15476 PORPHYRITIC RADIATE QUARTZ-NORMATIVE MARE BASALT ST. 4 266.3 g

INTRODUCTION: 15476 is a pigeonite-porphyritic mare basalt with large phenocrysts, a radiate, finer-grained groundmass, and a distinct foliation or lineation (Fig. 1). It is an average-composition member of the quartz-normative mare basalt suite. It is light brown with green to brown zoned prismatic pyroxene phenocrysts and a few per cent vugs. It is coherent, slabby or tabular, and has a few zap pits on all faces.

15476 was collected about 28 m south-southeast of the rim crest of Dune Crater, a few centimeters from rocks 15475 and 15495. The immediate surface had a moderate cover of fragments. 15476 was dust-covered but not filleted or buried. Its orientation was documented.

Figure 1. Pre-split view of 15476, showing foliation and small vugs. S-71-46905

Fig. 2a

Fig. 2b

Figure 2. Photomicrographs of 15476,32. Widths about 3 mm.
a)d) transmitted light; b)c) crossed polarizers.
a) Radiate or variolitic portions of groundmass;
b) irregularly-grown pigeonite phenocrysts, with hollows filled with crystallized groundmass;
c)d) common phenocryst, with filled hollow core and sharply bounded augite rim; groundmass is coarser than variolitic portion shown in a).

Fig. 2c

Fig. 2d

PETROLOGY: 15476 is a porphyritic basalt in which long (up to 3 x 15 mm) pigeonite crystals lie in a much finer-grained, radiate groundmass (Fig. 2). Although the pyroxenes are as big as in some other coarse-grained rocks, they are not so abundant, only 20 to 30%. The groundmass consists of a frequently radiate mass of plagioclase (An_{93} to An_{87}; Kushiro, 1972, 1973), augite, cristobalite, opaque phases, and a sparse mesostasis. The texture is not the same everywhere, varying from radiate masses (Fig. 2a) to more subophitic patches. The plagioclases are lathy, rarely up to 4 mm long, and both they and the pigeonite phenocrysts are very roughly foliated. Opaque phases range from euhedral chromite in pigeonite cores, through ulvospinel, to ilmenite. Fe-metal and troilite are also present. Tridymite appears to be absent. Mason et al. (1972) reported 0.70% cristobalite. The sample has a density of 2.8 g/cm^3 (O'Kelley et al.,1972).

The pigeonite phenocrysts(although large, are different from those in other coarse-grained quartz-normative basalts in that, although some have homogeneous cores, several are irregular and appear to have grown as hollow crystals in which groundmass later crystallized (Figs. 2b-d). The pigeonite phenocrysts also lack the twinning common in basalts with a coarser groundmass. They have sharply-banded rims of augitic pyroxene. Kushiro (1972, 1973) reported pyroxene compositions (Figs. 3, 4). Brunfelt et al.(1973) also reported a few pyroxene analyses. The variation observed is similar to that in other Apollo 15 mare basalts. Kushiro (1972, 1973) noted that the pigeonite cores are overgrown discontinuously with subcalcic augite; ferroaugite and subcalcic ferroaugite are intergrown with anhedral plagioclase crystals, with which they must have crystallized rapidly. The sharp break at the rim, corresponding also with the sharp change in Ti/Al ratios, he believes to result from plagioclase crystallization, and the Ti/Al ratios less than half to reflect Ti^{3+} and very reducing conditions. Kushiro (1972a,b) interprets the textures and mineral chemistry as resulting from the subsurface crystallization of pigeonite and then extrusion and rapid crystallization of the remaining liquid. Virgo (1972, 1973) studied the separated phenocryst fragments ($En_{65.5}Wo_{6.5}$ average) with x-ray diffraction and Mossbauer techniques. X-ray diffraction single crystal precession pictures had no visible exsolved augite spots along the expected planes after 90 hours exposure. The Mossbauer studies showed no evidence for Fe^{3+}; site occupancies for Fe^{2+}-Mg and calculated distribution coefficients were tabulated. The K values (0.08) show the Fe^{2+} and Mg to be somewhat ordered, indicating equilibration temperatures (520°C) significantly less than the critical temperature for ordering (600°-810°C) and suggests slow cooling over the range T critical - T annealing, i.e., about 600 to 480°C. Hence Virgo (1972) suggested that crystallization was characterized by an initially fast growth of pigeonite crystals, then at lower temperatures a rapid and heterogeneous crystallization of rims and groundmass. The lack of augite exsolution indicates rapid cooling in the 1200°C to 950°C range. In the 1000°C to 950°C range, pigeonite undergoes a transition from C_2/c to P_{21}/c space group; the x-ray diffraction reflections indicate small P_{21}/c domains. The domain size, absence of unmixing, and the low temperature Fe-Mg ordering appear to be incompatible with a single cooling cycle, and suggest a post-crystallization heating event, such as from superimposed lava flows.

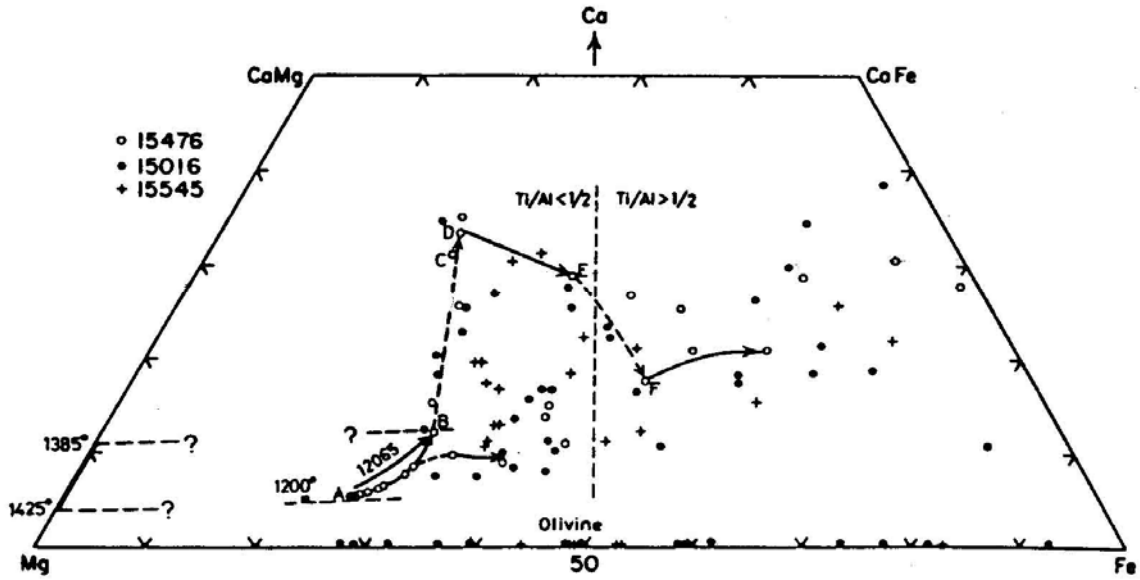

Figure 3. Compositions of pyroxenes in 15476 (open circles) and two other Apollo 15 mare basalts. Solid lines show continuous, dashed lines show discontinuous, zoning ina single crystal (Kushiro, 1973).

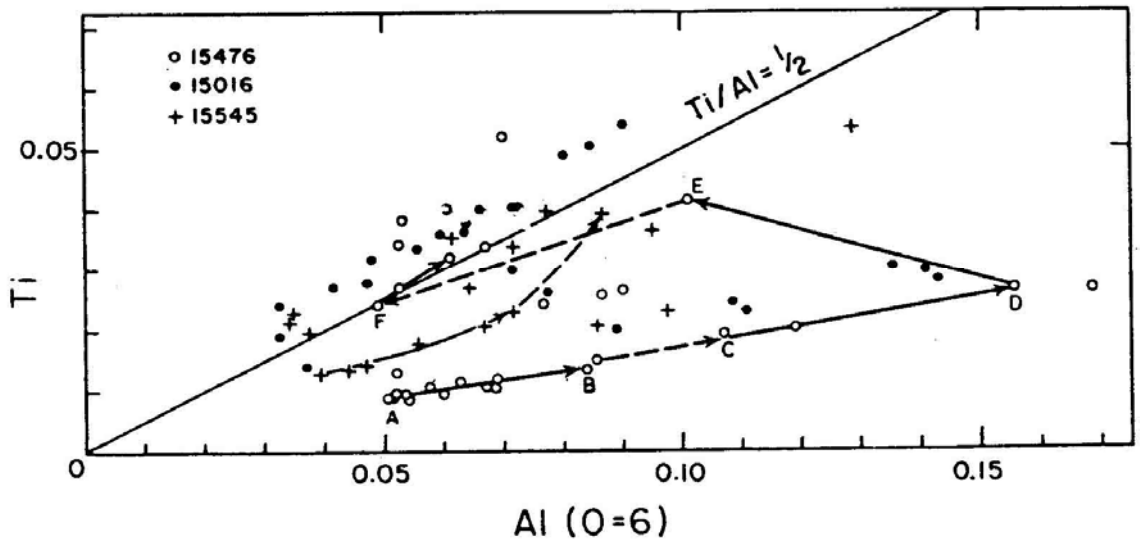

Figure 4. Ti-Al variations in pyroxenes in 15476 (open circles) and two other Apollo 15 mare basalts (Kushiro, 1973).

Lofgren et al. (1975), in a comparison of natural textures with those produced in dynamic crystallization experiments, inferred a cooling rate of less than 1°C/hr (but near 1°C to 2-5°C/hr limit) for the phenocrysts, and 1 to 5°C/hr for the radiate groundmass.

CHEMISTRY: Bulk rock analyses are listed in Table 1 and the rare earths are shown in Figure 5. The analyses are generally fairly consistent and demonstrate that 15476 is a rather average-composition Apollo 15 quartz-normative basalt. The Rb analysis of 6.0 ppm of Brunfelt et al. (1972) is very high and apparently in error; their CaO is also higher than normally found for Apollo 15 quartz-normative basalts.

RADIOGENIC ISOTOPES: Tatsumoto et al. (1972) reported U, Th-Pb isotopic data for a whole-rock sample. 15476 lies on a 3.5 to 4.65 b.y. discordia line with samples from Elbow Crater but has a distinctly higher $^{207}Pb/^{206}Pb$ ratio. Rosholt (1974) compared the expected Th^{232}/Th^{230} ratio with the measured ratio, discussing possible and probably reasons why the expected/measured (=1.13) is high, like other Apollo 15 mare basalts.

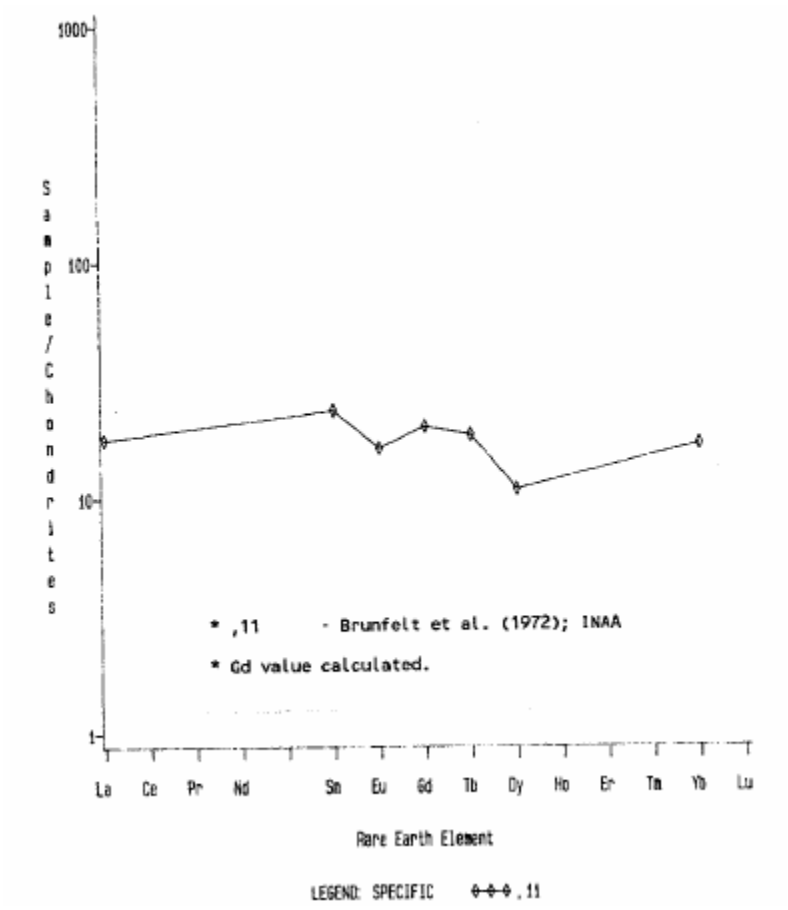

Figure 5. Rare earths in 15476.

TABLE 15476-1. Bulk rock chemical analyses

		,5	,11	,9	,0	
Wt %	SiO2	48.46		47.84		
	TiO2	1.75	1.90	1.82		
	Al2O3	9.54	9.17	10.02		
	FeO	20.76	19.5	19.79		
	MgO	8.69	8.3	8.35		
	CaO	10.50	13.9	10.74		
	Na2O	0.28	0.35	0.35		
	K2O	0.07		0.043	0.049	
	P2O5	0.05		0.081		
(ppm)	Sc		40.6			
	V	90	220	160		
	Cr	2945/3600	3280	3200		
	Mn	2170	2180	2020		
	Co	37	34.4	38		
	Ni	27	20	15		
	Rb	<5	6.0	1.5		
	Sr	98	114	115		
	Y	42		31.4		
	Zr	105		110		
	Nb			5.6		
	Hf		3.6			
	Ba	63	54	75		
	Th		0.52		0.51	0.7334
	U		0.21		0.14	0.1919
	Pb	<2				0.354
	La		5.9			
	Ce					
	Pr					
	Nd					
	Sm		4.3			
	Eu		1.13			
	Gd					
	Tb		0.88			
	Dy		3.5			
	Ho					
	Er					
	Tm					
	Yb		3.4			
	Lu					
	Li	8				
	Be					
	B	2				
	C					
	N					
	S			670		
	F					
	Cl					
	Br					
	Cu	7		4		
	Zn			<1.5		
(ppb)	I					
	At					
	Ga	3000				
	Ge					
	As					
	Se					
	Mo					
	Tc					
	Ru					
	Rh					
	Pd					
	Ag					
	Cd					
	In					
	Sn					
	Sb					
	Te					
	Cs		310			
	Ta		4100			
	W					
	Re					
	Os					
	Ir					
	Pt					
	Au					
	Hg					
	Tl					
	Bi					
		(1)	(2)	(3)	(4)	(5)

References and methods:

(1) Mason et al. (1972); general silicate, gravimetric, flame photometry, colorimetry, emission spec.
(2) Brunfelt et al. (1972); INAA
(3) Duncan et al. (1975); XRF
(4) O'Kelley et al. (1972); gamma ray spectroscopy
(5) Tatsumoto et al. (1972); ID/MS

EXPOSURE, TRACKS, (AND RARE GAS): Eldridge et al. (1972) reported disintegration count data for ^{22}Na, ^{26}Al, ^{46}Sc, ^{54}Mn, and ^{56}Co. The ^{26}Al is unsaturated (confirmed by Yokoyama et al., 1974), and indicates a surface residence age of 0.8 to 1.5 m.y. Bhattacharya et al. (1975) briefly reported track data, with a density in the general range of 6 to 20 x 10^6 tracks/cm^2, and an exposure age of l0 to 30 m.y. Schaeffer et al. (1976) erroneously referred to 15476 in a discussion of argon in sample 15465; they never were allocated any of 15476.

PROCESSING AND SUBDIVISIONS: Samples were removed from 15476 by chipping (Fig. 6), and most allocations made by subdivisions of those (exterior) chips. ,3 was made into a potted butt and produced all the thin sections (,32 and ,33 to ,38). ,0 is now 206.91 g, and no other single piece is as large as 5 g except for the remains of ,3.

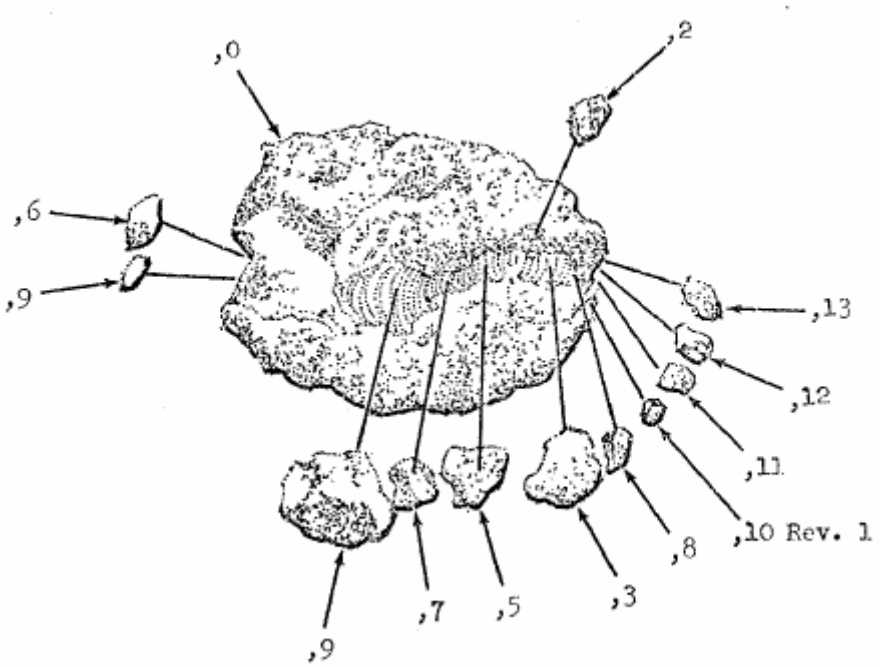

Figure 6. Chipping of 15476.