MINERALOGY OF MICACEOUS KIMBERLITES FROM THE NEW ELANDS AND STAR MINES ORANGE FREE STATE, SOUTH AFRICA.

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Micaceous kimberlites occur at the New Elands and Star Mines, Orange Free State, South Africa. At New Elands there occur three east-west striking dikes which cross-cut an approximately north-south trending system of thin dikes. The Star Mine consists of three sub-parallel dikes named the Burns, Wynandsfontein and New Star dikes.

Kimberlites at both localities are predominantly fine grained hypabyssal phlogopite kimberlites that in some examples contain abundant macrocrystal olivine. Megacrystal($>$ 10 mm) micas, magnesian ilmenite and Ti-pyrope are absent. Micro-xenoliths of eclogite and harzburgite occur in the Star dikes.

In the New Elands dikes microphenocrystal(0.2-1.5 mm) micas occur in three petrographically and compositionally distinct types; 1. colorless-to-pale brown titanian phlogopite(mg=0.87-0.96, FeO_T = 2.4-6.5%, TiO_2= 0.15-2.44%, Cr_2O_3= 0.1-1.0%), 2. fluid inclusion-rich brown titanian phlogopite(mg = 0.85-0.91, FeO_T=4.1-6.8%, TiO_2 =1.14-3.5%, Cr_2O_3 = 0.18-0.84%) and 3. rare olive green titanian magnesian biotite(mg = 0.56-0.61, FeO_T=15.4-17.6%, TiO_2 = 1.71-4.28%, Cr_2O_3 0.05%). Complex mantling and zoning with respect to TiO_2, Cr_2O_3 and FeO_T are characteristic. Continuous zoning is commonly from colorless or pale brown cores to darker brown margins relatively richer in TiO_2 and FeO_T. The pattern of discontinuous mantling is varied and mantles that are normally or reversely zoned relative to the core composition are equally common. Boundaries between the cores and mantles are well-defined and are sub-parallel in the case of multiple overgrowths. The relationships suggest that the mantles are epitaxial overgrowths rather than passive reaction mantles formed by interactions between the microphenocrysts and the late stage groundmass fluids.

At the Star Mine microphenocrystal micas are pale brown relatively low Cr_2O_3($<$0.5%) low TiO_2 (0-0.8%), low FeO_T (2.5-4.2%) titanian phlogopites and relatively higher Cr_2O_3 (0.96-1.39%), TiO_2(1.59-2.10%) and FeO_T(4.3o-5.39%) darker brown titanian phlogopites. Complex mantling and zoning similar to that observed in the New Elands kimberlites is characteristic.

Groundmass micas(0.01-0.15 mm) form a dense interlocking mass of euhedral-to-subhedral tabular crystals. Commonly they are continuously zoned either from colorless cores to brown margins or from brown cores to colorless margins. All types are titanian phlogopites(mg = 0.87-0.96, FeO_T =2.41-7.8%, TiO_2 =0.15- 2.59%, Cr_2O_3 =0.1-1.0%). In the New Elands kimberlites the groundmass micas commonly exhibit reaction rims of red tetraferriphlogopite, although at the Star Mine such rims are found only in the Wynandsfontein dike.

Representative compositions of the micas are given in Table 1. The paragenesis and composition of mica in the New Elands and Star kimberlites are similar. The presence of reverse and normally zoned and mantled crystals of different composition in close proximity is interpreted as suggesting that the bulk of the micas have not crystallized in-situ. The simplest explanation of the mica compositional variation and mantling is that they represent the products of crystallization of several batches of kimberlite magma of broadly similar but slightly different composition. Incorporation of crystals derived from one batch of magma into another will result in the development of epitaxial mantles, these mantles representing the composition of the current liquidus phlogopite. Concentration of crystals derived from different batches of magma at different stages of crystallization together with batch mixing and hybridization results in the observed heterogeneous mica population. These mica-rich dikes were probably emplaced as a crystal-rich slurry produced by the flushing out of a differentiated continuously replenished magma chamber. Only the outermost Fe-rich margins of the crystals and the tetraferri-phlogopites probably crystallized in-situ. This interpretation of the mica population implies that the "groundmass" micas in these micaceous kimberlites are in reality small microphenocrysts. Direct comparison of the whole rock composition of such micaceous kimberlites with those of rocks derived from other magmas e.g. lamproites,is thus considered to be inappropriate.

Spinels in the New Elands dikes are Ti-poor(< 0.5% TiO_2) magnesian aluminous chromites that exhibit a considerable range in their Cr/ Cr+Al(0.56-0.86) and Mg/ Mg+Fe (0.55-0.72) ratios.

All of the Star dikes contain compositionally uniform titanian magnesian chromites (Mg/ Mg+Fe = 0.39-0.50, Cr / Cr+Al = 0.90-0.95) that are poor in Al_2O_3(< 1%). Titaniferrous magnesian magnetite(Mg / Mg+Fe =0.8-0.9) exhibiting a wide range in Ti / Ti+Cr+Al ratios(0.39-0.95) occurs only in the Burns dike. The absence of Ti-rich spinels in other dikes is attributable to their resorption during the later stages of crystallization of the groundmass. Representative compositions are given in Table 2.

Fresh olivines are present only in the Star dikes. The largest crystals have magnesian cores (mg = 0.92-0.94) that are zoned towards relatively Fe-rich margins (mg = 0.91-0.93). Smaller crystals have compositions that are similar to these rims (mg = 0.90-0.91). The overall compositional range is thus very limited(mg = 0.90-0.94). Second generation euhedral groundmass olivine is absent.

In the New Elands dikes garnets are found as macrocrystal phases(in heavy mineral concentrates) and as an apparently primary groundmass phase. Macrocrystal garnets are all believed to be xenocrysts derived from eclogitic,lherzolitic and harzburgitic sources. The population consists of calcium pyrope almandine(29%), chrome pyrope(29%) and low calcium chrome pyrope(42%),classified as group 3,9 and 10 garnets by the Dawson and Stephens(1975) garnet classification scheme. Set in the calcite-chlorite rich groundmass are small(100-500 μm) brown euhedral Zr-rich garnets(Table 3). In the Star kimberlites xenocrystal garnets derived from eclogitic and lherzolitic sources are present. In the groundmass of the Burns dike there exists an apparently primary Ti-rich Zr-free garnet(Table 3).

Primary euhedral partially resorbed microphenocrysts of Al-poor(< 0.5%Al_2O_3), Cr-poor (< 0.2% Cr_2O_3) diopside occur in the New Elands kimberlites.

Other minerals present as minor late stage primary groundmass minerals in both the New Elands and Star dikes include perovskite,pyrite,rutile,apatite,calcite and K-Ba-V-titanates belonging to the hollandite group of minerals. The titanates occur as stellate clusters of reddish-brown prisms. In the New Elands dikes they are a previously unrecognized V and Ce-rich hollandite(Table 3) ,related to priderite and mannardite (Mitchell and Haggerty 1986). In the Star dike there occurs a V-free Cr-bearing Ba-rich hollandite(Table 3).

This study confirms and extends previous works(Smith et al.1978,Mitchell 1986) which have suggested that each micaceous kimberlite contains a characteristic assemblage of micas and that their general trend of evolution is towards Ti and Fe enrichment coupled with Cr_2O_3 depletion, and ultimately to the development of tetraferriphlogopite. Spinel compositional trends are similar to those determined for other micaceous kimberlites and are identical to those observed in lamproites.(Mitchell 1985).

The New Elands and Star kimberlites belong to a province of micaceous kimberlites which are isotopically different to the commoner serpentine-calcite-monticellite kimberlites. These isotopic group II(Smith 1983) kimberlites differ in their mineralogy to the isotopic group I kimberlites in containing primary microphenocrystal diopside, hollandite group minerals and Zr- and Ti-rich garnets in addition to their complex mica assemblages. Group II kimberlites also lack Ti-pyrope and magnesian ilmenite megacrysts,second generation groundmass olivines,monticellite and poikilitic eastonitic phlogopites. Spinel compositional trends are different in each kimberlite isotopic group. Geochemical and mineralogical evidence thus both support the hypothesis that the two varieties of kimberlite are derived from different sources in the mantle. There is no mineralogical evidence to support any relationship to each other by simple differentiation processes at high or low pressure.

The presence of hollandite group minerals and spinels similar in composition to those found in lamproites does not demonstrate any genetic relationship between lamproites and micaceous kimberlites. The hollandites are unlike priderite and the spinels are similar to those found in wide variety of other rock types. Importantly none of the characteristic minerals of lamproites e.g. potassian titanian richterite, leucite,sanidine,sodic titanian tetraferriphlogopite,wadeite etc.(Mitchell 1985) are found in isotopic group II micaceous kimberlites.

It is suggested that the micaceous kimberlites of the Barkly West,Boshof and Winburg districts may represent a third distinct class of mantle-derived diamond-bearing magmas.

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Table 1. Representative compositions of micas from the New Elands and Star Mines.

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	41.16	40.80	41.75	39.95	38.06	41.27	40.20	39.69	42.53	39.55	40.41	40.97	40.63
TiO_2	0.47	1.63	1.78	3.25	3.96	1.69	2.21	0.49	0.18	0.07	1.93	1.94	0.53
Al_2O_3	12.16	11.57	11.72	12.81	11.64	11.48	9.12	0.26	12.54	10.63	11.57	10.95	0.30
Cr_2O_3	0.84	0.08	0.46	0.30	0.13	0.52	0.12	0.13	0.68	0.07	1.28	0.15	0.09
FeO_T*	2.54	5.72	4.35	6.32	17.05	4.27	10.39	17.61	2.01	10.50	4.76	7.82	17.39
MnO	0.00	0.06	0.03	0.07	0.19	0.07	0.14	0.15	0.04	0.11	0.00	0.11	0.07
MgO	26.05	22.99	23.93	22.11	14.69	24.50	22.61	24.99	25.43	20.23	24.51	24.02	24.89
CaO	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Na_2O	0.13	0.08	0.18	0.34	0.29	0.18	0.21	0.25	0.28	0.32	0.00	0.09	0.00
K_2O	10.30	10.31	10.70	10.41	9.68	10.31	10.54	9.67	10.26	9.60	10.10	11.13	9.95
NiO	0.13	0.07	0.21	0.29	0.00	0.11	0.05	0.04	0.18	0.02	0.00	0.00	0.13
	93.78	93.22	95.11	95.85	95.69	94.45	95.59	93.83	95.03	94.10	94.56	97.18	94.03

* FeO_T = total iron expressed as FeO. Compositions 1-8 New Elands,9-13 Star. 1,2,9,10 colorless-to-brown microphenocrysts; 3,4 fluid inclusion-rich microphenocrysts; 5 Ti-magnesian biotite; 6,7,11,12 groundmass micas; 8,13 tetraferriphlogopite

Table 2. Representative compositions of spinels from the New Elands and Star Mines.

	1	2	3	4	5	6	7	8	9	10	11	12	13
TiO_2	0.43	0.27	0.40	2.47	3.40	2.06	3.79	2.55	3.19	7.74	7.61	8.11	8.19
Al_2O_3	6.90	15.42	22.66	2.69	3.12	2.96	3.25	3.35	3.47	1.18	0.48	0.25	0.07
Cr_2O_3	64.17	62.79	43.67	58.17	57.47	58.82	57.42	59.87	58.04	9.71	3.59	1.68	0.61
FeO_T*	14.87	15.42	19.63	22.48	22.54	22.11	23.57	20.83	22.94	69.40	75.48	77.98	78.33
MnO	0.21	0.23	0.59	0.56	0.42	0.46	0.46	0.39	0.39	0.71	0.65	0.93	0.73
MgO	13.77	13.89	13.51	13.20	13.14	12.37	12.90	13.89	12.94	6.38	5.80	5.71	5.52
	100.41	99.89	101.0	99.57	100.1	98.48	101.4	100.9	101.9	95.12	93.61	94.65	93.46
Fe_2O_3+	-	-	-	-	-	-	-	-	-	46.13	52.93	54.70	54.95
FeO	-	-	-	-	-	-	-	-	-	27.88	27.84	28.75	28.87
										99.83	99.49	100.3	99.16

*Total iron expressed as FeO. + Fe_2O_3 and FeO calculated from stoichiometry. 1-9 chromites; 1-3 New Elands,4-5 New Star,6-7 Wynandsfontein,8-9 Burns;10-13 titaniferous magnesian magnetites, Burns.

Table 3. Representative compositions of garnet and K-Ba-titanates.

	1	2	3	4
SiO_2	23.44	28.43	0.37	0.69
TiO_2	13.92	25.46	75.73	70.01
ZrO_2	14.40	0.00	0.08	-
Al_2O_3	0.00	0.37	0.00	1.30
Cr_2O_3	0.12	0.14	0.50	1.66
Fe_2O_3	14.14	5.98	3.52	5.50
V_2O_3	-	-	4.51	0.00
Ce_2O_3	-	-	1.52	-
MnO	0.10	0.83	0.17	-
MgO	2.35	3.79	0.94	0.00
CaO	30.08	34.43	0.00	1.56
Na_2O	1.06	0.95	0.00	0.00
K_2O	-	-	8.69	3.27
BaO	-	-	3.92	14.41
	99.21	99.86	99.95	98.40

1. Zr-rich garnet,New Elands.
2. Ti-rich garnet,Star.
3. K-Ba-V-titanate,New Elands.
4. Ba-K-Cr-titanate,Star.