Aspects of Some High Magnesia Eruptives in Southern Africa

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Abstract. Basaltic compositions from the Onverwacht, Great Dyke, Ventersdorp and Karroo eruptive sequences are compared in terms of the CMAS system with magma compositions and trends predicted from experimental work. Each of the abovementioned eruptive sequences include high magnesia members having compositions consistent with derivation from partial melts of garnet lherzolite at elevated pressures followed by rapid eruption from depths of ca 90 km. Less magnesian compositions in each igneous sequence appear to be related to their more basic associates mainly by polybaric olivine and to a lesser extent orthopyroxene fractionation. The high magnesia eruptives associated with the Ventersdorp and Karroo igneous activity include those with composition closely similar to the komatiites of the Barberton Mountain Land; komatiite type volcanics have, therefore, appeared more than once during the geological evolution of Southern Africa.

Introduction

Although an extensive literature exists for the high magnesia eruptives characteristic of the earliest and latest volcanic events recorded in Southern Africa, less attention has been paid to the significance of basaltic rocks of intermediate ages characterised by magnesia contents in excess of the range 7–8%. Moreover, the relationships between associated high and low magnesia eruptives have in many cases remained obscure when only the low-pressure environment is considered. The model of polybaric evolution of basaltic magmas (O'Hara, 1968a) permits a reassessment of the relationships between the two types of eruptives. Towards this end basaltic compositions from the Onverwacht (3.5 b.y., Jahn and Shih, 1974), Great Dyke (2.6 b.y., Robertson and van Bree men, 1970), Ventersdorp (2.3 b.y., van Niekerk and Burger, 1964), and Karroo (150–200 m.y., McDougall, 1963) eruptive cycles were compared in terms of the CMAS system with magma compositions and trends predicted from experimental work. All these eruptive cycles reveal a recurring similarity with each cycle containing rocks having compositions consistent with derivation from partial melting of compositions such as or approximating garnet lherzolite in kimberlite (GLIK) (O'Hara, 1968a) at elevated pressure. Polybaric fractionation of olivine and to a lesser extent orthopyroxene from the initially formed liquid appears to have been the main factor in the evolution of the associated rocks of lower magnesia content. Differences between the rocks of the various sequences are possibly related to degree of mantle melting, depth of melting and possibly eclogite fractionation.

The problems relating to the graphical representation of phase relationships in complex basalt systems have been considered by O'Hara (1968a) and Jamieson (1970). O'Hara (1968a) devised a system of projection of data into various planes within the CMAS tetrahedron whereby natural rock compositions can be compared with experimentally determined phase boundaries. The latter, in turn, permit
the prediction of evolutionary paths of melts derived from partial melting of GLIK together with composition trends of ascending magma. Fig. 1 shows in diagrammatic form in the clinopyroxene projection of the CMAS system, the path followed by a partial melt of garnet lherzolite at 30 kb together with some possible paths of magma evolution should the partial melt begin to ascend from the zone of partial melting. Relatively slow ascent from depth will, due to the expansion of the olivine primary phase volume with decreasing pressure (O'Hara, 1968a) result in olivine or olivine plus orthopyroxene fractionation as the liquid approaches the low-pressure invariant point. It also follows that the composition of a liquid on an evolving magma trend gives an indication of the minimum depth at which it was last in equilibrium with mantle materials. In contrast, rapid ascent of a liquid from a depth range of say 30 kb will permit the appearance at high crustal levels of liquids having compositions more in keeping with those in equilibrium with mantle material in depth.

As any point on an evolving trend may be related to unrepresented more-magnesian compositions no conclusion can be drawn from Fig. 1 as to the depth of origin of the magma. For example, compositions which plot on or near the 30 kb olivine-orthopyroxene boundary may be developed from melts originating at higher pressures for which the position of the pseudo-invariant point is imperfectly known. O'Hara (personal communication) has indicated that at 40 kb the position of the pseudo-invariant point is situated within the area defined by the 30 kb minimum melting point, the orthopyroxene point and the olivine point.

Fig. 2 shows in diagrammatic form the projected positions of the pseudo-invariant points within the plane CS–MS–A when viewed from the olivine point together with the locus of magma compositions which could develop by melting of GLIK at 30 kb and 40 kb. The exact position of the 40 kb pseudo-invariant