PLATINOIDS IN A 3.6 GA NICKEL-IRON OCCURRENCE: IMPLICATIONS FOR EARLY TERRESTRIAL EVOLUTION AND IRIDIUM ANOMALIES

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An unusual NiFe oxide-olivine-spinel assemblage, the Bon Accord deposit (BA), occurs in the 3.5-3.6 Ga ultramafic rocks of the Barberton greenstone belt, South Africa. Trevorite is the predominant nickel oxide, liebenbergite (nickel olivine) and two rare spinels (cobalt-rich cochromite and the nickel-rich nicochromite) also occur. It has been suggested that BA was an Archean meteorite fall (1). The trace element composition of BA is distinctive and peculiar. Nine whole rock samples analysed from BA are 2-4 times enriched in nickel compared with iron-meteorites (FeM). The extreme Ni enrichment can be seen in their high Ni/Fe and Ni/Co ratios with respect to FeM (Table 1). These ratios (0.6-0.9) are much lower than Awaruite ($\sim$3). On the other hand cobalt, which is more siderophile than Ni, is only slightly depleted (0.7-0.8) compared with FeM, whilst Cr is even more strongly depleted: Co/Cr ratios are very high compared to any meteoritic value. Au is extremely depleted relative to FeM; it's values are more akin to those in CI chondrites.

BA is rich in Platinum Group Elements (PGE). PGE concentrations are shown on a CI chondrite normalized plot (Fig. 1). The normalized noble metal field is very assymetric, with concentrations of the high-melting-temperature PGE's (HTPGE;$>2500^{\circ}$C) Os and Ir that range from highly depleted to slightly enriched relative to CI chondrite, and with the lower-melting-temperature PGE's (LTPGE; 1500°C - 2000°C), Rh, Pt and Pd ranging from slightly depleted to extremely enriched relative to CI chondrite. There are distinct Rh-positive and Pt-negative anomalies. $\lceil$PGE + Au$\rceil$ concentrations in the BA samples are unlike these of FeM (Table 1): they are more akin to the values from chondritic meteorites. However, the PGE patterns are very distinct: meteorites do not display the Rh and Pt anomalies we observe in BA (Fig. 2). Moreover, the Pd/Ir and the Ni/Ir ratios (Table 1) are distinctly higher than any in meteorites. We conclude, on geochemical grounds, that the BA deposit does not correspond in composition to any known meteorite. On the contrary, a 3.5 Ga model Pb-age for BA suggests a cogenetic origin for the deposit and the similar age host rocks. The regional geochemistry and geological observations show that the BA deposit occurs in an extensive sheet of Alpine-type ultramafics which generally contain elevated nickel values. We believe our results to be more consistent with an endogeneous relationship between the ultramafic host rock and BA. The partial depletion of HTPGE values, the non-chondritic ratios of Fe, Ni, and Co and the resetting of the U-Pb systematics is best explained if we interpret the BA deposit as derived from a dynamically emplaced mantle heterogeneity which developed, at least partially, during the ascent of a 3.5 Ga mantle material, from a source region at temperatures greater than 2600°C and a geochemistry "left over" from inefficient core formation.

We suggest that similar ultramafic rocks, with BA-like inclusions, form a significant proportion of the southern African tectosphere known to contain old material from the occurrence of 3.2-3.3 Ga diamonds in kimberlites (2). This cratonic keel has been episodically traversed and sampled by magmas of major igneous provinces, including upper Cretaceous kimberlites (diamonds may contain up to 160 ppm Iridium) and Cretaceous-Tertiary (K-T) basalts. PGE patterns at BA are similar to the PGE patterns recorded in the Danish K-T boundary clay (Fig. 3). We suggest that the lower lithosphere may be a source for such PGE-spikes, brought to the surface by igneous processes. Whether or not such major igneous events were triggered by extraterrestrial impacts or by extraordinary mantle crises, remains to be seen.

References: (1) DeWaal, S. A. (1975) Geol. Soc. S. Afr. Spec. Publ. 4, p. 87-98. (2) Richardson, S. H., et. al. (1984), Nature 30, p. 198-200. (3) Taylor, S. R. and McLennan, S. M. (1985), Blackwell, Oxford, 328 pp. (4) Ganapathy, R. (1980), Science 209, p. 921-923.

SAMPLE	Ni/Fe	Ni/Co	Sb/(Ni+Fe) $(\times 10^{-4})$	Ni/Ir $(\times 10^{4})$	Pd/Ir	Total PGE+Au ppb
BA-84.1	0.61	55.8	0.31	0.153	6.02	3070
BA-84.2	0.89	42.0	0.67	0.233	11.61	3108
D-4.5	0.78	72.1	3.30	0.245	4.74	3495
R-4.5	0.94	78.2	25.48	0.054	3.13	6948
BA-83.B	0.92	82.2	82.39	0.032	1.65	7944
BA-83.1	0.83	74.9	68.85	–	–	
DBS-3	0.91	82.4	34.95	0.062	3.68	6859
BA-84.3	0.82	68.0	38.83	0.073	4.04	6537
L-4.5	0.82	67.6	69.92	0.102	–	
Fe Meteorite	0.09	16	0.003	0.003	1.3	27700
Chondrite	0.06	21.7	0.008	0.002	1.18	5515

– : Data not available for both relevant elements.

TABLE 1

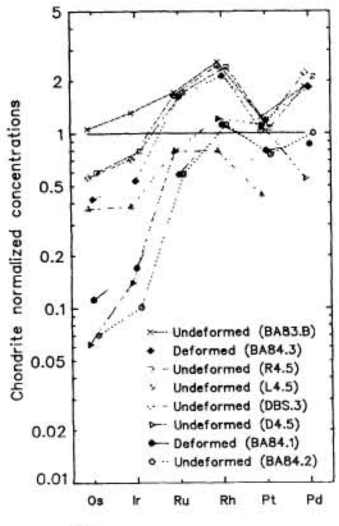

Fig 1

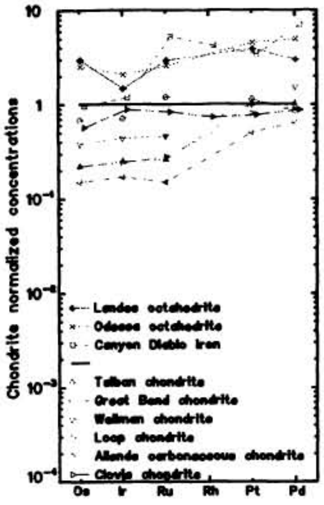

Fig 2

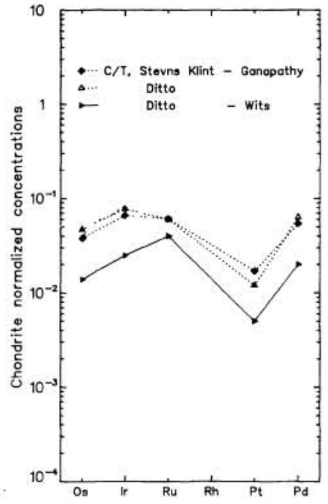

Fig 3

Figure captions: (1) PGE plots of Bon Accordite samples. PGE are plotted in order of decreasing melting temperatures from left to right. Note the large range in Os and Ir values and the distinct negative Pt anomaly in most of the samples. Chondrite values from ref. 3. (2) PGE plots of various meteorites which we have measured, note the contrast with Bon Accord samples. (3) PGE plots of the Danish Cretaceous-Tertiary (K-T) boundary clay, measured on independently collected samples in two different laboratories. There is good agreement between Ganapathy's (ref. 4) and ours (Wits). Note the distinct negative Pt anomaly, which is also present in some of the BA samples, but not in the meteorites which we have measured.