

64. ALTERED BASALTS, LEG 37, HOLE 332B

Robert B. Scott, Department of Geology,
Texas A & M University, College Station, Texas

Four samples of basalt with evidence of two types of alteration were studied chemically and mineralogically to determine the nature of the alteration. The first type of alteration, found throughout the samples, is recognized by the presence of green smectite in amygdules and in the groundmass. The second consists of iron oxide discoloration along fractures and brecciated zones.

Sample 33-3, 22-25 cm (572.72 to 572.74 m core depth) contains junctions between an aphyric basalt, a plagioclase-olivine-microglomerophyric glassy basalt, and an amygdaloidal plagioclase-phyric basalt; this complex was then brecciated and filled with calcite. Sample 36-6, 4-5 cm (605.54 to 605.55 m core depth) is 0.54 meter from the top of a 5.5-meter-thick unit of plagioclase-glomerophyric basalt and Sample 37-2, 72-74 cm is 0.36 meter from the bottom of the same unit. Sample 42-1, 20-22 cm (655.20 to 655.22 m core depth) is 0.58 meter from the base of an olivine-phyric basalt unit more than 6.8-meters thick.

Results of chemical studies are shown in Table 1. The aphyric basalt and calcite-free, plagioclase-olivine-microglomerophyric, glassy basalt of Sample 33-3, 22-25 cm were analyzed together because they were inseparable. The oxidized margins of Samples 36-6, 4-5 cm and 37-2, 72-74 cm were selected for analysis. Sample 42-1, 20-22 cm is uniformly oxidized.

Comparison with fresher rocks is difficult because of the highly variable chemistry of basalts from Hole 332B. However, another sample from the same unit as Sample 42-1, 20-22 cm is not described as significantly altered; its composition is 47.5% SiO₂, 15.8% Al₂O₃, 10.1% Fe₂O₃ (total), 0.15% MnO, 9.75% MgO, 12.0% CaO, 1.94% Na₂O, 0.07% K₂O, and 4.18% H₂O (total) (see Chapter 2, this volume). The water content alone indicates that Sample 42-1, 59-61 cm is also altered, but the degree of alteration is less than that for the highly oxidized and veined Sample 42-1, 20-22 cm. If this comparison is valid, it suggests that a greater degree of alteration involves a loss of SiO₂ and MgO and a gain of iron, K₂O, and CaO. Sample 42-1, 20-22 cm has obviously been oxidized, as has Sample 33-3, 22-25 cm; both have abundant hematitic coloration and higher iron values than Samples 36-6, 4-5 cm and 37-2, 72-74 cm without hematitic coloration. These major element trends do not fit those of high-temperature alteration (Hajash, 1974; Mottl et al., 1974; Scott and Hajash, 1975; Bischoff and Dickson, 1975) where Mg and Na are lost from the fluid phase and Ca, Fe, Mn, Si, and K are gained by the fluid phase. The trends do fit the low-temperature submarine weathering trends (Thompson, 1973) better.

From Haughton et al. (1974) and Scott and Frank (1974), it is clear that significant quantities of S have been lost from the rock; these rocks should have had about 850 ppm originally. Cu, Ni, Cr, Co, Hf, and Sc values are close to those typical of oceanic tholeiites (Gast, 1968; Corliss, 1971). The rare-earth-element patterns (Figure 1) appear to be similar to those found in rocks associated with the transition between "normal" depleted ridge basalts and nondepleted plume basalts as those of Iceland and the Afar (Schilling, 1975, 1973a, b, c; Hart et al., 1973). La/Sm ratios of chondrite-normalized values of Hole 332B basalts average 0.8; this is also typical of the transition between depleted ridge and plume basalt chemistries. However, the Ce values form a positive anomaly. Probably the oxidizing conditions that created the hematitic coatings along veins also concentrated Ce in a similar fashion as manganese nodules are enriched in Ce (Goldberg et al., 1963; Ronov et al., 1967).

A grayish-green clay fills amygdules in Samples 33-6, 4-5 cm and 37-2, 72-74 cm and appears as a yellow, fibrous clay in thin section (see Sample Descriptions). This clay is found in both oxidized and nonoxidized zones; thus it formed in all the rock prior to local oxidation-type alteration along fractures. From powder camera patterns (Table 2), this clay appears to be the same as that found by Scott and Swanson (1976) in Leg 34 basalts; it is chemically and structurally similar to nontronite (Nagelschmidt, 1938). Isotopic studies of Leg 34 basalts suggest that the altering fluids were close to ambient seawater temperatures (Seyfried et al., 1976; Muehlenbachs, 1974), not higher temperatures as postulated by Scott and Swanson (1976) for pyrite-nontronitic smectite veins. A similar clay was experimentally grown by reacting seawater with oceanic tholeiite at 400° and 500°C at 0.8 kbar (Hajash, 1974) so the temperature of alteration cannot be uniquely determined by the presence of an iron-rich smectite. Determination of the temperature of fluids that altered Leg 37 rocks will await definitive oxygen isotope studies. In addition to the clay, several amygdules contain analcite and calcite.

Two phases were found in most of the veins. The dominant phase is calcite; no aragonite lines were seen in X-ray powder patterns. However, a Na-zeolite has been tentatively identified in thin section and by X-ray. Small rosettes of a very weakly to nonbirefringent, low index phase with prisms terminated by pyramidal faces has an X-ray powder pattern (Table 3) that is very similar to a tetragonal Na-P group zeolite, Na-Pc (352), synthesized by Taylor and Roy (1964). More

TABLE 1
Chemical Analyses of Altered Zones, Leg 37, Hole 332B

	33-3, 22-25 cm (%)	36-6, 4-5 cm (%)	37-2, 72-74 cm (%)	42-1, 20-22 cm (%)	Precision (1 σ) (%)
SiO ₂ ^a	45.8	45.2	45.7	45.6	±0.5
Al ₂ O ₃	15.58	16.97	17.84	14.71	±0.4
Fe ₂ O _{3T}	12.49	9.63	8.19	11.57	±0.2
MnO	0.16	0.14	0.13	0.17	±0.007
MgO	5.78	6.83	7.86	9.28	±0.01
CaO	13.89	13.51	14.55	11.13	±0.2
Na ₂ O	2.22	1.94	1.75	1.86	±0.02
K ₂ O	0.141	0.230	0.114	0.120	±0.001
H ₂ O _T ^b	2.59	3.90	2.34	4.19	±0.2
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
S ^c	80	140	40	20	±20
Cu	87	88	92	79	±3
Ni	210	135	155	225	±50
Cr ^d	405	260	270	525	±30
Co ^d	30	29	33	44	±1
Sc ^d	42	44	41	42	±<1
Hf ^d	1.5	2.2	1.8	2.3	±0.1
La ^d	2.0	1.6	2.2	2.3	±0.05
Ce ^d	10	13	9.4	20	±1.2
Sm ^d	1.4	1.3	1.4	1.5	±0.05
Eu ^d	0.74	0.64	0.65	0.66	±0.02
Tb ^d	0.31	0.22	0.35	0.60	±0.03
Yb ^d	1.7	0.95	1.4	2.0	±0.1
Lu ^d	0.27	0.24	0.38	0.38	±0.03

Note: Subscript "T" = Total.

^aBy colorimetry.

^bBy gravimetric analysis.

^cBy titration.

^dBy instrumental activation analysis; rest by atomic absorption spectrophotometry.

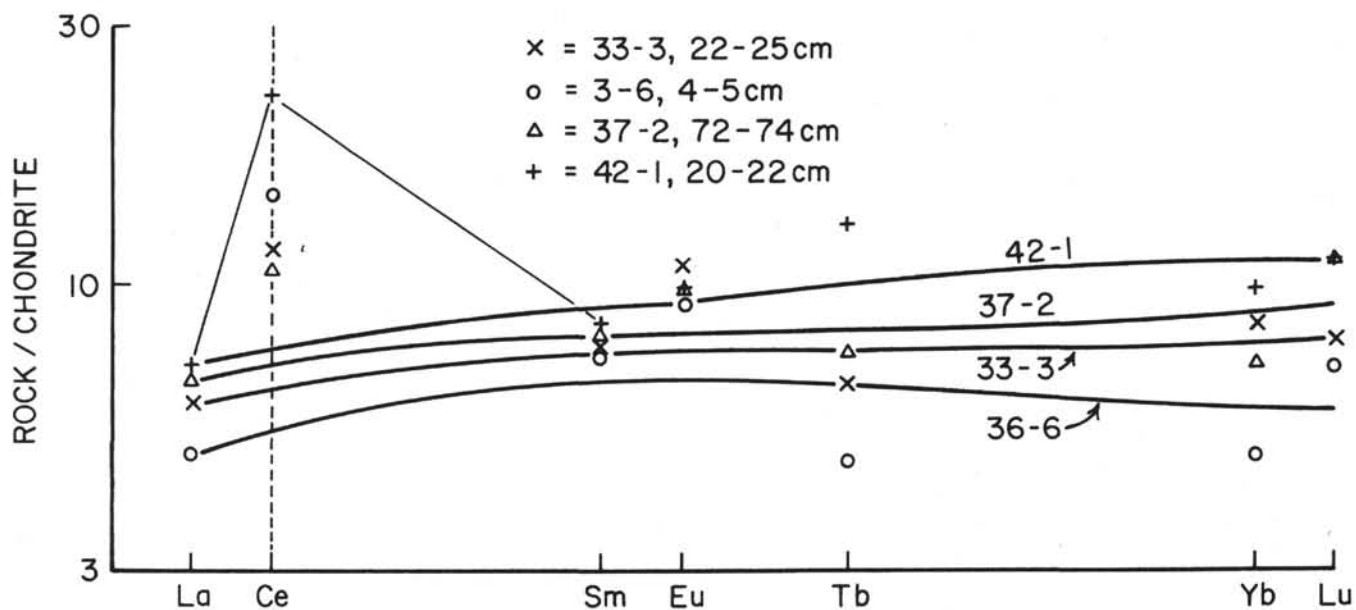


Figure 1. Rare-earth-element abundances normalized to chondritic meteorite abundances. Note positive Ce anomaly.

TABLE 2
X-Ray Powder Camera Pattern,^a Leg 37, Hole 332B

Green Clay in Amygdules 36-6, 4-5 cm		Nontronite-Like Clay Nontronite-Like Clay Leg 34, Hole 319A ^b		Nontronite ^c	
d-A	I	d-A	I	d-A	I
14-16 broad	[100]	15 broad	[100]	15.4	[100]
4.60	[80]	4.58	[70]	4.56	[100]
4.15	[30]				
3.07 broad	[40]	3.21		3.11	
2.63 broad	[50]			2.64	
2.53 broad	[50]	2.65-2.40 broad		2.56	
2.39				2.43	
1.72	[20]	1.74		1.72	
				1.67	
1.53	[100]	1.53	[40]	1.52	[100]
1.32	[40]	1.32 broad		1.32	
				1.30	

^aCu-K α radiation, Ni filter.

^bScott and Swanson (1976)

^cX-ray analysis of nontronite reported by Nagelschmidt (1938).

mineralogical work seems warranted before positive identification is made.

SAMPLE DESCRIPTIONS

Sample 33-3, 22-25 cm

Orientation relative to top unknown, four zones oblique to core axis. Zone 1 is 5 mm thick. No phenocrysts. Groundmass of 20% plagioclase (P) + 75% pyroxene-plagioclase (Px-P) intergrowths + 5% opaques (Op). Crystal size decreases sharply at the Zone 1-2 boundary and an oxidized band obliquely crosses the boundary. 5% amygdules, filled with smectite and calcite. Zone 2 is 7 mm thick. 10% microphenocrysts, 60% P + 40% olivine (O1). O1 replaced by calcite near Zone 3. Variolitic glassy groundmass with hematitic veinlets is palagonitized near Zone 3. Zone 3 is 18 mm thick. 50% brecciated glass in matrix of calcite. Microphenocrysts same as Zone 2 except all O1 replaced by calcite. Borders of zone have less palagonite and more variolites than center. Glass is oxidized and fractures are hematite filled. Zone 4 is 10 mm thick. Same as Zone 2 except: 1-3 mm long P phenocrysts besides microphenocrysts that are 80% P + 20% O1; also larger (3 mm long) irregular calcite amygdules are present.

Sample 36-6, 4-5 cm

Oxidized near calcite and zeolite veins. Less oxidized zone has 20% P phenocrysts and one euhedral reddish-brown spinel; groundmass of P laths + Px-P intergrowths + 10% fibrous, greenish-yellow clay in interstices and replacing O1(?) + fine opaques. Oxidized zone is 6 mm thick and has abundant hematite. Veins are 1 mm thick with rosettes of euhedral isotropic zeolite prisms on rims; botryoidal growths of fibrous calcite fill the center.

Sample 37-2, 72-74 cm

Oxidized near calcite veins. Less oxidized zone has 20% phenocrysts of P + greenish-yellow fibrous clay

replacing O1. Slightly ophitic groundmass has 40% P + 40% Cpx + 3% O1(?) replaced by clay + 5% opaques + 5% clay replacing interstices. 7% amygdules of calcite + clay + isotropic and anisotropic zeolites. Oxidized zone is 2 mm thick. Hematite-coated crystal boundaries are abundant. Zeolites in amygdules are common. Veins are <0.5 mm thick. Vein sequence: Rock surface | opaque hematite (0.01 mm) | green, fibrous clay (0.01 mm) | hematite (0.03 mm) | calcite (0.2 mm thick).

Sample 42-1, 20-22 cm

Highly oxidized. 6% euhedral O1 phenocrysts. Groundmass has P laths + highly oxidized P-Px intergrowths. Ubiquitous hematite coats crystal boundaries. 2% amygdules are filled with calcite + clay + hematite.

TABLE 3
X-Ray Powder Patterns,
Leg 37, Hole 332B

Prisms in Veins of 36-6, 4-5 cm		Na-Pc (352) Taylor and Roy (1964)	
d-A	I ^a	d-A	I
7.25	[50]	7.10	[55]
5.40	[25]	—	
5.03	[25]	5.01	[35]
4.11	[75]	4.10	[55]
3.17	[100]	3.16	[100]
2.69	[25]	2.67	[55]
Broad calcite	overlap	2.52	[5]
2.38	weak	2.36	[7]
Broad calcite	overlap	2.054	[5]
1.98	weak	1.965	[10]
1.78	weak	1.771	[7]
1.72	weak	1.719	[7]
1.67	weak	1.667	[7]
Broad calcite	overlap	1.623	[5]

^aIntensity corrected to 100 maximum by ignoring calcite lines. Cu-K α radiation, Ni filter.

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