10044

Ilmenite Basalt (low K)

247.5 grams

Figure 1: Photo of 10044,54. Cube is 1 cm. NASA S75-31692.

Introduction

Lunar sample 10044 was collected in the area between the LM and the double elongate crater to the southwest of the LM and was returned in ALSRC #1003. It is a low-K variety of ilmenite basalt typical of Apollo 11, although analyses show it has lower Ti that the others. Figure 1 is an enlargement showing the igneous texture of a piece of 10044.

The crystallization age of 10044 has been determined as 3.7 b.y. and the cosmic ray exposure age is ~80 m.y. (age of West Crater?).

Petrography

Schmitt et al. (1970) termed 10044 as a "coarse-grained, vuggy, ophitic, cristobalite basalt" and James and Jackson (1970) termed it a "medium grained ophitic basalt" (figure 2). Bailey et al. (1970) reported that the pyroxene was equant and up to 2 mm, and plagioclase was 1.5 mm in size. Smith et al. (1970) and others have termed 10044 a "microgabbro". Albee and Chodos (1970) and Agrell et al. (1970) also reported petrographic details.

McGee et al. (1977) describe 10044 as "a coarse-grained porphyritic basalt which consists of subhedral to anhedral phenocrysts of pyroxene (1.0 -2.0 mm) set in a subophitic matrix of plagioclase tablets (0.2 x1.0 to 0.4x2.0 mm), anhedral pyroxene grains (0.6-0.8 mm), and ilmenite." Pyroxene is chemically zoned to Fe-rich pyroxferroite at the rims. Ilmenite is present

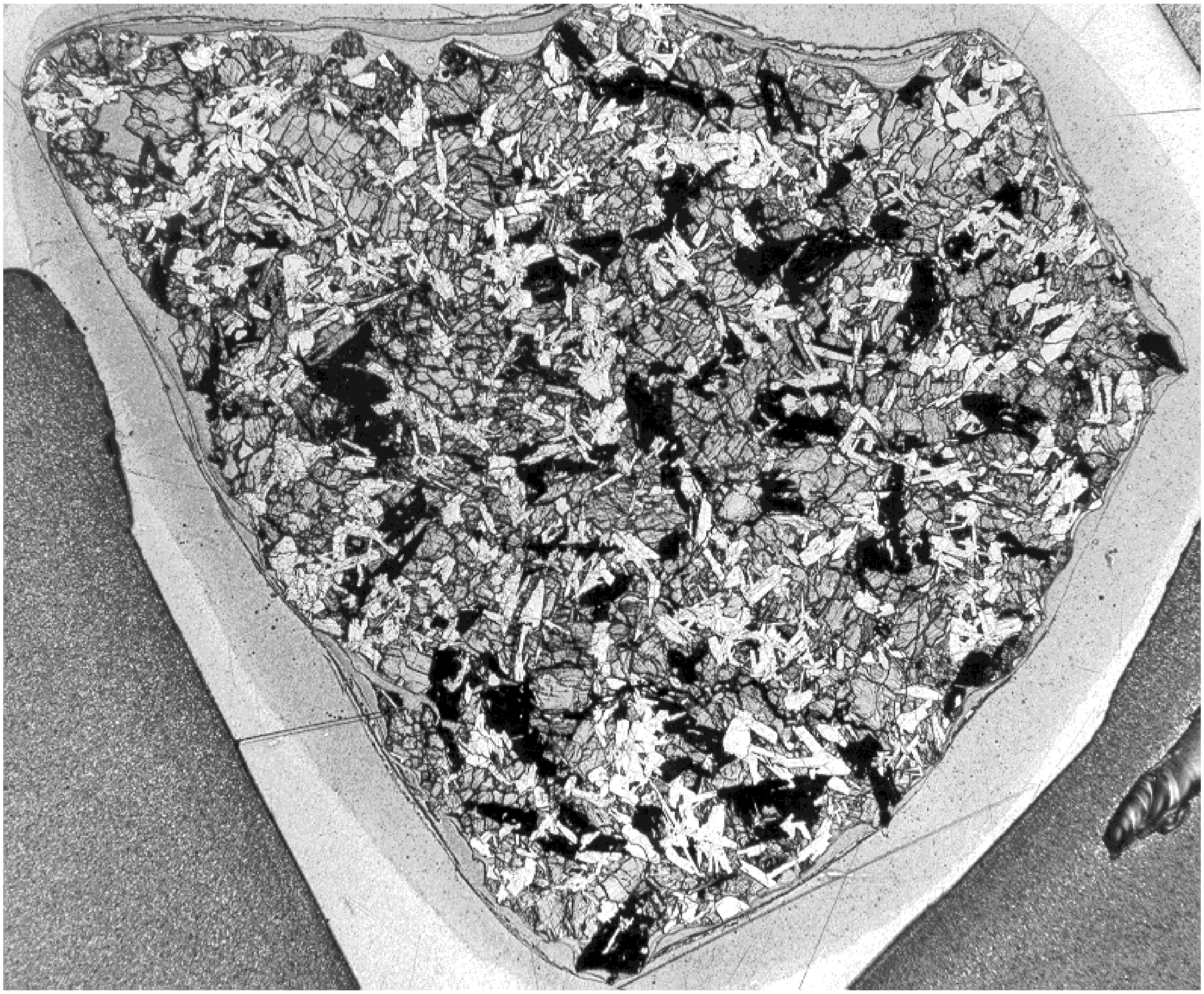


Figure 2: Thin section of 10044 showing coarse basaltic texture. Field of view about 1 cm. NASA S69-59344.

as laths (0.3-0.8 mm) and as irregular-shaped bodies. Interstitial areas are filled with anhedral cristobalite, troilite with metallic iron "blebs", K-rich glass and irregular-shaped vugs up to 0.3 mm (figure 3).

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."

Dymek et al. (1975) also noted the remarkable similarity of 10044 to 75055.

Mineralogy

Olivine: There is essentially no olivine in 10044, but Fuchs (1970) reported a thin grain of fayalite between ilmenite and pyroxferroite.

Mineralogical Mode for 10044

	Beaty and Albee 1978	Bailey et al. 1970		McGee et al. 1977
Olivine	0.1			
Pyroxene	44.8	46.4	47.3	45 - 59
Plagioclase	35	34.1	33.1	33 - 37
Ilmenite	12.6	12.3	14.4	6 - 12
mesostasis				
silica	6.7	6.3	5.2	4 - 6
troilite	0.4			tr.
phosphate	0.1			tr.

Figure 3: Photomicrographs of thin section of 10044 (top is plane polarized light, bottom is with crossed-polarizers). Field of view is 2.5 mm. NASA S70-49983 and 49984.

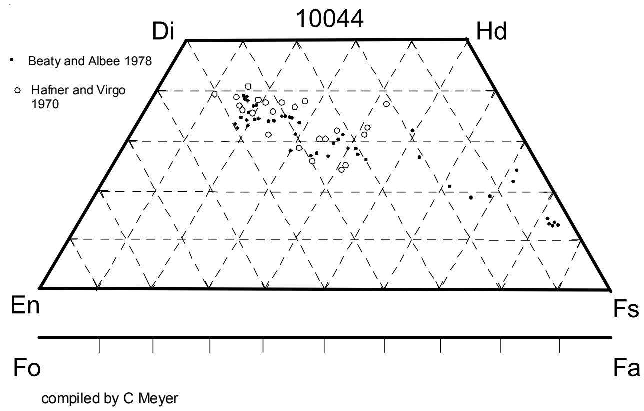


Figure 4: Pyroxene composition of 10044 (replotted from Beaty and Albee 1978).

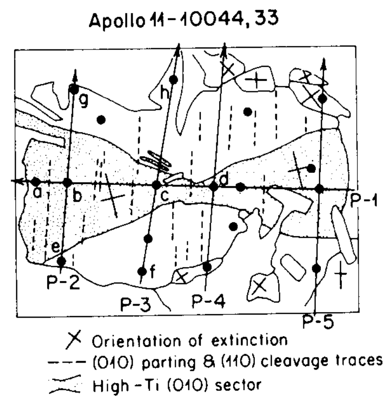


Figure 5: Sketch map of sector-zoned pyroxene in 10044 (from Albee and Chodos 1970).

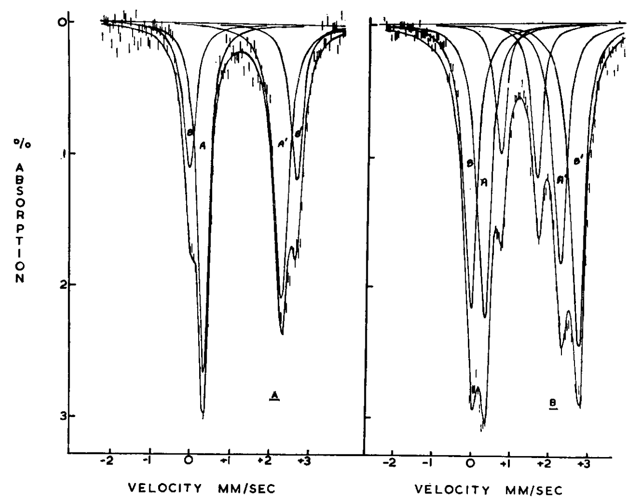


Figure 6: Mossbauer spectra at 80 deg K for pyroxene fractions of 10044 (from Gay et al. 1970).

Pyroxene: Albee and Chodos (1970), Hafner and Virgo (1970) and Beaty and Albee (1978) reported the composition of pyroxene (figure 4). Albee and Chodos (1970) discovered that the pyroxene in 10044 was chemically zoned in sectors (figure 5). They found that the (010) sector contains about twice as much Ti, Al and Cr as the adjacent (001) sector; the substitution of $^{4+}$Ti for divalent 6-fold coordinated cations is balanced by twice as much $^{3+}$Al replacing 4-flold coordinated $^{4+}$Si. Bailey et al. (1970) reported the cell dimensions for exsolved pyroxene. The exsolution of pyroxene in 10044 was studied by Fernandez-Moran et al. (1970). Hafner and Virgo (1970) and Gay et al. (1970) determined the Mossbaurer spectra (figure 6) and determined the site distribution of cations in pyroxene.

Pyroxferroite: Chao et al. (1970) give the optical, chemical and crystallographic data for pyroxferroite.

Plagioclase: Goles et al. (1970) and Philpotts and Schnetzler (1970) determined the trace element content of plagioclase separates for 10044 (*however, see note about sample mix-up*).

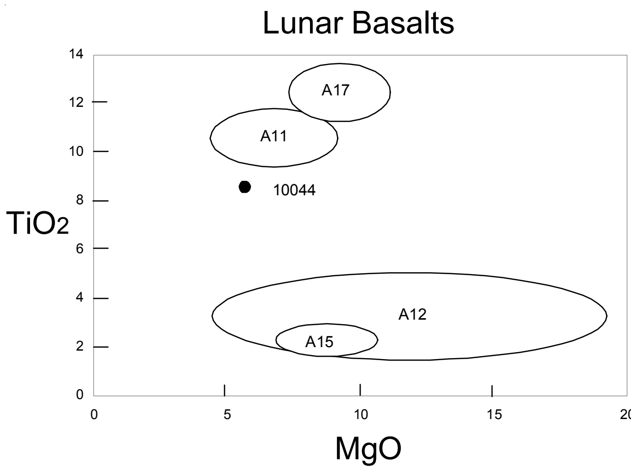


Figure 7: Composition of 10044 compared with that of other Apollo lunar samples.

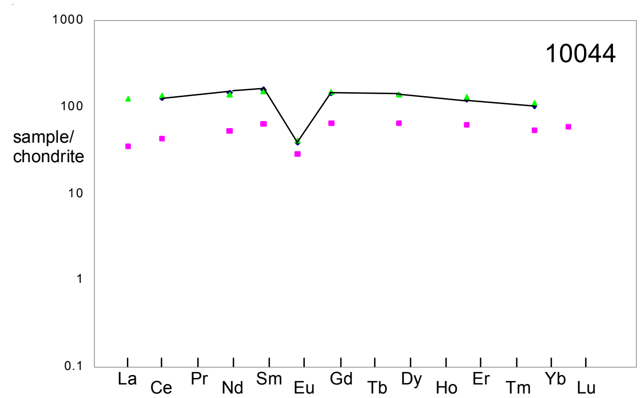


Figure 8: Normalized rare-earth-element composition for high-K basalt 10044 (the line) compared with that of low-K basalt 10020 and high-K basalt 10049 (the dots) (data from Wiesmann et al. 1975).

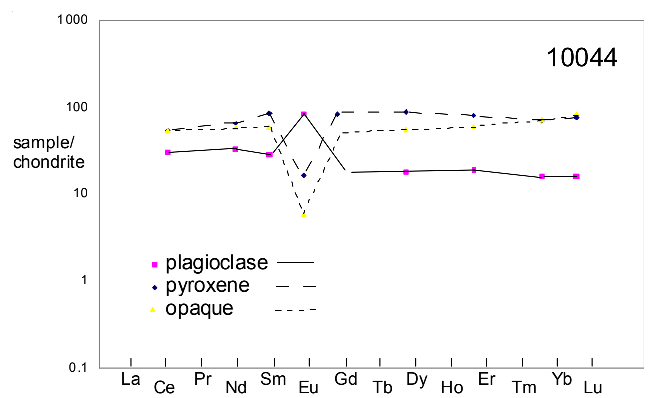


Figure 9: Normalized rare-earth-element diagram for mineral seperates of 10044 (data from Philpotts and Schnetzler 1970).

Ilmenite: Cameron (1970) and Smith et al. (1970) found ilmenite was uniform in composition. Philpotts and Schnetzler (1970) determined the trace element content of ilmenite separate (figure 9), but clearly the ilmenite separate was contaminated by attached mesostasis with high trace element content.

Ulvospinel: Cameron (1970) reported ulvospinel with associated ilmenite and native iron.

Silica: This rock has abundant cristobalite (Beaty and Albee 1978) as well as tridymite (Smith et al. 1970).

Apatite: Albee and Chodos (1970) reported an analysis apatite in 10044. Fuchs (1970) gives analyses with 3.3 wt. % fluorine included.

Y-Zr silicate: Cameron (1970) reported a new mineral with abundant yttrium and zirconium in 10044.

Chemistry

Engel and Engel (1970) and others reported the chemical composition (table 1). Rhodes and Blanchard (1980) and Neal (2001) reanalyzed the sample. Sample 10044 may have lower Ti than the other Apollo 11 basalts (figure 7), but it has similar REE (figure 8). Reed and Jovanovic (1970) determined F, Cl, Br, I, Li and Hg in 10044. Moore et al. (1970) reported 102 ppm C and 98 ppm N *(and termed it breccia)*.

Both Goles et al. (1970) and Philpotts and Schnetzler (1970) analyzed carefully prepared mineral separates (figure 9).

Note: the analysis of 10044 by Philpotts and Schnetzler (1970) may be that of 10024 instead – see page 1473.

Radiogenic age dating

Albee et al. (1970) and Papanastassiou et al. (1970) determined the Rb/Sr isochron age as ~ 3.7 b.y. for 10044 (figure 10). Davis et al. (1971) determined 4.00 ± 0.07 b.y. Turner (1970) and Guggisberg et al. (1979) determined the precise ages as 3.73 ± 0.05 b.y. and 3.71 ± 0.04 b.y. (figure 11) by the Ar/Ar plateau technique Murthy et al. (1970) determined the Sr isotopes.

Cosmogenic isotopes and exposure ages

Hohenberg et al. (1970) determined a ^{81}Kr exposure age of 70 ± 17 m.y. and 72 m.y. by ^{126}Xe (as calculated by Srinivasan 1974). Hintenberger et al. (1971) determined an ^{38}Ar exposure age of 93 m.y. Turner et

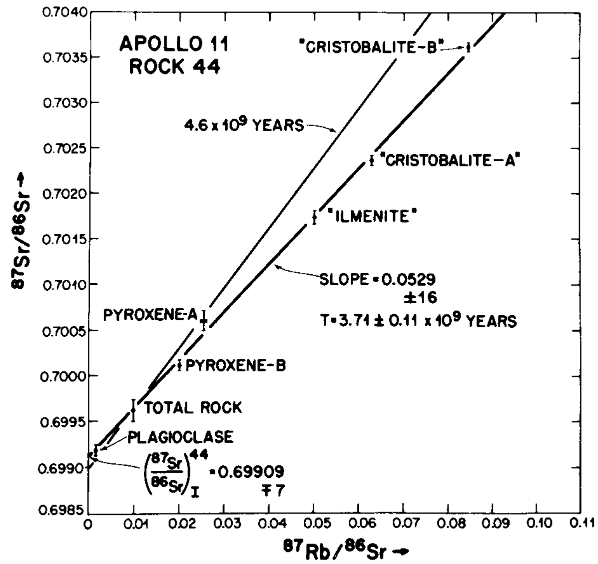


Figure 10: Rb/Sr crystallization age of 10044 (from Papanastassiou and Wasserburg 1970).

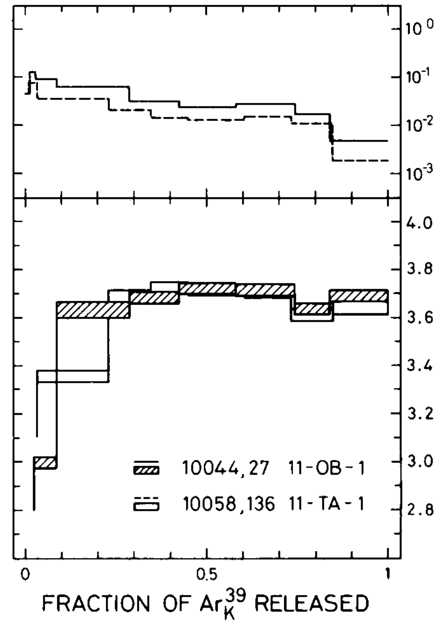


Figure 11: Ar/Ar plateau age of high K and low K Apollo 11 basalts (from Guggisberg et al. 1979).

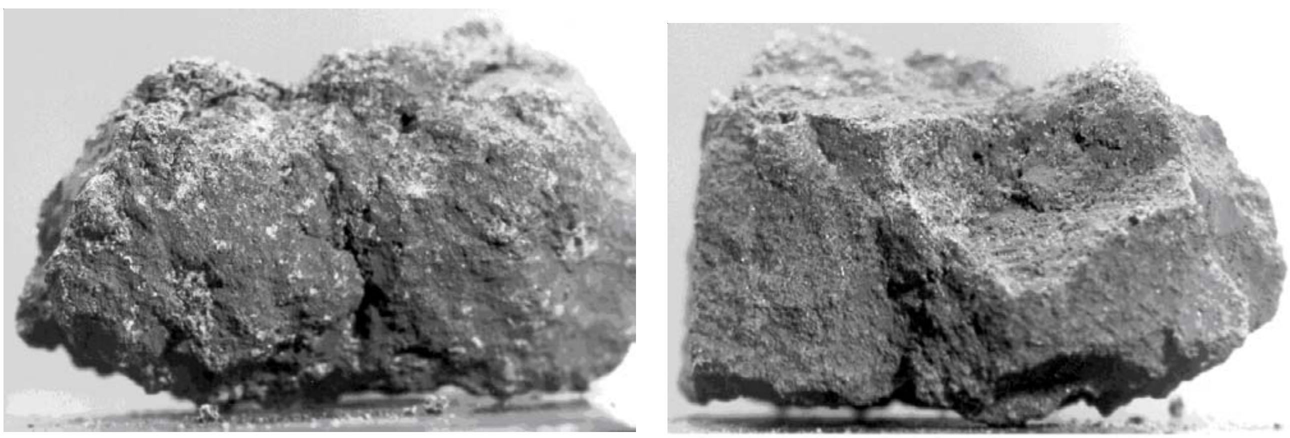
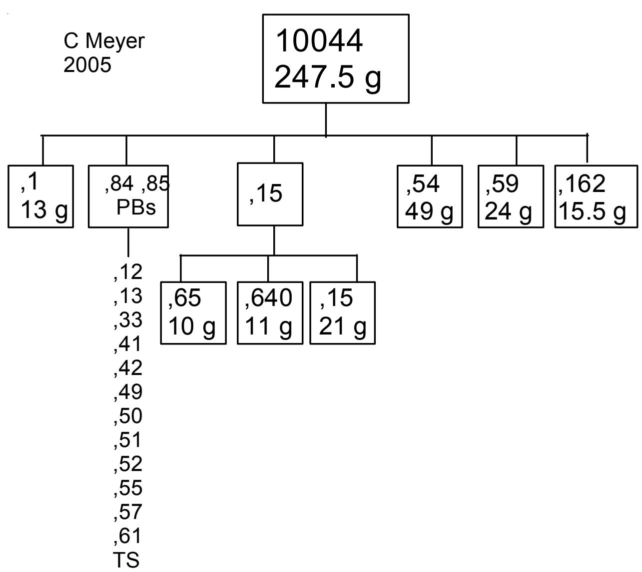


Figure 12: Front and back photos of 10044 from PET. NASA S69-45540 and 541.

al. (1970) and Guggisberg et al. (1979) determined ^{38}Ar exposure ages of 70 m.y. and 82 m.y. respectively.

Other Studies

Oxygen isotopes were reported for mineral separates of 10044 by Onuma et al. (1970) and Taylor and Epstein (1970) (figure 13).



Summary of Age Data for 10044

	Rb/Sr	Ar/Ar plateau
Albee et al. 1970	3.70± 0.07 b.y.	
Papanastassiou et al. 1970	3.71 ± 0.11	
Turner 1970		3.73 ± 0.05
Hintenberger et al. 1970		3.9 whole rock
Davis et al. 1971		4.00 ± 0.07
Guggisberg et al. 1979		3.71 ± 0.04

Disclaimer: Ages not corrected for new decay constants.

Table 1a. Chemical composition of 10044.

							Philpotts69										
reference	Engel70		Tera70		Wanke70		*Philpotts70*		Rhodes80		Wakita70			Kharkar71		Murthy 70	
weight							*286 mg*		1.33 g		849 mg	1.027 g		Turekian 70			
SiO2 %	42.01	(a)			43		***10024***		42.89	(d)	52	41.5	(c)				
TiO2	8.81	(a)			10.5		***?????***		8.47	(d)	9.84	9.5	(c)	8.5	(c)		
Al2O3	11.67	(a)			11.9				10.49	(d)	8.7	11.3	(c)				
FeO	17.98	(a)			17.1				18.46	(d)	20.4	18.5	(c)	17.5	(c)		
MnO	0.24	(a)			0.26				0.28	(d)	0.3	0.26	(c)	0.25	(c)		
MgO	6.25	(a)			6.47				5.98	(d)	6.8	5.8	(c)				
CaO	12.18	(a)	11.7	(b)	7.13				12.4	(d)	11.7	12.5	(c)	12.7	(c)		
Na2O	0.48	(a)	0.45		0.48				0.38	(d)	0.37	0.5	(c)	0.49	(c)		
K2O	0.11	(a)	0.094	(b)	0.1		*0.29*	(b)	0.11	(d)	0.11	0.13	(c)			0.1	(b)
P2O5	0.08	(a)							0.12	(d)							
S %																	
sum																	
Sc ppm	100	(a)			92	(c)			78	(c)	105	84	(c)	100	(c)		
V	66	(a)									50	27	(c)				
Cr	1700	(a)			1300	(c)			1250	(c)	1570	1190	(c)	1420	(c)		
Co	12	(a)			11	(c)			9.5	(c)	15	16	(c)	13	(c)		
Ni	7	(a)															
Cu	9	(a)			4.2	(c)											
Zn																	
Ga					5.1	(c)			8.9	(d)							
Ge ppb																	
As																	
Se																	
Rb			0.886	(b)	5.1	(c)	*5.64*	(b)	1.4	(d)						1.15	(b)
Sr	130	(a)					*167*	(b)	230	(d)						224	(b)
Y	180	(a)							148	(d)							
Zr	400	(a)									1140	420	(c)				
Nb																	
Mo																	
Ru																	
Rh																	
Pd ppb																	
Ag ppb																	
Cd ppb																	
In ppb					3.2	(c)											
Sn ppb																	
Sb ppb																	
Te ppb																	
Cs ppm			0.034	(b)													
Ba	130	(a)	95	(b)	234	(c)	*285*	(b)			260	230	(c)			128	(b)
La					12	(c)			9.9	(c)	8.7	10	(c)	10.5	(c)		
Ce					44	(c)	*76.6*	(b)	38	(c)				37.6	(c)		
Pr																	
Nd					50	(c)	*66.1*	(b)									
Sm					17.9	(c)	*23.4*	(b)	16.3	(c)	17.7	19.7	(c)	11.4	(c)		
Eu					2.69	(c)	*2.21*	(b)	2.28	(c)	2	3.4	(c)	3	(c)		
Gd					24	(c)	*28.6*	(b)									
Tb					4.5	(c)			3.4	(c)				3.9	(c)		
Dy							*33.6*	(b)						27.6	(c)		
Ho																	
Er							*19.3*	(b)									
Tm																	
Yb					15	(c)	*16.6*	(b)	13	(c)	16	16	(c)	10.4	(c)		
Lu					1.96	(c)			1.86	(c)	2.1	2.2	(c)	2.11	(c)		
Hf					12	(c)			11.6	(c)	15	18	(c)	14	(c)		
Ta					2	(c)			2.5	(c)				1.5	(c)		
W ppb					240	(c)											
Re ppb																	
Os ppb																	
Ir ppb																	
Pt ppb																	
Au ppb					1.9	(c)											
Th ppm					0.98	(c)			0.8	(c)	0.6	1.4	(c)				
U ppm					0.28	(c)											

technique: (a) wet and mixed, (b) IDMS, (c) INAA & RNAA (d) XRF

Table 1b. Chemical composition of 10044.

reference	Agrell70		Bailey70		Brown70		Dymek75	Beaty78		Neal2001	
weight											
SiO2 %	42.46	(a)					41.61	42.21	(e)		
TiO2	9.18	(a)					10.05	10.25	(e)		
Al2O3	10.21	(a)					11.1	10.35	(e)		
FeO	17.6	(a)					17.73	17.88	(e)		
MnO	0.28	(a)					0.27	0.27	(e)		
MgO	5.96	(a)					5.58	5.95	(e)		
CaO	12.25	(a)					12.33	12.08	(e)		
Na2O	0.48	(a)					0.51	0.5	(e)		
K2O	0.11	(a)					0.16	0.03	(e)		
P2O5	0.04	(a)					0.07	0.04	(e)		
S %	0.18	(a)					0.06	0.22	(e)		
sum											
Sc ppm										90.9	(f)
V										45.2	(f)
Cr	1430	(a)	1180	(d)			1570	1630	(e)	1168	(f)
Co										14.3	(f)
Ni					4	(d)				1.46	(f)
Cu					4	(d)				37.6	(f)
Zn					3	(d)				64.1	(f)
Ga										4.97	(f)
Ge ppb											
As											
Se											
Rb					1	(d)				1.22	(f)
Sr			250	(d)	206	(d)				215	(f)
Y			215	(d)	147	(d)				159	(f)
Zr			465	(d)	366	(d)				334	(f)
Nb			41	(d)	21	(d)				28.4	(f)
Mo										0.12	(f)
Ru											
Rh											
Pd ppb											
Ag ppb											
Cd ppb											
In ppb											
Sn ppb											
Sb ppb										30	(f)
Te ppb											
Cs ppm										0.02	(f)
Ba					82	(d)				118	(f)
La										11.7	(f)
Ce										42.1	(f)
Pr										7.75	(f)
Nd										43.1	(f)
Sm										17.1	(f)
Eu										2.76	(f)
Gd										24.6	(f)
Tb										4.23	(f)
Dy										27.7	(f)
Ho										5.64	(f)
Er										16	(f)
Tm										2.2	(f)
Yb										14.4	(f)
Lu										1.9	(f)
Hf										11.7	(f)
Ta										1.67	(f)
W ppb										160	(f)
Re ppb											
Os ppb											
Ir ppb											
Pt ppb											
Au ppb											
Th ppm										0.86	(f)
U ppm										0.24	(f)

technique: (a) wet and mixed, (b) IDMS, (c) INAA & RNAA (d) XRF, (e) elec. Probe, (f) ICP-MS

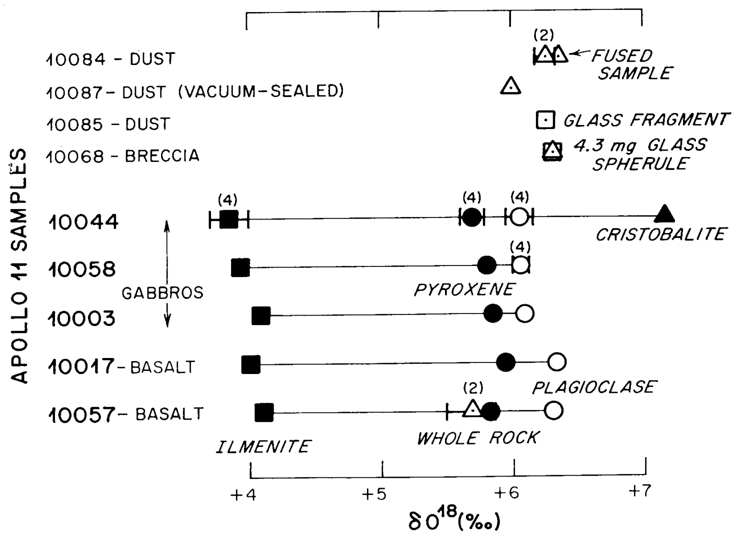


Figure 13: Variation in oxygen isotopes in mineral separates of lunar basalts including 10044 (from Taylor and Epstein 1970).

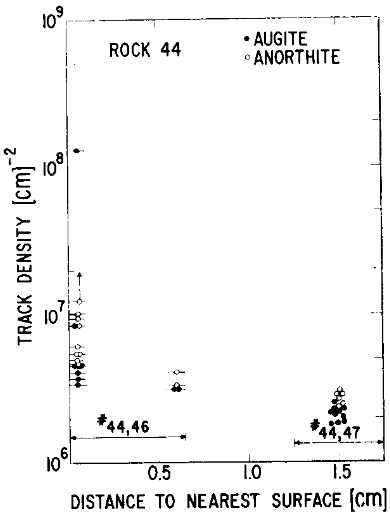


Figure 14: Cosmic ray track density as a function of depth in 10044 (from Fleischer et al. 1970).

Funkhauser et al. (1970), Hohenberg et al. (1970), Hintenberger et al. (1971) and Bogard et al. (1971) reported the abundance and isotopic composition of rare gasses from 10044.

Fleischer et al. (1970) carefully determined the U content and track density in minerals in 10044 (figure 14) and estimated a "proton exposure age" of ~250 m.y.

Processing

Figure 12 shows the external surfaces of 10044. Apollo 11 samples were originally described and cataloged in 1969 and "re-cataloged" by Kramer et al. (1977). There are 18 thin sections.

List of Photo #s for 10044

S69-45538 – 555	B&W mug	
S69-45564 – 581		
S69-59344	TS	B&W
S69-59828	TS	
S70-48950 – 955	TS color	
S70-49981 – 984		
S74-27031	,54 display	
S75-31691 – 692	,54 color	
S76-26295	TS	
S76-25541 – 543	color	
S79-27072 – 074	TS	

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