grains in 282-18-3, 35-43 KT is also distinctive.

TECHNIQUE

Analyses for 10 rare-earth elements (REE) were performed by rapid nondestructive instrumental neutron activation analysis (INAA) using the 2-mw research reactor of the Rhode Island Nuclear Science Center. La, Sm, and Na were obtained by a 7-hr irradiation and 4000-sec counting on a 35.2 cc Ge(Li) detector after 5 days of cooling; and Ce, Nd, Eu (Gd), Tb, Tm, Yb, Lu by a 400-min counting with a low-energy photon spectrometer, after 25 days of cooling. Fe, Sc, Co, Cr, and Eu were obtained by a 8000-sec count after 35 days of cooling. The same samples were then re-irradiated for 5 min, 2 months after the first irradiation, and Dy determined by 800-sec counting on the same Ge(Li) detector, after 90 min of cooling. All REE concentrations were calculated against a synthetic REE standard irradiated at the same time. Other elements were calculated using the BCR-1 rock standard. Spatial neutron flux variation was monitored with $Co_{0.17}Al_{99.83}$ alloy and pure Fe wire, previously weighted and mounted on each sample and the standards. Accuracy of the REE technique of analysis can be estimated from BCR-1 rock standard, usually analyzed at the same time.

All the samples analyzed for REE were carefully broken down into small fragments in order to avoid veinlets of calcite or serpentine, as well as altered patches. The freshest fragments were selected and ground in an agate mortar.

RESULTS OF RARE-EARTH ELEMENT ABUNDANCES

The REE results are presented in Table 1 for six DSDP Leg 29 basement samples. The corresponding chondrite-normalized REE fractionation patterns are shown in Figure 1. Table 2 lists additional element concentrations easily obtained at the same time with the INAA for REE.

Site 278

Both tholeiitic basalt samples (278-35-3, 25-35 KT and 278-35, CC [-] KT) show very similar flat, unfractionated REE patterns, enriched approximately 10 times relative to chondrites, except for La in 278-35, CC(-)KT which is 25%-30% lower. Sample 278-35-3, 25-35 KT REE pattern is nearly identical to a Macquarie Island basalt reported by Jakes and Gill (1970, Table 3, analysis 26). Such REE patterns are quite common in rocks of island arc tholeiitic series (see Jakes and Gill, 1970, and references therein). Similar REE patterns are also found, but much less commonly, in submarine tholeiitic basalts erupting along mid-ocean ridges, and are usually restricted to transitional zones between "normal" mid-ocean ridge segments and plume regions (Schilling, 1973).

A frontal (trench side) island arc volcanic affinity is suggested for the Site 278 basalt.

Site 279

Both 279A-12-1, 40-46 and 279A-13-2, 126-130 (quartz-normative tholeiites) have identical REE patterns, within experimental errors, suggesting both are part of the same flow. The two REE patterns are slightly light-REE enriched. Relative to one another the two patterns compare well with another Macquarie Island basalt (Jakes and Gill, 1970, Table 3, analysis 48), but show a 1.5 factor overall total REE enrichment. Such patterns are common among island arc basalts occurring at intermediate positions across island arc lateral chemical zonation (Sugimura, 1968), apparently corresponding also to intermediate evolutionary stages of island arc development (Jakes and White, 1972). The closer proximity to the Macquarie Ridge and the estimated younger age of the basement at Site 279, relative to Site 278, appear to be in agreement with the evolutionary sequence suggested.

Both Site 278 and 279 basement basalt appears to be connected with the earlier development of the Macquarie Ridge as an arc and show little affinity with basalts derived from "normal" ridge spreading centers.

Site 280 (Hole 280A)

The REE pattern of basalt (280A-23-1, 88-96 KT) shows a pronounced light-REE depletion. This is characteristic of basalts erupting along "normal" mid-ocean ridge spreading centers (Schilling, 1971). The extent of light-REE depletion is comparable to basalts erupted along the Reykjanes Ridge south of 61°N, or along the northern part of the Red Sea Trough (Schilling, 1971). The results are apparently in general agreement with derivation of this basalt from a normal spreading ridge or trough, during the early stage of separation of Antarctica from Australia.

Site 282

The REE pattern of the 282-20-3, 45-53 KT basalt is light REE depleted. The extent of depletion and overall REE enrichment are within the range of basalts erupted along "normal" mid-ocean ridge segments of the Mid-Atlantic Ridge, or East Pacific Rise (Schilling, 1971).

TABLE 1
Rare-Earth Concentrations (in ppm)[a]

Sample	REE											
	La	Ce	Nd	Sm	Eu	Gd	Tb	Dy	Tm	Yb	Lu	$(La/Sm)_{EF}$
278-35, CC (-) KT	2.2	8.0	(6.2)	1.9	0.81	–	0.50	3.3	0.29	1.9	0.27	0.81
278-35-3, 25-35 KT	2.8	7.3	(7.0)	2.0	0.83	3.2	0.51	3.5	0.32	2.2	0.25	0.99
279A-12-1, 40-46	8.0	20.8	12.6	3.6	1.33	–	0.84	4.7	0.48	2.7	0.36	1.54
279A-13-2, 126-130	8.2	20.4	11.0	3.6	1.26	–	0.82	5.4	0.35	2.8	0.28	1.61
280A-23-1, 88-96 KT	1.3	4.8	(5.1)	1.8	0.76	3.2	0.56	3.8	0.32	2.4	0.32	0.50
282-20-3, 45-53 KT	3.5	10.6	–	3.5	1.32	–	0.79	4.7	0.43	3.0	0.40	0.69
BCR-1 (Avg. of 4)	28	62	33	7.8	2.25	–	1.56	6.3	0.68	3.8	0.49	2.51

[a]Estimated precision is ±5%, except for Tm, Yb, and Lu which varies between ±10% to 15%.

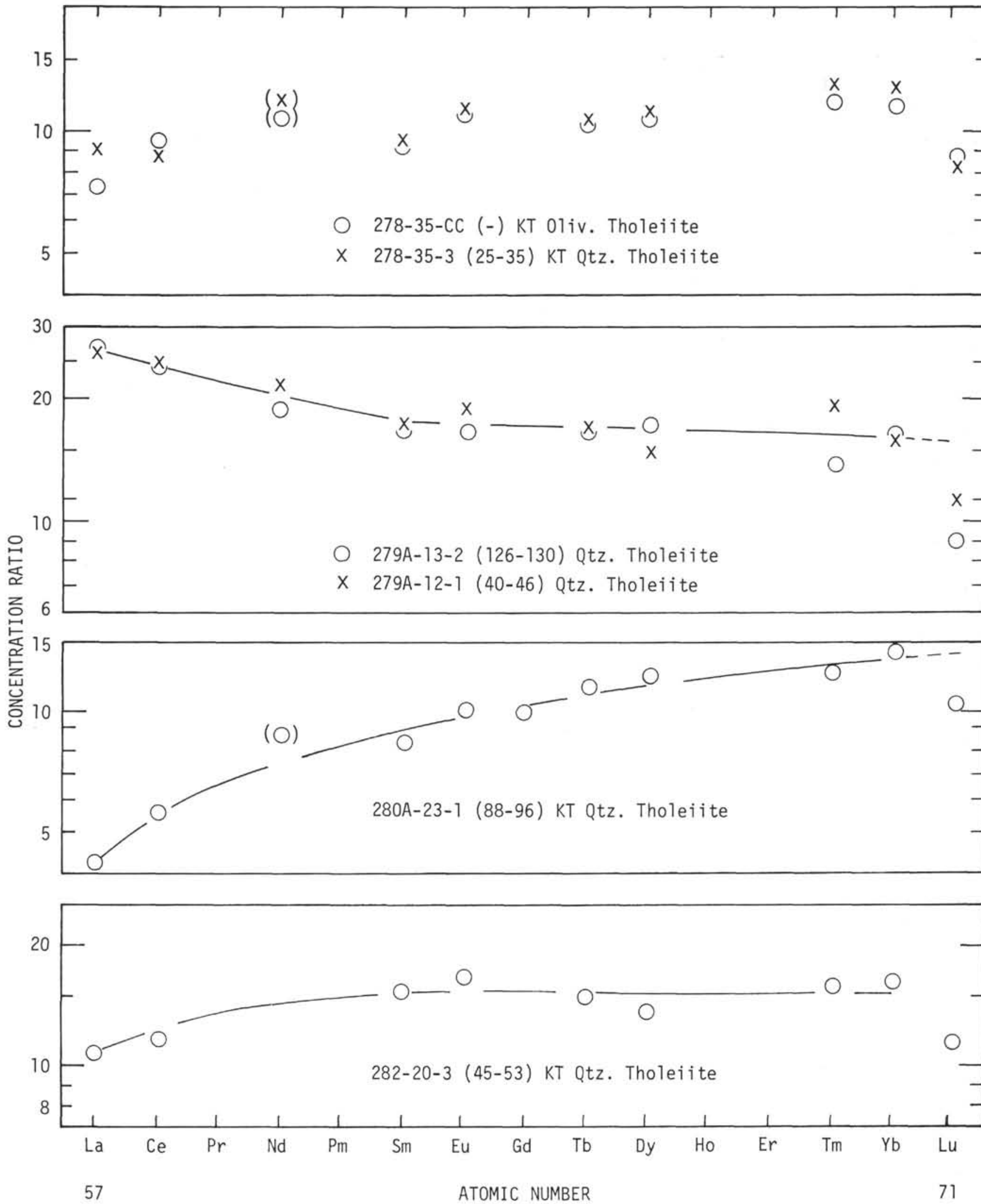

Figure 1. *Rare-earth abundances relative to averages of 20 chondritic meteorites as a function of their atomic number.*

TABLE 2
Concentration of Various Bonus Elements Easily Obtained During INAA for RE[a]

Sample	Element				
	Na_2O (%)	ΣFe_2O_3 (%)	Sc (ppm)	Co (ppm)	Cr (ppm)
278-35, CC (-) KT	2.3	7.9	33	37	293
278-35-3, 25-35 KT	2.4	7.9	35	46	310
279A-12-1, 40-46	2.8	9.1	44	70	105
279A-13-2, 126-130	3.0	10.5	42	46	100
280A-23-1, 88-96 KT	3.0	9.4	39	50	494
282-20-3, 45-53 KT	3.4	10.6	39	56	641

[a]Estimated precision is ±3%, except ±20% for Cr.

GENERAL COMMENTS RELATING PETROGRAPHY TO REE

Samples from Site 279 (Hole 279A) are slightly enriched in light REE. Both samples represent magma which erupted without a significant contribution of large phenocrysts. Sample 279A-13-2, 126-130 is notable for the high content of mesostasis glass. The occurrence of mesostasis biotite suggests the possible presence of a small amount of residual alkalic glass despite the low K_2O content for the whole rock. This should be investigated further. However, this would be compatible with fractionated REE pattern.

REE patterns are almost identical for samples 278-35-3, 25-35 KT and 278-35, CC(-) KT from Site 278, consistent with their similar mineralogy. Noteworthy is the lack of a [tve] europium anomaly even though both samples contain approximately 20% plagioclase phenocrysts. The samples may represent a high-alumina basalt that began to crystallize prior to eruption, and maintained its equilibrium phenocrysts. All samples from Site 282 are essentially aphyric, and therefore would represent liquid compositions. This also holds true for the analyzed sample from Site 280 (Hole 280A).

Nearly all samples show evidence for hydrothermal alteration and some degree of low-grade metamorphism as well as various degrees of weathering. The samples from Site 280 (Hole 280A) and Site 282 are most extensively altered and are cut by calcite veins. Sample 278-35, CC(-)KT is also cut by calcite veins. However, the degree of alteration in all cases is probably insufficient to affect REE patterns.

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