SILICATE AND OXIDE INCLUSIONS IN DIAMONDS FROM THE FINSCH KIMBERLITE PIPE

J.J. Gurney (Dept. of Geochemistry, University of Cape Town, Rondebosch, S.A.)
J.W. Harris (Grant Institute of Geology, University of Edinburgh, Scotland)
R.S. Rickard (Dept. of Geochemistry, University of Cape Town, Rondebosch, S.A.)

Inclusions in diamonds from the Finsch Kimberlite Pipe, South Africa are predominantly peridotitic. (See Table 1.)

The Peridotitic Minerals

Apart from black inclusions many of which may be sulphide, olivine is by far the most abundant mineral followed by garnet, orthopyroxene and chromite in that order. Chrome diopside has not been found either in the initial inspection of 232,000 diamonds or in subsequent examinations of Finsch production.

The olivines are forsterites (See Fig.1) and do not have high Cr_2O_3 contents. The orthopyroxenes are also highly magnesian (See Fig.2) and are characterised by extremely low CaO (less than 0.3 wt.%) and Na_2O (less than 0.15 wt.%), Cr_2O_3 in the range 0.15 - 0.34 wt.% and by low but variable Al_2O_3 (0.26 - 0.66 wt.%). Garnet co-exists in the same diamond with both extremmes of the alumina contents reported. The majority of the garnets are exceptionally low in CaO, have high Mg/Mg+Fe ratios and high Cr_2O_3 contents. (See Fig.3). The lowest calcium contents are largely outside both the previously reported range for garnets from diamond and the range for xenocryst garnets from Finsch (Gurney & Switzer, 1973). (See Fig.4 A and B). The chromites all have more than 61.5 wt.% Cr_2O_3.

The Eclogitic Minerals

Rare eclogitic minerals found in Finsch diamonds included garnet and sulphide in the initial search, and subsequently clinopyroxene and kyanite. The garnets and pyroxenes are iron-rich. The garnets are very different from the peridotitic diamond inclusions at Finsch, not only with respect to Ca:Mg:Fe (See Fig.4) but also in their TiO_2, Cr_2O_3, MnO and Na_2O contents. A garnet clinopyroxene pair gives a temperature of equilibration of 1020°C at 40 Kb, using the Raheim & Green (1974) geothermometer and gives an intercept with the diamond graphite reaction curve at approximately 42 Kb and 1030°C.

Discussion

It is suggested that most of the Finsch diamonds may have crystallised from a partial melt which was derived from garnet lherzolite mantle and also contained water and CO_2. This melt formed at depths where the temperatures and pressures defined by the ambient geothermal gradient were within the diamond stability field. Melting is considered to have occurred close to or on the normal geotherm probably at temperatures between 1000°C and 1130°C. This required high partial pressures of water to depress the peridotite solidus temperature. The CO_2 (probably present in the silicate melt as CO_3^{2-}) is considered to have captured most of the calcium in the melt from which low calcium garnet and orthopyroxene along with olivine, chromite, (and presumably sulphide) crystallised.

Coarse garnet lherzolite xenoliths have been found at Finsch giving equilibration temperatures on the diopside solvus (Davis & Boyd, 1966) of between 950°C and 1075°C.

The water and CO_2 rich melt in which it is suggested that most Finsch diamond forms, would be of Kimberlitic composition. It is possible that this melt subsequently broke through to the surface, sampling eclogite en route, capturing some diamonds from the disaggregated diamondiferous rock and finally forming the Finsch diatreme or a portion of it.

If such a model were to apply, the Precambrian Age obtained for at least one diamond inclusion from Finsch (Kramers; personal communication 1977) would have to be an eclogitic inclusion and if the majority of Finsch diamonds grew in what is essentially the Kimberlite then such diamonds should not show plastic deformation. At present we cannot verify these aspects.

This proposed model for Finsch will not be directly applicable to other diamond inclusion suites but high Mg/Mg+Fe ratios for peridotitic minerals, low temperatures of equilibration, low calcium contents for most peridotitic garnets and orthopyroxenes and a great scarcity of chrome diopside in diamonds appear to be common features of diamond inclusions on a world wide basis. The model may therefore have more than simply local significance, and is simillar to the ideas proposed by Wyllie & Huang (1975) on the basis of both their own experimental results and those of others.

TABLE 1

The relative abundance of inclusions in diamonds of sieve class -6+5[(a)] from the Finsch Pipe, based on observation of the inclusions within the diamonds.

1. Peridotitic Paragenesis	No	%	2. Eclogite Paragenesis	No	%
* Olivine (enstatite, other)	381	37.2	Orange garnet	8	0.8
Olivine + purple garnet	50	4.9	Orange garnet+sulphide	2	0.2
Purple garnet	63	6.2		10	1.0
Purple garnet+sulphide	3	0.3	**3. Other Inclusions**		
Chromite	4	0.4	Sulphides (b)	358	35.0
	501	49.0	Graphite	132	12.9
Totals (1+2+3)	1024	100.1	Clouds(dense particles)	23	2.2
				513	50.1

Estimated No. of carats inspected 14,500
Estimated No of stones 232,000

(a) Sieve class -6+5. Diameter in mm. of circular aperture = 1.829
Approximate average weight in carats/stone = 0.0427

(b) Sulphides occur with both peridotite paragenesis and eclogite paragenesis minerals: [The majority of silicates are olivine (i.e. peridotite paragenesis)]. * All essentially colourless inclusions are placed under this heading. > 70% are olivine. Most of the rest are orthopyroxene. Rare SiO_2 (coesite?) phases have been found.

References

B.T.C. Davis and F.R. Boyd (1966): Jour. Geophys. Res. 71 3567 - 3576

J.J. Gurney and G.S. Switzer (1973): Contr. Min. and Pet. 39 103 - 116

H.O.A. Meyer and H.M. Tsai (1976): Min. Sci. and Eng. News 8 242 - 261

A. Raheim and D.H. Green (1974): Contr. Min. and Pet. 48 179 - 208

P.J. Wyllie and W.L. Huang (1975): Geology 3 621 -624

Key to Figures 1 - 4

Fig.1(a) Olivines from Finsch: □ in diamond; ■ in diamond and co-existing with garnet; ▨ in garnet lherzolite xenoliths.

1(b) Other published analyses of olivines in diamond from Meyer & Tsai 1976.

Figs. 2(a) and (b) Orthopyroxenes. Symbols as for Fig. 1.

Fig.3 Chrome-garnet inclusions in diamond from Finsch, grouped according to calcium content.

Fig.4(a) and (b) ○ Garnet inclusions in Finsch diamonds.
● Xenocryst garnets from Finsch.

Fig.4(a) The unshaded field is for low calcium garnet inclusions in Finsch diamonds (44). The shaded field is for xenocryst garnets from Finsch.

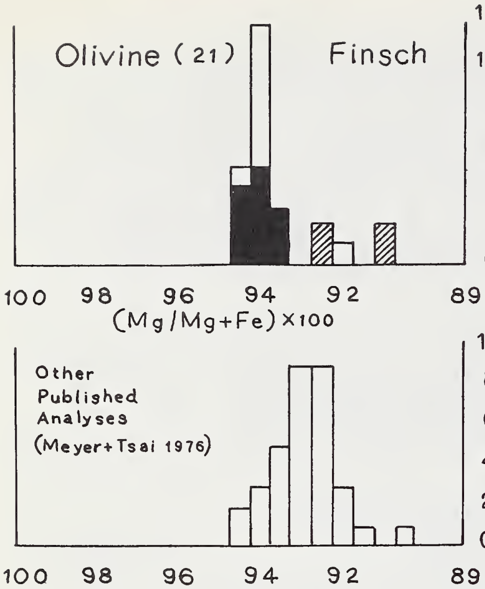

Fig 1

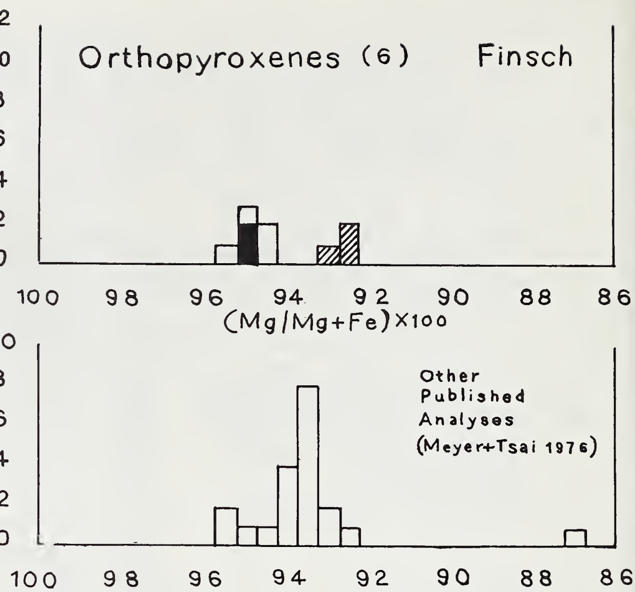

Fig 2

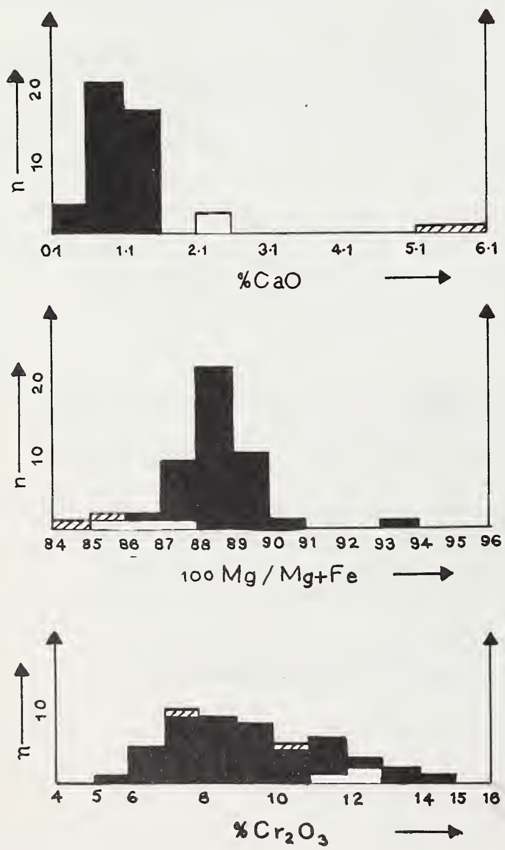

Fig 3

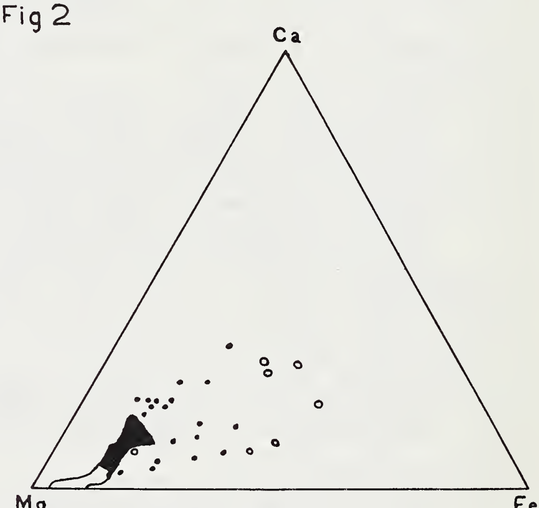

Fig 4 (a)

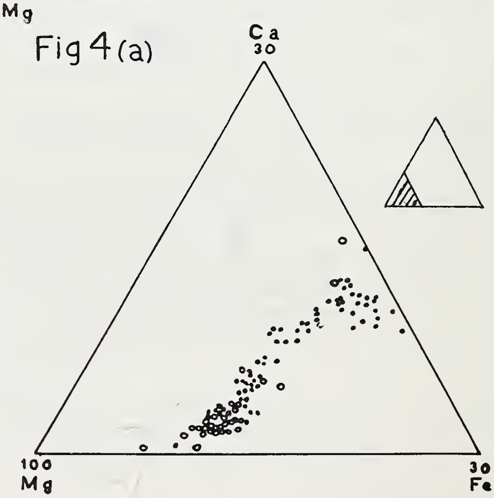

Fig 4 (b)