

On the importance of fluids for diamond growth

P. Deines

*Department of Geosciences, The Pennsylvania State University,
University Park, PA 16802*

J.W. Harris

*Department of Geology and Applied Geology, University of
Glasgow, Glasgow, G12 8QQ, Scotland.*

Introduction

Two major mineral inclusion parageneses in diamonds have been recognized worldwide, i.e. diamonds with eclogitic (E-Type) and peridotitic (P-Type) inclusions. In addition minor parageneses known as websteritic (W-Type) and lherzolitic (L-Type) have been observed. Furthermore, Meyer (1987) has proposed that the existence of a separate sulphide paragenesis (S-Type) should be recognized. While the relationships between silicate inclusion chemistry and carbon isotopic composition have been examined in some detail for south African diamonds, similar studies for diamonds with sulphide inclusions have been lacking. The present work provides the first systematic investigation of the carbon isotope geochemistry and sulphide inclusion chemistry of south African diamonds. Sample suites from Koffiefontein, Orapa, Premier Mine, Roberts Victor, Jagersfontein, Sierra Leone, Star Mine, Mwadui and Alamasí were analyzed. The data are used to examine the role of fluids in diamond formation.

Results

The study shows that for a particular type of sulphide mineral inclusion differences in composition exist within one kimberlite and between kimberlites. The same observation had been made earlier for olivine, pyroxene, and garnet inclusions. It is also found that the nickel content of monosulphide solid solution (mss) inclusions from south African diamonds has a mode at about 10 wt% which lies between the mean Ni content of mss from E-Type (3wt%) and P-Type (23 wt%) Siberian diamonds (Gurney, 1989). It can be demonstrated, considering experimental and empirical Ni/Fe distribution coefficients between olivine and monosulphide solid solution (Fleet and MacRae, 1988, Naldrett 1989), that less than 20% of the diamond mss inclusions could have been in equilibrium with typical mantle olivines.

For each of the kimberlites investigated, the carbon isotopic composition distribution of diamonds with sulphide inclusions is indistinguish-

able from that of diamonds with silicate inclusions. There are, however, significant differences in the carbon isotope distribution between kimberlites.

Detailed studies of the relationship between Ni content of the mss inclusions and the carbon isotope composition of the host were carried out for each of the kimberlites. These investigations demonstrated that in several kimberlites evidence can be found that mss inclusions of high Ni content are present in diamonds with low as well as high $\delta^{13}\text{C}$ values.

Discussion

In earlier studies it had been established that within one kimberlite and within the E- and P-Type parageneses several chemically and isotopically distinct sub-parageneses could be recognized. This observation can now be extended to sulphide containing diamonds. Also, the characteristic Ni content of the mss of South African diamonds, intermediate between that of E- and P-Type Siberian diamonds (Sobolev 1984, Yefimova *et al.* (1983), lends support to the suggestion (Meyer, 1987) that a separate sulphide paragenesis might be recognized. There is no evidence to support the proposition that mss inclusions of high Ni contents are restricted to diamonds with $\delta^{13}\text{C}$ values between approximately -5% and -9% vs PDB.

There are a number of diamond features which have not yet been explained very well (see e.g. Gurney, 1989). These include, among others: the over abundance of sulphide compared to silicate inclusions; the association of volatile elements such as sulphur, carbon, nitrogen and hydrogen with refractory silicate compositions; equilibration temperatures of P-Type diamonds close to or below the wet solidus of peridotitic magmas; the existence of chemical disequilibria between coexisting silicates and between sulphide inclusions; the variability in trace element concentrations in inclusions; the significant differences in $\delta^{13}\text{C}$ between kimberlites; the occurrence of several isotopically and chemically distinct diamond sub-parageneses within individual kimberlites; the

wide and similar range in $\delta^{13}\text{C}$ for E-Type, P-Type and S-Type diamonds; the higher relative abundance of ^{13}C -depleted E-Type diamonds in some kimberlites and the great similarity in the $\delta^{13}\text{C}$ distribution among E-Type, P-type and S-Type diamonds in others.

An examination of these features from the point of view of diamond growth from a magma or alternatively from a fluid leads to the conclusion that fluid rather than melt equilibria may be important in diamond formation. The dominance of fluid equilibria would have significant implications for the correct interpretation of the chemical and geochronological record of diamond inclusions. In particular it would raise questions about the meaning of the model ages which have been computed for some diamonds.

References

Fleet M.E. and MacRae (1988) *Contrib. Mineral.*

- Petrol.*, **100**, 462–9.
- Gurney J.J. (1989) *Diamonds*. Geological Society of Australia Special publications No. 4, 936–65.
- Meyer H.O.A. (1978) Inclusions in diamond. In Nixon P.H. ed., *Mantle Xenoliths*, pp 501–22. John Wiley and Sons, Chichester, England.
- Naldrett A. J. (1989) *Reviews in Economic Geology* V. 4. Eds. J.A. Whitney and A. J. Naldrett, Society of Economic Geologists, pp 5–20.
- Sobolev N.V. (1984) Kimberlites of the Siberian Platform: Their geological and mineralogical features. In Glover J.E. and Harris P.G. eds., *Kimberlite Occurrences and Origin: a Basis for Conceptual Models in Exploration*. pp. 257–87. Geology Department and University Extension, University of Western Australia, Publication No.8.
- Yefimova E.S., Sobolev N.V. and Pospelova L.N. (1983) *Zapiski Vses. Mineral. Obshchestva*, **112**, 300–10.