75055

High-Ti Mare Basalt
949.4 g, 21 x 14 x 1.8 cm

INTRODUCTION

75055 was described as a white to brownish-gray, equigranular mare basalt with a few planar fractures and a micro-diabasic texture (Apollo 17 Lunar Sample Information Catalog, 1973). It was collected from Station 5 near Camelot Crater. This sample was, before subdivision, a flat slab (see dimensions and Fig. 1) which was homogeneous, except for irregularly distributed vugs which covered < 5% of the surface. These vugs had a maximum size of 8 mm and were filled with euhedral crystals of plagioclase, pyroxene, and ilmenite. A few zap pits were present on all exposed surfaces.

PETROGRAPHY AND MINERAL CHEMISTRY

The petrographic features of 75055 were initially described in the Apollo 17 Lunar Sample Information Catalog (1973) from sections 8, 16, and ,17. This description stated that plagioclase laths (up to 3.2 mm) were randomly oriented with interstitial anhedral (zoned) olivine (up to 0.8 mm) and clinopyroxene (up to 0.8 mm) (Fig. 2), which occasionally exhibits an hour-glass structure. A small trace of residual glass occurs in the interstices. Euhedral to subhedral ilmenite (up to 1.8 mm) has a "swiss cheese" texture with glassy melt inclusions (Fig. 3 a,b). Anhedral troilite (0.2-0.7 mm) with FeNi metal globules (up to 0.1 mm) is associated with the glassy mesostasis, which includes cristobalite (up to 1.2 mm). No spinet or rutile exsolution features were observed in ilmenite. The reported mode was: 29% plagioclase, 19% clinopyroxene, 33% olivine, 14% ilmenite, 3% cristobalite, < 1% troilite, < 1% FeNi metal, and < 1% glass.

Dymek et al. (1975) gave a more detailed description which will be reported here. Dymek et al. (1975) reported 75055 as a medium- to fine-grained intergranular to subophitic, ilmenite basalt. It is comprised

Figure 1: Hand specimen photograph of 75055,0,

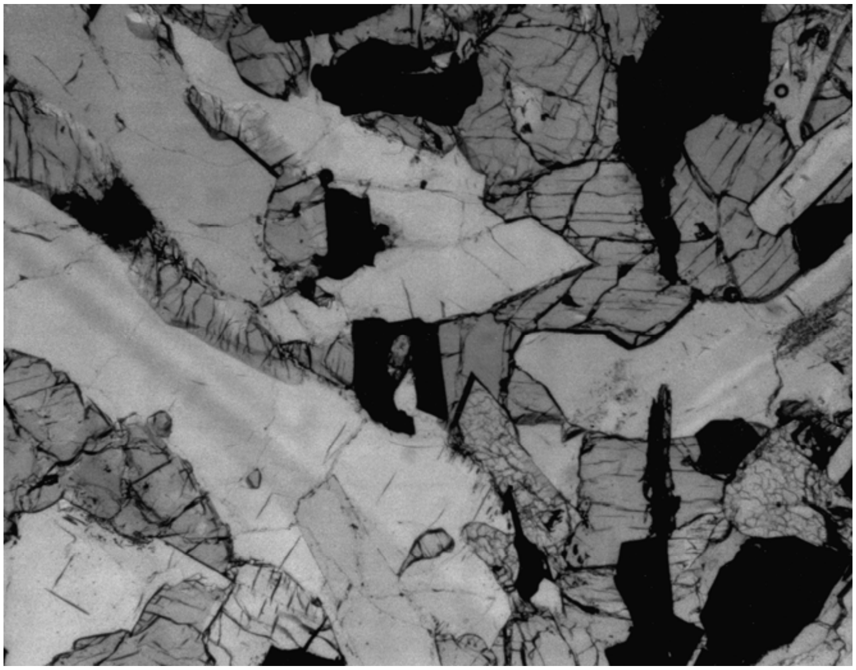

Figure 2: Photomicrograph of 75055. Field of view is 2.5 mm.

of 33% plagioclase, 50% clinopyroxene, 12% ilmenite, and 3% SiO2, with minor amounts of troilite, FeNi metal, ulvospinel, Ca-phosphate, "tranquillityite", and mesostasis. Plagioclase forms a discontinuous, interlocking network of stubby tablets to elongate laths (~ 0.1-3.5 mm in length) enclosing pyroxene and ilmenite (Figs. 2 and 3). Several grains contain numerous aligned glassy inclusions and rare inclusions of pyroxene and ilmenite. However, most of the plagioclase is inclusion-free. The margins of the plagioclase grains tend to be rounded and irregular, and are intergrown with pyroxene and ilmenite. Pyroxene occurs as pale-pink to pale-yellow-brown to nearly colorless, subhedral to anhedral grains (~ 0.1-1.0 mm) that fill the interstices between plagioclase laths. Many grains include and are intergrown with ilmenite and plagioclase. Optical zoning is pronounced, but hour-glass structures are poorly developed. [lmenite tends to form elongate grains with subhedral and lobate outlines (Figs. 2 and 3). Most contain abundant subrounded melt and pyroxene inclusions (Fig. 3b) and rarely plagioclase. The vast majority of ilmenite grains are either intergrown with or included in pyroxene. "Graphic" intergrowths of ilmenite and pyroxene are quite common. No armalcolite or Cr-spinel were observed. The $Si0_2$ phase occurs predominantly as subhedral to euhedral interstitial grains (up to 0.3 mm across) with the characteristic mosaic fracture pattern of lunar cristobalit:e (Figs. 2 and 3a). A few grains occur as needles (up to ~1mm long) intergrown with plagioclase and pyroxene, and are probably tridymite. Both types of SiO_2 contain infrequent grains tiny (10-50u) inclusions of dark-brown K- and Si-rich, devitrified glass. The SiO_2 needles are uniformly higher in K than the angular grains

Brown et al. (1975) described 75055,48 as a Type 11 Apollo 17 ilmenite basalt. No detailed description of this basalt was given, but Brown et al. (1975) reported a modal mineralogy of: 15.9% opaques, 28.6% plagioclase, 50.2% clinopyroxene, 4.5% silica, and 0.8% mesostasis. Note that both Dymek et al. (1975) and Brown et al. (1975) do not report any olivine in their samples, unlike that the the Apollo 17 Lunar Sample Information Catalog (1973).

The mineral chemistry of 75055 has been extensively reported by Dymek et al. (1975). These authors reported a measured range of pyroxene compositions of $Wo_{40}En_{44}Fs_{81}$ - $Wo_{16}En_{3}Fs_{81}$, with the variation in many grains spanning this range (Fig. 4). The most Fe-rich compositions are extremely Cr-poor, and are distinguished by a different symbol in Fig. 4. Both the Ti/Al ratio (1:2) and the Al-Ti-Cr abundance (inset in Fig. 4) indicate the presence of some TO+ and no A1V1. Both relationships are consistent

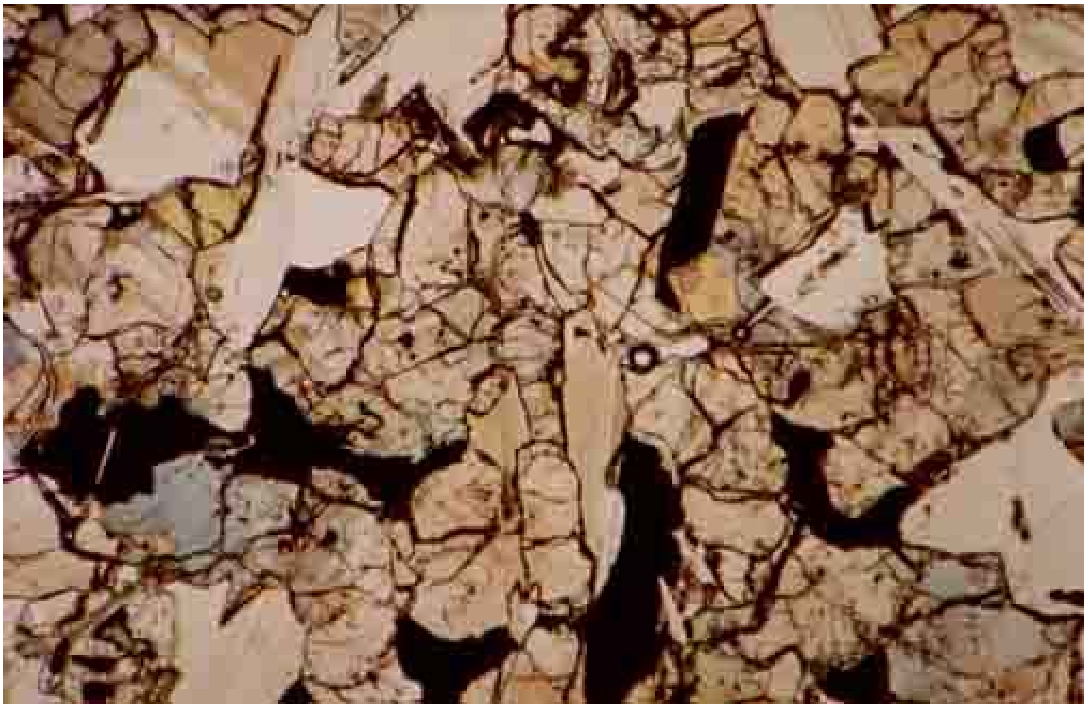

Figure 3a.

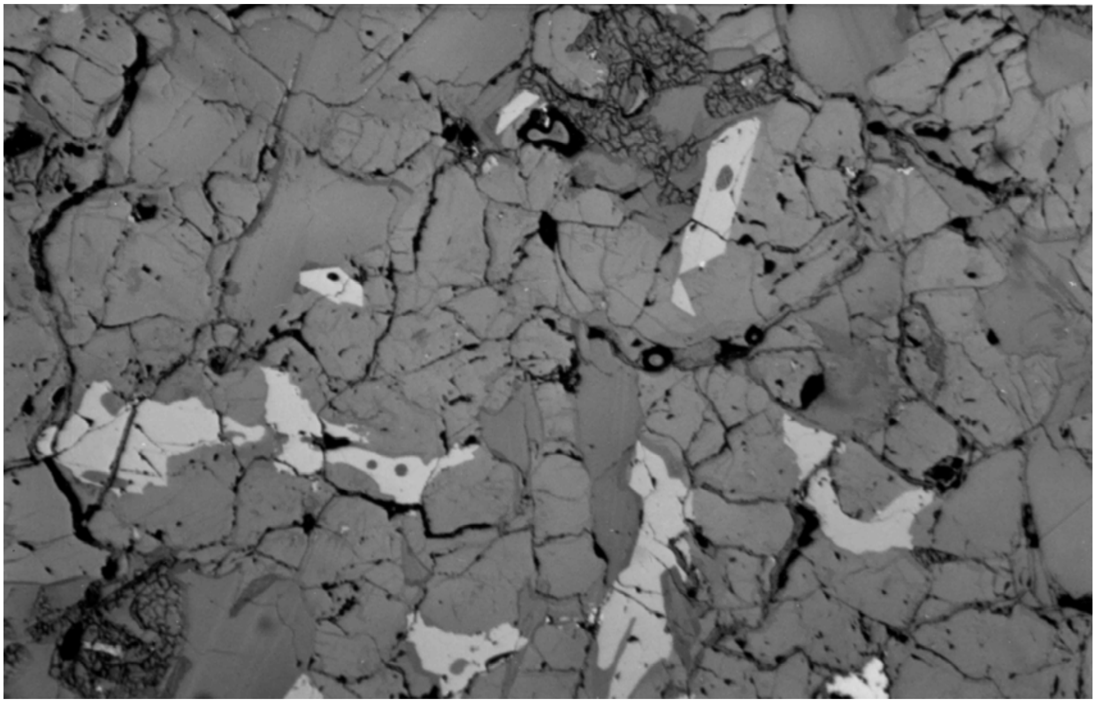

Figure 3b.

Figure 3: Photomicrohraphs of 75055. Field of view is 2.5 mm.

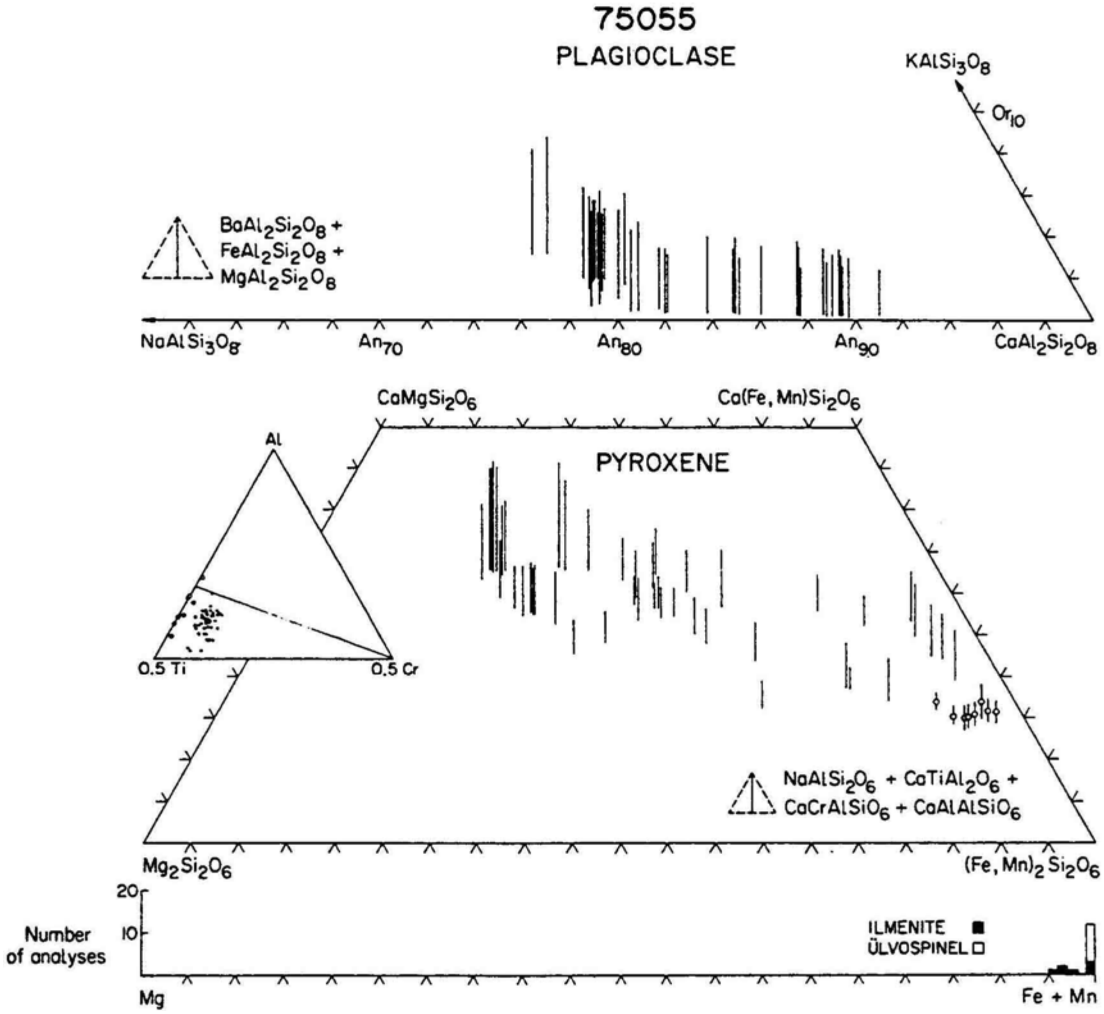

Figure 4: Compositions of the principal silicate and oxide phases in mare basalt 75055. (Triangular inset as in Figure 1.) The pyroxene compositions marked by the open circles are presumed to be pyroxferroite.

with pyroxene-plagioclase coprecipitation or crystallization of some plagioclase prior to pyroxene growth. This is supported by the Fe/ (Fe + Mg) ratio of the most calcic plagioclase, which is ~0.4, whereas the Fe/ (Fe + Mg) ratio of the earliest formed pyroxene is - 0.28. From petrography, it appears as if plagioclase began to crystallize just before pyroxene and would, therefore, have a lower Fe/(Fe + Mg) ratio, but this is the reverse of what is observed, demonstrating that the Fe/(Fe + Mg) ratio in plagioclase is not a reliable indicator of the composition of the first formed plagioclase. The plagioclase has a measured range in composition of $An_{72.90}$ (Fig. 4), with zonation up to 15 mole % within a single grain (most calcic compositions form the cores). The Fe/ (Fe + Mg) ratio increases uniformly with decreasing An content (Fig. 5). However, MgO exhibits a alight but steady depletion from An_{90} to ~ An_{80}, with the decrease becoming more rapid at lower An contents (Fig. 5). Ilmenite is Fe-rich [Fe/(Fe+Mg) = 0.95-0.991 and in one instance was overgrown and resorbed by ulvospinel [Fe/(Fe+Mg)= 0.99].

The paragenetic sequence reported by Dymek et al. (1975) is as follows. Ilmenite and plagioclase were the first phases to form and were joined by pyroxene and then tridymite. Solidification was completed with the (minor) "replacement" of ilmenite by ulvospinel, and the formation of cristobalite in the mesostases and interstices.

WHOLE-ROCK CHEMISTRY

The whole-rock chemistry of 75055 has been determined to various degrees by several authors (Table 1). The elements

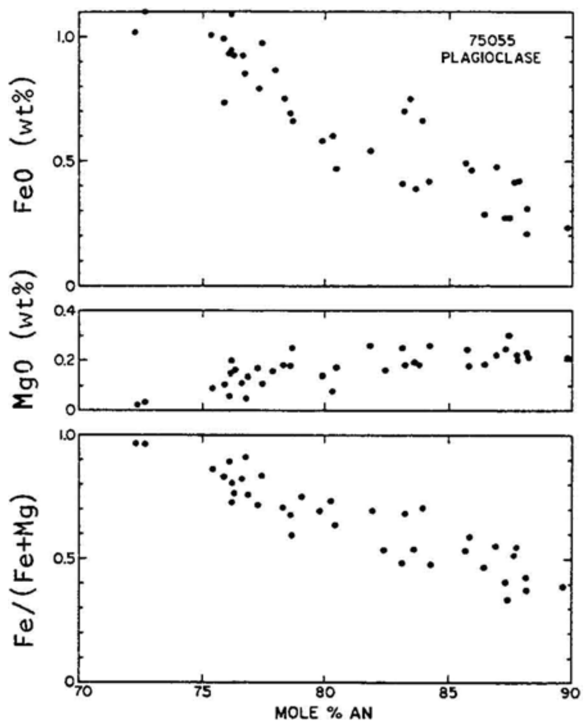

Figure 5: Diagram illustrating the FeO and MgO contents, and Fe/(Fe +Mg), in plagioclase in mare basalt samples 70215 and 75055. After Dymek et al. (1975).

reported depend on the type of study being undertaken. Two major element analyses are available (Boynton et al., 1975; L SPET, 1973a,b), although the first analysis in Table 1(Boynton et al., 1975) does not include MgO. The only MG# determination is 40.0 (LSPET,1973a,b), 713055 is classified as a Type A Apollo 17 high-Ti basalt using the scheme of Rhodes et al. (1976) and Warner et al. (1979). Detailed siderophile element data for 75055 are reported by Wolf et al. (1979) (Table 1). The REE profile has been deter-mined by Boynton et al. (1975) and twice by Shih et al. (1975), as well as a partial analysis by Garg and Ehmann (1976) (Table 1 and Fig. 6). The two analyses from Shih et al_ (1975) exhibit differences in REE abundance, but the profiles have the same shape (Fig. 6) and a negative Eu anomaly of approximately the same magnitude [(Eu/Eu*)N = 0.50 and 0.55]. The analysis of Boynton et al. (1975) is similar to those of Shih et al. (1975) in the light and heavy REE, but is lower in the middle REE,

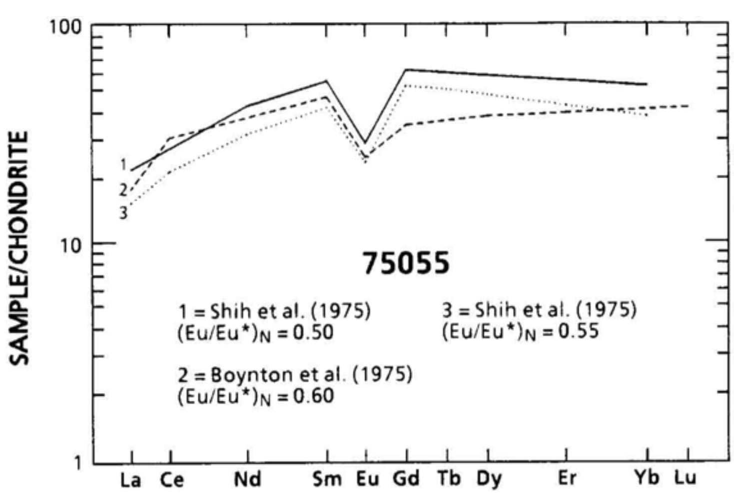

Figure 6: Chondrite-normalized rare-earth-element profiles of 75055. $(Eu/Eu^*)_N$ values are noted.

specifically Tb. Therefore, the negative Eu anomaly is not as deep as in the analyses of Shih et al. (1975) $[Eu/Eu^*]_N = 0.60$].

RADIOGENIC ISOTOPES

Basalt 75055 has been analyzed for a variety of isotopes. Nunes et al. (1974) and Tera and Wasserburg (1974, 1976) undertook a thorough study of the U-Th-Pb isotopic composition of 75055 (Table 2). Nunes et al. (1974) reported an age of 4.49 Ga. Tera and Wasserburg (1974, 1976) reported a crystallization age of ~3.8 Ga and noted that the internal isochron intersected the concordia at 4.41-4.42 Ga (Fig. 7), consistent with the results of Nunes et al. (1974). Chen and Wasserburg (1980) reported the U isotopic composition of 75055 (Table 2), noting a U concentration of 43ng and a $^{238}U/^{235}U$ ratio of 137.83± 0.36.

The Rb-Sr isotopic composition of 75055 has been reported by Tera and Wasserburg (1974), Nyquist et al, (1975), and Murthy and Coscio (1976) (Table 3). Murthy and Coscio (1976) reported a crystallization age of 3.77 ± 0.06 Ga. Generally, these analyses are within error, except for the $^{87}Rb/^{86}Sr$ rELtio of 75055,75 (0.0077±3) reported by Nyquist et al. (1975) which is lower than that for 75055,6 ($^{87}Rb/^{86}Sr$ = 0.0099) reported by these authors and that reported by Tera et al. (1974) ($^{87}Rb/^{86}Sr$ = 0.0099). Absolute concentrations of Rb and Sr are also variable (Table 3). Sm-Nd compositions data for 750155 have been reported by Lugmair and Marti (1978) and Unruh et al. (1984). Lugmair and Marti (1978) used the Ar-Ar age for 75055 to calculate an £Nd value of 6.0 ± 0.5 and a model age of 4.57± 0.07 which is the age at which the Sm-Nd evolution of 75055 intercepts that of chondrites. Unruh et al. (1984) also reported the Sm-Nd composition o£75055 and found it to be similar to that of Lugmair and Marti (1978) (Table 3). Unruh et al. (1984) also reported the Lu-Hf composition of 75055 (Table 3) in their study of source compositions for and derivation of the mare basalts.

Several workers have analyzed 75055 for the Ar isotopes (Table 4) and have reported ages of 3.78 Ga (Huneke et al., 1973) and apparent ages of 3.55-3.59 Ga (Turner et al., 1973). Kirsten et al. (1973) and Kirsten and Horne (1974) reported a total Ar Age of 3.62 ± 0.07 Ga and a plateau age of 3.83 ± 0.05 Ga for 75055. These three studies have reported values of different Ar isotopic ratios (Table 4).

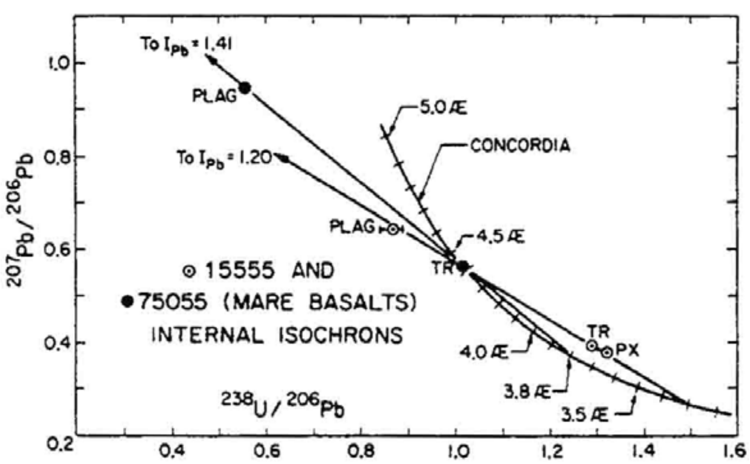

Figure 7: Internal isochrons for two mare basalts of different ages and different initial Pb. Note the isochron both intersect concordia at 4.42 AE. After Tera and Wasserburg (1976).

STABLE ISOTOPES

Specialized studies using 75055 have reported the isotopic composition of Ti (Niederer et al., 1980), Ca (Russell et al., 1977), and Si (Taylor and Epstein, 1973) (Table 5). Taylor and Epstein also reported the $s^{18}0$ of 75055,5 and noted that slight fractionation of these isotopes may occur on meteorite impact. However, Meyeda et al, (1975) noted no evidence for impact-induced fractionation of the oxygen isotopes in their study of 75055, 40. Gibson et al. (1975) reported the $^{834}S_{CDT}$ of 75055 to be -0.2%o.

EXPOSURE AGE AND COSMOGENIC RADIONUCLIDES

Exposure ages using the Ar dating method have been reported by three independent studies (Huneke et al,, 1973; Turner et al., 1973; and Kirsten and Horne, 1974). These three studies reported essentially the same exposure age for 75055: 95 ± 15 Ma, 90 Ma, and 85 ± 10 Ma, respectively. The cosmogenic radionuclide abundances of 75055 have been reported by the Lunar Sample Preliminary Examination Team (LSPET 1973a), Rancitelli et al. (1974), and Yokoyama et al. (1974). Rancitelli et al. (1974) reported the same analysis as in LSPET (1973a) (Table 6), and the study of Yokoyama et al. (1974) did not yield reliable results for the abundance of $^{26}A1$ and ^{22}Na in 75055.

MAGNETIC STUDIES

Magnetic data for 75055,6 has been reported by Pearce et al. (1974) (Table 7). These authors used the results to calculate the equivalent wt% of Fe^o and Fee+ and thus, the Fe^o/Fe^{2+} ratio.

EXPERIMENTAL STUDIES

75055 has been used in experiments to determine the liquid line of descent and ultimate immiscibility of high-Ti mare basalts (Rutherford and Hess, 1975; Hess et al., 1975). It was noted by these authors that basalt 75055 hit the immiscibility gap between 1016°C and 991°C, producing high-Si and high-Fe melts.

Gamble and Taylor (1979) used 75055 to study the effects of kinetics on the crystal-liquid partitioning in augite. These authors noted that the partitioning of major elements between augite and liquid is rate independent and insensitive to composition and to the nature and order of appearance of coexisting phases. However, partitioning of the minor elements is complex: the K_ds seem to be cooling-rate dependent.

PROCESSING

The original sample 75055,0 has been entirely subdivided. The largest remaining samples are 1 (~470g),, 3 (~52g), and ,20 (~69g). Another large sample reported by the JSC inventory is ,61 at ~ 63g. However, this came from, 19 which only weighed 27.2g. Nine thin sections are available: 75055,15;,46-,51; and ,54 and ,55.

Table 1: Whole-rock chemistry of 75055.

Sample	,37	,6	,6	,75	,69	,34	,6		,92		,92	,33	
Method	N,R	X	I,N	I,N	N	N	C	A		A	A	R	I
Ref.	1	2,3,4	5	5	6	7	8,9	10	11	12	13	14	15
SiO_2 (wt%)		41.27											
TiO_2	10.07	10.17											
Al_2O_3	10.77	9.75											
Cr_2O_3	0.285	0.27											
FeO	16.90	18.24			20.38								
MnO	0.252	0.29											
MgO		6.84											
CaO	12.6	12.30											
Na_2O	0.46	0.44											
K_2O		0.09	0.075	0.056									
P_2O_5		0.07							0.07				
S		0.19					0.221	0.1696					
Nb (ppm)		25											
Zr		272			356	150							
Hf	7.4				11.56	6.9							
Ta													
U			0.13						0.15			0.128	0.136
Th			0.44										
W													0.447
Y		112											
Sr		209	201	180									
Rb		0.7	0.685	0.482								0.538	
Li			10.1	8.6									
Ba			86.4	66.0									
Cs												0.019	
Be													
Zn	1.7	7											
Pb													0.311
Cu													
Ni	1.5	2										<4	
Cr	1950		1857		1660								
Co	16			14.5	16.7								
V													
Sc	79			82.7	83.3								
La	6.0		7.14	5.39									
Ce	26		24.5	18.5	49.6								
Nd			27.1	20.7									
Sm	9.6		11.3	8.80									
Eu	2.00		2.27	1.91	2.39								
Gd			17.5	13.9									
Tb	2.1				3.0								
Dy			20.1	16.1									
Er			11.9	9.54									
Yb	9.1		10.9	8.68									
Lu	1.40				1.9								
Ga	4.5												
F													
Cl										3.4			
C											0.013		
N													
H													
He													
Pd (ppb)												<1.1	
Ge	3.5											2.54	
Ag												0.76	
Se												119	
Ir	0.019												
Au	0.029											0.007	
Cd	1.9											1.92	
Sb												0.99	
In	0.45											0.57	
Tl												0.37	

1 = Boynton et al. (1975); 2 = LSPET (1973a); 3 = LSPET (1973b); 4 = Rhodes et al. (1976); 5 = Shih et al. (1975); 6 = Garg and Ehmann (1976); 7 = Hughes and Schmitt (1985); 8 = Gibson and Moore (1974); 9 = Gibson et al. (1976); 10 = Gibson et al. (1975); 11 = Jovanovic and Reed (1978); 12 = Jovanovic and Reed (1980a); 13 = Jovanovic and Reed (1980b); 14 = Wolf et al. (1979); 15 = Nunes et al. (1974).

N = INAA; R = RNAA; X = XRF; I = Isotope Dilution; C = Combustion; A = Acid Hydrolysis.

Table 2: U-Th-Pb data of 75055.
Data from Nunes et at. (1974).

Analysis	Whole rock		Whole-rock	
Comp./Conc.	P	C*	C1P	C1
Weight (mg)	621.4	553.8		
U (ppm)		0.1359		
Th (ppm)		0.4472		
Pb (ppm)		0.3111		
$^{232}Th/^{238}U$		3.40		
$^{238}U/^{204}Pb$		250		
$^{206}Pb/^{204}Pb^{1}$	179.7	231.3		
$^{207}Pb/^{204}Pb^{1}$	106.9	134.0		
$^{208}Pb/^{204}Pb^{1}$	179.5	---		
$^{206}Pb/^{204}Pb^{2}$	236.4	260.1		
$^{207}Pb/^{204}Pb^{2}$	139.2	150.0		
$^{208}Pb/^{204}Pb^{2}$	229.0	---		
$^{207}Pb/^{206}Pb^{2}$	0.5888	0.5767		
$^{208}Pb/^{206}Pb^{2}$	0.9725	---		
$^{206}Pb/^{238}U^{3}$			1.001	1.004
$^{207}Pb/^{235}U^{3}$			78.30	77.09
$^{207}Pb/^{206}Pb^{3}$			0.5675	0.5572
$^{208}Pb/^{232}Th^{3}$			0.2596	---
$^{206}Pb/^{238}U^{4}$			4,512	4,523
$^{207}Pb/^{235}U^{4}$			4,499	4,483
$^{207}Pb/^{206}Pb^{4}$			4,492	4,464
$^{208}Pb/^{232}Th^{4}$			4,792	---

1 = Observed; 2 = Corrected for Blank; 3 = Corrected for Blank and Primordial Pb;
4 = Single-Stage Ages in Ma.

Table 3: Isotopic data from 75055.

Reference	1	2	2	3	4	5
K (ppm)	602					
Rb (ppm)	0.796	0.685	0.482			
Sr (ppm)	188	201	180			
$^{87}Rb/^{86}Sr$	0.0099	0.0099 ± 3	0.0077 ± 3			
$^{87}Sr/^{86}Sr$	0.69969 ± 5	0.69971 ± 4	0.69965 ± 4			
I(Sr)				0.69919 ± 3		
AGE (Ga)				3.77 ± 0.06		
T_{BABI}	4.98 + 0.35[a]	4.3 + 0.4[b]	5.0 ± 0.5[b]			
T_{LUNI}		4.8 + 0.4[c]	5.6 ± 0.5[c]			
U (ng)					43	
$^{238}U/^{235}U$					137.83 ± 0.36	
$\delta^{235}U$ (‰)					+0.36 ± 2.59	
Sm (ppm)						10.576
Nd (ppm)						25.188
$^{147}Sm/^{144}Nd$						0.2538 ± 1
$^{143}Nd/^{144}Nd_O$						0.514432 ± 50
εNd_O						+35.0 ± 1.0
$^{143}Nd/^{144}Nd_I$						0.50882 ± 5
εNd_I						+8.0 ± 1.0
Lu (ppm)						1.661
Hf (ppm)						9.610
$^{176}Lu/^{177}Hf$						0.02450 ± 2
$^{176}Hf/^{177}Hf_O$						0.282419 ± 46
εHf_O						-15.7 ± 1.6
$^{176}Hf/^{177}Hf_I$						0.28060 ± 5
εHf_I						+8.0 ± 1.8

1 = Tera and Wasserburg (1974); 2 = Nyquist et al. (1975); 3 = Murthy and Coscio (1976); 4 = Chen and Wasserburg (1980); 5 = Unruh et al. (1984).

a = I(Sr) = 0.69898 and $\lambda^{87}Rb$ = 0.0139 Ga^{-1}; b = I(Sr) = 0.69910 (BABI + JSC bias); c = I(Sr) 0.69903 (Apollo 16 anorthosites for T = 4.6 Ga).

Table 4: Ar-Ar data from 75055.

Reference Sample	1 Plagioclase	1 K-rich	1 Whole-Rock	2	3	3
^{40}Ar x 10^{-8} cc STP/g	2303	20200	3486			
$^{36}Ar/^{40}Ar$	473+3	81+2	438+5			
$^{37}Ar/^{40}Ar$	4300+12	3195+35	1935+45			
$^{38}Ar/^{40}Ar$	647+3	70+1	397+8			
$^{39}Ar/^{40}Ar$	342+2	364+1	368+1			
Age (Ga)			3.78+0.04			
$^{39}Ar/^{40}Ar$ Age (Ga)				3.82+0.05		
$Ca/^{38}Ar$ Age (Ga)				85+10		
K (ppm)				480+29		
Ca%				8.0+0.3		
$^{36}Ar/^{38}Ar$					1.09	1.87
$^{38}Ar/^{37}Ar$					0.0076	0.0094
$^{39}Ar/^{37}Ar$					0.0115	0.0107
$^{40}Ar/^{39}Ar$					110.6	114.0
^{39}Ar x 10^{-8} cc STP/g					22.8	19.5
Apparent Age (Ga)					3.55	3.59

1 = Huneke et al. (1980); 2 = Kirsten et al. (1973); 3 = Turner et al. (1973).

Table 5: Stable Isotopic Ratios from 75055.

Reference Sample	1	2	3 Chromite	3 Plag	3 Px	3 Ilmenite	4 Plag	4 Px	5 Plag	5 Px
$\delta^{18}O$ (‰)			+6.86	+5.67	+5.47	+3.98	+6.07±0.05	+5.59		
$\delta^{30}Si$ (‰)							-0.14±0.11	-0.37±0.1		
$\delta^{34}S_{CDT}$ (‰)		-0.2								
$\delta^{40}Ca$ (‰)									-0.6±0.2	-0.1±0.1
$^{47}Ti/^{48}Ti$	0.3±2.0									
$^{49}Ti/^{48}Ti$	-2.9±2.0									
$^{50}Ti/^{48}Ti$	-1.6±2.0									

1 = Niederer et al. (1980); 2 = Gibson et al. (1975); 3 = Mayeda et al. (1975); 4 = Taylor and Epstein (1973); 5 = Russell et al. (1975).

Table 6: Cosmogenic Radionuclide.
Data from LSPET (1973) and Rancitelli et al. (1974).

Sample No.		,2
Th (ppm)		0.40 ± 0.02
U 0.10 ± 0.01		
K (%)0.065 ± 0.005		
^{26}Al (dpm/kg)		69 ± 7
^{22}Na	"	85 ± 5
^{54}Mn	"	139 ± 15
^{56}Co	"	210 ± 15
^{46}Sc	"	62 ± 7
^{60}Co	"	4 ± 2
^{7}Be	"	140 ± 25
^{51}Cr	"	75 ± 40
^{57}Co	"	7.4 ± 1.7
^{58}Co	"	7.0 ± 3.5

Table 7: Magnetic Data from 75055.
Data from Pearce et al. (1974).

Sample No.	75055,6
J_s (emu/g)	0.155
X_p (emu/g Oe) x 10^6	33.3
X_o (emu/g Oe) x 10^4	2.3
J_{rs}/J_s	0.003
H_c (Oe)	20
H_{rc} (Oe)	---
Equiv. wt% Fe^o	0.07
Equiv. wt% Fe^{2+}	15.3
Fe^o/Fe^{2+}	0.005