OPAQUE MINERALS IN BASALTIC ROCK 75035

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Rock 75035 is a coarse grained basalt believed to have probably been derived from the sub-floor of Camelot crater. Mineralogically, the rock consists of zoned pyroxene, plagioclase and opaque minerals which are associated with low cristobalite. An abundance of opaque phases are present that include, ulvospinel, Fe-metal, troilite, tranquillityite, baddeleyite and zirconolite.

Ilmenite is the major opaque mineral and it is present as coarse tabular or subhedral crystals. Skeletal crystals are rarely found as inclusions in low cristobalite. Occasionally blebs of troilite or troilite-metallic Fe intergrowths are associated with ilmenite. Also troilite-metallic Fe intergrowths are found as immiscible phases in rare silicate inclusions within ilmenite. A single ilmenite crystal contained minute, thin, needle-shaped lamellae of spinel. Chemically the ilmenite is stoichometric in composition and shows little variation within and between grains (Table 1).

Ulvospinel is relatively rare in the sample examined. It occurs as fine grained idiomorphic crystals and rarely as skeletal inclusions in cristobalite. Various stages of subsolidus reduction to ilmenite and iron are visible. Initially the breakdown consists of ilmenite lamellae parallel to the octahedral planes of ulvospinel plus minute inclusions of iron. Advanced stages are indicated by ilmenite forming interlocking grains and associated blebs of metallic Fe. Partial, or complete sulfidization to troilite is commonly observed. Analyses of ulvospinel and coexisting ilmenite are presented in Table 1. The Cr content of ulvospinel is very low and probably indicates a low activity for this element in the melt from which this rock crystallized. Compared with discrete ilmenite the ilmenite coexisting with ulvospinel is depleted in both Cr and Mg, and enriched in Zr. The partition coefficient of Zr between ilmenite and ulvospinel varies between 2.0 and 2.4, indicating a temperature of partitioning between 975°C and 1050°C (1.).

Metallic Fe occurs mostly as blebs in troilite, or as grains at the peripheries of troilite and rarely as discrete grains that occasionally display partial sulfidization to troilite at their margins. Ni and Co contents of metal range between < 0.01 to 0.12 and < 0.01 to 1.14 wt.% respectively. These ranges are within those previously reported for lunar metal and are outside those of meteoretic iron (2). Ti content varies between < 0.01 to 0.44 wt.%. (Table 2).

Troilite is next to ilmenite in abundance, and is present as discrete grains or as troilite-metallic iron intergrowths. Representative analyses are shown in Table 2. Troilite grains associated with ilmenite are more enriched in Ti compared to other troilite in the rock. Conversely in troilite- metal Fe intergrowths the Ti partitions in favor of the metal phase which has been previously observed (3) .

Tranquillityite occurs as thin laths or aggregates of lath shaped crystals sometimes associated with baddelyite. It is comparable in composition

OPAQUE MINS.: 75035

Meyer, H.O.A.

to tranquillityite from Apollo 12 and 14 basaltic rocks, though it is more depleted in Cr . (Table 3).

Baddelyite forms discrete, idiomorphic crystals, although commonly it is intergrown with tranquillityite or zirconolite. When associated with this latter mineral (anal. 2, Table 3) it is more enriched in Y and Nb compared to discrete baddelyite.

Zirconolite is associated with baddelyite and occurs as very tiny grains. Analyses (Table 4) indicate a remarkable enrichment in Y, Nb and other rare earth elements. Compositionally it is similar to zirconolite from mare basalts. (4). Most of the zirconium bearing minerals have probably crystallized late from a Zr-rich residual liquid.

References

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Table 1

	Ulvospinel		Ilmenite			
TiO_2	32.9	33.3	52.5	52.9	53.1	53.0
ZrO_2	0.18	0.15	0.36	0.36	0.04	0.11
Al_2O_3	2.06	1.47	0.20	0.13	0.15	0.16
Cr_2O_3	0.04	0.20	< 0.01	< 0.01	0.39	0.55
FeO	64.9	65.1	46.8	47.0	45.7	45.7
MnO	0.38	0.38	0.38	0.38	0.42	0.44
MgO	< 0.01	0.15	< 0.01	0.14	0.72	1.18
	100.5	100.8	100.2*	100.9*	100.5	100.9

*Coexists with ulvospinel

Table 2

	Metallic Fe*			Troilite*		
Fe	98.0	99.2	99.0	63.4	63.6	64.1
Co	1.06	0.73	< 0.01	< 0.01	< 0.01	< 0.01
Ni	0.08	0.07	0.04	0.03	0.03	0.02
S				35.9	36.2	36.0
	99.1	100.0	99.0	99.3	99.8	100.1

*Ti < 0.01 in both metallic Fe and troilite and P < 0.01 in metallic Fe.

OPAQUE MINS.: 75035

Meyer, H.O.A.

Table 3

	Tranquillityite		Baddeleyite		Zirconolite				
CaO	1.06	0.94	0.08	0.12	2.75	Ca	196		
MgO	0.35	0.02	< 0.01	< 0.01	< 0.01	Mg	0		
FeO	42.4	40.9	0.96	3.22	10.3	Fe	575	A	
MnO	0.09	0.35	< 0.01	< 0.01	0.13	Mn	7		A 778
Y_2O_3	3.01	2.69	0.24	2.65	12.8	Y	454	M_1	
La_2O_3	< 0.01	< 0.01	< 0.01	< 0.01	0.02	La	1		
Pr_2O_3	< 0.01	< 0.01	< 0.01	0.07	0.32	Pr	8		B 222
Nd_2O_3	0.02	0.30	< 0.01		2.40	Nd	57	B	1000
Gd_2O_3				0.31	2.34	Gd	51		
Yb_2O_3				< 0.01	0.50	Yb	10		B 641
Eu_2O_3				< 0.01	< 0.01	Eu	0	M_2	
ZrO_2	16.2	18.5	95.4	85.1	31.5	Zr	1021		
HfO_2	0.25	0.25	2.07	1.52	0.71	Hf	14	C	C 359
ThO_2	0.03	0.03	< 0.01	0.15	0.06	Th	1		1000
TiO_2	21.2	20.5	1.01	5.46	28.7	Ti	1435		D 1615
SiO_2	13.9	14.7	0.16	0.23	0.29	Si	19	M_3	
Nb_2O_5	0.68	0.82	0.68	1.26	4.25	Nb	131	D	Zr 395
Ta_2O_5	< 0.01	< 0.01	0.06	0.05	0.05	Ta	1		2010
Al_2O_3	1.02	1.22	< 0.01	< 0.01	0.37	Al	29		
	100.2	101.1	100.7	100.1	97.5	Atomic Props. based on 7 Oxygen (x 1000)			

Cr_2O_3 and P_2O_5 < 0.01 in all analyses