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." Beaty and Albee (1978) describe 10020 as "relatively-fine grained (200 microns) with a porphyritic to glomeroporphritic, 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 $Fo_{77\text{-}59}$, and contain ilmenite, chromite and melt inclusions.

Pyroxene: Beaty 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 gains up to 200 microns is size (Haggerty et al. 1970).

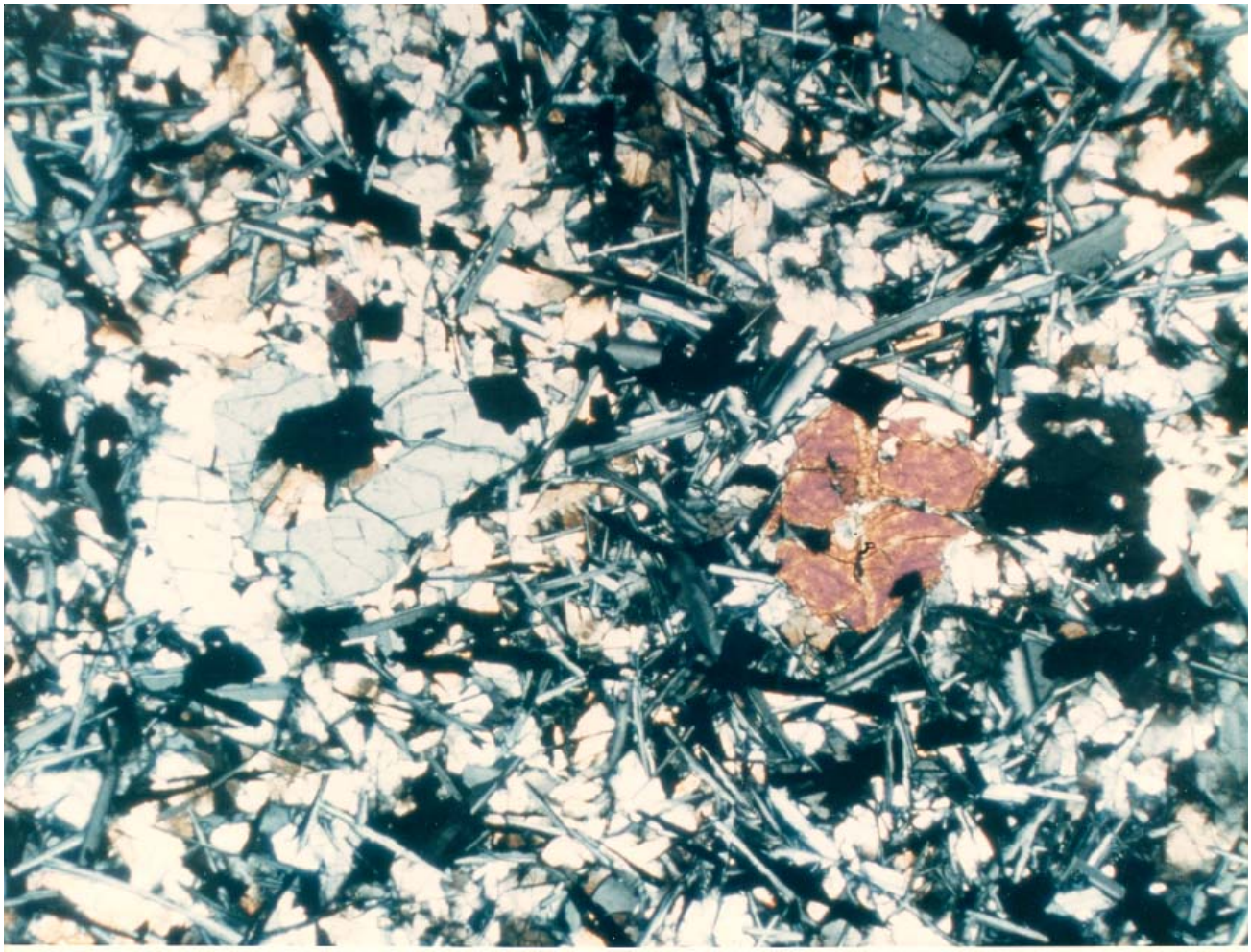


Figure 2: Photomicrograph of 10020,40 showing apparent xenocrysts in basaltic texture. Field of view 2.5 mm across. NASA S70-49470.

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 $^{37}Ar/^{38}Ar$ 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

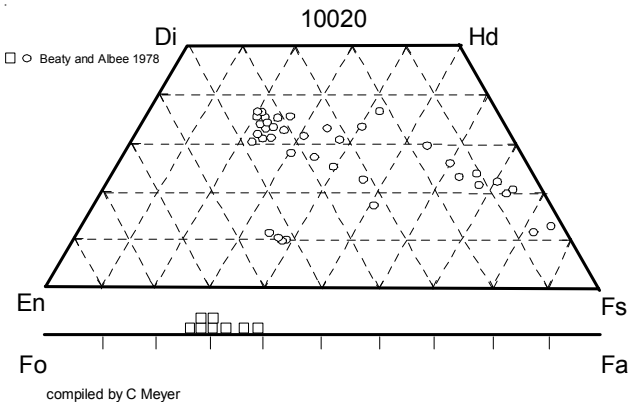


Figure 3: Pyroxene and olivine composition of 10020 (compiled from Beaty and Albee 1978).

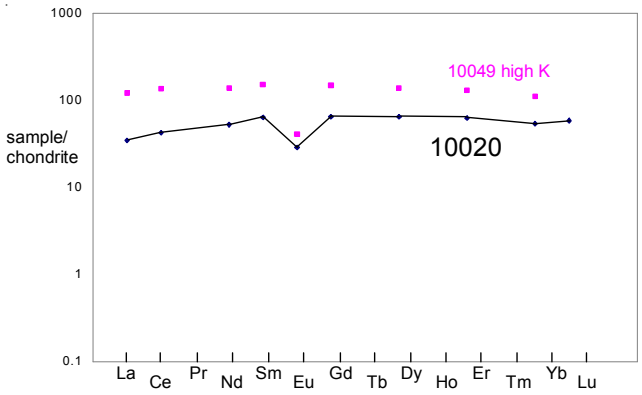


Figure 4: Normalized rare-earth-element composition for low-K basalt 10020 (the line) and high-K basalt 10049 (the dots) (data from Wiesmann et al. 1975).

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 experiements 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.

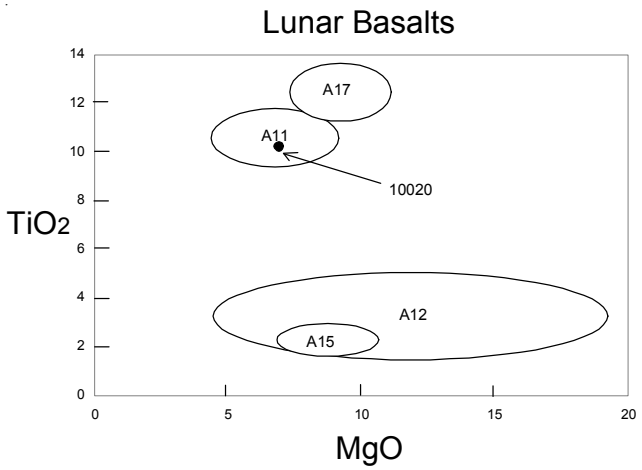


Figure 5: Composition of 10020 compared with that of other Apollo lunar samples.

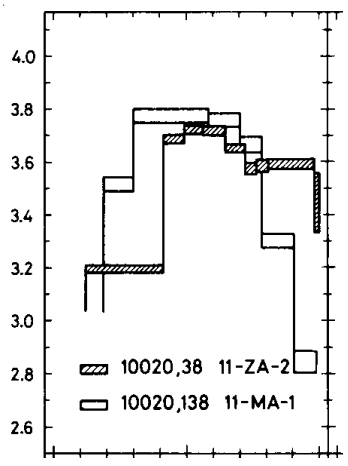


Figure 6: Argon plateaus for plagioclase and clionpyroxene/ilmenite samples of 10020 (from appendix to Guggisberg et al. 1979).

Table 1a. Chemical composition of 10020.

reference	LSPET69		Maxwell69			Maxwell69		Gast69		Wiesmann75		Dickinson89		Rhodes80		Haskin70	
weight			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		0.3		0.38	(f)		
K2O	*0.064*		0.05	0.05		0.05		0.058	(e)	0.058	(e)			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	(f)
Ce								25.8		25.8		25	(f)	27	(f)	25.6	(f)
Pr																	
Nd								23.9		23.9		23	(f)			31	(f)
Sm								9.47		9.47		8.5	(f)	9.6	(f)	9.94	(f)
Eu								1.6		1.6		1.5	(f)	1.58	(f)	1.75	(f)
Gd								12.8		12.8						16	(f)
Tb												2.3	(f)	2.5	(f)	2.59	(f)
Dy								15.8		15.8						17.8	(f)
Ho																	
Er								10		10						9	(f)
Tm												1.6	(f)				
Yb	*2.5*							9.87		8.78		8.2	(f)	8.8	(f)	9.8	(f)
Lu								1.43		1.43		1.3	(f)	1.36	(f)	1.41	(f)
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	Ganapathy		Kharkar71		Duncan76		Morrison 70		Beaty 78		Hurley 70		Tatsumoto70		
weight															
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.

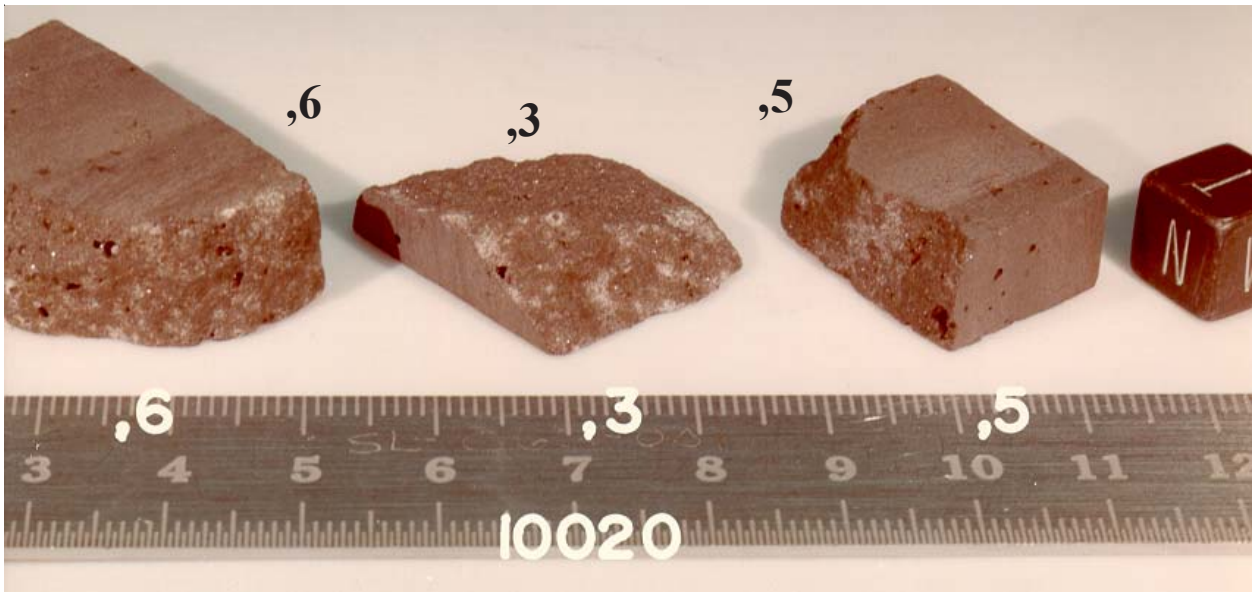
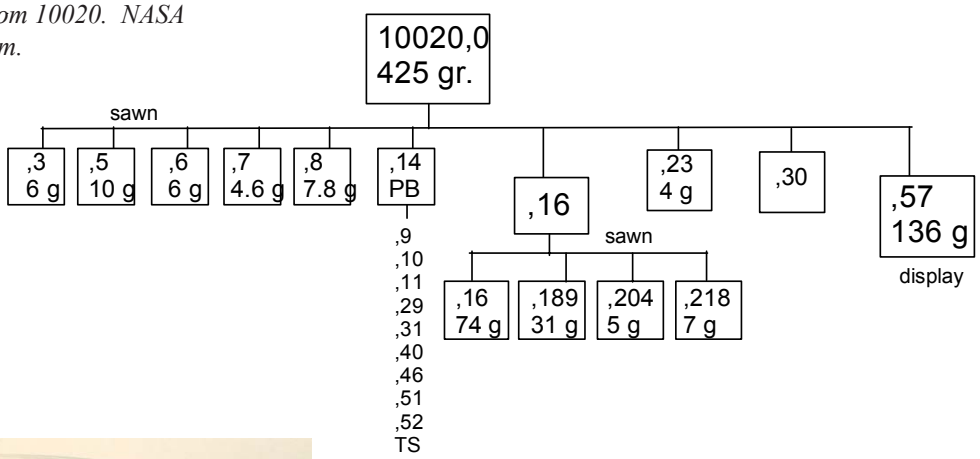


Figure 8: Pieces sawn from 10020. Cube is 1 cm. NASA S76-25879.

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



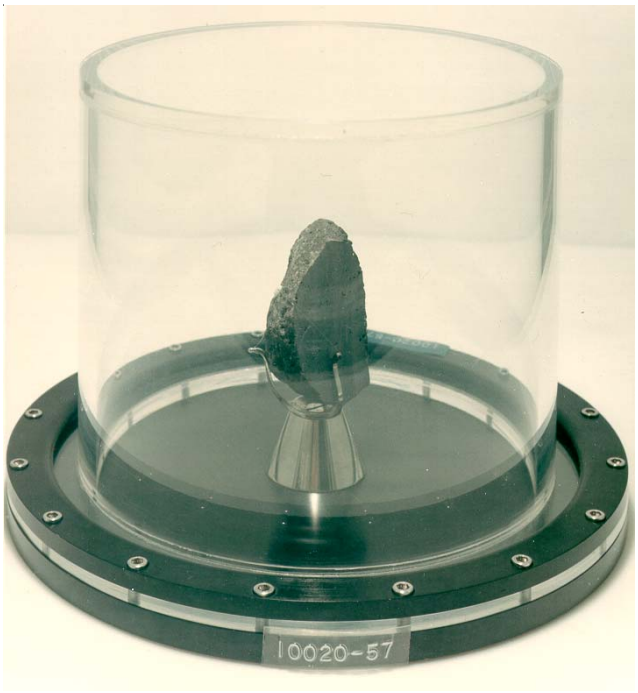


Figure 10: Old and new public display cases for 10020. NASA S70-18177 and S84-35321.

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