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Occurrence of platinum group minerals in the Western Bastar Craton, Chandrapur District, Maharashtra

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The occurrence of platinum group minerals (PGMs) and gold is reported in association with Fe–Ni–Cu sulphides and chromite in mafic–ultramafic rocks (gabbro–pyroxenite) of Gondpipri area in the Western Bastar Craton. These minerals are mainly moncheite and palladium moncheite and are identified using scanning electron microscope. Chemical analysis of bed-rock samples shows anomalous platinum group element values in which palladium dominates over platinum. This communication highlights the distribution of PGMs and their mineralogical association.

Keywords: Gabbro, gold, platinum group minerals, pyroxenite.

THE importance of platinum group element (PGE) in modern industrial applications gives a new dimension to PGE exploration across the globe. In India, PGE exploration is given more attention not only to reduce the burden on import, but also to meet the growing demand. At present three potential deposits of PGE mineralization have been identified in India, viz. (i) Baula–Nausahi Complex in Orissa, (ii) Sittampundi anorthosite Complex in Tamil Nadu and (iii) mafic–ultramafic Hanumalapur Complex in Karnataka[1,2]. Besides this, PGE occurrences have also been reported from Kondapalli ultramafics of Andhra Pradesh[3], Manipur–Nagaland ophiolites, Nidar ophiolites of Jammu and Kashmir, ophiolites of Andaman and Nicobar Islands, auriferous load in Sakoli fold belt in Maharashtra[4], and Chitradurga schist belt in Karnataka. In this communication, we report PGE–Au–Ni–Cu sulphide mineralization in Bastar Craton[5] from the mafic–ultramafic rocks of Sukma Group around Gondpipri area, though PGE geochemistry has already been studied[6].

The Precambrian craton is bounded by Godavari graben in the south, Eastern Ghats Mobile Belt in the east and Central Indian Suture Zone in the north. The Proterozoic Pakhal Group of rocks, Gondwana sedimentaries and Deccan traps occur to the west of the Bastar Craton. The study area is located about 200 km south of Nagpur in the western part of the Bastar Craton (Figure 1).

In this area, the Archaean to Palaeo-Proterozoic Sukma Group[7,8] comprises of dominantly high-grade metamorphic rocks (charno-enderbite) and gneiss with subordinate mafic–ultramafic rocks, which we will refer to as the Gondpipri complex. This is described as a part of the passive continental margin or back-arc compressional basin setting[7]. The mafic–ultramafic suite occurs as scattered enclaves in the gneissic terrain[9].

The charno-enderbites and the mafic–ultramafic rocks form the basement for the overlying Meso- to Neoproterozoic platformal sediments of Pakhal Group in the western part of the Gondpipri area[10]. The main rock types of the area include charnockite, pyroxenite and gabbro (Figure 1).

The Gondpipri complex consists of several tectonically dismembered gabbro–pyroxenite bodies disposed intermittently in a 10 km long linear belt trending NE–SW. This set-up is more or less similar to the Chennagiri layered complex of Dharwar craton[2].

The mafic–ultramafic rocks show sharp contact with the surrounding charnockite in a few outcrops. However, their exact field relationship could not be convincingly established due to the paucity of outcrops. The length of these lensoidal bodies of gabbro and pyroxenite varies from 10 m to 1 km and the width between < 1 m and about 200 m. These are medium to coarse and exhibit primary magmatic layering defined by parallel arrangement of plagioclase laths and tabular pyroxene at places, without any evidence of recrystallization and post-crystallization deformation. The foliation trends ENE–WSW with moderate dip towards SE.

A majority of these gabbro and pyroxenite bodies are fresh or weakly altered at places. Alteration is manifested

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by the development of pink mantle of albite and/or alkali feldspar on plagioclase[11]. The canary-yellow oxidation after pyrite[12] and pyrrhotite[13] as well as the presence of fine disseminated sulphides in freshly broken surface of pyroxenite and gabbro are the surface indication of Fe–Ni sulphide mineralization.

Gabbro is a medium to coarse-grained meso- to melanocratic dark-grey rock showing granular texture. It is composed primarily of plagioclase ($An_{0.51}Ab_{0.49}$), Cpx and Opx with biotite and opaques as accessories. Pyroxenite is a coarse-grained melanocratic rock exhibiting cumulate texture. It is composed of sub-equal proportion of Opx ($Fe_{0.34–0.29}Mg_{0.71–0.65}Ca_{0.007–0.003}$) and Cpx ($Fe_{0.13–0.10}Mg_{0.42–0.37}Ca_{0.48–0.46}$) with inter-cumulus plagioclase of andesine to labradorite composition ($An_{0.41}Ab_{0.48}Or_{0.01}$). Biotite and hornblende occur as accessories. The opaques are mainly Ni–Fe–Cu sulphides, and subordinate Cr–Fe–Ti oxides as well as minor Pt–Pd–Te–S and native gold.

The Ni–Fe–Cu sulphides, mainly pyrrhotite, pentlandite, and chalcopyrite with rare pyrite occur as disseminations or clots within the gabbro–pyroxenite. The oxide phases include magnetite, chrome–magnetite, ilmenite and minor chromite. The oxides occur at the grain margins of silicate phases. Pyrrhotite seldom occurs alone, but is usually accompanied by one or more of the other main sulphides. Pentlandite shows granular habit as well as forms flame-like exsolved lamellae within pyrrhotite. Sulphide–silicate grain contacts are typically smooth, rounded and lobate-shaped, which suggest that the sulphides originally occurred as a liquid phase interstitial to cumulate silicate phase[14]. The sulphide minerals exhibit two main occurrences: (i) the earlier sulphides occur as fine specks, irregular blebs and grains occupying the interstices between either silicate or oxide minerals or both, and (ii) the later mineralization is represented by minor veinlets and stingers of chalcopyrite redistributed along the fracture planes is linked to post-magmatic disturbances.

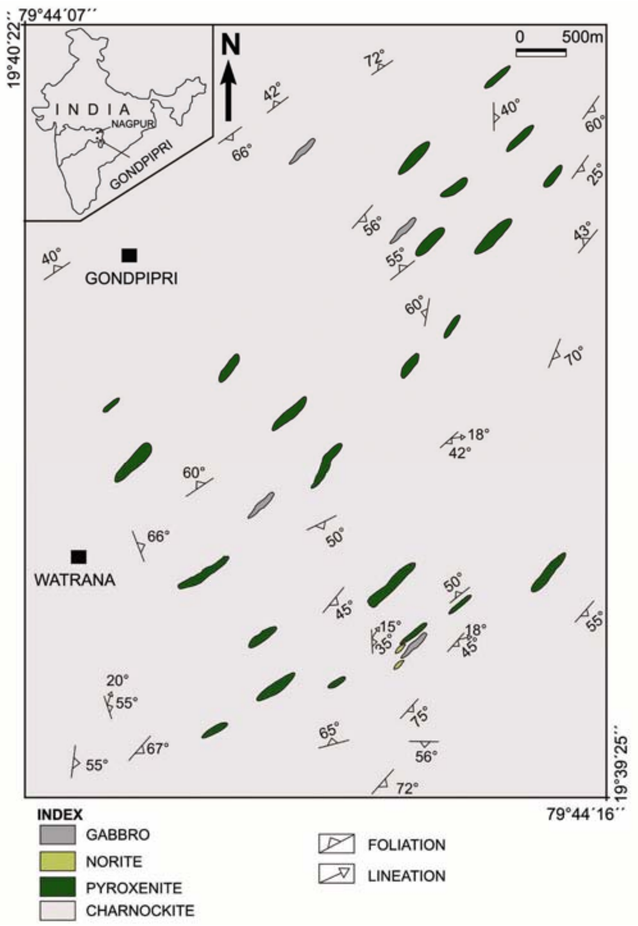

Figure 1. Geological map of Gondpipri area, Western Bastar Craton, Chandrapur District, Maharashtra.

These mineral phases were quantitatively determined using electron probe micro-analyzer (EPMA–CAMECA SX-100) using Wavelength Dispersive Spectrometry (WDS) at the Central Petrological Laboratory, GSI, Kolkata[14]. A beam of 1 μm was used for analysis of minerals under the working conditions of an accelerating voltage of 15 kV and current intensity of 12 nA. Natural standards were used for all elements, except Mn and Ti, for which synthetic standards were used. The composition of the identified Ni–Fe–Cu sulphide phases is presented in Table 1.

Platinum group minerals (PGMs) occur along the interface of silicates and sulphides in pyroxenite. The PGMs identified are essentially all tellurides. Three different types of PGMs were identified by scanning electron microscope (SEM) in sulphide–chromite assemblage, i.e. palladium moncheite (PtPdTe), moncheite ($PtTe_2$) and one unknown mineral described as 'Mineral K' (Pt–Te–Fe–S) (Figures 2–5). The composition of PGMs and associated sulphides was determined by quantitative energy dispersive spectrometry (EDS) using SEM–EDS (CARL ZEISS-EVO 40) at GSI, Kolkata (Table 2). These semi-quantitative data permit identification of the minerals[15].

The spatial distribution of PGE was studied by collecting bedrock samples of gabbro–pyroxenite which were processed in nickel sulphide fire assay pre-concentration followed by chemical analysis in Inductive Coupled Plasma–Mass Spectrometer (ICP–MS)[16]. Analysed samples show anomalous PGE values (Table 2) in which Pd dominates over Pt. Precision and accuracy of PGE determination was based on repeated analyses[16]. Abundance of Ru, Os, Rh and Ir was insignificant. It has been observed that Pd, Ru, Os, Rh and Ir are incorporated in pentlandite without forming an individual mineral phase elsewhere[17].

The total PGE content varies from 189 to 707 ppb (5E) in pyroxenite, 400 ppb (Pt + Pd + Ru) in gabbro and 48 ppb (Pt + Pd) in charnockite occurring at the contact of gabbro–pyroxenite. The concentrations of Ni, Cu, Cr and Co (Table 3) were determined by atomic absorption spectrometry (AAS) at the Chemical Laboratory, GSI, Nagpur[18]. It was also observed that the PGE content increases in the presence of sulphides in the host rock.

Table 1. Representative composition (in wt%) of sulphides by EPMA in Gondpipri area

Analysis	Pentlandite	Pentlandite	Chalcopyrite	Chalcopyrite	Pyrrhotite	Pyrrhotite
S	33.38	33.09	35.07	33.15	39.49	39.96
Fe	29.86	29.93	29.88	30.22	59.71	59.24
Co	0.88	1.48	0.04	0.05	0	0.08
Ni	36.35	35.05	0	0.06	0.41	0.63
Cu	0.14	0	34.14	34.38	0.09	0.06
As	0	0.05	0	0.03	0.04	0.07
Ag	0	0	0	0.06	0.01	0.03
Au	0.22	0.01	0	0	0	0
Zn	0	0	0.02	0	0	0
Bi	0	0	0.11	0.15	0	0
Total	100.83	99.61	99.25	98.09	99.76	100.07

Table 2. SEM-EDS analyses of PGM and associated minerals of Gondpipri area

	Element weight (%)									
Sample no.	Pt	Pd	Te	Fe	Au	S	Ni	Ag	Total	Mineral
16JU/3C	41.62	–	56.33	2.05	–	–	–	–	100	Moncheite
16JU/3A	30.53	7.67	60.74	1.06	–	–	–	–	100	Pd–moncheite
16JU/3B	32.71	6.76	58.36	2.17	–	–	–	–	100	Pd–moncheite
16JU/3D	26.65	–	36.12	13.00	–	24.22	–	–	100	(K ?)
18M/11A				2.75	84.47			12.78	100	Argentium gold
18M/11B				28.77		35.73	35.70		100	Pentlandite

Table 3. Chemical analysis of PGE and base metals of Gondpipri area

		Pt	Pd	Ir	Rh	Ru	Ni	Co	Cu	Cr
Sample no.	Rock type	Values in (ppb) by ICP–MS					Values in (ppm) by AAS			
16JU/19	Gabbro	60	137	4	5	10	550	75	150	–
6J/15	Pyroxenite	78	95	6	3	7	350	75	100	925
K9my/19	Pyroxenite	135	403	25	26	115	350	100	200	–
K9my/22	Pyroxenite	58	218	3	7	9	350	75	175	–
6J/4a	Charnockite	13	35	< 3	< 3	< 3	25	15	35	40
K9MY/15	Pyroxenite	78	210	3	10	10	400	60	75	–
K9MY/28	Pyroxenite	89	231	5	9	17	–	–	–	–

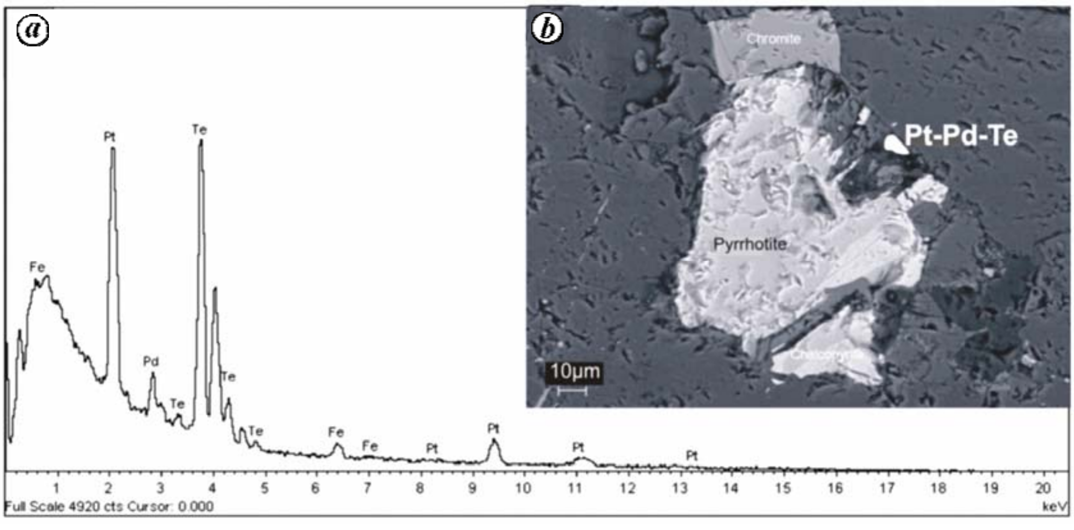

Figure 2. Bright grain is platinum group mineral identified as palladium-bearing moncheite associated with silicates and sulphides. EDS spectrum (***a***) and SEM-backscattered electron image (***b***) of palladium-bearing moncheite.

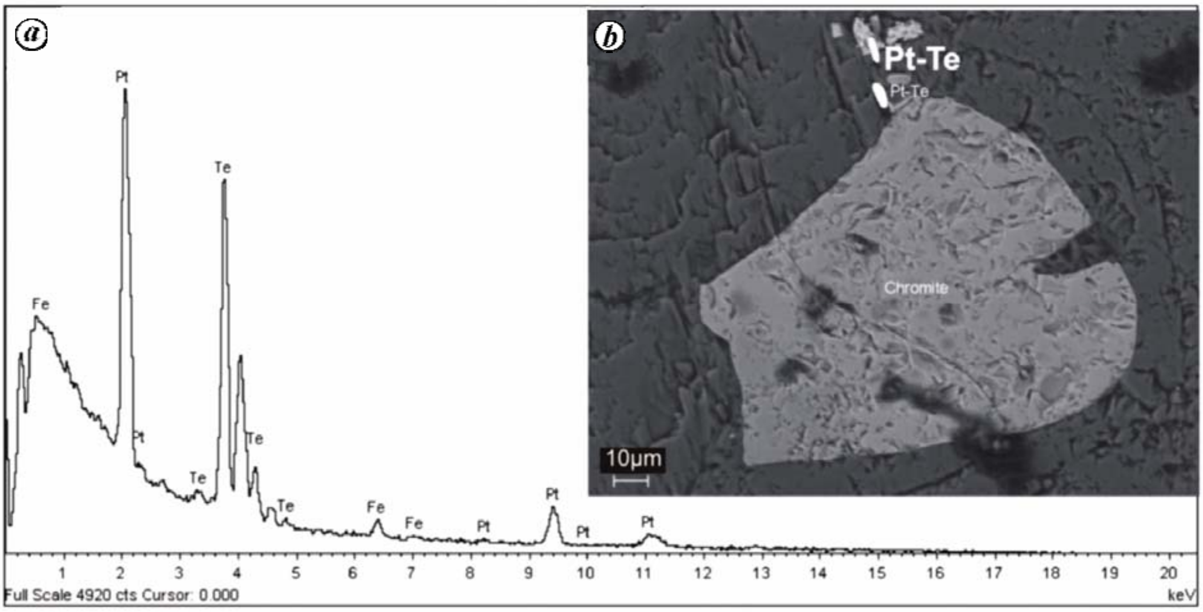

Figure 3. Bright grain is PGM identified as moncheite associated with silicates and chromite. EDS spectrum (***a***) and SEM-backscattered electron image (***b***) of moncheite.

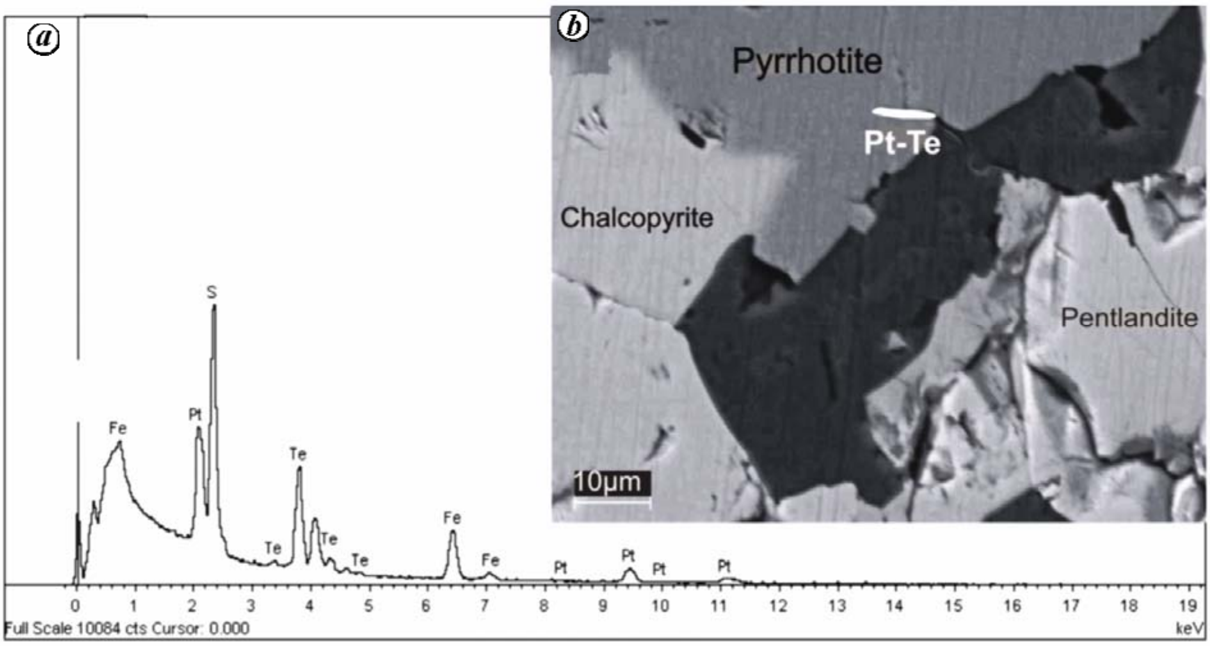

Figure 4. Bright grain is PGM–mineral-K associated with silicates and sulphides. ***a***, EDS spectrum of Pt–Te–Fe–S alloy. ***b***, SEM-backscattered electron image of mineral-K.

PGE content shows positive correlation with sulphides in the host rocks. The PGE occurrence in Gondpipri area resembles the Pd–PGE Group of the Geordie Lake Intrusion, Ontario[10], as it contains Pd, Pt, Rh and Au.

PGMs in association with silicate, base-metal sulphides and chromite are also reported in several ultramafic–mafic intrusions of ophiolites, alpine-type peridotites and stratiform complexes[19–22]. Important PGE deposits of the Bushveld complex (UG-, MG- and UG2-chromitite) and the A-horizon of the Stillwater complex[19] are associated with chromite and sulphide respectively. On the basis of mineralogical association, the Gondpipri occurrences can be closely compared with the sulphide–chromite association of the Baula–Nuasahi PGM deposit of Singbhum Craton, India[23,24] and The Geordie Lake Intrusion, Coldwell Complex, Canada[25]. The occurrence of PGE in

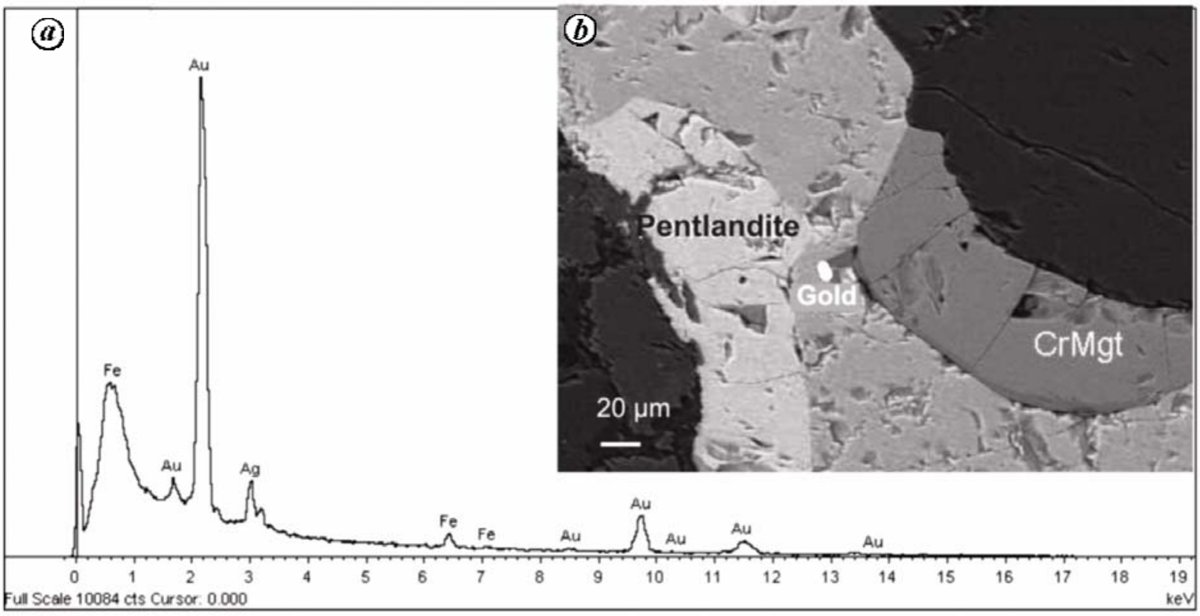

Figure 5. Bright grain is gold identified as silver-bearing gold. EDS spectrum (***a***) and SEM-backscattered electron image (***b***) of silver-bearing gold.

ultramafic–mafic rocks and its genetic relation with the source magma have now become a thrust area for research. PGM occurrence of Gondpipri is yet to be characterized. In similar geological settings elsewhere, some workers have suggested that Pt could enter the structure of the chrome spinel[25–27]. The effect of crystallization of chromite on the concentration of PGE in this type of association has also been reported[28,29]. A majority of the PGMs associated with telluride are either believed to have crystallized as discrete phases prior to the earliest sulphides or along with them from the magma enriched in PGE[30–32].

The Gondpipri finding is expected to provide certain basic field guides for PGE mineralization in the Bastar Craton and may serve as a stimulus for intensified exploration activities in the adjoining areas. So far as the PGE exploration in the Bastar Craton is concerned, this occurrence has great significance, where massive bands of chromite and/or magnetite, typical of layered complexes, are missing. This discovery of platinum and gold mineralization in association with chromite and Fe–Ni–Cu sulphides of Gondpipri ultramafic complexes opens up a new horizon for PGE exploration in the Bastar Craton, Central India.

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