ULTRAMAFIC XENOLITHS FROM VAJRAKARUR KIMBERLITES, INDIA

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INTRODUCTION

The Vajrakarur diamond bearing kimberlite pipes have been described for their physical setting, age, general mineralogical, petrological and chemical characteristics by several earlier authors, including Reddy (1986a, 1986b). To date, eight pipes have been indentified and some dated at 840-1150 million years (Paul et. al., 1975). While kimberlite is the most dominant rock type, a few of these pipes are lamproites. Crustal xenoliths and megacrysts of a variety of minerals are present in all the pipes. Xenoliths of mantle origin are present in some of them only. Pipes 1, 3, 4 and 6 are kimberlites (1 and 6 brecciated); 2 and 5 are phlogopite-rich lamproites; 7 and 8 are recent finds.

PRESENT INVESTIGATION AND ITS SCOPE

The ultramafic xenoliths obtained from deep pits and bore holes are the focus of the present study. From scores of samples collected, a total of 32 reasonably fresh samples have been studied. Many of them are from pipe 3, the smallest of the well developed pipes. A detailed investigation of the mineral chemistry of these samples, using an automated ARL SEMQ electron microprobe has yielded data which are used in interpreting the PT conditions of equilibration of the ultramafic xenoliths. These data points define the proterozoic geotherm in the southern part of India and place constraints on the minimum depth of origin of the kimberlites and lead to a better understanding of the occurrence of diamonds in the pipe rocks of Vajrakarur area.

PETROGRAPHY AND MINERALOGY

Among the different varieties of ultramafic xenoliths present in the area the most common are the garnet lherzolites and garnet harzburgites. Eclogites are rare and mostly confined to pipe 3. Olivine orthopyroxenites, wehrlites and related olivine cpx rocks are also rare. Texturally, most xenoliths are coarse-grained and granoblastic with 120^{o} triple junctions. Shearing is present only occasionally. Detailed accounts are given by Reddy (1986a, 1986b) and Ganguly and Bhattacharya (in press).

Olivine (altered to serpentine), orthopyroxene, clinopyroxene and garnet are the most abundant minerals. Spinels (chromite, ilmenite, magnetite and titanomagnetite) are common accessories along with lesser amounts of perovskite, rutile, richterite, and apatite. All the major minerals plus spinel and ilmenite occur as megacysts. The kimberlites and lamproites have fragments of all the major and minor minerals mentioned above and are highly altered and have abundant carbonates.

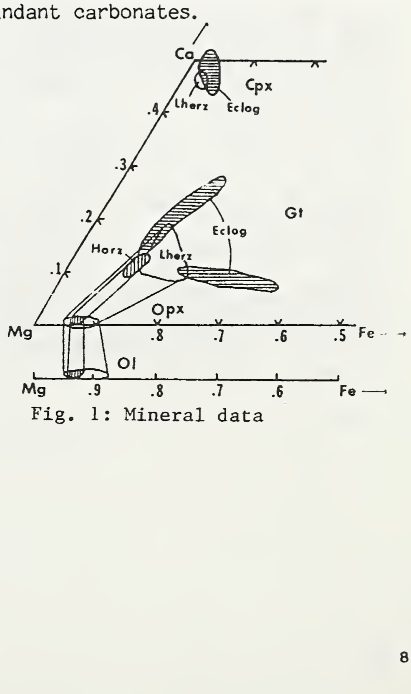

Fig. 1: Mineral data

The mineral compositions from the different xenoliths are broadly similar but have distinctive characteristics of their own from each of the xenolith groups. A summary of this information is presented in Fig. 1. Olivines in all the olivine-bearing xenolith types are essentially similar (Fo_{84-94} with low Cr_2O_3 values). Those in kimberlites are lower in Fo (to Fo_{78}). Orthopyroxenes from lherzolites and harzburgites are similar. Cr_2O_3 values of orthopyroxenes are higher than those in co-exisitng olivines; NiO is the reverse. The Ca, Mg, Fe values as well as the Al_2O and Na_2O contents of the cpx of lherzolites and eclogites are broadly similar. Garnets from lherzolites and harzburgites are comparable. Garnets in eclogites are variable; there are two types, the Ca-rich and the Ca-poor varieties. The later belong to a higher PT regime. Cr_2O_3 in garnets is variable (1 to 5 wt %). Values up to 10 wt % have been noted from some garnet megacrysts.

Iron-titanium oxide minerals are represented by chromite, ilmenite, magnetite and titanomagnetite. Ilmenites are mostly present in lherzolites and kimberlite matrix. Titanomagnetites are confined to kimberlites. Most ilmenites are high in MgO (14 to 19 wt %) and have variable Cr_2O_3 content (<1 to 7 wt %). Some of the ilmenites are zoned with Mg-rich rims. Ilmenites from the kimberlite matrix are intimately intergrown with titanomagnetite and have rims of perovskite. The one ilmenite analyzed from an eclogite was very poor in Cr_2O_3.

Chromites are mostly confined to lherzolites and the kimberlite matrix. The data are plotted in Fig. 2. Those from the lherzolites define a trend of iron enrichment coupled with Cr/(Cr + Al) enrichment. In contrast, the chromites in the kimberlite matrix are variable from one pipe to another. Those from pipe 3 kimberlite matrix define a parallel trend to the pipe 3 lherzolite chromite trend but extend to slightly lower Mg/(Mg + Fe) ratio and much lower Cr/(Cr + Al) ratio. Chromites from pipe 2 lamproite are extremely poor in Mg/(Mg + Fe) and moderately rich in Cr/(Cr + Al). Chromites from pipe 5 lamproite span a large Mg/(Mg + Fe) ratio but are confined to the intermediate values of the Cr/(Cr + Al) ratio. No diamonds are reported from pipes 2 and 5.

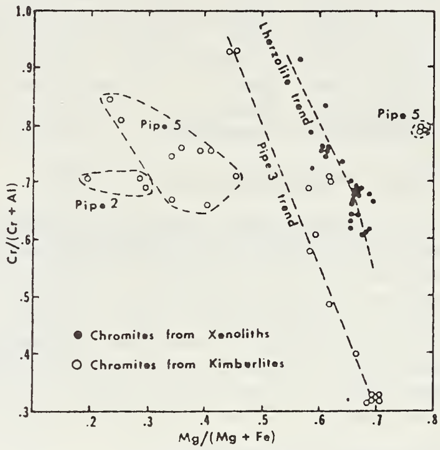

Fig. 2: Chromite trends

THE VAJRAKARUR GEOTHERM

Several geothermometric and geobarometric calculations for garnet peridotites have been evaluated by Finnerty and Boyd (1984). Following the equations of Lane and Ganguly (1980) and Perkins et. al., (1981) for Al-opx/gt equilibrium data, the gt-opx thermometer (modification of Lee and Ganguly, 1984, Ganguly, personal communication), and the gt-cpx thermometer of (Ganguly 1979), the mineral compositional data are used to solve simultaneously for the PT condition of each xenolith sample. In the case of the eclogites (and samples without opx) the gt-cpx PT tragectory is calculated and its intersection with the geotherm established from the other samples, is taken as a reasonable estimate of the PT value of the sample. The PT values and the resulting geotherm are shown in Fig. 3.

From a total of 32 samples studied data sets of 21 samples are used to define the Vajrakarur geotherm. Also included are data from Ganguly and Bhattacharya (in press) on nine xenolith samples and three from Akella et. al., (1979). The excellent linear fit of all the PT values of the xenoliths indicates a steady state thermal condition in the mantle beneath south India during the Proterozoic time. This geotherm is in general agreement with the geotherm proposed by Ganguly and Bhattacharya (in press) for the proterozoic of India and Lesotho.

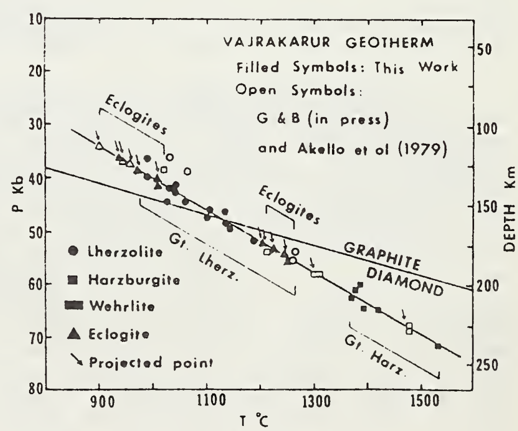

Fig. 3: The Vajrakarur Geotherm

The garnet lherzolite samples occupy an extended PT regime along the geotherm from about 40 kb, 1050°C all the way up to 55 kb 1275°C. Most harzburgites occupy the highest PT portion of the geotherm. The eclogites occupy two regions, one at the low PT and the other at intermediate PT. The low PT samples represent the lowest PT values from the Vajrakarur xenoliths. The intermediate ones are nearly coincident with lherzolites. There is an apparent sparsity of samples between the PT regimes of eclogites and lherzolite groups on one hand, and the harzburgite group on the other. The significance of these gaps is uncertain. In Vajrakarur, garnet harzburgites are at higher PT regimes than garnet lherzolites. This apparent discrepancy may be due to mantle heterogeneity. Some of the Vajrakarur harzburgites do fall in the PT regime of the lherzolites.

Interestingly, the graphite-diamond transition curve (Kennedy and Kennedy 1977) passes through the intermediate PT cluster of eclogites (which is also the high end of the lherzolite group). Most Vajrakarur harzburgites plot in the diamond stability field. Using these data it is possible to develop garnet compositional criteria that could be used as diagnostic of diamond incidence in the Vajrakarur pipes.

CONCLUSIONS

The PT regime of the ultramafic xenoliths from Vajrakarur, India are determined using opx ± cpx ± garnet assemblage geothermometers and geobarometers. The values define a linear geotherm similar to the ones from parts of south Africa and suggest a steady state in the mantle in south India during the Proterozoic. Heterogeneity of the mantle is indicated by the PT regimes of garnet harzburgites, garnet lherzolites and the two different types of eclogites. The compositional properties of garnets in the different xenolith varieties may be used as diagnostic for PT regimes which in turn can help in determining the likelihood of diamond occurence in the pipe rocks. PT regimes of the xenoliths indicate that the kimberlites containing diamonds must have originated at depths of about 225 km and temperatures near 1500°C.

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