

OXIDE AND SULFIDE MINERALS IN KIMBERLITE FROM GREEN MOUNTAIN, COLORADO

- N. Z. Boctor (Department of Geosciences, Purdue University, West Lafayette, IN 47907)
- H. O. A. Meyer (Department of Geosciences, Purdue University, West Lafayette, IN 47907)

The opaque minerals in kimberlite from the Green Mountain, Colorado are represented by an assemblage of spinel solid solutions, ilmenite, rutile, perovskite, and minor sulfide minerals.

Spinel occurs as primary phases in the groundmass and as reaction mantles on ilmenite xenocrysts and rutile-ilmenite intergrowths. The groundmass spinels are characterized by their low Cr content and thus are different from the Cr rich spinels that are common in kimberlites (Haggerty, 1975; Mitchell and Clarke, 1976). They occur as euhedral crystals which are either zoned or unzoned. The cores of the zoned crystals are Ti and Mg rich (Table 1, Analysis 1), whereas the rims are more depleted in these elements and more enriched in Fe (Table 1, Analysis 2). Unzoned spinels are uniform in composition in the same specimen, and their chemical composition overlaps with that of the mantles in zoned crystals (Table 1, Analysis 3). Magnetite-ulvöspinel solid solution (Table 1, Analysis 4) and Ti poor magnetite are rarely present as groundmass spinels. Occasionally, magnetite-ilmenite intergrowths are also observed in the groundmass. The spinels in the Green Mountain kimberlite are solid solutions in the system $\text{Fe}_2\text{TiO}_4\text{-Mg}_2\text{TiO}_4\text{-MgAl}_2\text{O}_4\text{-MgFe}_2\text{O}_4\text{-Fe}_3\text{O}_4$. The spinels that are close in composition to the Ti rich spinels in kimberlite from the Green Mountain are those from Benfontein (Dawson and Hawthorne, 1973) and Lihobong (Haggerty, 1973).

Ilmenite is represented mainly by primary xenocrystic microilmenite (Table 1, Analysis 5), which commonly displays fine exsolution lamellae of spinel, and secondary microilmenite (Table 1, Analysis 6) in the groundmass and in reaction mantles on ilmenite xenocrysts. Secondary microilmenite is more enriched in Mg and Cr relative to the ilmenite xenocrysts. A Mn rich and Mg poor ilmenite occurs occasionally in the groundmass and as rims on rutile-ilmenite intergrowths (Table 1, Analysis 7).

Reaction mantles on ilmenite xenocrysts display different mineralogy in different specimens. In some cases, the ilmenite xenocryst is mantled by an inner zone of secondary microilmenite followed by a discontinuous rim of rutile-ilmenite intergrowth and an outermost zone of spinel. In general the spinel in these mantles is more enriched in Ti and FeO relative to the groundmass spinel (Table 1, Analysis 8) though its composition occasionally overlaps with that of the cores in zoned spinels. In some cases the Ti rich spinel mantles the ilmenite xenocryst followed by a discontinuous zone of secondary microilmenite and an outer zone of a second spinel that is more enriched in Fe_2O_3 and depleted in Ti (Table 1, Analysis 9) relative to the spinel of the inner zone. Occasionally the outermost spinel zone is a Ti poor magnetite (Table 1, Analysis 10). In some ilmenite xenocrysts a discontinuous rim of perovskite mantles an inner zone of secondary microilmenite or Ti rich spinel. Perovskite in the mantles and the groundmass has a low FeO content.

Rutile-ilmenite intergrowths have bulk compositions similar to armalcolite. They are commonly mantled by Ti rich spinel and/or Mn rich ilmenite. In rare instances the coexisting spinel and secondary microilmenite

in the reaction mantles are more enriched in Cr relative to the ilmenite and spinel in the groundmass or reaction mantle on ilmenite xenocrysts. The spinel contains up to 12 wt % Cr_2O_3 (Table 1, Analysis 11), while the secondary microilmenite contains up to 5.5 wt % Cr_2O_3 .

The mineral assemblages observed in the reaction mantles on ilmenite xenocrysts and on rutile-ilmenite intergrowths in the Green Mountain diatreme suggest that fluctuations in $f\text{O}_2$ prevailed during their formation. Also large fluctuations in $f\text{O}_2$ are demonstrated by the presence in the same specimen of magnetite-ilmenite intergrowths produced by subsolidus oxidation together with ilmenite with magnetite lamellae produced by subsolidus reduction. The fluctuations in $f\text{O}_2$ are probably a reflection of the changes in CO/CO_2 and $\text{H}_2/\text{H}_2\text{O}$ ratios during the progressive crystallization of the different phases in the reaction mantles.

The sulfide minerals are heazlwoodite, Ni bearing bornite, and covellite. They are associated with serpentine. Heazlwoodite (Table 2, Analyses 1,2,3) occurs as platelets oriented in two or more directions in serpentine; as veinlets in association with bornite; and as irregular masses. Bornite (Table 2, Analysis 4) is occasionally replaced by covellite. The mineralogy and textures displayed by the sulfide minerals in Green Mountain kimberlite are not suggestive of an origin by sulfide liquid immiscibility. More likely the sulfides were the products of sulfurization reactions during serpentinization.

References:

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Table 1. Chemical Compositions of Oxide Minerals in Green Mountain Kimberlite

	1	2	3	4	5	6	7	8	9	10	11
TiO ₂	22.82	19.04	19.77	5.55	54.39	56.40	52.33	33.25	9.85	0.99	23.66
FeO	15.79	19.97	21.15	33.46	25.78	10.39	42.28	31.75	12.67	30.85	27.09
Fe ₂ O ₃	24.68	30.69	28.91	53.87	5.57	6.60	---	11.93	52.73	66.85	12.33
MnO	0.82	0.55	1.01	1.66	0.25	0.64	4.96	0.97	0.91	0.28	2.19
MgO	24.45	19.97	18.90	0.69	12.86	22.63	0.66	19.43	17.80	1.65	19.57
CaO	0.08	0.02	0.03	0.88	0.04	0.04	0.07	0.01	0.05	0.02	0.12
Al ₂ O ₃	9.28	9.54	9.17	0.89	0.51	0.33	0.01	1.84	5.45	0.05	3.63
Cr ₂ O ₃	1.11	0.82	1.48	0.35	0.65	2.16	0.04	0.85	0.46	0.03	11.79
	99.06	100.60	100.42	99.35	100.05	99.19	100.35	100.03	99.03	100.72	100.38

Table 2. Chemical Compositions of Sulfide Minerals in Green Mountain Kimberlite

	1	2	3	4
S	26.71	26.86	26.97	25.55
Fe	1.04	1.10	1.22	11.34
Ni	72.58	71.85	72.22	1.28
Cu	<0.01	<0.01	<0.01	61.14
	100.33	99.80	100.41	99.30