32. PETROLOGY OF BASALT DREDGED FROM THE CENTRAL AXIS OF THE GALAPAGOS SPREADING CENTER

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ABSTRACT

A dredge haul from the axis of the Galapagos spreading center near 87°W yielded ferrobasalts (FeO*/MgO = 1.9) compositionally similar to others from the Galapagos region (e.g., Site 424; Fodor et al., this volume), but slightly higher in SiO_2 and lower in Na_2O contents. Textures vary from vitrophyric (at glassy margins) with phenocrysts of olivine, pyroxene, and plagioclase, to microcrystalline groundmasses (with or without phenocrysts) composed largely of plagioclase, pyroxene, and oxides. Phenocryst compositions are olivine, Fo_{79}; clinopyroxene, $Fs_{11}Wo_{40}En_{49}$; orthopyroxene, $Fs_{22}Wo_5En_{73}$; and plagioclase, An_{74}. Glassy margins are virtually the same in composition as the bulk rock. The bulk-rock FeO*/MgO ratio of 1.9 indicates that these ferrobasalts probably represent a sampling of a stage of differentiation from "normal" mid-ocean ridge parent basalt that is earlier (more primitive) than represented by most other Galapagos ferrobasalts, including those drilled at Site 424.

INTRODUCTION

Although the Leg 54 drilling in the Galapagos area achieved the goals set for that program, it provided a sampling of basement rocks at only two localities (Sites 424 and 425), both of which were situated away from the spreading axis. For this reason and because the petrology and chemistry of the two localities were somewhat different, a dredge haul was obtained from the Galapagos spreading axis (Figure 1) during the CENT Expedition of the R/V *Washington* (S.I.O., 1978). The petrology and chemistry of this dredge haul are discussed in this paper and compared with both other dredge hauls in the Galapagos region and the drilling results at Sites 424 and 425.

GENERAL DESCRIPTION

The dredged samples are boulders up to about 25 cm in size. Outside surfaces have virtually no development of manganese crust, although substantial areas are colored yellow-brown from Fe-oxide staining. Most samples are covered in part by black, glassy pillowy rinds that average 1 cm in thickness. Rock interiors are gray-black in color, and several specimens have sparse phenocrysts (≤4 mm) of olivine, pyroxene, and plagioclase; other samples are aphyric.

Thin section examination revealed a range in textures reflecting slightly different cooling histories among these samples. Glassy rinds are vitrophyric, containing mainly phenocrysts (2 to 4 mm) and microphenocrysts (~1mm) of plagioclase, pyroxene, and rare olivine in a matrix composed of clear yellow glass; the glass, however, is mottled with dark brown spherulitic patches that are weakly birefringent (Figure 2a). These dark-colored patches surround centers of plagioclase and pyroxene nucleation and probably represent incipient crystallization of the clear glass.

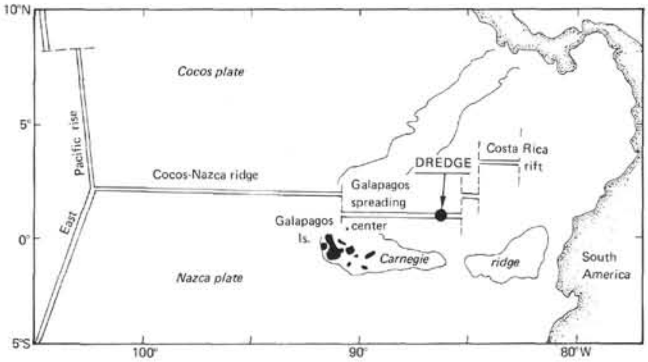

Figure 1. *Index map of the dredge location.*

Elsewhere, groundmass crystallization is more advanced, and abundant plagioclase and pyroxene crystals (0.01 to 0.05 mm) are associated with skeletal Fe-Ti oxide grains and small amounts of glass; these textures are intersertal. The most highly crystallized samples contain small percentages (<5 vol. %) of clinopyroxene, orthopyroxene, plagioclase, and olivine phenocrysts and microphenocrysts (commonly as glomerocrysts) set in a groundmass composed of a network of plagioclase and pyroxene grains (≤0.1 mm), Fe-Ti oxides, interstitial sheaf-like arrangements of weakly birefringent microlites (probably pyroxene and plagioclase), and rare intersertal glass (Figure 2b).

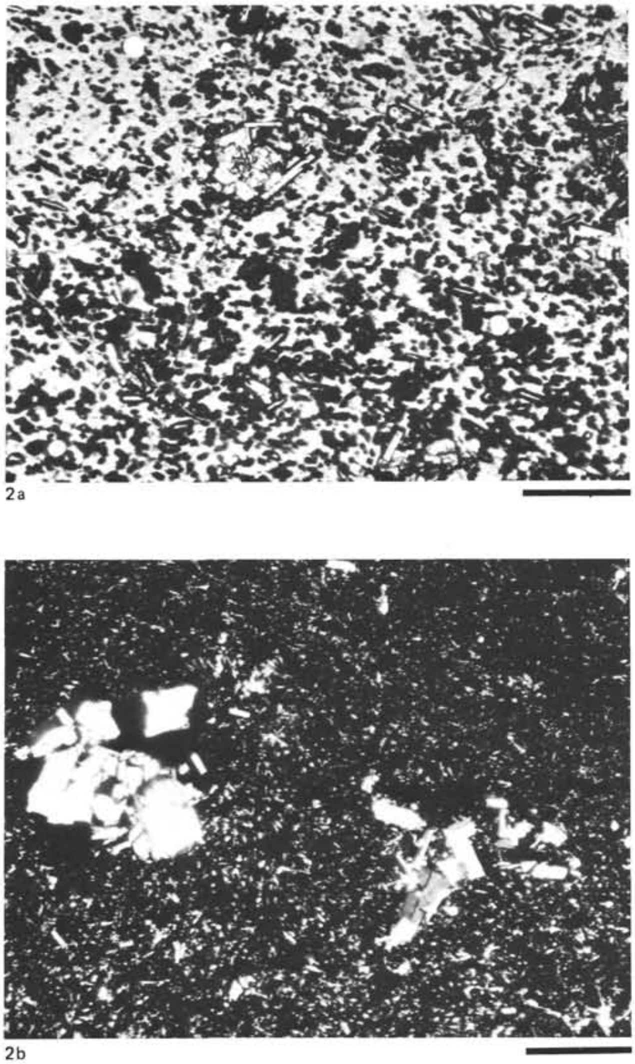

Figure 2. *(a) A plane-polarized transmitted-light photograph of a glassy rind (vitrophyric) on a dredged basalt sample. Crystals and crystallites of plagioclase and pyroxene are surrounded by dark, weakly birefringent areas. Scale bar = 1 mm. (b). Glomerocrysts of plagioclase, pyroxene, and olivine in the dredged basalt sample analyzed (see Table 1). The groundmass is actually more crystalline than displayed in this crossed-nicols photo. Scale bar = 1 mm.*

WHOLE-ROCK AND MINERAL CHEMISTRY

A chemical analysis of one sample that represents advanced crystallization and contains olivine, orthopyroxene, clinopyroxene, and plagioclase phenocrysts (in a groundmass of mainly plagioclase, pyroxene, and oxide grains) is presented in Table 1. The sample is assumed to be representative of the entire dredge haul. Relatively high SiO_2 (51.3 wt. %) and low K_2O (0.16 wt. %) and Zr (70 ppm) contents show that this is a tholeiitic basalt, and the high TiO_2 (1.85 wt.%) and FeO* (12.8 wt.%) (where $FeO^* = FeO + 0.9\ Fe_2O_3$) contents place it into the group of ferrobasalts (FETI; high Fe, high Ti) which are abundant in the region of the Galapagos spreading center (Anderson et al., 1975; Schilling et al., 1976; Fodor et al., this volume). This sample is not, however, compositionally identical to ferrobasalts previously recovered. For example, the FeO*/MgO ratio is 1.9, whereas most other high-FeO* basalts have values >2. Also, SiO_2 is notably higher and Na_2O (2.3 wt. %) lower; in this sense, it resembles the high SiO_2, low Na_2O (but not FeO*-rich) basalts recovered from Site 425, 62 km away from the dredge site (Fodor et al., this volume).

TABLE 1
Bulk-Rock Compositions (wt. %) of Samples Dredged from the Galapagos Spreading Center, East Pacific Ocean

Oxide Element	Porphyritic Basalt[a]	Glassy Rind[b]
SiO_2	51.32	50.7
TiO_2	1.82	1.9
Al_2O_3	13.10	13.6
Fe_2O_3	2.29	–
FeO	10.79	12.7
MnO	0.21	–
MgO	6.86	6.7
CaO	10.70	10.7
Na_2O	2.29	2.3
K_2O	0.16	0.12
H_2O^-	0.06	–
H_2O^+	0.30	–
P_2O_5	0.17	0.18
Total	100.17	98.90
FeO*/MgO	1.87	
Rb	<8	
Ba	215	
Sr	70	
Cr	266	
Ni	6	
Cu	<4	
Zn	145	
Y	30	
Zr	115	
Ga	20	

[a] By wet-chemical analysis, trace elements by XRF.
[b] By electron microprobe. Also present: X = 0.16, Cl = 0.30 (average of five points).

The olivine analysis (Table 2) yields 20 mole per cent fayalite (Fa) — a composition characteristic of tholeiitic basalt (e.g., Fodor et al., 1977). Similarly, clinopyroxene phenocrysts and microphenocrysts containing 40 mole per cent wollastonite (Wo), and the presence of orthopyroxene phenocrysts (Fe_{22}) are typical of tholeiites (e.g., Fodor et al., 1975). However, the occurrence of orthopyroxene phenocrysts has not been reported from other Galapagos ferrobasalts. Neither the clinopyroxene nor the orthopyroxene is enriched in FeO, as might be expected for pyroxene in high-FeO basalts. But the ~5μm-sized grains of groundmass pyroxene (not analyzed) in these dredged samples are presumably relatively rich in FeO based on observations in ferrobasalts at nearby Site 424 (Fodor et al, this volume).

Like the plagioclase in the Site 424 ferrobasalts (Fodor et al., this volume), the groundmass plagioclase in the dredged samples is mainly labradorite in composi-

TABLE 2

Representative Compositions of Phenocrysts, Microphenocrysts, and Groundmass Grains in Basalt Dredged from the Galapagos Spreading Center, East Pacific Ocean (wt. %)

	Olivine	Ortho-pyroxene	Clinopyroxene		Plagioclase	
	p[a]	p[a]	p[a]	mp[b]	p[a]	g[c]
SiO_2	39.3	55.3	52.9	53.1	51.2	53.4
TiO_2	0.02	0.26	0.46	0.57	–	–
Al_2O_3	–	1.2	2.6	2.7	30.8	28.7
Cr_2O_3	0.02	0.06	0.35	0.32	–	–
FeO	18.9	14.4	6.7	7.4	0.63	1.1
MnO	0.20	0.17	0.13	0.19	–	–
MgO	40.8	26.8	17.2	17.0	0.22	0.28
CaO	0.28	2.3	19.6	19.3	14.8	13.1
Na_2O	–	0.02	0.19	0.22	2.8	3.7
K_2O	–	–	–	–	0.04	0.05
Total	99.52	100.51	100.13	100.80	100.49	100.33
Molecular endmembers						
Fa	20.6	Fs 22.4	10.7	11.9	An 73.7	66.1
Fo	79.4	En 73.0	49.9	48.5	Ab 26.1	33.7
		Wo 4.6	40.2	39.6	Or 0.2	0.3

[a] p = phenocrysts.

[b] mp = microphenocrysts.

[c] g = groundmass grains.

tion (Table 2). Plagioclase phenocrysts are slightly richer in CaO content and are bytownite in composition (Table 2); all plagioclase grains are very low in K_2O content.

The composition of a glassy rind containing phenocrysts and microphenocrysts of olivine, pyroxene, and plagioclase agrees well with the bulk-rock analysis (Table 1). Clearly, the small percentage of phenocrysts precipitating from the liquid represented by the glassy rind had little effect on the composition of the remaining liquid (the glass).

DISCUSSION AND CONCLUSIONS

The tholeiitic basalt dredged from the center of the Galapagos spreading center resembles the general compositional characteristics of other ferrobasalts (high in Fe and Ti) recovered from the surrounding regions. In detail, however, it differs by having slightly higher SiO_2, somewhat lower FeO*, FeO*/MgO, and Na_2O values, and by containing modal orthopyroxene.

High-FeO basalts, whether from the Galapagos or elsewhere in the Pacific (e.g., Thompson et al., 1978), are products of fractional crystallization of more "normal" oceanic tholeiite (Schilling et al., 1976; Clague and Bunch, 1976; Fodor et al., this volume), and the variations in oxide concentration from one ferrobasalt to another depend greatly on how much of the parental magma crystallized, and on the proportions of plagioclase, clinopyroxene, and olivine that crystallized from the parent magmas. Clague and Bunch (1976) displayed this dependency in their computer model of a sequence of increasingly FeO-rich differentiates theoretically produced by progressive crystallization of a "normal" tholeiitic parent.

Although not perfectly duplicating previously known FETI basalts, the Galapagos dredged samples do fit into the modeling scheme of Clague and Bunch (1976) and likely represent the sampling of the progressive fractionation process at an earlier stage than most other FETI rocks do (i.e., they have lower FeO*/MgO). Largely on the basis of FeO* content, these spreading-axis samples are closer in composition to normal mid-ocean ridge basalt, namely the high-Si, low Na basalt at nearby Site 425 (Fodor et al., this volume), than most other reported Galapagos ferrobasalts. Applying the criteria of Clague and Bunch (1976), these dredged ferrobasalts represent residual liquid produced from a parental mid-ocean ridge tholeiite after about 58 per cent of it crystallized as plagioclase, clinopyroxene, and olivine in the respective mineral proportions of about 8:6:1.

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