

10020
Ilmenite Basalt (low K)
425 grams



Figure 1: Photo of 10020 taken in the F-201 during initial processing. Sample is 6 cm across. NASA S-69-45261.

Introduction

10020 is a low-K variety of fine-grained ilmenite basalt. It is rounded and covered with micrometeorite craters (figure 1). It has been formed from a high Ti-, Fe-rich volcanic liquid that cooled rapidly and contains both Mg-rich olivine (as phenocrysts) and cristobalite (in the mesostasis). It originally crystallized at 3.77 b.y. and has been exposed to cosmic radiation for 130 m.y.

Petrography

Schmitt et al. (1970) termed 10020 a “fine-grained, vesicular, vuggy, ophitic olivine basalt.” Beatty and Albee (1978) describe 10020 as “relatively-fine grained (200 microns) with a porphyritic to glomeroporphyritic, intergranular-ophitic basalt”. The overall texture is characterized by an open network of randomly-oriented plagioclase laths and ilmenite platelets (figure 2). Olivine phenocrysts are up to three times as large as the other major minerals and are commonly clumped together in groups, suggesting that olivine may have formed before the magma was extruded, and could be responsible for variations in the compositions of different samples.

Mineralogy

Olivine: Mafic olivine phenocrysts are zoned Fo_{77-59} , and contain ilmenite, chromite and melt inclusions.

Pyroxene: Beatty and Albee (1978) carefully determined the olivine and pyroxene composition in 10020 (figure 3).

Plagioclase: Stewart et al. (1970) and Appleman et al. (1971) determined the cell dimensions of calcic plagioclase (An_{78}).

Ilmenite: Haggerty et al. (1970) carefully studied ilmenite, discussing exsolution of rutile, overgrowth of chromite etc.

Chromite-Ulvospinel: About 10 % of the opaques in 10020 are chromian ulvospinel solid solution, present as euhedral grains up to 200 microns in size (Haggerty et al. 1970).



Figure 2: Photomicrograph of 10020,40 showing apparent xenocrysts in basaltic texture. Field of view 2.5 mm across. NASA S70-49470.

Chemistry

Morrison et al. (1970) and others provide a complete analysis of 10020 (table 1). The rare earth analysis by Wiesmann et al. (1975) is plotted in figure 4.

Radiogenic age dating

Geiss et al. (1977) and Guggisberg et al. (1979) report ages of 3.77 ± 0.04 by Ar/Ar plateau (figure 5) and 3.36 ± 0.02 by K/Ar.

Cosmogenic isotopes and exposure ages

Guggisberg et al. report an $^{37}\text{Ar}/^{38}\text{Ar}$ cosmic ray exposure age of ~130 m.y.

Other Studies

Hurley and Pinson (1970) determined the Sr isotopes. Pepin et al. (1970), Funkhauser et al. (1970) and Bogard et al. (1971) reported the isotopic ratio and abundance

Mineralogical Mode for 10020

	James and Jackson 70	Beaty and Albee 78	Haggerty et al. 70	
Olivine	6.4	4.7	4.8	2.9
Pyroxene	43.3	45.7	54.8	52.9
Plagioclase	30.6	31.4	21.4	28.5
Ilmenite	14.3	12.5	17	13.5
Glass		0.2		
silica	3.6	4.9	0.9	1.7
troilite	0.6	0.47		
phosphate		0.17		

List of Photo #s for 10020

S69-45261 – 279	
S69-45368 – 372	PET mug
S70-18177 – 179	TS
S70-48937 – 941	
S70-49470	
S70-50544 – 546	
S73-17980 – 986	
S76-25459	,16 ,89
S76-25469	,16 ,89
S76-25879 – 880	,3 ,5 ,6
S84-35316 – 323	,57 display

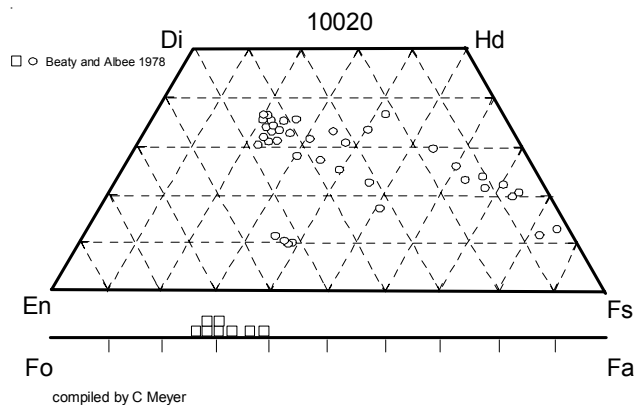


Figure 3: Pyroxene and olivine composition of 10020 (compiled from Beatty and Albee 1978).

of noble gasses in 10020. Oxygen isotopes were reported for mineral separates of 10020 by Onuma et al. (1970).

Herzenberg and Riley (1970) showed a Mossbauer spectra of 10020.

Adams and McCord (1970) compared the spectrum of 10020 with telescopic observations of the moon.

O'Hara et al. (1974) did experiments relative to the phase diagram for 10020. They established that chromite was the first phase to crystallize (1163 deg C), followed by olivine (1160 deg), plagioclase and ilmenite together at 1151 deg and pyroxene (1145 deg).

Note: Apollo 17 samples 75015, 75035 and 75055 from Camelot Crater have nearly identical composition and age with Apollo 11 low-K basalts. And they are thousands of miles apart!

Processing

10020 was one of the rocks in the F-201 at the time of the glove rupture (exposure to Houston air). Apollo 11 samples were originally described and cataloged in 1969 and "re-cataloged" by Kramer et al. (1977).

There are 16 thin sections of 10020.

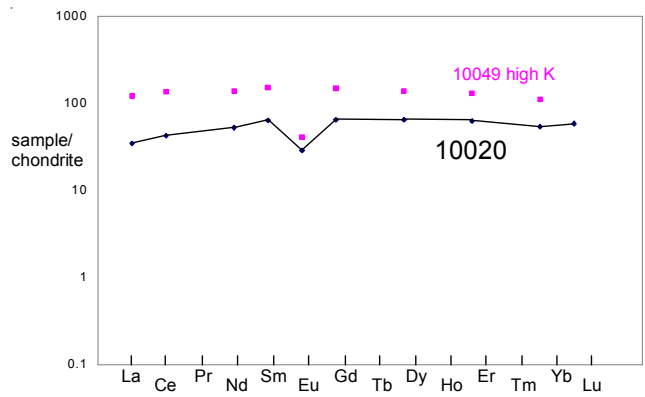


Figure 4: Normalized rare-earth-element composition for low-K basalt 10020 (the line) and high-K basalt 10049 (the dots) (data from Wiesmann et al. 1975).

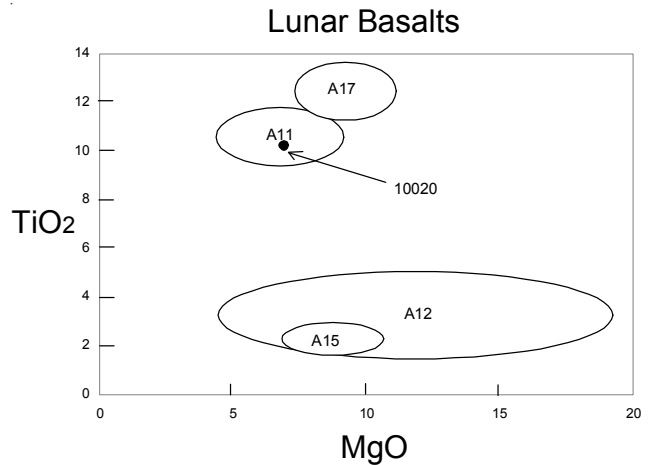


Figure 5: Composition of 10020 compared with that of other Apollo lunar samples.

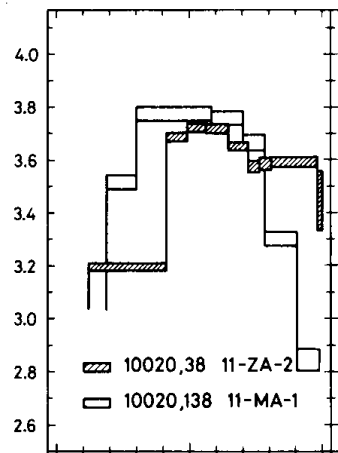


Figure 6: Argon plateaus for plagioclase and clinopyroxene/ilmenite samples of 10020 (from appendix to Guggisberg et al. 1979).

Table 1a. Chemical composition of 10020.

reference weight	LSPET69	Maxwell69		Maxwell69	Gast69	Wiesmann75	Dickinson89	Rhodes80	Haskin70
		GSC	USGS	Abbey		222 mg			
SiO2 %	38	(a) 39.92	39.95	(b) 41	(c)			40.8	(d)
TiO2	12	10.72	10.52	10.28				10.35	(d)
Al2O3	11	10.04	10.19	9.83				10.31	(d)
FeO	18	19.35	19.14	19.03			16.1	(f) 18.79	(d)
MnO	0.32	0.24	0.27	0.27				0.27	(d)
MgO	8	7.81	7.87	7.77				7	(d)
CaO	10	11.24	11.31	11.96			10.1	(f) 11.99	(d)
Na2O	0.59	0.37	0.39	0.37	0.38	0.38		0.38	(f)
K2O	0.064	0.05	0.05	0.05	0.058	(e) 0.058	(e) 0.3	0.07	(d)
P2O5		0.08	0.07	0.07				0.12	(d)
S %		0.15	0.18						
sum									
Sc ppm	110	78					77	(f) 84	(d)
V	20	120							
Cr	2100	3000		2736			1600	(f) 2020	(f)
Co	3						15	(f) 15.3	(f)
Ni									
Cu	4.5								
Zn		26							
Ga	5							7.5	(d)
Ge ppb							3.1	(f)	
As									
Se									
Rb	1.5				0.63	(e)		0.9	(d)
Sr	85	130			150		189	(f) 155	(d)
Y	185	120						87	(d)
Zr	980	210					266	(f)	
Nb									
Mo									
Ru									
Rh									
Pd ppb									
Ag ppb									
Cd ppb									
In ppb									
Sn ppb									
Sb ppb									
Te ppb									
Cs ppm									
Ba	50	67			77.1	77.1	75	(f)	
La					8.11	8.11	7.2	(f) 7.9	(f) 8.4
Ce					25.8	25.8	25	(f) 27	(f) 25.6
Pr									
Nd					23.9	23.9	23	(f)	31
Sm					9.47	9.47	8.5	(f) 9.6	(f) 9.94
Eu					1.6	1.6	1.5	(f) 1.58	(f) 1.75
Gd					12.8	12.8			16
Tb							2.3	(f) 2.5	(f) 2.59
Dy					15.8	15.8			17.8
Ho									
Er					10	10			9
Tm							1.6	(f)	
Yb	2.5				9.87	8.78	8.2	(f) 8.8	(f) 9.8
Lu					1.43	1.43	1.3	(f) 1.36	(f) 1.41
Hf							6.8	(f) 7.6	(f)
Ta							1.3	(f) 1.8	(f)
W ppb									
Re ppb									
Os ppb									
Ir ppb									
Pt ppb									
Au ppb									
Th ppm								0.7	(f)
U ppm									

technique: (a) OES, (b) mixed, (c) AA, (d) XRF, (e) IDMS, (f) INAA, (g) RNAA

Table 1b. Chemical composition of 10020.

reference weight	Ganapathy	Kharkar71	Duncan76	Morrison 70	Beaty 78	Hurley 70	Tatsumoto70
SiO2 %			39.5	(d) 41.5	(h) 40.47	(i)	
TiO2		9.7	(f) 10.62	(d) 10.2	(h) 10.61	(i)	
Al2O3			9.57	(d) 11.15	(h) 9.73	(i)	
FeO		17.6	(f) 19.15	(d) 18.91	(h) 18.29	(i)	
MnO		0.25	(f) 0.263	(d) 0.26	(h) 0.25	(i)	
MgO			8.12	(d) 8.29	(h) 7.97	(i)	
CaO		12.2	(f) 11.4	(d) 14.4	(h) 12.04	(i)	
Na2O		0.36	(f) 0.41	(d) 0.38	(h) 0.37	(i)	
K2O			0.034	(d) 0.063	(h) 0.04	(i)	
P2O5			0.131	(d) 0.16	(h) 0.07	(i)	
S %			0.176	(d)	0.24	(i)	
sum							
Sc ppm		91	(f)	85	(h)		
V			81	(d) 59	(h)		
Cr		2350	(f) 2709	(d) 2200	(h)		
Co	5.65	(g) 18	(f) 18	(d) 20	(h)		
Ni			<2	(d)			
Cu	6.57	(g)		3.7	(h)		
Zn	1.29	(g)		2.1	(h)		
Ga	1.9	(g)		3.5	(h)		
Ge ppb							
As				0.03	(h)		
Se				0.4	(h)		
Rb	0.74	(g)	1.7	(d) 2.8	(h)	0.74	(e)
Sr			142	(d) 170	(h)	152	(e)
Y			84	(d) 130	(h)		
Zr			224	(d) 360	(h)		
Nb			17.6	(d) 36	(h)		
Mo				0.4	(h)		
Ru							
Rh							
Pd ppb	1.5	(g)					
Ag ppb	2.27	(g)		100	(h)		
Cd ppb	6.37	(g)					
In ppb	14.6	(g)					
Sn ppb							
Sb ppb				10	(h)		
Te ppb	13	(g)					
Cs ppm	0.03	(g)		0.2	(h)		
Ba			89	(d) 96	(h)		
La		6.6	(f)	11	(h)		
Ce		25	(f)	34	(h)		
Pr				8.7	(h)		
Nd				40	(h)		
Sm		9.5	(f)	14	(h)		
Eu		1.4	(f)	1.6	(h)		
Gd				17	(h)		
Tb		2.6	(f)	3.5	(h)		
Dy		17.3	(f)	30	(h)		
Ho				7	(h)		
Er				19	(h)		
Tm				1.2	(h)		
Yb		6.5	(f)	15	(h)		
Lu		1.45	(f)	1.5	(h)		
Hf		8.2	(f)	11	(h)		
Ta		1.1	(f)	1.3	(h)		
W ppb				130	(h)		
Re ppb							
Os ppb							
Ir ppb	0.027	(g)					
Pt ppb							
Au ppb	0.075	(g)					
Th ppm				1.5	(h)	0.694	0.662 (e)
U ppm				0.14	(h)	0.202	0.182 (e)

technique: (a) OES, (b) mixed, (c) AA, (d) XRF, (e) IDMS, (f) INAA, (g) RNAA, (h) various, (i) elec. Probe



Figure 7: Photo of 10020,57 showing micrometeorite craters (zap pits). Sample is 6 cm long. NASA S84-35315.

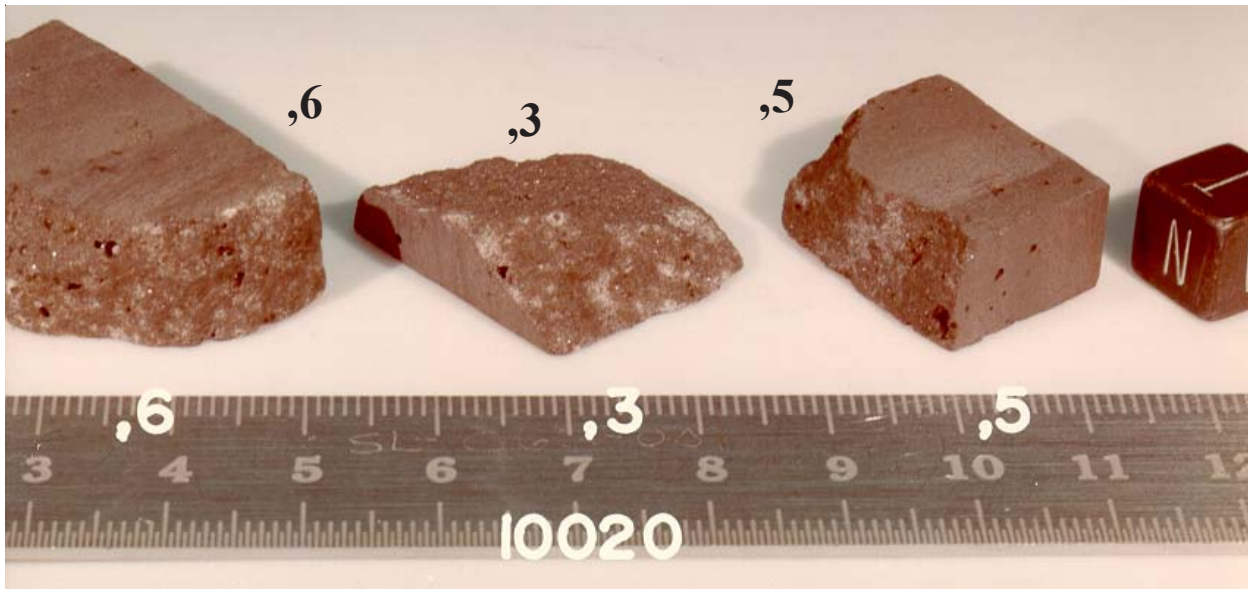


Figure 8: Pieces sawn from 10020. Cube is 1 cm. NASA S76-25879.



Figure 9: Pieces cut from 10020. NASA S76-25459. Scale in mm.

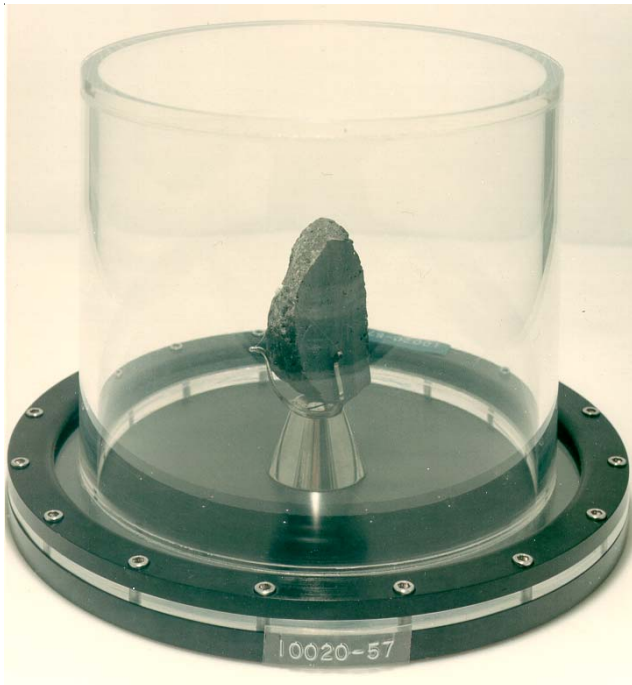
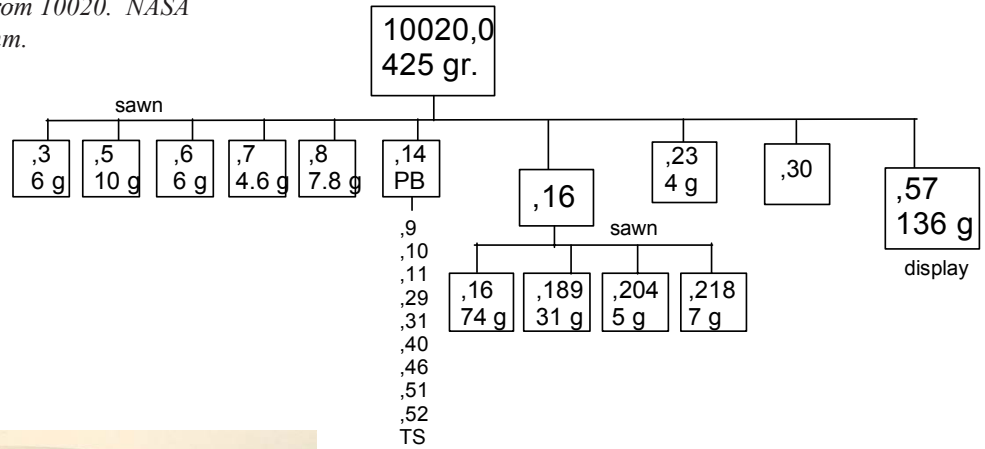


Figure 10: Old and new public display cases for 10020. NASA S70-18177 and S84-35321.

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