# 1. PETROLOGY, GEOCHEMISTRY, AND PETROGENESIS OF LEG 142 BASALTS-SYNTHESIS OF RESULTS<sup>1</sup>

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#### ABSTRACT

During ODP Leg 142, an engineering leg to test the diamond coring system, samples were recovered from two flow units at the axis of the East Pacific Rise, ~9°30'N. Unit 1 is the surface sheet flow mapped during pre-drilling surveys and is up to 12 m thick. Unit 2 is of unknown thickness. The units are very similar petrographically and most carry <1% phenocrysts of plagioclase (An<sub>69-85</sub>) with complex, irregular zonation. A single sample of Unit 1 has rare clinopyroxene phenocrysts whereas two samples of Unit 2 have small gabbroic xenoliths of plagioclase (An<sub>66-81</sub>) and clinopyroxene (En<sub>51-55</sub>). Groundmass olivine and clinopyroxene compositions are homogeneous in both units. Although very fresh, the samples show small amounts of incipient alteration and subtle associated chemical effects.

Each unit shows homogeneous trace element and isotopic abundances and even though the units are isotopically identical, their trace element abundances for some elements are significantly different. Apparently both units have the same mantle source but differ slightly in their melting history. Overall, the rocks of Units 1 and 2 are slightly fractionated normal mid-oceanridge basalt (N-MORB) with typical abundances of major elements, trace elements, and volatiles; their isotope ratios also typify N-MORB, as do their phase compositions and mantle-melting relations.

### INTRODUCTION

The purpose of this chapter is to provide a synthesis of the scientific results of Ocean Drilling Program (ODP) Leg 142. In addition, this chapter includes sections on silicate mineral chemistry not present elsewhere in the volume. Storms, Batiza, Allan et al. (1993) discussed in detail the drilling operations, background, and objectives of the leg and presented the results of shipboard petrographic and chemical studies of rocks from the two chemically distinct flow units sampled in Holes 864A (Units 1 and 2) and 864B (Unit 1). Although Leg 142 fell far short of its objectives to drill deeply into the

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volcanic and intrusive section at the axis of the East Pacific Rise (EPR) at ~9°30'N, the recovered samples provide an interesting opportunity to characterize diverse samples from a single flow. Accordingly, and as discussed in the foregoing chapters of this volume, basalt samples of Leg 142 have been thoroughly characterized. In this chapter, we summarize these new results of onshore laboratory studies.

### PETROGRAPHY

Detailed descriptions of 25 thin sections are given in the "Site 864" chapter, Initial Reports Volume 142 (Shipboard Scientific Party, 1993): 20 are representative of Unit 1 and five are from Unit 2. Additional petrographic descriptions are given by Artamonov et al. (this volume). Except for the coarse-grained plagioclase-clinopyroxene xenoliths found in some samples from Unit 2, the rocks are unremarkable. They are similar mineralogically and texturally to other sparsely phyric samples from nearby on the EPR (Batiza and Niu, 1992) and other normal mid-ocean-ridge basalt (N-MORB) samples from the northern EPR and near-EPR seamounts (e.g., Allan et al., 1989; Natland, 1980, 1991). All the samples examined have <2% total phenocrysts and all but one have  $\leq 1\%$  total phenocrysts, which are, with one exception, all plagioclase. In a single sample of Unit 1 there are trace amounts of clinopyroxene phenocrysts. Two samples of Unit 2 have coarse-grained xenoliths of intergrown poikilitic clinopyroxene and plagioclase. Texturally, the samples range from glassy to intergranular and exhibit a variety of textures commonly observed in samples of MORB sheet flows and lobate pillows.

### MINERAL CHEMISTRY

Fifteen representative shipboard thin sections (10 from Unit 1 and five from Unit 2) were analyzed by electron microprobe (Cameca Camebax) at the University of Hawaii (analyst - Y. Niu). Table 1

<sup>&</sup>lt;sup>1</sup>Batiza, R., Storms, M.A., and Allan, J.F. (Eds.), 1995. Proc. ODP, Sci. Results, 142: College Station, TX (Ocean Drilling Program).

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#### Table 1. Silicate mineral chemistry of lavas.

		Phen	ocrysts		Groundmass	
Thin section	Unit	Plagioclase (An)	Clinopyroxene (En, Fs)	Olivine (Fo)	Plagioclase (An)	Clinopyroxene (En, Fs)
142-864-						
1M-1, 0-10 cm	1	71-81 (5)		_	66-70(3)	
1M-3, 0-35 cm	1	73-82 (2)		-	_	
1M-3, 100-150 cm	1	70-77(1)		81.2 (1)	62-70 (5)	39-54, 23-10 (7)
1M-4, 0-9 cm	1	_		80.6-81.7 (5)	52-75(10)	43-48, 18-12 (7)
1M-4, 9-20 cm	1	69-83 (5)		-	65-73 (5)	_
1M-4, 20-30 cm	1	75-85 (4)			68-81 (5)	
1M-5, 100-118 cm	1			82.6-83.3 (3)	57-85 (10)	40-57, 24-10 (10)
1M-6, 75-140 cm (Piece 1)	1	75-81 (2)	49-52, 10-9		73-81 (3)	
1M-6, 75-140 cm (Piece 2)	1	70-81 (3)		80.2-82.9 (10)	66-71 (5)	48, 12 (2)
3Z-1, 0-6 cm <sup>a</sup>	2	69-76 (2)		_	_	47-53, 15-12 (6)
4Z-1, 9-15 cm (Piece 3)a,b	2	73-78 (3)		81.3-82.0 (3)	53-69 (4)	50-60, 15-12 (4)
	15	69 - 79(3)			55-69 (5)	46-60, 18-13 (5)
5Z-1, 0-5 cm (Piece 1)	2	75-81 (2)		80.6-81.6 (7)	_	45-55, 16-12 (3)
5Z-1, 15-19 cm (Piece 5)	2	70-85 (2)		80.1-83.2 (5)	58-72 (5)	42-48, 24-15 (5)
142-864B-						
2W-1 (Piece 3)	1	-		80.1-82.4 (4)	65-75 (10)	44-51, 20-13 (7)

Notes: (#) = no. of grains analyzed; 1-10 point analyses per grain (average 2-4). Blank space = not present; --- = not analyzed.

<sup>a</sup> = with coarse-grained inclusions.
<sup>b</sup> = two thin sections.

shows the range of analyzed phenocryst and groundmass phases in these 15 thin sections.

Olivine phenocrysts are absent from the Leg 142 samples that we examined and occur only very rarely in the vicinity of the drill site (Batiza and Niu, 1992). Olivine in the groundmass is common, however, with a very limited range of composition:  $Fo_{80-83}$  (Table 1). Table 2 gives representative olivine analyses, all of which appear to be equilibrium compositions on the basis of comparison with the data of Batiza and Niu (1992) for axial samples from near Site 864.

Plagioclase phenocrysts are common in the lavas but are not abundant. Their zoning patterns are extremely variable, as shown by Nomarski images and compositional profiles (J. Brophy and J. Allan, pers. comm., 1994). The phenocrysts are generally smaller than ~1 mm and appear (optically) to be mostly unzoned or only slightly zoned. Nomarski images and probe traverses reveal a much more complicated picture, however, with reverse, normal, and complex sinusoidal zoning patterns showing a total compositional range for a single crystal of 4–9 mol% An (J. Brophy and J. Allan, pers. comm., 1994). None of the phenocrysts examined by Brophy and Allan showed evidence of resorption; thus, even though their compositional zoning profiles are highly variable and in many cases complex, their growth appears to have been steady.

Additional microprobe analyses (~300 individual analyses) confirm the variable zoning patterns found by Brophy and Allan and extend somewhat the compositional range of plagioclase phenocrysts (Tables 1 and 3). Phenocryst populations within a given thin section show a range of 5–15 mol% An, with a mean of 9 mol% An. Individual crystals show a similar range of variation, though the range tends

Core, section: Interval (cm):	864A-1M-4 0-9	864A-1M-5 100-118	864A-1M-6 75-140	864A-1M-6 75-140	864A-1M-6 75-140	864A-4Z-1 0-5	864A- 5Z-1 0-5	864B-2W-1	864B-2W-1
Piece:			2	2	2	3	1	3	3
SiO <sub>2</sub>	38.61	38.39	39.58	39.16	39.17	39.03	38.94	38.78	39.60
FeO	17.67	15.36	15.71	16.37	16.98	16.72	17.25	17.69	15.61
MnO	0.29	0.28	0.28	0.35	0.30	0.21	0.37	0.28	0.35
MgO	43.41	45.46	43.79	43.00	43.39	42.83	42.70	42.31	43.94
CaO	0.38	0.37	0.49	0.52	0.38	0.44	0.45	0.58	0.53
NiO	0.14	0.09	0.17	0.15	0.20	0.06	0.11	0.04	0.13
Total	100.50	99.95	100.03	99.55	100.42	99.29	99.82	99.68	100.16
Fo	80.6	83.3	82.3	81.4	81.2	81.3	80.6	80.1	82.4

Table 2. Representative groundmass olivine analyses.

Table 3. Representative plag	ioclase analyses.
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Core, section: Interval (cm): Piece:	864A-M-1 0-50	864A-1M-1 0-50	864A-1M-1 0-50	864A-1M-3 0-35	864A-IM-4 0-9	864A-IM-4 0-9	864A-IM-4 9–20	864A-IM-4 9–20	864A-1M-4 9–20	864A-IM-4 20-30	864B-2W-1 16-19 3
SiOa	49.00	50.44	48.05	50.56	55 34	56.09	51.99	48.93	51.24	47.59	52.27
Al2Õ2	31.62	30.89	32.12	30.98	27.67	27.26	29.07	32.03	29.75	32.73	29.58
FeŐ	0.62	0.62	0.52	0.58	1.29	1.29	1.01	0.63	1.03	0.49	0.78
MgO	0.22	0.23	0.23	0.25	0.12	0.14	0.45	0.24	0.50	0.20	0.24
CaO	15.64	14.09	16.07	14.67	10.61	10.21	13.83	15.86	14.06	16.95	13.19
Na <sub>2</sub> O	2.39	3.08	2.34	2.76	5.03	5.24	3.69	2.52	3.36	2.04	3.40
K <sub>2</sub> Ô	0.02	0.00	0.00	0.02	0.12	0.07	0.09	0.02	0.02	0.09	0.02
Total	99.51	99.34	99.32	99.81	100.15	100.29	100.13	100.23	99.96	100.09	99.48
An	78.6	71.5	81.1	73.5	54.1	52.1	70.6	79.4	72.2	84.8	66.8
Туре	Р	р	р	р	g	g	р	р	g	р	g

Note: p = phenocryst, g = groundmass.

Table 4.	Representative	clinopyroxene	analyses.
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Core, section: nterval (cm):	864A-1M-3 100-150	864A-1M-3 100-150	864A-1M-3 100-150	864A-1M-5 100-118	864A-1M-5 100-118	864A-1M-5 100-118	864A-1M-6 75-140	864A-3Z-1	864A-4Z-1
Piece: Thin section:							4000 4000 0	1	3 #2
SiO <sub>2</sub>	50.69	50.05	52.62	49.04	53.27	50.42	52.79	50.61	53.42
TiO <sub>2</sub>	0.84	1.62	0.48	1.59	0.36	1.36	0.50	1.04	0.54
Al <sub>2</sub> O <sub>3</sub>	4.79	4.10	1.93	6.56	2.13	3.53	3.44	6.22	2.94
Cr <sub>2</sub> O <sub>3</sub>	0.58	0.04	0.05	0.32	0.31	0.05	0.69	0.13	0.17
FeO	6.40	13.80	10.84	6.84	7.08	14.04	5.46	6.92	8.33
MnO	0.29	0.31	0.30	0.22	0.28	0.31	0.12	0.22	0.24
MgO	17.20	13.07	19.61	15.76	20.71	13.40	17.66	17.11	21.33
CaO	18.95	17.42	14.33	19.50	15.72	17.07	19.43	16.93	12.78
Na <sub>2</sub> O	0.30	0.47	0.13	0.32	0.19	0.42	0.33	0.28	0.19
Total	100.05	100.89	100.29	100.14	100.06	100.63	100.42	99.46	99.93
En	49.7	39.0	54.2	46.7	57.3	39.7	50.8	51.4	60.4
Fs	10.9	23.6	17.3	11.7	11.4	23.9	9.0	12.0	13.6
Type	g	g	g	g	g	g	р	g	g

Note: p = phenocryst, g = groundmass.

Table 5. Silicate mineral chemistry of coarse-grained inclusions.

Thin section sample	Olivine (Fo)	Plagioclase (An)	Clinopyroxene (En, Fs)	Orthopyroxene (En,Fs)
142-864A-			50 55 10 0 (00)	
3Z-1, 0-6 cm 4Z-1, 9-15 cm no. 11		66-81 [4]	52-55, 10-9(23) 51-55, 10-9(17)	
4Z-1, 9–15 cm, no. 2		68-80 [2]	51-54, 10-9 (11)	
RHYN (13°N EPR)	69, 86 [4]	57-84 [15]	44-47, 17-15 [3]	69-70, 27-26 [7]

Note: (#) = number of spot analyses; [#] = number of grain analyses; 3-8 analyses per grain. Blank space = not present.

to be more variable. The total range of composition of plagioclase phenocrysts is  $An_{69}$  to  $An_{85}$  with a mean of  $An_{75}$ . The distribution of mol% An values for all the phenocryst analyses is skewed, with a tail extending to lower values; the median value of the population is  $An_{76}$ .

Texturally, the plagioclase phenocrysts appear to be in equilibrium with their host liquids. Furthermore, there is no textural evidence that the crystals were ever, during growth, grossly out of equilibrium with their host liquids. These observations and the fact that the chemical ranges of variation are virtually identical for (1) individual zoned crystals, (2) populations of crystals within a thin section, and (3) the 12 thin sections we examined suggest that the plagioclase phenocrysts comprise a uniform population with similar histories. However, this conclusion is contradicted by the complex and highly variable zoning patterns of individual phenocrysts. One possible explanation is that the complex zoning patterns reflect the interplay between diffusion-limited (oscillatory) growth and complications to such growth by the physical conditions experienced by individual crystals during growth (i.e., relative motion between the crystal and the surrounding melt). Such motion might effectively remove growth-induced compositional gradients in the melt and consequently could interrupt or modulate oscillatory growth occurring under static conditions. This is highly speculative, as the origin of oscillatory zoning in plagioclase is still not completely understood (Brophy and Allan, 1994; Dowty, 1980). Reconciling the evidence of complex and variable zonation of individual crystals with the absence of resorption, and the textural/compositional evidence for a homogeneous phenocryst population with a relatively simple petrogenetic history is problematic and presently unresolved.

The groundmass plagioclase compositions are similar to those of phenocrysts but extend to more sodic compositions (down to  $An_{52}$ ), as is commonly the case in mid-oceanic-ridge balsat (MORB) samples.

Clinopyroxene is found as phenocrysts in only one sample (Table 1), where it is very rare. Except for  $TiO_2$ , its composition (Table 4) is

indistinguishable from the groundmass clinopyroxene present in all the samples with some crystalline groundmass. Unlike the phenocryst, the TiO<sub>2</sub> contents of the groundmass crystals reflect the effects of quench growth (J. Casey, pers. comm., 1994). The mean groundmass clinopyroxene composition based on about 120 analyses is  $En_{50}Fs_{13}Wo_{37}$  with a typically wide range ( $En_{39-60}Fs_{10-24}$ ) presumably due to rapid crystal growth in greatly undercooled MORB (e.g., Lofgren, 1980).

#### **Coarse-grained Xenoliths**

Some thin sections of Unit 2 contain small (up to 7-8 mm) xenoliths of intergrown poikilitic clinopyroxene and plagioclase. Photomicrographs and descriptions are given in Storms, Batiza, Allan et al. (1993). These gabbroic xenoliths are similar texturally to those described from elsewhere along the EPR (Hekinian et al., 1985) and the Juan de Fuca Ridge (Dixon et al., 1986). They contain complexly zoned plagioclase (An66-81) and clinopyroxene that is essentially homogeneous (En<sub>51-55</sub>) despite a sectored appearance under crossed nicols that resembles strain banding in olivine but is much less regular. Tables 5 and 6 give the mineral chemistry and representative analyses of the gabbroic xenoliths of Leg 142. In addition, we give new analyses of a xenolith from the EPR at ~13°N (RHYN, Tables 5 and 6), which has a bimodal mineralogy and relatively fractionated chemistry identical to those analyzed previously by Hekinian et al. (1985) from the same locality. The 13°N xenoliths are interesting because they contain olivine (Fo69), relatively homogeneous plagioclase (An<sub>58</sub>), clinopyroxene (En<sub>45</sub>Fs<sub>15</sub>), and orthopyroxene (En<sub>70</sub>Fs<sub>26</sub>) and have interacted with the hot liquid that itself contains higher temperature minerals than those comprising the inclusions. Although the 13°N inclusions are clearly xenoliths, the Leg 142 ones may be cognate, at least on the basis of the similarity of mineral chemistry between inclusions and their Unit 2 host.

Table 6. Representative mineral analyses of coarse-grained inclusions.

	Oli	vine			1	Plagioclase	5					Pyroxene		
	1	2		3	4	5	6	7		8	9	10	11	12
SiO <sub>2</sub> FeO MnO MgO CaO NiO Total Fo	36.87 26.84 0.59 35.36 0.44 0.09 100.01 69.2	40.29 12.52 0.28 46.38 0.58 0.02 99.96 85.9	SiO <sub>2</sub> Al <sub>2</sub> O <sub>3</sub> FeO MgO CaO Na <sub>2</sub> O K <sub>2</sub> O Total	52.35 29.61 0.50 0.27 13.28 3.68 0.04 99.74	47.80 32.61 0.39 0.23 16.19 2.04 0.00 99.26	50.10 31.32 0.53 0.25 14.47 2.84 0.00 99.52	48.42 32.47 0.57 0.18 16.20 2.39 0.00 100.23	54.32 28.98 0.62 0.16 11.40 4.50 0.02 100.00	SiO <sub>2</sub> TiO <sub>2</sub> Al <sub>2</sub> O <sub>3</sub> Cr <sub>2</sub> O <sub>3</sub> FeO MnO MgO CaO Total En	51.42 0.49 3.86 0.47 5.95 0.12 18.48 18.56 99.68 52.5	52.48 0.46 3.56 0.52 6.19 0.10 19.12 16.85 99.56 55.0	53.30 0.32 2.85 0.32 5.82 0.21 18.20 18.67 99.95 52.0	51.09 0.86 2.99 0.31 9.08 0.17 15.35 19.14 99.34 44.8	53.99 0.36 0.96 0.06 16.86 0.36 25.78 1.95 100.33 70.0

Note: 1 = RHYN (13°); 2 = RHYN (13°); 3 = 864A-3Z-1, 0-6 cm; 4 = 864A-3Z-1, 0-6 cm; 5 = 864A-4Z-1, 9-15 cm, no. 1; 6 = 864A-4Z-1, 9-15 cm, no. 1; 7 = RHYN (13°N); 8 = clinopyroxene-864A-3Z-1, 0-6 cm; 9 = clinopyroxene-864A-3Z-1, 0-6 cm; 10 = clinopyroxene-864A-4Z-1, 9-15 cm, no. 1; 11 = clinopyroxene-RHYN (13°N); 12 = orthopyroxene-RHYN (13°N).

Table 7. Electron n	nicroprobe	glass	anal	vses.
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		Average of 10				
	864A-IM-6, 0–75 cm	864A-IM-2, 0-35 cm	864A-IM-5, 0–100 cm	864A-1M-3, 0–35 cm	Average, standard deviation	Unit 1 average (shipboard XRF)
SiO <sub>2</sub>	50.66	50.45	50.09	50.60	50.24, 0.82	49.91
TiO <sub>2</sub>	1.68	1.70	1.68	1.66	1.69, 0.07	1.64
Al2O3	14.54	14.49	14.38	14.47	14.43, 0.17	14.30
FeO	10.64	10.71	10.51	10.45	10.61, 0.30	10.45
MnO	0.24	0.20	0.19	0.23	0.22, 0.05	0.20
MgO	7.20	7.13	7.03	6.97	7.01, 0.25	7.30
CaO	11.88	11.93	11.91	11.87	11.85, 0.22	11.72
Na <sub>2</sub> O	2.62	2.61	2.57	2.60	2.58, 0.08	2.55
K <sub>2</sub> Õ	0.14	0.15	0.14	0.14	0.14, 0.02	0.14
PoOs	0.13	0.12	0.12	0.13	0.13, 0.02	0.11
Total	99.74	99.49	98.61	99.11	99.32	(99.49)*

Note: \* = original total with iron reported as Fe<sub>2</sub>O<sub>3</sub>.

## LAVA CHEMISTRY

Table 7 contains four new microprobe glass analyses (made at the University of Hawaii) of Unit 1. Except for lower MgO values, they are analytically indistinguishable from the shipboard X-ray fluorescence (XRF) analyses. The problem of slightly lower MgO values for glass analyses made with the Hawaii probe was recognized previously (Batiza and Niu, 1992) and has been remedied. Four additional probe analyses of glass are provided by Artamonov et al. (this volume). These differ slightly from the University of Hawaii analyses in Na<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, and possibly CaO, but are otherwise indistinguishable. Boström and Bach's (this volume) careful major element data comparisons of shipboard XRF analyses with analyses are of high quality based on agreement with calibration runs made during Leg 142 (Storms, Batiza, Allan et al., 1993).

Trace element determinations of V, Cr, Ni, Cu, Zn, Sr, Y, Zr, and Nb were carried out on the ship using XRF (Storms, Batiza, Allan et al., 1993). The values are in general agreement with values obtained for these elements by onshore XRF and inductively coupled plasmaatomic emission spectroscopy (ICP-AES) reported by Boström and Bach (this volume). These authors also reported values for S, Ba, Cd, Co, Sc, La, and Yb. Harpp (this volume) determined Y, Zr, Nb, Hf, Ta, Ba, and rare earth elements (REE) by inductively coupled plasma-mass spectrometry (ICP-MS) and Allan (this volume) determined Sc, Cr, Co, Ni, Zn, Hf, Ta, and REE by instrumental neutron activation analysis (INAA). Their data are in good agreement and in general agreement (mostly within analytical error) with shipboard traceelement data and the data of Boström and Bach.

These data show values typical of somewhat fractionated normal MORB. Both the major elements and trace elements indicate small but significant differences between Unit 1 and Unit 2. These differences suggest but do not prove that these units are distinct flow units, consistent with the observation that Unit 2 carries gabbroic xenoliths whereas none was found in Unit 1.

Abundances of the volatiles  $CO_2$ ,  $H_2O$ , S,  $H_2$ ,  $N_2$ , He,  $CH_4$ , CO, and  $Fe^{3+}/Fe^{2+}$  for 11 samples are reported by Bach and Erzinger (this volume). Polyak et al. (this volume) gave additional determinations of  $H_2O$ ,  $CO_2$ ,  $N_2$ ,  $O_2$ ,  $H_2$ , CO,  $CH_4$ , He, and  ${}^{3}He/{}^{4}He$  for three samples. Abundances of  $H_2O$  and  $CO_2$  in these two studies are in good agreement and comparable to the abundances determined on the ship by a much less precise technique (Storms, Batiza, Allan et al., 1993). The abundances of CO,  $CH_4$ ,  $H_2$ ,  $N_2$ , and He of Polyak et al. are systematically higher than those of Bach and Erzinger. At present, these differences are unexplained. Overall, the volatile abundances are in the range of N-MORB, as are the  ${}^{3}He/{}^{4}He$  values of Polyak et al.

Isotopic data for Sr, Nd, and Pb reported by Harpp (this volume) show remarkable homogeneity. Isotopically, Units 1 and 2 are indistinguishable, despite significant differences in the abundances of some trace elements.

### ALTERATION HISTORY

Haymon (this volume) showed that the rare secondary mineral coatings found on some of the Leg 142 rock fragments result from incipient alteration of the rocks. The coatings are white, greenish, and orange and probably correspond to Fe-Mg phyllosilicates, Al-oxyhydroxides, and Fe-oxyhydroxides precipated directly from hydrothermal fluids or by reaction of fluids with basalt glass. Alteration products are very rare, comprising <1% of the rock. No chemical evidence of alteration was found by Boström and Bach (this volume),

Artamonov et al. (this volume), or any other studies. Harpp (this volume) conducted acid-leaching experiments on both glasses and crystalline rock. The slightly lower <sup>87</sup>Sr/<sup>86</sup>Sr values shown by some samples of crystalline rock after strong acid leaching are perhaps indicative of seawater alteration. However, one sample of crystalline material showed a higher value of <sup>87</sup>Sr/<sup>86</sup>Sr after repeated leaching, as did another sample of rock powder prepared on the ship. The results of leaching experiments are thus somewhat inconclusive, but may indicate very minor and heterogeneously distributed alteration. This is consistent with the very low overall Fe<sup>3+</sup>/Fe<sup>2+</sup> measured by Bach and Erzinger (this volume) and the fact that crystalline basalts have slightly more oxidized iron than the glasses.

## **RADIOMETRIC DATING STUDIES**

Goldstein (this volume) reported  $(^{231}Pa)/(^{235}U)$  for Leg 142 samples and used those activity ratios to calculate eruption ages on the assumption of constant initial  $(^{231}Pa)/(^{235}U)$ . Those data complement the data set of Goldstein et al. (1994) for samples in the vicinity of the drill site. The Leg 142 samples give very young ages (~5-6 ka), as expected from their location within the axial summit caldera. Interestingly, Goldstein et al. (1994) found very young samples off-axis as well, and concluded that the active zone of accretion at ~9°30'N is about 8 km in width.

### **GEOPHYSICAL STUDIES**

Storms, Batiza, Allan, et al. (1993) reported standard shipboard measurements of seismic and magnetic properties of the Leg 142 samples. Additional measurements of seismic velocities up to confining pressures of 6 kb were made by Johnston et al. (this volume) for Leg 142 samples as well as for dredged samples. By comparing these measurements with in-situ velocities from near-bottom refraction studies (Christeson et al., 1992), Johnston et al. concluded that seafloor basalts may commonly suffer damage (microfracture) in decompression associated with being brought to the surface. Furthermore, they show scanning electron microscope (SEM) photographs and other evidence indicating that microfracturing occurs preferentially in coarser grained basalts.

## PETROGENESIS

The basalts of Unit 1 and Unit 2 are both moderately fractionated N-MORB for which the fractionation-corrected Na<sub>8</sub> and Fe<sub>8</sub> values (e.g., Klein and Langmuir, 1987) are not significantly different. If they were produced by column melting (e.g., Niu and Batiza, 1991), the inferred initial depth of melting and the total extent of melting are essentially identical, as is true for other dredged basalts from nearby (Batiza and Niu, 1992). Harpp (this volume) presented convincing evidence that the parental liquids for Units 1 and 2 differ in the abundances of some, but not all, incompatible trace elements. In spite of these differences, Units 1 and 2 are indistinguishable isotopically, so Harpp argued that the parental liquids of Units 1 and 2 represent distinct products of melting of a common mantle source. Harpp concluded that the parental melt of Unit 1 was produced by a slightly smaller extent of melting than the parental melt of Unit 2. Harpp also found small but significant differences in trace element abundances and ratios among different samples of the same unit and interpreted these intraunit differences as the result of small amounts (6%-10%) of fractional crystallization. Such fractionating could presumably occur either within a magma chamber prior to eruption or by solid-liquid fractionation accompanying solidification.

Brophy (this volume) argued that magma fractionating in the ~9°30'N segment of the EPR occurs in small melt bodies within the mush zone of the magma chamber (Sinton and Detrick, 1991). Batiza et al. (unpubl. data) made a similar argument based on off-axis sampling out to ~40 km on both sides of the EPR at 9°30'N, 10°30'N, and 11°20'N. In a model proposed by J. Brophy and J. Allan (pers. comm., 1994), the small melt pockets of the mush zone migrate eventually to the melt lens where they erupt, whereas in the model of Batiza et al. (unpubl. data) the melt pockets feed eruptions directly to the surface. Evidence for the latter comes partly from the data of Goldstein et al. (1994), who showed that the zone of active eruptions at ~9°30'N is about 8 km wide (the width of the low-velocity mush zone) and much wider than the width of the melt lens at 9°30'N (1.0 to 1.2 km wide, Kent et al., 1993).

On the basis of one-atmosphere melting experiments on a Leg 142 basalt, Brophy (this volume) argued that melts in the  $\sim 9^{\circ}30'$ N area underwent fractionation at pressures ranging from  $\sim 2$  to 1.5 kb, in rough agreement with Grove et al. (1992), who favored fractionation at pressures of 2.0 to 0.001 kb for the  $10^{\circ}-12^{\circ}$ N region of the EPR. The pressure estimates of Brophy are based on the slope of trends on diagrams of MgO vs. CaO. Because the data from the  $9^{\circ}30'$ N area (Batiza and Niu, 1992) exhibit a fair amount of scatter, pressure estimates from their CaO-MgO trends are not tightly constrained. Nevertheless, these indicate fractionation in the crustal low-velocity zone (mush/transition zone of the magma chamber) at pressures of <2 kb.

### CONCLUSIONS

The shipboard and onshore laboratory analyses of Leg 142 basalts permit the following conclusions:

1. Two geochemically distinct units were sampled during Leg 142.

2. The two units are petrographically distinct. Unit 1 has rare phenocrysts of clinopyroxene and Unit 2 carries small gabbroic fragments.

3. The mineralogy of the basalts is unremarkable with phenocrysts of plagioclase (An<sub>69-85</sub>) and groundmass olivine (Fo<sub>80-83</sub>), plagioclase (An<sub>52-85</sub>), and clinopyroxene (~ $En_{50}Fs_{13}$ ).

 The mineralogy of gabbroic inclusions with plagioclase and clinopyroxene is similar to that of the lavas, indicating that the inclusions could be cognate.

5. The complex and irregular zoning of the plagioclase phenocrysts is an interesting feature of the lavas. Although there are no signs of resorption, the zonation patterns may have resulted from growth within multiple host liquids. Alternatively, the phenocrysts may have grown within a single liquid, in which case significant kinetic effects must be invoked to explain their heterogeneous compositions.

 The analyzed samples are all moderately fractionated N-MORB with typical abundances of major elements, trace elements, volatiles, isotopic compositions, and typical MORB mantle melting relations.

The presence of small amounts of secondary minerals and slight oxidation of the rocks indicates incipient alteration of some of the samples.

8. U-disequilibrium dating shows the samples to be young (~5–6 ka), as expected from their location at the axis of the East Pacific Rise.

 Seismic velocity studies of the samples indicate that seafloor basalts may develop decompression fractures during or after collection.

10. The two units have the same mantle source but their inferred parental liquids differ slightly in their melting paths. The slight dif-

ferences in their crystallization histories that are also preserved indicate that magma chambers at the EPR do not completely homogenize the diverse melts fed into them.

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<sup>\*</sup>Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).