12015

Olivine Vitrophyre

191.2 grams

Figure 1: Photo of 12015 showing large vesicle (~3 cm dia.). Sample is 6 cm across. NASA #S74-34503.

Introduction

12015 is an olivine vitrophyre generally similar to 12009. It is black because of its fine grained opaque matrix and also has a portion of a very large gas bubble (figure 1). The bulk composition of 12015 (and 12009) is thought to represent the original magma composition of Apollo 12 mare basalts.

Petrography

12015 is an olivine vitrophyre with skeletal and dendritic olivine and pyroxene phenocrysts (Baldridge et al. 1979). Microphenocrysts of chromite are also an early phase. These phenocrysts are set in a nearly opaque fine-grained matrix of dendritic pyroxene, plagioclase, filamental ilmenite, cristobalite, troilite, Fe-metal and glass.

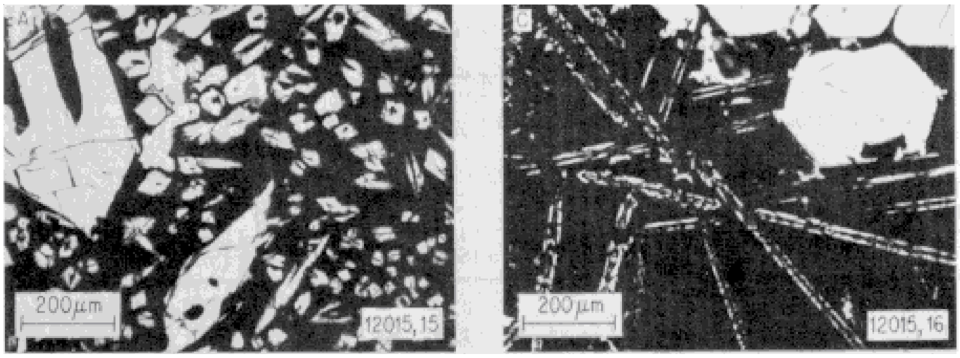


Figure 2: Copies of photomicrographs of two thin sections of 12015 (from Baldridge et al. 1979).

Two thin sections of 12015 studied by Baldridge et al. (1979) had different textures (figure 2), both containing olivine phenocrysts set in fine-grained opaque matrix.

Mineralogy

Olivine: Olivine phenocrysts (Fo_{76} to Fo_{59}) occur as equant to elongate grains <1 mm in size with slot-shaped inclusions of matrix. Rims of olivine contain chromite and metallic iron inclusions.

Pyroxene: Pyroxene compositions in 12015 were determined by Baldridge et al. (1979) (figure 3). The pyroxene compositions are very aluminous (> 9 wt. %)

Chromite: Chrome spinel is an early forming phase in 12015 (Baldridge et al. 1979).

Chemistry

The bulk chemical composition of 12015 appears to be similar to that of 12009 (table 1, figure 4 and 5). However, Baldridge et al. (1979) reported that the composition of "12015 lies on the extension of the fractionation trend defined by pigeonite basalts." Baldridge et al. noted that removal of olivine and chromite from 12015 liquid composition could account for the composition of 12011 and 12043.

Walker et al. (1976), Rhodes et al. (1977) and Lindstrom and Haskin (1978) discuss the composition of 12015 (also 12009) as the starting magma composition of the Apollo 12 olivine basalt series. The olivine basalts correspond to a simple mixture of phenocryst olivine and 12015-like liquid.

Radiogenic age dating

Nyquist et al. (1979) and Snyder et al. (1997) reported the isotopic composition of Sr and Nd, but it was not possible to determine an isochron age.

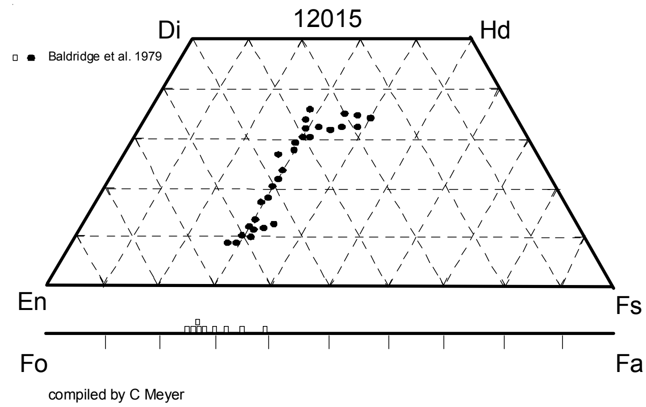


Figure 3: Pyroxene and olivine composition of 12015 (adapted from Baldridge et al. 1979).

Other Studies

Bogard et al. (1971) reported the content and isotopic composition of rare gases in 12015.

Processing

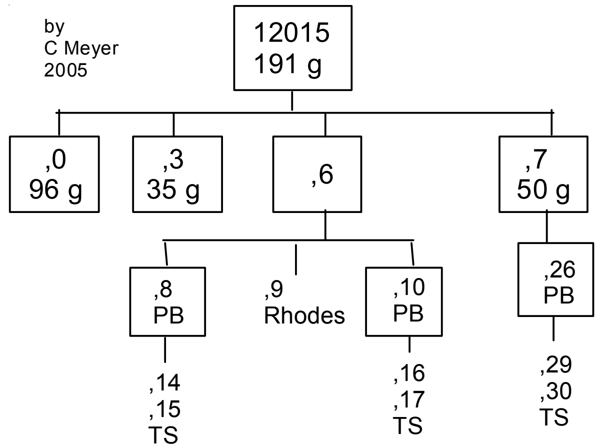
12015 broke into three large pieces. There are 6 thin sections.

List of Photo #s for 12015

S69-23391-393 B&W
S69-62872-873
S69-63342-350
S69-64103
S69-64128
S70-24713-721
S74-34502-503

Mineralogical Mode for 12015

	Neal et al. 1994	Baldridge et al. 1979	
Olivine	62.3	10.3	20.4
Pyroxene		43	13.6
Plagioclase			
Ilmenite			
Chromite +Usp	3.2	0.3	0.2
mesostasis	33.7	46.3	65.7



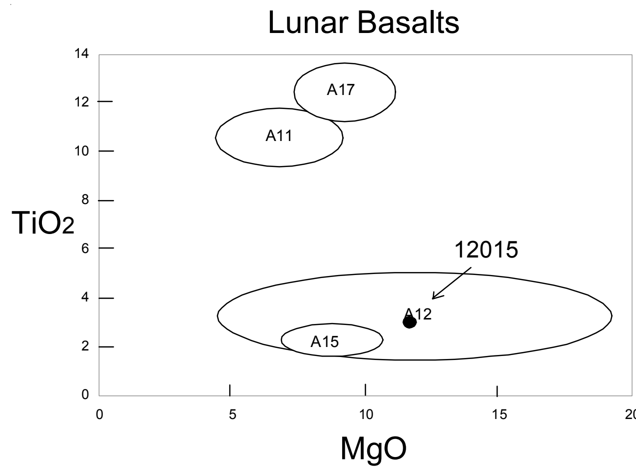


Figure 4: The composition of 12015 compared with that of other lunar basalts.

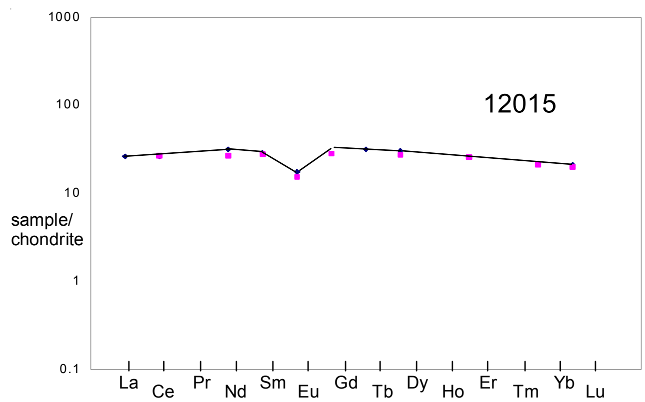


Figure 5: Normalized rare-earth-element pattern for 12015 (from Nyquist 1979).

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Table 1. Chemical composition of 12015.

reference	Neal 94		Rhodes77		Nyquist79		LSPET70	Baldridge79		Snyder97		Neal2001	
weight	.548 g				41 mg								
SiO2 %			44.98	(c)			38	47	(d)	45			
TiO2	2.9	(a)	2.86	(c)			3.2	2.9	(d)	2.86			
Al2O3	8.7	(a)	8.57	(c)			11	9.26	(d)	8.57			
FeO	20.5	(a)	20.18	(c)			22	18.2	(d)	20.2			
MnO	0.269	(a)	0.29	(c)			0.33	0.27	(d)	0.29			
MgO	12.3	(a)	11.88	(c)			14	11.44	(d)	11.9			
CaO	8.9	(a)	9.21	(c)			9.8	10.02	(d)	9.21			
Na2O	0.239	(a)	0.23	(a)			0.37	0.22	(d)	0.23			
K2O	0.06	(a)	0.06	(c)	0.054	(b)	0.062	0.05	(d)	0.06			
P2O5			0.06	(c)				0.06	(d)	0.06			
S %			0.07	(c)				0.1	(d)				
sum													
Sc ppm	48.4	(a)	46.1	(a)			44			47	(e)	44	(e)
V	186	(a)					95					118	(e)
Cr	4250	(a)	4600	(a)			3900			2470	(e)	2820	(e)
Co	47.8	(a)	51	(a)			47			51.9	(e)	52.6	(e)
Ni	62	(a)	50	(a)			70			73.5	(e)	56.5	(e)
Cu										12.4	(e)	12.4	(e)
Zn										12	(e)	17.1	(e)
Ga										3.63	(e)	2.83	(e)
Ge ppb													
As													
Se													
Rb					1.05	(b)	1			1.094	(e)	0.94	(e)
Sr	84	(a)	94	(c)	98.4	(b)	115			102.1	(e)	90	(e)
Y			35	(c)			46			34.5	(e)	37	(e)
Zr			110	(c)			160			127.6	(e)	102	(e)
Nb			6.6	(c)						8.01	(e)	6.8	(e)
Mo												0.12	(e)
Ru													
Rh													
Pd ppb													
Ag ppb										218	(e)		
Cd ppb													
In ppb													
Sn ppb													
Sb ppb												20	(e)
Te ppb													
Cs ppm										0.078	(e)	0.1	(e)
Ba	65	(a)	94	(b)	60.1	(b)	44			67	(e)	64.3	(e)
La	6.2	(a)								6	(e)	5.49	(e)
Ce	16	(a)	16.3	(a)	16.1	(b)				16.7	(e)	16.9	(e)
Pr										2.7	(e)	2.34	(e)
Nd	14.4	(a)			12.2	(b)				16.1	(e)	12.6	(e)
Sm	4.3	(a)	4.31	(a)	4.14	(b)				4.77	(e)	4.51	(e)
Eu	0.98	(a)	0.81	(a)	0.869	(b)				1.07	(e)	0.75	(e)
Gd					5.6	(b)				6.1	(e)	5.77	(e)
Tb	1.16	(a)	1.05	(a)						1.1	(e)	1.01	(e)
Dy	7.4	(a)			6.7	(b)				6.98	(e)	6.52	(e)
Ho										1.5	(e)	1.34	(e)
Er					4.07	(b)				4.09	(e)	3.89	(e)
Tm										0.57	(e)	0.54	(e)
Yb	3.6	(a)			3.52	(b)				3.59	(e)	3.53	(e)
Lu	0.52	(a)	0.53	(a)	0.486	(b)				0.5	(e)	0.51	(e)
Hf	3.3	(a)	3.5	(a)								2.87	(e)
Ta	0.38	(a)								0.432	(e)	0.4	(e)
W ppb												160	(e)
Re ppb													
Os ppb													
Ir ppb													
Pt ppb													
Au ppb													
Th ppm	0.74	(a)								0.68	(e)	0.72	(e)
U ppm										0.33	(e)	0.22	(e)

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