KIMBERLITIC, MELILITITIC, TRACHYTIC AND CARBONATITIC ERUPTIVES AT SALTPETRE KOP, SUTHERLAND, SOUTH AFRICA

J.R. McIver (University of the Witwatersrand, Johannesburg, South Africa)
John Ferguson (Bureau of Mineral Resources, Canberra, Australia)

In the western portion of southern Africa a large number of post Karroo alkaline eruptive centres occur in a zone parallel to the coast. One of these, the Saltpetre Kop volcano near Sutherland, Cape Province, is characterised by the association of kimberlitic rock, olivine melilitite, trachyte and carbonatite which are present in some twenty relatively small volcanic necks and vents situated in the immediate vicinity of the main Saltpetre Kop crater. The latter forms the centre of a regular circular updomed region within the otherwise near flat lying Karroo sediments with dips of up to 60° being present in the vicinity of the throat of the volcano.

The main vent occupies an area of some 1000 x 1500 m and is filled with lithic pyroclasts which in the vicinity of carbonatite intrusions have a carbonate cement. Pyroclastic rocks having a strong macroscopic resemblance to certain types of kimberlite comprise the least abundant of the satellite eruptives. In these rocks inclusions and groundmass for the most part comprise equal volumes; crustal rocks are volumetrically dominant but are accompanied by ilmenite grains up to 2.5 cm across, brown amphiboles up to 3 cm across, augite crystals measuring 0.5 cm and prominent biotite flakes. The groundmass is dominated by carbonate and perovskite but ghost outlines of pre-existing crystals possibly represent original olivine grains. Analysis of the ilmenite present revealed it to be low in MgO and TiO_2 compared to kimberlitic ilmenites (Frick, 1973). Olivine melilitites represent the most widespread intrusives being recorded up to 20 km from Saltpetre Kop. These rocks are invariably porphyritic or microporphyritic containing an abundance of olivine and minor magnetite set in matrices containing variable proportions of melilite, augite, phlogopite, olivine, perovskite, apatite, zeolites, magnetite and rare monticellite and nepheline. A feature of many of these rocks is the presence of well developed reaction rims and internal areas around and within olivine phenocrysts where olivine-liquid reaction has produced assemblages of phlogopite, melilite, magnetite, perovskite and minor monticellite. Trachytic rocks, in part nepheline bearing, comprise the most abundant of the eruptives and frequently contain an abundance of crustal rock fragments. Both sövitic and ankeritic varieties of carbonatite are present and some outcrops contain an abundance of amphibole, biotite and ilmenite megacrysts.

Danchin et al. (1975) and Ferguson et al. (1975) have established seven major cluster Groups based on statistical comparison of 126 analyses of kimberlites and associated ultrabasic rocks. The distribution of these within the CMAS tetrahedron (O'Hara, 1968) was determined and Fig.1a shows the projection of these points into the CMS plane where they define a linear olivine dominated trend from magnesian (kimberlitic) compositions (Groups 5, 6 and 7) to less magnesian (melilititic, alnöitic) compositions (Groups 1, 2 and 3); Group 4 contains both kimberlitic and non-kimberlitic compositions. The average analysis of Saltpetre Kop and other olivine melilitites from south western South Africa define an additional point on this trend. Also shown in Fig.1a is the trend of the ultrabasic komatiite - tholeiite sequence of the Onverwacht eruptives of the Barberton Mountain Land (McIver and Lenthall, 1974). Both trends are largely linearly away from the olivine point indicating the importance of olivine fractionation in both series and represent compositional locii of evolving magmas providing natural parallels to the two trends predicted by Boettcher et al. (1975) shown in Fig. 1b.

Eggler (1974) has shown that under CO_2 saturated conditions the minimum melting point in the assemblage Di-Fo-En moves to the larnite normative side of the Di-Fo join between 15 and 30 kb. At higher pressures contraction of the olivine volume is likely to occur and the kimberlite - olivine melilitite trend of Fig. 1a possibly mimics the movement of the minimum melting point at higher pressures. Mixing calculations show that both olivine and orthopyroxene subtraction is required to permit derivation of compositions such as Groups 4, 5 and 7 from Group 6; subtraction of olivine alone from Group 4 was, however, sufficient to yield compositions akin to Groups 1, 2 and 3.

The foregoing, together with the data of Fig. 1a, strongly suggest the evolution of magma compositions such as the Saltpetre Kop olivine melilitites by polybaric fractionation initially of orthopyroxene and olivine and then olivine alone from kimberlitic magma. The olivine-liquid reaction phenomena preserved in the olivine melilitites would appear to provide the natural analogue of the forsterite - liquid reaction in the system Ne-La-Fo-SiO_2 (Schairer and Yoder, 1964). This reaction would be constrained to low pressure regimes (<6 kb) by the stability of melilite in the presence of CO_2 (Yoder 1975). The Ne-La-Fo-SiO_2 system has been shown to fractionate to a wollastonite, diopside, nepheline, feldspar assemblage which Platt and Edgar (1972) suggest may simulate phonolite; in the natural system this end product is likely to be represented by the trachytic rocks of Saltpetre Kop. At Saltpetre Kop kimberlitic eruptives are characterised by the presence of amphibole megacrysts and iron-rich ilmenite and in terms of the evolutionary model suggested by Fig. 1a probably represent kimberlite equilibrated at and erupted from shallower depths ($\pm$ 60 km) than many other kimberlites.

Based on the foregoing, the following sequence of events is envisaged as being involved in the formation of Saltpetre Kop: 1. Kimberlitic magma with dissolved H_2O and CO_2 was generated by melting of hydrous carbonate-bearing garnet lherzolite at depths probably between 100 - 200 km; 2. Initial slow uprise of this magma accompanied by olivine and orthopyroxene fractionation; 3. Arrest of a portion of the magma in a pressure regime where amphibole was the stable phase followed by rapid transport to surface to give rise to the kimberlitic pyroclastic rocks; 4. Further slow uprise accompanied by olivine fractionation and arrest of the remaining magma at depths of less than 18 km and the onset of the olivine-liquid reaction; 5. Possibly concomitant with 4 the separation of a carbonatite phase (Wyllie and Huang, 1976) accompanied by increasing volatile pressure which culminated in the formation of the central vent at Saltpetre Kop; 6. Exploitation of fractures in the vicinity of the vent by olivine, melilitite and carbonatite; 7. Continued fractionation of olivine melilitite magma in a crustal regime to beyond the limit of melilite stability to produce a potassium-rich feldspar system.

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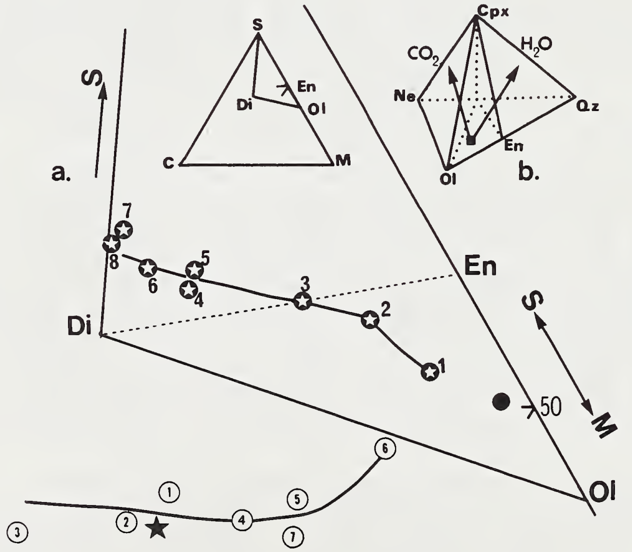

Fig. 1a. Projection from A into the C-S-M plane. Circled figures - average CO_2-free cluster Group analyses; solid star - average olivine melilitite; circled stars - Onverwacht eruptives, 1 and 2, high magnesia peridotitic komatiites, 3, 4, 5, Geluk, Badplaas and Barberton basaltic komatiites, 6, 7, 8. tholeiitic eruptives. Circle - Garnet lherzolite in kimberlite (O'Hara, 1968).

1b. Inferred magmatic trends occasioned by mantle melting in the presence of H_2O and CO_2, after Boettcher, et al., 1975.