ABUNDANCES OF PALLADIUM, IRIDIUM AND GOLD IN KIMBERLITES AND ASSOCIATED NODULES

D. K. Paul (Geochronology Division, Geological Survey of India, Calcutta 16, India)
J. H. Crocket (Dept. Geology, McMaster University, Hamilton, Ontario, Canada)
P.H. Nixon (Dept. Geology, University Papua New Guinea, Port Moresby, New Guinea)

INTRODUCTION

Garnet peridotite nodules found in kimberlitis are accepted as direct samples of the mantle and have been studied extensively. Abundances of the noble metals in kimberlites and associated nodules are,however, poorly known. This study reports neutron activation data for Pd, Ir and Au in twenty-two kimberlites and associated nodules from India and Southern Africa (Fig. 1). The data are compared with mafic and ultramafic rocks and Type I carbonaceous chondrites in Table 1. Fig. 2 is a plot of Pd, Ir and Au proportions in kimberlites and nodules.

DISCUSSION

Geochemical properties

From Table 1 and Fig. 2 the following generalizations are drawn:

1) The average Ir content of the nodules is six times higher than that of the kimberlites; the reverse is true for Pd and Au which are lower by a factor of two in the nodules (omitting PHN 2829).

2) The Pd/Ir ratios of the kimberlites average 2.7 ± 1.4 and are more consistent than those of the nodules which average 0.56 ± 0.85. The kimberlite average is three times chondritic. It is similar to alpine peridotite although lower than that of komatiitic peridotites. The average Pd/Ir ratio of the nodules is unusual as sulfur-poor silicate rocks with Pd/Ir < 1 are rare.

3) Ratios of Pd or Ir with respect to gold are highly variable due to the great range in gold contents of both nodules and kimberlites.

4) The Ir contents of the nodules are high by comparison with sulfur-poor mafic or ultramafic rocks.

5) Systematic geographic variation in noble metal content is absent at the sampling density employed. An exception is the gold content of the Indian kimberlites which is three times that of the Southern African kimberlites.

Contamination

Nodules may be contaminated by alkalis, uranium and thorium from the host kimberlites (Gurney et al., 1966). The distribution pattern of the noble metals, however, indicates that contamination of the nodules by host kimberlite would not affect the abundances of Ir and Au in the former.

Lateral and vertical variability of mantle with respect to iridium

Textural and mineralogical data indicate that the nodules are samples of the mantle from depths of up to 200 km. Iridium, a refractory element, is apparently concentrated in the residua when liquid is extracted from the mantle. The iridium content in the nodules should be inversely related to the degree of partial melting provided their source region was initially of uniform Ir content. If the nodules are samples of a heterogeneous mantle, a simple relationship would not exist. The Ir content of the nodules do not correlate with the abundances of easily extractable elements (unpublished data, P. H. Nixon) suggesting that the Ir content in the mantle source region was variable. Further, there is no systematic variation in Ir (or Au) content of the nodules with respect to depth of origin as qualitatively inferred from texture and content of fusible constituents (Fig. 2).

Partition of noble metals in partial melting of peridotite nodules

Recent studies indicate that kimberlites are products of small amounts of partial melting in the mantle (Paul et al., 1975). Rozhkov et al. (1973) found that Au content in the major mantle minerals was equal to that in the whole rock. Ir and Pd contents of mantle minerals are unknown but the partition coefficients of Ir in some relevant minerals can be calculated from available data (Gijbels et al., 1976; Crocket et al., 1976; Gottfried and Greenland, 1972). The abundance levels of Ir in a hypothetical melt derived by partial melting of a garnet peridotite mantle containing 15 ppb Ir in the major silicate and oxide phases would range from 2.6 ppb (1% melt) to 6.3 ppb (10% melt), a range similar to that found in the kimberlites.

The possibility that minor phases are carriers of noble metals cannot be excluded as Fe-Ni-Cu sulfides and metallic Fe, Ni-Fe and Cu are common in kimberlitic ultramafic nodules (Bishop et al., 1975; Haggerty, 1975). These phases should be significant contributors to early partial melts. A preferential partition of Pd and Au into kimberlite relative to the nodules would result if these metals were hosted in such early melting phases. However, the same partition trend would also be expected of Ir, as opposed to that actually observed. This suggests that part of the Ir is hosted by a relatively refractory phase.

Noble metal fractionation during kimberlite emplacement

Noble metals in the kimberlites are not correlated with Ni, Fe, P, Ti or the Fe/Mg index. Apparently they have not been fractionated during emplacement.

FIG 1

FIG 2

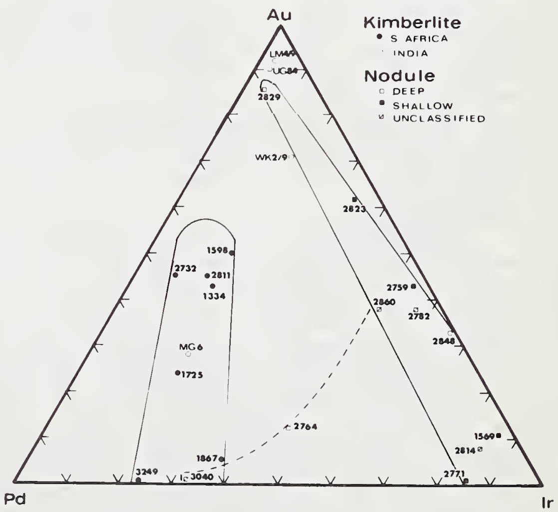

Table 1 -- Pd, Ir and Au contents in kimberlites and associated nodules

Sample No.	Locality	Pd	Ir	Au	Pd/Ir
			in ppb		
Kimberlite					
UG	Majhgawan, Central India	4.1	5.9	24	0.7
MG 6	Majhgawan, Central India	4.3	1.5	2.3	2.9
LM 4/9	Lattavaram, South India	2.3	1.5	43	1.5
WK 2/9	Wajraharur, South India	1.3	0.49	17	2.7
PHN 1598	Thaba Putsoa, Lesotho	7.7	3.5	11	2.2
PHN 1334	Kolo, Lesotho	5.0	2.0	5.2	2.5
PHN 1725	Ramatseliso, Lesotho	15	5.0	6.4	3.0
PHN 1867	Monastery, South Africa	3.5	2.2	0.34	1.6
PHN 3249	Frank Smith, South Africa	19	5.9	0.14	3.3
PHN 2811	Jagersfontein, South Africa	8.9	2.6	10	3.4
PHN 2732	Wessleton, South Africa	18	2.8	16	6.4
Nodules					
PHN 2848	Thaba Putsoa, Lesotho	0.27	33	16	0.008
PHN 1569	Thaba Putsoa, Lesotho	1.0	32	4.1	0.03
PHN 2823	Liqhobong, Lesotho	1.0	6.3	12	0.16
PHN 2860	Matsoku, Lesotho	1.3	5.5	4.1	0.24
PHN 2829	Kao No. 2, Lesotho	11	4.9	103	2.3
PHN 2771	Monastery, South Africa	3.4	21	0.28	0.16
PHN 2782	Frank Smith, South Africa	1.2	13.5	8.9	0.09
PHN 2814	Jagersfontein, South Africa	4.6	53	5.3	0.09
PHN 2759	Bultfontein, South Africa	0.7	12	9.6	0.06
PHN 2764	Bultfontein, South Africa	7.1	7.8	2.0	0.9
PHN 3040	Abbotsford, South Africa	9.3	4.5	0.16	2.1
Averages					
All kimberlites		8.1	3.0	12	2.7
Indian kimberlites		3.0	2.3	22	2.0
S. African kimberlites		11	3.4	7.0	3.2
Ultramafic nodules		3.8	18	15	0.56
Comparison with other mafic and ultramafic rocks and meteorites					
Komatiitic peridotite, S. Africa (Au) and Munro Twp., Ont. (Pd & Ir)		8.3	1.1	1.1	7.5
Alpine peridotite-dunite, Mt. Albert, Que.		7.9	2.4	1.1	3.3
Sea-floor basalt, MAR, Leg 37		<0.7	<0.025	2.8	--
Intra-plate and mid-ocean ridge basalt		2.0	0.33	2.1	6.1
Continental plateau-building basalt		5.5	0.10	3.3	5.5
Type I Carbonaceous chondrites		570	510	140	1.1

REFERENCES

Bishop, F., Smith, J. and Dawson, J. (1975). Physics and Chemistry of the Earth, 9, 323.

Crocket, J., Teruta, Y. and Garth, J. (1976). Econ. Geol., 71, 1308.

Gijbels, R., Henderson, P. and Zels, J. (1976). Econ. Geol., 71, 1364.

Gottfried, D. and Greenland, L. (1972). XXIV Intl. Geol. Congress, 10, 135.

Gurney, J., Berg, G. and Ahrens, L. (1966). Nature, 210, 1025.

Haggerty, S. (1975). Physics and Chemistry of the Earth, 9, 295.

Paul, D., Potts, P., Gibson, I. and Harris, P. (1975). E.P.S.L., 25, 151.

Rozhkov, I., Kaminskiy, F. and Frantsesson, Ye, V. (1973). Geochem. International, 10, p. 1385.