THE CHEMISTRY OF CONCENTRATE MINERALS AND DIAMOND INCLUSIONS OF THE DOKOLWAYO KIMBERLITE, SWAZILAND

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The Dokolwayo diatreme has the petrographic character of a Type II kimberlite (Smith, C.B. 1983) is diamondiferous and has a preferred emplacement age of 200 ± 5 m.y. (Allsopp, H.L. and Roddick, J.C. 1985) It therefore just predates the Stormberg volcanism which in the vicinity of Dokolwayo commenced at ± 190 m.y.

Probably due to the extensive secondary alteration in the near-surface kimberlite sampled to date, only a few highly altered mantle xenoliths have been found. This study is therefore confined to mantle derived megacryst and macrocryst garnets (55%) and chromites (45%) and most significantly of diamonds with mineral inclusions.

CHROME POOR GARNETS

The majority of the garnets (±60%) have chrome poor compositions and are confined to a restricted range of high Mg/Fe ratios. MgO is within the range of 15-22 wt %, FeO 7-15 wt % and CaO 2.8-6 wt %. Two more calcic compositions extending this range were reported in an extensive earlier study of Dokolwayo garnets (Hawthorne et. al. 1979) Na_2O lies in the range 0.04-0.0.22 wt % and shows a positive correlation with TiO_2. Both megacryst and macrocryst garnets with similar compositional ranges and trends as have been established for the Monastery (Jakob, W.R.O. 1977) and Lekkerfontein (Robey, J.V.A. 1980) Cr-poor discrete garnet megacrysts are present. These have not previously been reported from Type II kimberlites. In addition garnet macrocrysts with chemistry similar to Group II eclogites from Roberts Victor (Hatton, C.J. 1978) have also been identified.

CHROME RICH GARNETS

The chromiferous peridotitic macrocrysts are bimodal with respect to both CaO and TiO_2, suggesting at least three populations are present. These are inferred to be derived from disaggregated garnet harzburgites, coarse garnet lherzolite and high temperature deformed garnet lherzolite. The presence of the latter in Type II kimberlite has also not been suspected previously. The sub-calcic (G10) garnet population present (~1%) has been inferred to be derived from garnet harzburgite. It is consistent with the presence of diamonds in the kimberlite. (Gurney, J.J. 1984). Green garnets form a very minor part of the macrocryst suite.

Chromite Macrocrysts

The outstanding feature of the macrocryst chromites is the consistently high chrome content. More than 77% contain >60 wt % Cr_2O_3, with a highest determined concentration of 71,7 wt %. There is no correlation between the chromite compositions and grain size, texture or shape, although both euhedral and anhedral population groups are present. The presence of high chrome chromites is frequently observed in diamondiferous kimberlites, but this population is exceptional.

The unusually high Cr_2O_3 content (70-75 wt %) in meteoritic chromites, above the stoichiometric 67,9 %, has been suggested to be due to tetrahedrally coordinated chromium (Bunch, T.E. and Olsen, E. 1975) Divalent, tetrahedrally coordinated Cr^{2+} has been demonstrated for a kimberlitic spinel which was equilibrated at 1400°C and $fO_2 = 10^{-11.5}$atm. (Mao, H.K. and Bell, P.M. 1974) The presence of Cr^{2+} in the mantle has been suggested by several authors.(Mao, H.K. and Bell, P.M. 1974; Meyer, H.O.A. and Boyd, F.R. 1972; Burns, R.G. 1975).

It is possible that the very high chrome chromites from Dokolwayo contain Cr^{2+}. It is envisaged that the macrocryst chromites are metasomatic in origin. A generalised reaction could be:

garnet+olivine+diopside+(enstatite)+fluid(K_2O,H_2O,CO_2,CrO,$\pm TiO_2$)

= phlogopite+spinel+calcite+(enstatite).

Diamond Inclusions

The diamond inclusions can be readily assigned to the eclogitic and peridotitic parageneses universally reported to be present at other localities. The eclogitic paragenesis predominates in contrast to most diamond sources (Gurney, J.J. et. al. 1978). and to other well described inclusion suites from Type II kimberlites (Gurney, J.J. et. al. 1979; Gurney, J.J. et. al. 1984) The peridotitic paragenesis suggests garnet harzburgite and garnet lherzolite as the source rocks for the diamonds.

Both the eclogitic inclusions and the sub-calcic (G10) peridotitic inclusions have distinctly different compositions compared to the macrocrysts. The eclogitic diamond inclusions have CaO > 7 wt %, FeO > 14 wt % and MgO < 12 wt %. Na_2O ranges up to 0.52 wt %. The sub-calcic macrocrysts have < 8 wt % Cr_2O_3 whilst the sub-calcic peridotitic inclusions have Cr_2O_3 > 9 wt %. The chromite inclusions have Cr_2O_3 content ranging from 62.0 - 66.2 wt %, Al_2O_3 content 4.7 - 8.5 wt % and TiO_2 0 - 0.32 wt %. On average they have distinctly lower TiO_2 than the macrocrysts (0.90 wt % ave.).

Such differences between the diamond inclusions and the macrocryst minerals preclude a simple single stage model for derivation of the diamonds from common xenoliths. The diamonds must be derived from disaggregation of xenoliths which are either very rare or which have re-equilibrated post-diamond formation. The latter infers that the diamonds with the inclusions are older than the diatreme as supported by several independent lines of evidence for some other localities (Kramers, J.D. 1979; Melton, C.E. and Giardini, A.A. 1980; Ozima, M., et. al. 1983; Richardson, S.H., et. al. 1984). It would appear that the local tectonic setting and the unusual age of emplacement of the Dokolwayo diatreme are not reflected in the diamond inclusion compositions which are similar to those reported from other localities world-wide.

The inferred presence of high temperature sheared peridotites and the presence of Cr-poor discrete garnet megacrysts in Dokolwayo is indicative of high temperature and pressure regimes implying a depth of derivation similar to that of Type I kimberlites.

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