12011

Pigeonite Basalt

193 grams

Figure 1: Photo of 12011. NASA # S69-64122. Sample is 5 cm.

Introduction

12011 is a porphyritic pigeonite basalt. It had an encrustation of dirt (figure 1) and numerous micrometeorite pits (figure 2).

Petrography

The petrology of 12011 is discussed in Baldridge et al. (1979). Phenocrysts of olivine (1 mm) and pyroxene (up to 4 mm long) and microphenocrysts of chromite occur in a "fine-grained, variolitic-textured groundmass of pyroxene, plagioclase, ilmenite, ulvöspinel, metallic iron and mesostasis."

Mineralogical Mode of 12011

	Baldridge et al. 1979	Neal et al. 1994
Olivine	7.7	7.6
Pyroxene	53	52.9
Plagioclase	31	30.6
Ilmenite	2.9	2.9
Chromite	0.5	0.6
"silica"	3.4	3.4
mesostasis	1.2	1.4

Mineralogy

Olivine: Baldridge et al. (1979) state that "olivine compositions in 12011 range from Fo_{73-62} and some grains are zoned over almost this entire range."

Pyroxene: The pyroxene composition of 12011 is given by Baldridge et al. (1979) (figure 3). Pigeonite cores are rimmed by augite. Some pigeonite phenocrysts are long and "hollow".

Plagioclase: The average composition of plagioclase in 12011 is An_{78}.

Ilmenite: Fine needles of ilmenite form a network in the mesostasis.

Chemistry

The chemical composition of 12011 has been determined by Rhodes et al. (1977) and Snyder et al.

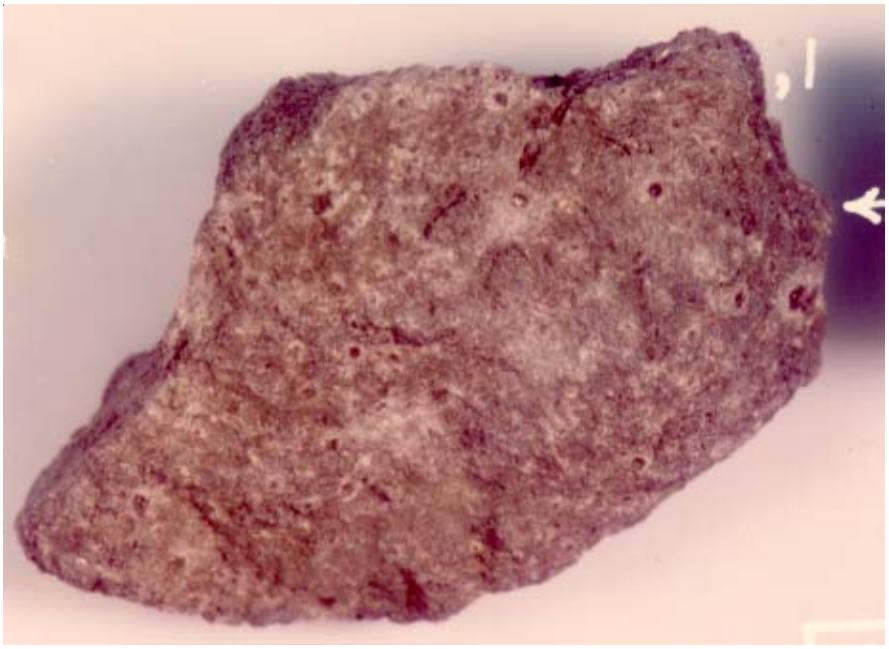


Figure 2: Closeup of 12011,1 showing "zap pits". NASA #S76-26081. Piece is 2.2 cm across.

(1997). Nyquist et al. (1977) determined the trace elements by isotope dilution (figure 5).

Radiogenic age dating

Snyder et al. (1997) reported the isotopic composition of Sr and Nd, but the age has not been determined.

Other Studies

Bogard et al. (1971) reported the content and isotopic composition of rare gases in 12011.

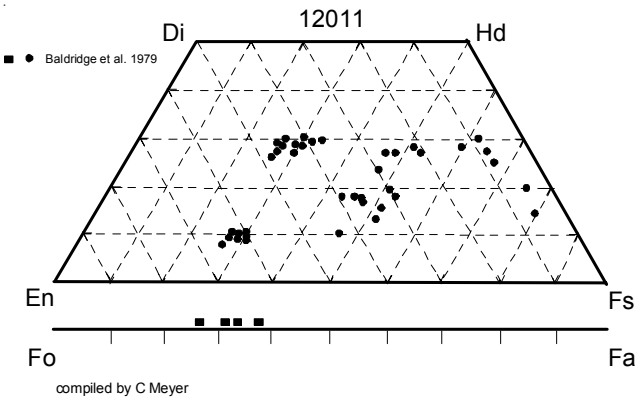


Figure 3: Pyroxene composition in 12011 (adapted from Baldridge et al 1979).

List of Photo #s for 12011

S69-64096 – 64122
S70-53773 – 53778 TS
S76-26081

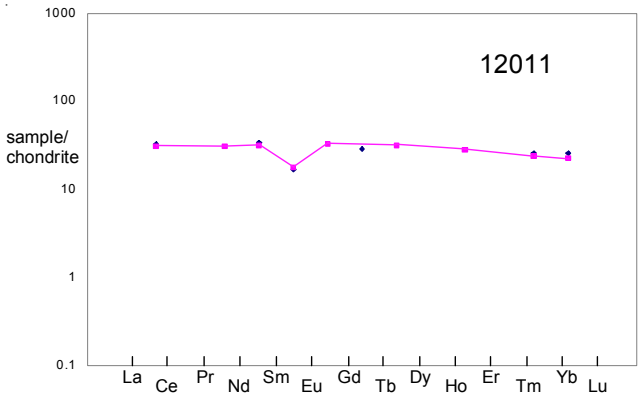


Figure 4: Normalized rare-earth-element composition diagram for 12011 (data from Rhodes et al. 1977, and Nyquist et al. 1979 (highlighted).

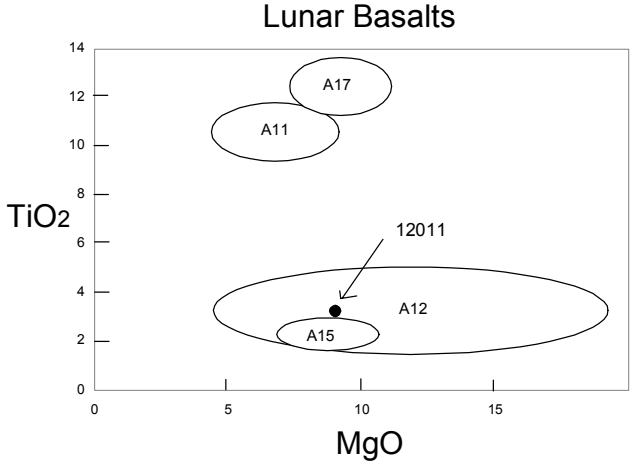
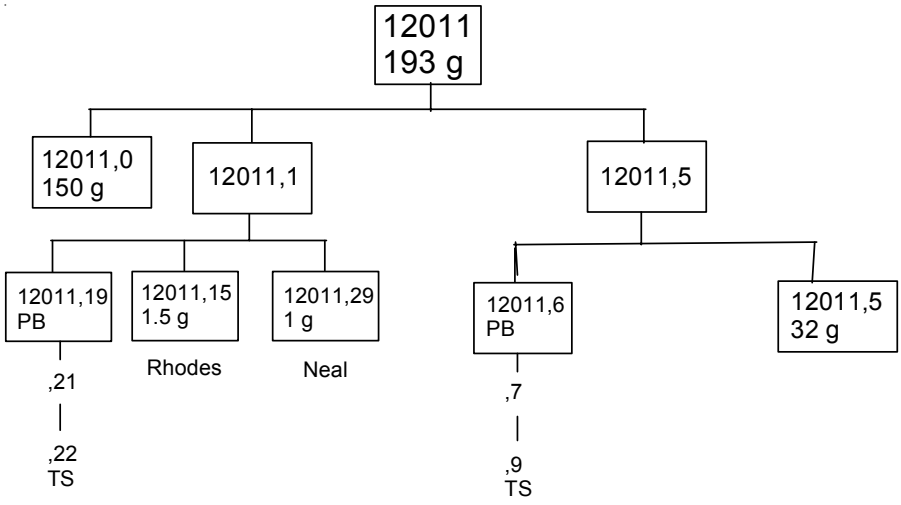


Figure 5: Composition of lunar basalts with 12011 indicated.



References for 12011

Baldridge W.S., Beaty D.W., Hill S.M.R. and Albee A.L. (1979) The petrology of the Apollo 12 pigeonite basalt suite. *Proc. 10th Lunar Planet. Sci. Conf.* 141-179.

Bogard D.D., Funkhouser J.G., Schaeffer O.A. and Zahringer J. (1971) Noble gas abundances in lunar material-cosmic ray spallation products and radiation ages from the Sea of Tranquillity and the Ocean of Storms. *J. Geophys. Res.* **76**, 2757-2779.

LSPET (1970) Preliminary examination of lunar samples from Apollo 12. *Science* **167**, 1325-1339.

Neal C.R. (2001) Interior of the moon: The presence of garnet in the primitive deep lunar mantle. *J. Geophys. Res.* **106**, 27865-27885.

Neal C.R., Hacker M.D., Snyder G.A., Taylor L.A., Liu Y.-G. and Schmitt R.A. (1994a) Basalt generation at the Apollo 12 site, Part 1: New data, classification and re-evaluation. *Meteoritics* **29**, 334-348.

Neal C.R., Hacker M.D., Snyder G.A., Taylor L.A., Liu Y.-G. and Schmitt R.A. (1994b) Basalt generation at the Apollo 12 site, Part 2: Source heterogeneity, multiple melts and crustal contamination. *Meteoritics* **29,** 349-361.

Nyquist L.E., Bansal B.M., Wooden J. and Wiesmann H. (1977) Sr-isotopic constraints on the peterogenesis of Apollo 12 mare basalts. *Proc. 8th Lunar Sci. Conf.* 1383-1415.

Nyquist L.E., Shih C.-Y., Wooden J.L., Bansal B.M. and Wiesmann H. (1979) The Sr and Nd isotopic record of Apollo 12 basalts: Implications for lunar geochemical evolution. *Proc. 10th Lunar Planet. Sci.* Conf. 77-114.

Rhodes J.M., Blanchard D.P., Dungan M.A., Brannon J.C., and Rodgers K.V. (1977) Chemistry of Apollo 12 mare basalts: Magma types and fractionation processes. *Proc. 8th Lunar Sci. Conf.* 1305-1338.

Snyder G.A., Neal C.R., Taylor L.A. and Halliday A.N. (1997a) Anataxis of lunar cumulate mantle in time and space: Clues from trace-element, strontium and neodymium isotopic chemistry of parental Apollo 12 basalts. *Geochim. Cosmochim. Acta* **61**, 2731-2747.

Table 1. Chemical composition of 12011.

reference	Rhodes77		Baldridge79		Nyquist79		Snyder97		Neal2001	
weight					59 mg					
SiO2 %	46.63	(c)	46.59	(d)			46.6			
TiO2	3.29	(c)	3.25	(d)			3.29			
Al2O3	9.77	(c)	10.02	(d)			9.77			
FeO	19.53	(c)	19.31	(d)			19.5			
MnO	0.29	(c)	0.28	(d)			0.29			
MgO	8.26	(c)	9.59	(d)			8.26			
CaO	10.63	(c)	10.55	(d)			10.6			
Na2O	0.25	(a)	0.33	(d)			0.25			
K2O	0.06	(c)	0.02	(d)	0.065	(b)	0.06			
P2O5	0.07	(c)	0.03	(d)			0.07			
S %	0.06	(c)								
sum										
Sc ppm	52.2	(a)							52	(e)
V									180	(e)
Cr	4050	(a)					2510	(e)	3632	(e)
Co	39	(a)					47.7	(e)		
Ni							30.9	(e)	37	(e)
Cu							14.9	(e)	12.1	(e)
Zn							13.2	(e)	6.8	(e)
Ga							4.2	(e)	3.1	(e)
Ge ppb										
As										
Se										
Rb					1.22	(b)	1.327	(e)	1.18	(e)
Sr	113	(c)			113	(b)	117.9	(e)	114.6	(e)
Y	39	(c)					38.4	(e)	39	(e)
Zr	128	(c)							120	(e)
Nb	7.4	(c)							7.5	(e)
Mo									0.1	(e)
Ru										
Rh										
Pd ppb										
Ag ppb							191	(e)		
Cd ppb										
In ppb										
Sn ppb										
Sb ppb										
Te ppb										
Cs ppm							0.072	(e)	0.06	(e)
Ba	71	(b)			70	(b)	79.1	(e)	73	(e)
La							7.77	(e)	6.84	(e)
Ce	19.9	(a)			18.5	(b)	18.5	(e)	18.5	(e)
Pr							2.79	(e)	2.9	(e)
Nd					14.1	(b)	14.2	(e)	14	(e)
Sm	5	(a)			4.78	(b)	4.8	(e)	4.9	(e)
Eu	0.95	(a)			1	(b)	1.11	(e)	1.01	(e)
Gd					6.47	(b)	5.22	(e)	7.43	(e)
Tb	1.06	(a)					0.94	(e)	1.17	(e)
Dy					7.72	(b)	5.87	(e)	7.77	(e)
Ho							1.32	(e)	1.6	(e)
Er					4.55	(b)	3.73	(e)	4.65	(e)
Tm							0.51	(e)	0.66	(e)
Yb	4.2	(a)			3.93	(b)	3.86	(e)	4.37	(e)
Lu	0.62	(a)			0.548	(b)	0.47	(e)	0.57	(e)
Hf	3.7	(a)							3.69	(e)
Ta									0.46	(e)
W ppb									200	(e)
Re ppb										
Os ppb										
Ir ppb										
Pt ppb										
Au ppb										
Th ppm							0.415	(e)	0.98	(e)
U ppm							0.291	(e)	0.24	(e)

technique (a) INAA, (b) IDMS, (c) XRF, (d) from mode, (e) ICP-MS