PETROGENESIS OF KIMBERLITES AND ASSOCIATED POTASSIC LAMPROPHYRES FROM WEST GREENLAND.

B.H. Scott, Grant Institute of Geology, University of Edinburgh, West Mains Road, Edinburgh 9, Scotland,.
Present Address: Anglo American Research Laboratories, P.O. Box 106, Crown Mines, 2025, Transvaal, R.S.A.

A suite of post-tectonic dykes, which occur in the region south of Holsteinsborg in Central West Greenland, were formed by numerous injections of magma. These dykes include both kimberlites and unusual potassic lamprophyres, most of which are extremely fresh and therefore particularly suitable for a whole-rock geochemical study.

The kimberlites contain rounded macrocrysts of olivine, phlogopite, picroilmenite and rare pyropic garnet in a matrix which contains often euhedral crystals of olivine, phlogopite, diopside, perovskite, spinel, apatite and both primary calcite and serpentine. They can be classified as diopside-phlogopite kimberlites (after Skinner and Clement, this volume). The kimberlite dykes sometimes contain abundant rounded ultrabasic inclusions dominated by dunites, which is unusual in comparison with inclusion suites known from other kimberlites.

The non-kimberlite dykes of the Holsteinsborg suite are referred to as potassic lamprophyres (despite the occurrence of felsic macrocrysts in some dykes). They contain macrocrysts of anhedral olivines with distinct reaction rims, euhedral pseudoleucite, phlogopite and diopside set in a finer grained groundmass which may include phlogopite, diopside, potassic richterite, potassium feldspar and both primary calcite and serpentine.

93 whole-rock analyses of samples from the Holsteinsborg dykes demonstrate an overall wide range of compositions, particularly in MgO and K_2O, while as can be seen from Fig. 1, the dykes form two compositionally distinct groups. The kimberlites have all the characteristics of micaceous kimberlites except for lower H_2O and Fe^{+++}/Fe^{++} values. The lamprophyres are characterised by high K_2O contents (up to 10 wt %) and are distinguished from the kimberlites by higher SiO_2, K_2O, Al_2O_3, Na_2O, P_2O_5, Rb Sr, Y, Zr, Ba, Ce and La but lower MgO, FeO, Fe_2O_3, CaO, MnO, H_2O^+, Cr, Ni and Cu. All the dykes are rich in volatiles, especially CO_2.

The extreme K_2O contents together with certain mineralogical features of the potassic lamprophyres indicate a similarity with the rare ultrapotassic volcanic rocks, such as lamproites, from the Leucite Hills, Wyoming and West Kimberley, Australia.

The close association of kimberlites and potassic lamprophyres near Holsteinsborg lends itself to speculation about possible genetic relationships between these rock types. One petrogenetic model is put forward here which suggests that the potassic lamprophyres were derived from a parental kimberlitic magma by a simple fractionation process.

For a discussion about the petrogenesis of such rock types to be meaningful the analyses should be considered on a volatile-free basis. Although the CO_2 and H_2O^+ are considered to be primary, some attempt must be made to account for the random loss of either volatiles or an immiscible carbonatitic fluid during emplacement. The concentration of the remaining oxides (recalculated to 100%), relative to each other, then becomes significant.

The whole-rock analyses of the Holsteinsborg dykes are summarised on oxide versus oxide variation diagrams (Fig. 1). In these plots the potassic lamprophyre dykes tend to plot on a continuation of the kimberlite dyke trends.

The variation in chemistry within each group of dykes can be explained largely by olivine fractionation or enrichment. The kimberlites trend away from an olivine with the composition, Mg_{85}, of the euhedral crystals found in the kimberlite dykes. The lamprophyres trend away from an olivine, with a composition, $Mg_{91.5}$, the mean composition of the olivines in the lamprophyres. The lamprophyre trend, in detail, is more accurately explained by extracting relatively minor amounts of clinopyroxene and phlogopite together with olivine.

Since most of the rocks considered in this study are porphyritic, it is difficult to distinguish between that part of the trend due to liquid evolution and that part of the trend which might be the result of phenocryst and/or xenocryst accumulation in the liquid. The MgO contents of the rocks do correlate with the modal content of olivine. The wide range of Mg/Mg + Fe ratios found in the olivine, particularly in the kimberlites (Mg_{79-93}), however, implies olivine fractionation. For the kimberlite dykes, the abundant dunite inclusions may represent cumulates from this fractionation. Both the kimberlite and potassic lamprophyre dykes, therefore, may have resulted from the pulsatory eruption from a magma system in which olivine was able to fractionate.

Any discussion of the possibility of a genetic relationship between the two groups requires an estimate of the composition of the initial liquids from which the two groups of dykes evolved. The average composition of each group was taken to represent these initial liquid compositions. For the lamprophyres this choice was reasonable since the average composition is similar to the most magnesian aphyric sample analysed. For kimberlites, however, it is impossible to be certain of any liquid composition. These average compositions (recalculated) are plotted on Figure 1.

Considering all the Holsteinsborg dykes as one group the trends observed (see Fig. 1) lie close to an overall olivine control line. It is clear, however, that the chemistry of the group as a whole cannot be explained solely by olivine fractionation. In the plot MgO vs TiO_2 (Fig. 1), for example, the evolution from a kimberlitic parental magma to a lamprophyre magma with a similar TiO_2 content cannot be explained by the fractionation of a TiO_2-free phase such as olivine. To explain the deviations from an olivine control line requires the crystallisation of a Fe-Ti phase together with olivine. The most abundant Ti-rich phase in the kimberlites, apart from perovskite, is titanomagnetite of fairly constant composition (also plotted on Fig. 1). The suggested olivine (Mg_{92}) plus spinel (titanomagnetite) fractionation trends are illustrated in Fig. 1. It can be seen that the evolution of the initial lamprophyric liquid from a parental kimberlitic magma is consistent with the fractionation of approximately 75% olivine (Mg_{92}) and 25% spinel. It should be noted that some modification to the estimated liquid compositions, within the range of observed compositions, does not alter the principal conclusions of this discussion.

In summary this model proposes

(1) the evolution of part of a kimberlitic parental magma by olivine fractionation which was then intruded to form the kimberlite dykes

(2) the evolution of the initial lamprophyric magma from a parental kimberlitic magma by the fractionation of olivine plus spinel

(3) further evolution of the lamprophyric magma by olivine plus clinopyroxene plus phlogopite ($\pm$ pseudoleucite) fractionation before intrusion.

Interpretation of the data is a variety of different ways including molar ratio comparisons, extract calculations and plots in FMA and CMAS all support this fractionation model deduced from the simple oxide versus oxide variation diagrams.

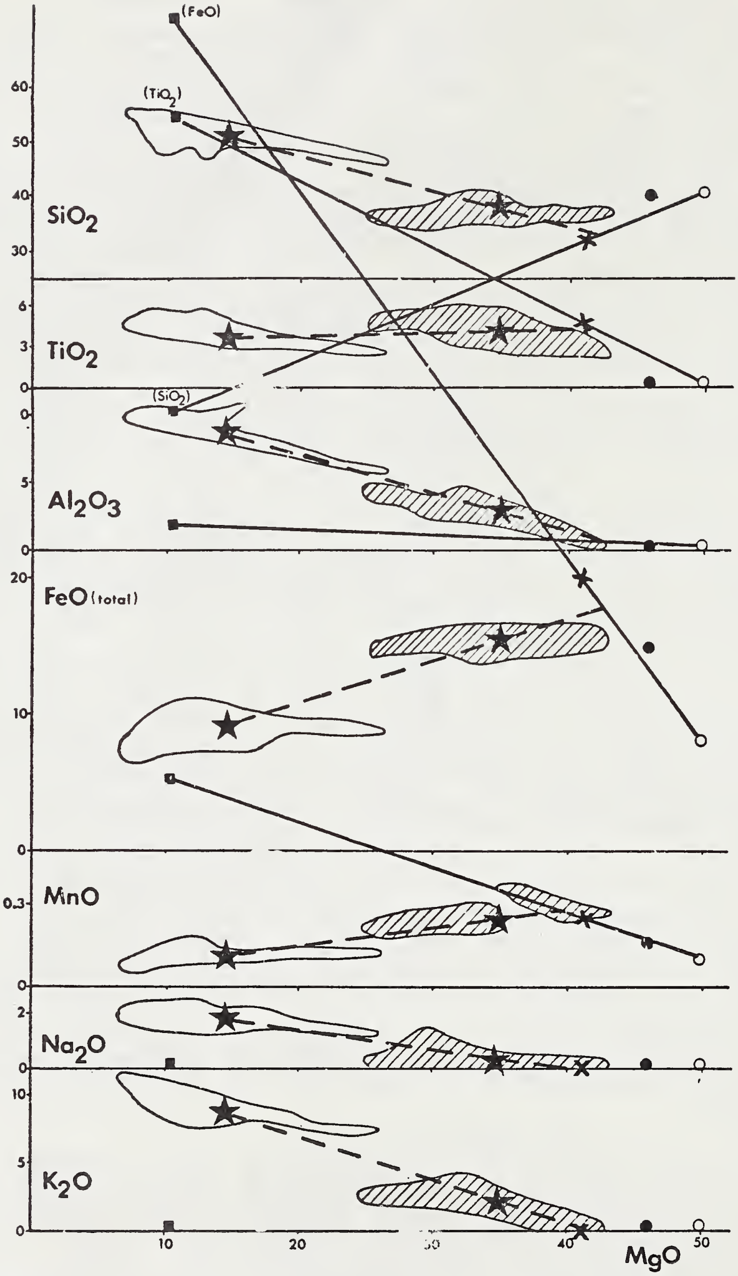

FIGURE I

Compositional fields of the Holsteinsborg kimberlite (shaded) and potassic lamprophyre (white) dykes plotted on oxide versus oxide (wt %) variation diagrams using $Ca(Mg)CO_3$- and H_2O^+-free analyses (recalculated to 100%).

Legend

stars = average compositions of each group of dykes
solid circles = olivine Mg_{85}
open circles = olivine $Mg_{91.5}$
solid squares = spinel (titanomagnetite)
dashed lines = possible fractionation paths
solid lines = olivine ($Mg_{91.5}$)-spinel join where the cross marks 22.5% spinel