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Precious metal association in the Jaduguda uranium ore deposit, Singhbhum Shear Zone, Bihar, and its significance

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Concentrations of Pt, Pd, Au and Ag in some ore samples and sulphide-rich flotation products from the Jaduguda uranium deposit in Singhbhum (Bihar) are reported. In all the samples analysed, Pd far predominates over Pt, and Ag over Au. The geochemical significance of these concentrations is discussed.

THAT the copper ores of Singhbhum Shear Zone, Bihar, contain significant trace quantities of valuable metals like Au, Ag, Te, Se, Bi, Co, Ni is well known[1]. Some of these metals, like Au, Ag, Te and Se are recovered from the anode slimes generated during electrolytic refining of copper in the smelter of Hindustan Copper Ltd at Ghatsila, Bihar. These metals are concentrated along with copper during flotation. The Mosabani ore is reported to contain an average of 0.25 ppm Au[1] and the Rakha copper ore 0.07 ppm (ref. 2). The occurrence of suspected osmiridium has been reported in the mineral separates from Mosabani[3]. However no data on the contents of PGE, Au and Ag in the different uranium ore deposits of the Singhbhum Shear Zone are available. Here we present some data on the Au, Ag, Pd and Pt contents in samples of uranium ore from Jaduguda and in the sulphide mineral-rich concentrates separated from the ore in the Jaduguda mill of Uranium Corporation of India Ltd.

The following six types of samples were analysed:

i) Two bulk samples drawn from two different levels of Jaduguda mine and one sample of run-of-mine ore from Narwapahar Mine;
ii) A Ni-rich grab sample from the 295 m level, and a Cu-rich grab sample from the 550 m level, both from the footwall lode in the Jaduguda mine;
iii) A number of samples drawn from the bulk sulphide float produced in the by-product recovery plant (JBRP) of Jaduguda mill;
iv) A sample of the heavy mineral fraction of the bulk sulphide float, obtained by tabling;
v) Two samples of copper concentrate produced in the JBRP; and
vi) Some test products of roasting and leaching of the bulk sulphide float.

Pt, Pd, Au and Ag contents of most of the samples have been analysed by ICP-MS, Model PR1, manufactured by Fisons Instruments Inc., UK, in the Geochemistry Laboratory of National Geophysical Research Institute, Hyderabad. The samples, ground to a state that passed through 230# BSS, were dissolved using aqua regia, bromine and hydrofluoric, perchloric and nitric acids. Rh at a concentration of 100 ng/ml was used as the internal standard, as the samples were found to contain negligible amounts of rhodium. The details of the analytical procedure are published elsewhere[4]. The precision of estimation is better than ± 10%. The Au contents of a few of the samples have been analysed by INAA in the Analytical Laboratory of AMD, while the Ag contents of some of the samples have been determined by AAS in the Ore Dressing Section of BARC. The precision of these analyses is not known, but as the values are in the same range as obtained in the ICP-MS, are believed to be good.

The results are given in Table 1. Where three or more samples of the same type have been analysed, the

Table 1. Some precious metal contents in samples of Jaduguda uranium ore (all values in ppm)

Sample	Pt	Pd	Au	Ag
Jaduguda ROM ore				
Lot I (0 m level)	0.12	1.54	0.064*	2.0@
Lot II (434 m level)	0.15	1.44	0.051*	2.0@
Lot III (Comp. May 93)	nd	nd	nd	2.4@
Mean	0.135	1.49	0.058	2.1
Jaduguda ore sample				
Ni-rich sample from 295 m level	0.08	3.51	0.13	2.14
Cu-rich sample from footwall side of FW Uranium lode at 555 m level	0.01	0.85	0.03	12.28
Narwapahar ROM ore sample	0.06	3.03	0.070*	3.0@
Bulk sulphide float from BRP, UCIL, Jaduguda				
1	nd	nd	1.25*	11.0@
2	0.15	6.60	1.56	15.94
3	0.10	7.06	1.79	11.25
4	0.10	6.60	2.40	12.99
5	0.10	6.06	3.68	22.27
6	0.08	4.76	4.58	11.71
7	0.04	5.67	1.68	8.11
8	0.06	5.68	0.38	10.83
9	0.06	5.17	1.34	81.91
Mean	0.083	5.95	2.18	13.01
Standard deviation	0.033	0.78	1.29	4.34
Table con. from bulk sulphide float	1.09	45.7	53.40	63.40
Copper concentrate from BRP, UCIL, Jaduguda				
1	0.10	3.17	2.81	13.58
2	0.14	4.76	2.26	17.20
3	nd	nd	2.70*	16.0@
Mean	0.12	4.0	2.59	15.59
Standard deviation	–	–	0.29	1.84
Processed samples of Jaduguda BSF				
Residue of sulphatizing roast-leach	0.13	6.08	2.80	11.58
Thiourea leach residue				
1	0.06	4.36	1.11	5.90
2	0.11	3.85	1.01	5.08

All analyses unless stated otherwise are by ICP-MS.
*Analysis by INAA by Analysis Group, A.M.D.
@Analysis by AAS by Analytical Chemistry Group, ODS, BARC.
nd = Not determined.

mean and standard deviation values are also given in Table 1.

Table 1 shows that the uranium ores of Jaduguda contain significant concentrations of Au, Ag and Pd, and that part of these are concentrated during flotation of sulphides. A typical bulk sulphide float (containing 9% Cu, 8% Ni, 3% Mo and 0.4% Co) analyses 2.2 ppm Au, 6 ppm Pd and 13 ppm Ag, and these values could be considerably concentrated by gravity concentration to 53, 46 and 63 ppm respectively. These are economically significant concentrations as by-products, but for the fact that the tonnage involved is very limited (about 1500 TPY of bulk sulphide float only). No data on the precious metal concentrations in the bulk sulphide floats from the copper ores of different parts of the Singhbhum shear zone are available, except that the copper concentrate from Mosabani is reported to analyse about 3 ppm Au[1] and average 50 ppb Pt (range 25–70)[5], and that from Rakha 2 ppm Au[2]. The present data, particularly the predominance of Pd over Au, underscores the necessity to analyse all the uranium and copper ores from the Singhbhum Shear Zone and the sulphide concentrates obtained from them for their precious metal concentrations.

An intensive ore microscopic study of heavy mineral fractions obtained from ground Jaduguda ore has shown the presence of distinct xenomorphic particles of native gold, and a group of PGE minerals tentatively identified as merenskyite–kotulskite [(Pd,Pt) $(Te,Bi)_2$–Pd $(Te, Bi)_{1-2}$] and potarite (Pd Hg)[6]. The former PGE mineral is in intimate intergrowth with a mineral resembling sopchite (Ag_4 Pd_3 Te_4). However, confirmation of the identity of these minerals is possible only after EPMA study. It is also known that 'invisible PGE' can occur within sulphide minerals[7]. Nickel minerals like pentlandite, gersdorffite, melonite and members of NiTe–$NiTe_2$ solid solution are the major carriers of PGE, especially Pd[8]. Besides common pentlandite, both gersdorffite and melonite of composition Ni_3 Te_5 are reported from the Jaduguda ore[9,10].

An interesting feature of the concentration of these metals is the relative enrichment of Pd, Pt and Au in the nickel-rich part of the lode and of Ag in the Cu-rich part of the lode. The analysed nickel-rich sample (containing about 2% Ni) is practically free from copper, while the Cu-rich ore sample is impoverished in Ni. This is to be expected because in the Jaduguda deposit the nickel lode nearly coincides with the foot wall lode of uranium, while the copper lode extends to the foot wall side of the uranium lode into the Dhanjori volcanics[11]. This spatial distribution may be taken to indicate different geochemical sources for U, Ni and Cu; while there is little doubt that the Dhanjori volcanics is the source for the copper[12], U and Ni seem to be derived from the Singhbhum granite-greenstone complex (SGGC)[13,14], a typical Archean cratonic mass occurring to the south of the Singhbhum shear zone. The PGE and Au concentrations are also probably derived from the SGGC. Further support to this view comes from the fact that the footwall uranium lode in the Jaduguda mine is confined, to a greater part, to a prominent quartz-pebble conglomerate (QPC) horizon and that the QPC horizons occurring elsewhere in the Singhbhum craton contain significant concentrations of gold[15,16].

A second interesting feature is the greater preponderance of Pd over Pt, a feature not generally recorded from primary occurrences of PGE. This may indicate a komatiitic parentage of the source rocks, which characteristically exhibit low Pt/(Pt + Pd) (enrichment of palladium) and Cu/(Cu + Ni) (enrichment of nickel)[17], or may be due to remobilization and precipitation, as Pd is geologically more soluble and hence mobile[18,19].

Considering that the weight of the bulk sulphide float in the JBRP is of the order of 0.6 to 0.8% of the feed to the flotation circuit, the recovery of the precious metals is only partial, though they are concentrated in the sulphide float. The Au/((Au + Pt + Pd) ratio in the ore samples analysed is about 0.03–0.04, which is within the range observed in most of PGE-mineralized rocks[8]. This ratio in the bulk sulphide float is 0.2 to 0.5 and hence it appears that gold recovery is better compared to PGE.

Can the PGE, Au and Ag values be recovered from the sulphide floats? Studies are in progress in the Ore Dressing group of BARC on the feasibility of recovering the Cu, Ni, Co and Mo values in the bulk sulphide float by sulphatising roasting, followed by leaching. From Table 1 it appears that the precious metal values remain in the roast-leach residue after sulphatizing roasting. Thiourea has been found to be a good leachant for gold[20,21], and the sulphatizing roast-leach residue was subjected to thiourea leaching in the presence of excess ferric sulphate for 6 h at a temperature of 70°C. The assays of the residue of this leaching are included in Table 1. While nearly 60% of the gold and silver values are leached out, the leachability of Pt and Pd are about 35%. It may be possible to improve the leachability of all these metals by optimization of leaching parameters.

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