10047

Ilmenite Basalt (low K)

138 grams

Figure 1: Photo of 10047 showing interior basaltic texture. NASA S75-26513. Cube is 1 cm.

Introduction

Lunar sample 10047 is a low-K, ilmenite basalt with a relatively coarse texture (figure 1). It has been extensively studied. The crystallization age of 10047 is 3.71 b.y. and it has a cosmic ray exposure age of 84 m.y.

Petrography

Schmitt et al. (1970) termed 10047 as a "coarse-grained, vuggy, ophitic, cristobalite basalt." James and Jackson (1970) termed it a "medium grained ophitic basalt". Beaty and Albee (1978) note that 10044, 10047 and 10058 "are so similar to one another that it seems quite likely that these rocks are fragments of a larger block." Smith et al. (1970) and others mistakenly refer to this rock as a "micrograbbro", but it has extensive mineral zoning.

Lovering and Ware (1970) and Beaty and Albee (1978) give a complete description of the mineral chemistry of 10047. Dence et al. (1970) reported pyroxene and plagioclase up to 2 mm in size. The residual mesostasis between the major minerals contains residual glass with fine-grained intergrowth of several minor phases.

Mineralogy

Olivine: Lovering and Ware (1970) reported fayalite in an "intergrowth region" and give an analysis. Beaty and Albee (1978) also give an analysis ($Fa_{99.5}$).

Figure 2: Photomicrograph of thin section of 10047. NASA S69-54011. Scale unknown (about 1 cm).

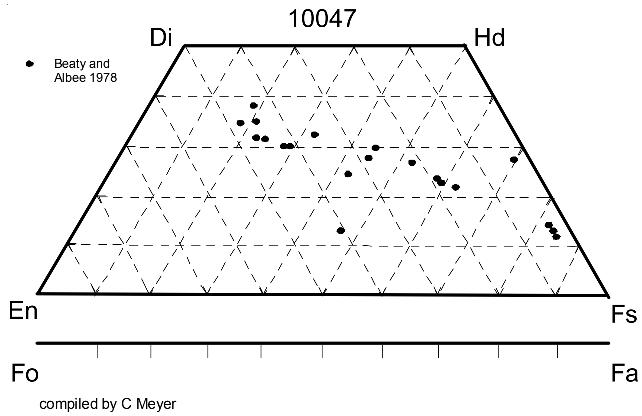

Figure 3: Pyroxene composition of 10047 (data from Beaty and Albee 1978).

Pyroxene: Lovering and Ware (1970) and Beaty and Albee (1978) determined the composition of pyroxene in 10047 (figure 3). Ross et al. (1970) and Essene et al. (1970) determined the abundance and zoning in trace elements (Cr, Mn, Ti and Al) in pyroxene from 10047. They found the cores of the large pyroxenes were highly aluminous with coupled substitution by Ti etc.

Pyroxferroite: Frondel et al. (1970) and Chao et al. (1970) give the optical, chemical and crystallographic data for pyroxferroite in 10047. Mason et al. (1970) give the composition as $Wo_{28}En_4Fs_{78}$. Burnham (1971) determined the crystal structure.

Mineralogical Mode for 10047

	James and Jackson 70	Beaty and Albee 1978	Lovering and Ware 1970
Olivine			
Pyroxene	44.8	46.53	45
Plagioclase	37.8	34.91	30
Ilmenite	10.1	11.2	17
mesostasis	1.9	0.1	
silica	4.5	6.22	
troilite	0.5	0.43	1
phosphate	0.1	0.36	

Plagioclase: Lovering and Ware report plagioclase cores with An_{90} and rims An_{75} with elevated K_2O. Essene et al. (1970) determined zoning from $An_{90}Ab_{9.8}Or_{0.2}$ to $An_{75}Ab_{21}Or_4$. Stewart et al. (1970) determined crystal structure and cell size.

Ilmenite: Beaty and Albee, Lovering and Ware determined the composition of ilmenite, while Stewart et al. (1970) determined cell size. Ilmenite in 10047 has abundant silicate melt inclusions (Roedder and Weiblen).

Ulvospinel: Smith et al. (1970) report that small subhedra of ulvospinel are found intergrown with ilmenite in the finely intergrown residuum.

Troilite: Lovering and Ware determined the composition of troilite (Fe:S = 1.0087). It contains blebs of Ni-free iron metal.

Cristobalite: Lovering and Ware determined the composition of silica and Dence et al. (1970) determined the cell dimensions.

K-rich Glass: Lovering and Ware (1970) and Beaty and Albee (1978) reported the composition of the residual glass (K_2O = 7-10 %). Dence et al. (1970) and Beaty and Albee found needles of Ba,K feldspar in the glass (6.7% Ba).

Tranquillityite: Dence et al. (1970) and others reported the analysis of a new Fe, Ti, Zr- silicate mineral in 10047. Lovering et al. (1971) defined it as “tranquillityite”, providing a full analysis (table 2). Hinthorne et al. (1979) and Rasmussen

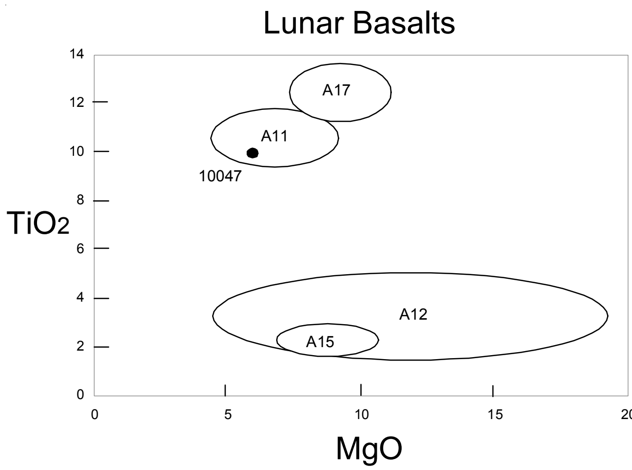

Figure 4: Composition of 10047 compared with that of other Apollo lunar samples.

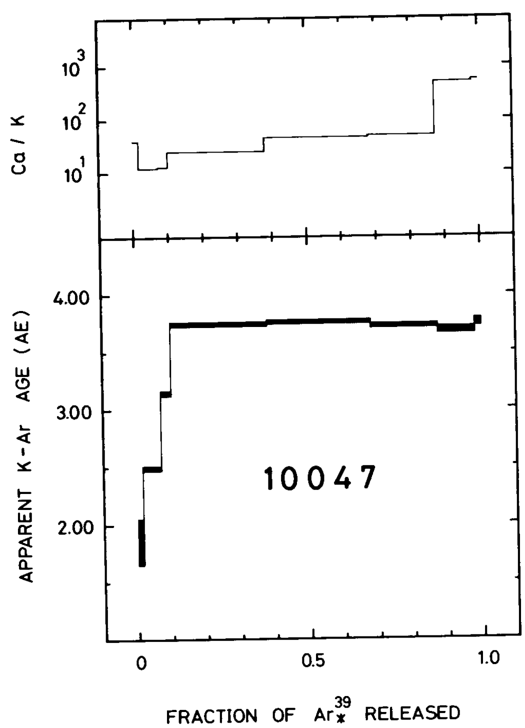

Figure 6: Argon plateau by Stettler et al. (1974).

et al. (2008) were able to date it by Pb/Pb ion probe techniques.

Zirconolite: Rasmussen et al. (2008)

Summary of Age Data for 10047

	Ar/Ar plateau	Pb/Pb
Stettler et al. 1974	3.74 ± 0.03 b.y.	
Guggisberg et al. 1979	3.71 ± 0.03	
Hinthorne et al. 1979		3.75 ± 0.05
Rassmussen et al. 2008		3.7095 ± 0.0042

Note: Not corrected for new decay constants.

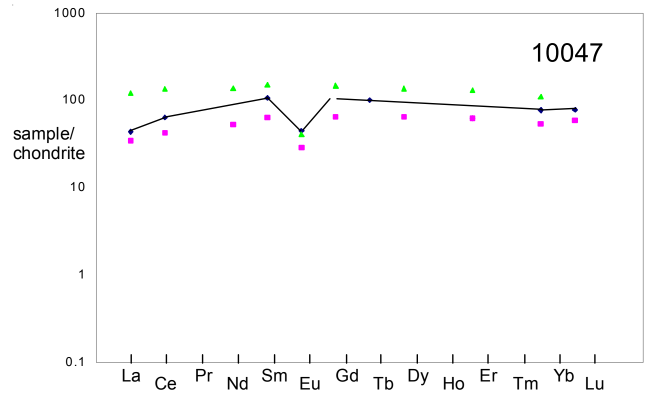

Figure 5: Normalized rare-earth-element composition for low-K basalt 10047 (the line) compared with that of low-K basalt 10020 and high-K basalt 10049 (the dots) (data from Wiesmann et al. 1975).

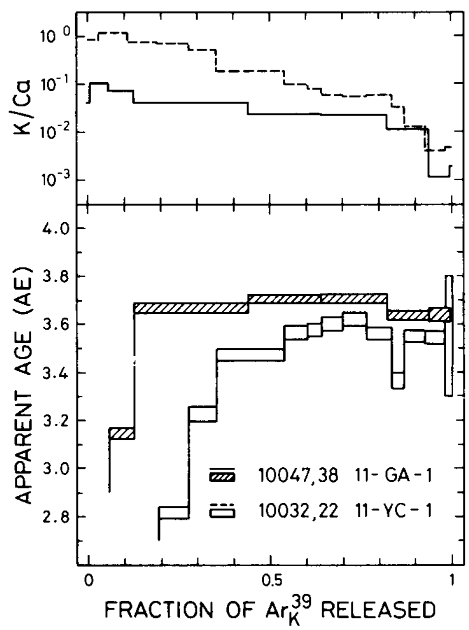

Figure 7: Argon plateau age by Guggisberg et al. (1979).

Baddeleyite: Rasmussen et al. (2008)

Phosphate: Beaty and Albee (1978) give an analysis of apatite. Lovering et al. (1974) reported the composition of a 15 micron grain of rare earth element phosphate (monazite?) they found included in heddenbergite in the mesostasis of 10047.

Table 1a. Chemical composition of 10047.

reference	Compston70		Rose70		Goles70		Rhodes80		Wakita70			Ganapathy70		Anders71	
weight									351 mg	563 mg					
SiO2 %	42.16	(a)	41.3	(b)	43	(c)	41.6	(a)	44.5	46	(c)				
TiO2	9.43	(a)	10.2	(b)	10	(c)	10.02	(a)	10.8	9.5	(c)				
Al2O3	9.89	(a)	9.8	(b)	10.6	(c)	10.27	(a)	7.4	11.1	(c)				
FeO	19.11	(a)	19	(b)	19.4	(c)	19.09	(a)	21.9	19.8	(c)				
MnO	0.28	(a)	0.29	(b)	0.27	(c)	0.3	(a)	0.35	0.29	(c)				
MgO	5.67	(a)	6.1	(b)	5.8	(c)	5.99	(a)	6.8	4.8	(c)				
CaO	12.15	(a)	12.2	(b)	12.2	(c)	12.16	(a)	13.6	12.6	(c)				
Na2O	0.45		0.65	(b)	0.47	(c)	0.44	(c)	0.35	0.49	(c)				
K2O	0.11	(a)	0.11	(b)			0.1	(a)	0.082	0.06	(c)				
P2O5	0.11	(a)					0.11	(a)							
S %	0.18	(a)													
sum															
Sc ppm					92	(c)	92	(c)	120	90	(c)				
V	13	(a)			63	(c)			73	57	(c)				
Cr	1220	(a)	1505	(b)	1250	(c)	1480	(c)	1810	1380	(c)				
Co	16	(a)			12.2	(c)	11.3	(c)	15	19	(c)	14.4	(d)	12	(d)
Ni	<20	(a)													
Cu	16	(a)										13.3	(d)		
Zn	13	(a)										5.76	(d)	1.8	(d)
Ga	4	(a)					8.9	(a)				5.35	(d)		
Ge ppb															
As															
Se														0.25	(d)
Rb	1.11	(a)					1.3	(a)				1.25	(d)	1.54	(d)
Sr	209	(a)					219	(a)							
Y	134	(a)					128	(a)							
Zr	334	(a)							70	800	(c)				
Nb	23	(a)													
Mo															
Ru															
Rh															
Pd ppb												2	(d)		
Ag ppb												25	(d)	1.89	(d)
Cd ppb												255	(d)		
In ppb												109	(d)	2.8	(d)
Sn ppb															
Sb ppb															
Te ppb												13	(d)		
Cs ppm												0.045	(d)	0.06	(d)
Ba	88	(a)							250	290	(c)				
La	20	(a)			11.3	(c)	10.4	(c)	8.5	12.2	(c)				
Ce	48	(a)			46	(c)	39	(c)							
Pr	13	(a)													
Nd	36	(a)													
Sm					18.9	(c)	15.8	(c)	16.1	20.2	(c)				
Eu					2.71	(c)	2.51	(c)	2.2	2.9	(c)				
Gd															
Tb					4.1	(c)	3.7	(c)							
Dy															
Ho					7.9	(c)									
Er															
Tm															
Yb					18.2	(c)	12.6	(c)	18	18	(c)				
Lu					2.88	(c)	1.93	(c)	2.3	2.3	(c)				
Hf					13.2	(c)	11.3	(c)	15	16	(c)				
Ta					2.6	(c)	2.2	(c)							
W ppb															
Re ppb															
Os ppb															
Ir ppb												0.24	(d)	0.005	(d)
Pt ppb															
Au ppb												0.33	(d)	0.029	(d)
Th ppm	0.6	(a)					0.8	(c)	2.4	1.6	(c)				
U ppm					0.16	(c)									

technique: (a) XRF, (b) micro XRF, (c) INAA, (d) RNAA

Table 1b. Chemical composition of 10047.

reference	Essene70	Beaty78		Hurley 70		Silver 70		
weight								
SiO2 %	41.8	42.51	(f)					
TiO2	9.6	9.21	(f)					
Al2O3	10.1	10.54	(f)					
FeO	18.6	19.31	(f)					
MnO	0.24	0.26	(f)					
MgO	5.7	5.51	(f)					
CaO	11.9	11.82	(f)					
Na2O	0.51	0.48	(f)					
K2O	0.08	0.02	(f)					
P2O5		0.13	(f)					
S %		0.22	(f)					
sum								
Sc ppm								
V								
Cr								
Co								
Ni								
Cu								
Zn								
Ga								
Ge ppb								
As								
Se								
Rb				0.93	(e)			
Sr				194	(e)			
Y								
Zr								
Nb								
Mo								
Ru								
Rh								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb								
Sn ppb								
Sb ppb								
Te ppb								
Cs ppm								
Ba								
La								
Ce								
Pr								
Nd								
Sm								
Eu								
Gd								
Tb								
Dy								
Ho								
Er								
Tm								
Yb								
Lu								
Hf								
Ta								
W ppb								
Re ppb								
Os ppb								
Ir ppb								
Pt ppb								
Au ppb								
Th ppm						0.849	0.6	(e)
U ppm						0.246	0.203	(e)

technique: (a) XRF, (b) micro XRF, (c) INAA, (d) RNAA, (e) IDMS, (f) elec. Probe

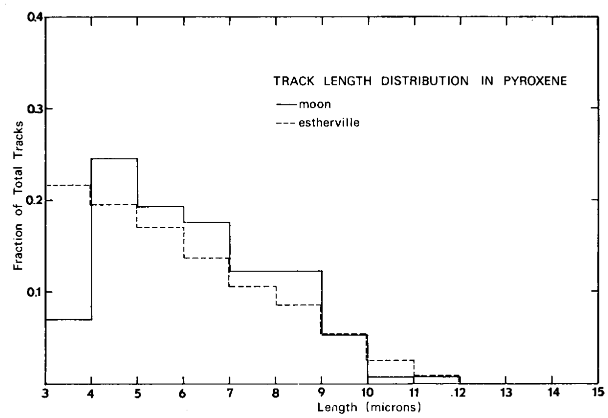

Figure 8: Track length in pyroxene from 10047 compared with Esterville meteorite (Crozaz et al. 1970).

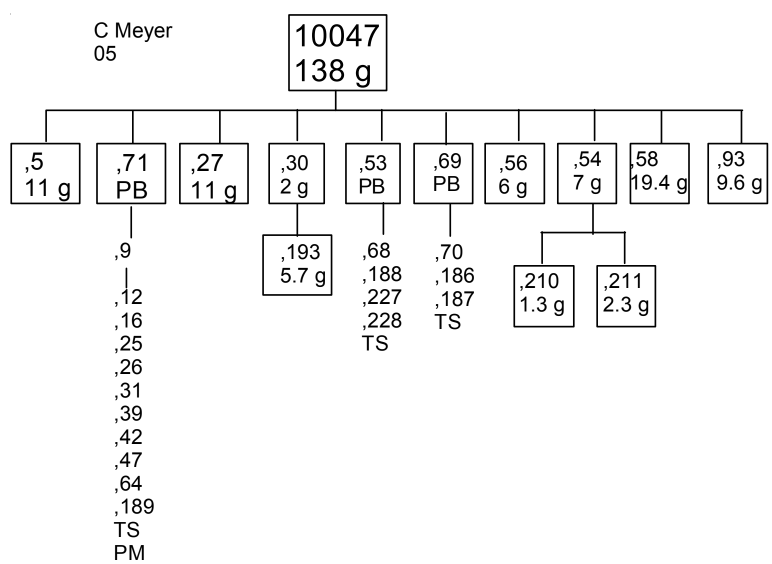

Table 2. Chemical composition of Tranquillityite and Zirconolite.

reference	Lovering et al 71							Rasmussen08
weight							tran.	zirconolite
SiO2 %	13.66	13.77	13.98	13.75	13.84	13.65	17	14.97	0.08
TiO2	19.75	20.66	20.01	20.28	19.95	19.8	18	20.43	28.51
Al2O3	0.87	0.9	0.83	0.85	0.76	0.92	0.5	1.13	0.41
FeO	43	42.37	42.9	42.34	42.68	42.5	41	42.71	9.7
MnO	0.36	0.3	0.34	0.3	0.31	0.5		0.34	
MgO	0.03		0.18	0.11	0.04			0.08	
CaO	1.04	1.11	1.17	1.2	1.15	1.2	1	1.1	3.18
Na2O	0.02							0	
K2O	0.03	0.04	0.04	0.05	0.02		0.5	0	
ZrO2	16.96	16.79	16.35	16.87	17.81	16.9	16	14.17	30.61
HfO2	0.05	0.06	0.04	0.05	0.05	0.49		0.29	0.6
Y2O3	2.5	2.73	2.61	2.58	2.36	3.5	5	2.5	9.05
Nb2O3								0.74	3.9

Chemistry

Numerous labs analyzed 10047 in 1970 (table 1, figure 4 and 5). Rhodes and Blanchard (1980) reanalyzed the sample with the same result. Essene et al. (1970) and Beaty and Albee (1978) determined the composition of thin sections by measuring the mode and combining with average mineral compositions (table 1b).

Ganapathy et al. (1970) analyzed a powder prepared from 10047, but when Anders et al. (1971) analyzed a chip instead they obtained much lower values for trace elements. Reed and Jonvanovic (1970) reported Li, F, Cl, Br and I.

Radiogenic age dating

Stettler et al. (1974) and Guggisberg et al. (1979) determined crystallization ages of 3.74 and 3.71 b.y. by the Ar/Ar plateau technique (figure 6 and 7). Small grains of zirconolite and tranquillityite have been precisely dated by Rassmussen et al. (2008).

Cosmogenic isotopes and exposure ages

Marti et al. (1970), Arvidson et al. (1975) and Eugster et al. (1984) reported ^{81}Kr exposure ages of 86 m.y., 84 m.y. (determined by Schwaller 1971) and 87.4 m.y., respectively. Stettler et al. (1974) and Guggisberg et al. (1979) determined an ^{37}Ar/^{38}Ar cosmic ray exposure age of 70 and 78 m.y. respectively. Eberhardt et al. (1970) calculated 110 m.y. from data by Funkhouser et al. (1970).

Other Studies

Oxygen isotopes were reported for mineral separates of 10047 by Onuma et al. (1970).

Rare gas abundance and isotopic ratios were reported by Eugster et al. (1984), Funkhouser et al. (1970) and Bogard et al. (1971).

Crozaz et al. (1970) studied the fossil comic ray track density as a function of depth in plagioclase and pyroxene crystals from 10047 (figure 8) and determined an exposure age of 16 m.y.

Processing

Apollo 11 samples were originally described and cataloged in 1969 and then "re-cataloged" by Kramer et al. in 1977.

List of Photo #s for 10047

S69-53977 B&W TS
S69-53980
S69-54011 – 12
S69-54044
S69-54048
S69-54064
S69-59269
S69-59277
S69-59282
S70-48962 – 3 color TS
S70-49212 – 3
S70-50541 – 2
S76-26298 – 9 B&W TS
S72-32082
S75-25083 – 87 Processing
S75-26511 – 14
S76-25537
S76-25542
S82-27857

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