Reconnaissance Mineralogical and Geochemical Examination of the Late Archaean Ultramafic Bodies in parts of Shimoga Schist Belt, Karnataka Craton, for Discovering Evidence of PGE Mineralization

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The Shimoga Supracrustal belt, the largest of all the schist belts of Karnataka, occupies about 30,000 Km^2 of western Dharwar craton. Available limited isotopic age data has indicated that the belt consists of 2.5 to 3.0 Ga old late Archaean volcano-sedimentory stratigraphic sequence overlying 3 to 3.4 Ga old middle Archaean basement granitoids (Radhakrishna and Vaidyanadhan 1997). The belt is known to include several mafic-ultramafic bodies, which intrude both basement granitoids and the supracrustal sequence. A large number of these occur forming an approximate girdle parallel to the western and southern borders of the belt, possibly defining a late Archaean hot-spot zone. Many of the mafic-ultramafic bodies of the belt are well known hosts of V-Ti magnetite deposits. They are also known to host chromite deposits, but less commonly. Evidence of PGE mineralization in one of these bodies viz., Hanumalapura block, about 15 km south of Channagiri, was brought to light in the nineties (Devaraju et al 1994, 1994a, Alapieti et al 1994). Encouraged by the finding, the present authors have carried out reconnaissance geochemical and mineralogical examination of 20 other occurrences in addition to detailed investigation of the Hanumalapur block. There is no quantitative data available regarding the time span covered by these mafic-ultramafic complexes, but, considering their field relationships, petrography and geochemical information, it is believed that they are all genetically related and their emplacement took place in the early stages of basin formation and deposition of the supracrustal sequence.

All the ultramafic bodies examined have experienced a combination of penetrative deuteric alteration (autometamorphism), deformation and greenschist to low-grade amphibole-facies metamorphism resulting in near complete replacement of the original silicates, olivine and pyroxenes by serpentine, chlorite, amphiboles, epidote and carbonates. Even the chromite is largely altered to Cr-rich magnetite/secondary magnetite with only the Cr-rich cores of the mineral retaining the original characters. The textural relationships of the PGE mineral inclusions, however, do not suggest any significant migration of the PGE associated with the ubiquitous alterations of the host ultramafic rocks.

The more important field, petrological, mineralogical information relevant to PGE mineralization in a few interesting cases examined is summarized in the following:

Usgao (Goa : ~60 km E of Panaji)

Layered lopolithic body, 12 km long and 1 to 4 km wide. Consists of layers of chromitite, dunite, peridotite, troctolite, gabbro and anorthosite (Balakrishnan et al 1992) .Only one of the three samples examined is found to contain within the limits of a thin section of 3.5 x 2.5 cm 2 minute inclusions laurite and one of Pt-Fe-Cu-Sn alloy, approximately comparable to tulameenite. The sparse occurrence of minute PGE mineral inclusions, low Pt content of about 0.5 ppm reported by Balakrishnan et al (1992) and also the location of the body in a protected biosphere reserve have discouraged a more detailed investigation.

Shankaragatta (24 km SSE of Shimoga city)

This is the smallest of the three tabular bodies of ultramafites which occur co-folded with quartz-chlorite schist and other lithologies of Shimoga Supracrustal belt. It is approximately 12 km long 0.5 km wide. Almost massive metadunite with no readily recognizable layered structure. Contains about five meters wide sulphide zone in the eastern section, which is picked up over a strike length of 2 km, and small isolated pods/patches of ultramafic chlorite rock, in the western section.

The sulphide zone localizes Ni-Au-Pd-Pt mineralization and the best sample from this zone analyses 1.3% Ni, 2.7 ppm Au, 0.8 ppm Pd and 0.2 ppm Pt. Millerite-pentlandite are the main Ni minerals and melonite is the chief carrier of Pd. This is the second best find of the present study. However, in spite of the promise this holds as Ni-Au-Pd-Pt deposit of possible commercial value, its unfavorable geographical location in the vicinity of

Bhadra reservoir and large settlements do not encourage further investigations.

Dismembered layered complex enclosed in the granitoids of the SE flanks of Shimoga belt (~60 km ESE of Shimoga)

This comprises more than 25 individual bodies which form a linear array spread over an area of 17 km x 15 km. Ten of these have been examined. None has yielded encouraging results to warrant a more detailed examination. Following is the brief description of the data obtained for the best preserved block of layered complex lying east of Rangapura village. Most part of this block consists of chromite-banded dunite-peridotite-pyroxenite with occasional small pods of chromitite and fine grained Al-Fe-rich chlorite rock. Gabbroic variations are limited to the western border of the block. Occupies about 4 km^2 area. 14 samples representing all the important ultramafic units including the chromitite of the block have been mineralogically and geochemically examined. Elevated Os (50-70 ppb), Ir (20-45 ppb) and Ru (48-115 ppb) and conspicuously low Rh (<8 ppb), Pt (<5 ppb) Pd (<2 ppb) and Au (<1 ppb) are recorded. Samples with a total of more than 150 ppb of Os-Ir-Ru invariably contain minute sporadic PGE mineral inclusions, largely in the range of ***laurite*** and ***irarsite.***

Segmented ultramafic complex forming a part of Hegdale Gudda Formation of Shimoga belt (~36 km ESE of Shimoga)

This is a tectonically segmented layered ultramafic complex constituting a large part of Hegdale Gudda Formation. Occupies the lower-most columns of the Supracrustal sequence of Shimoga belt. Extends in NE-SW direction for 37 km and has a maximum width of 15 km, tapering to about 3 Km at the SW end. Occurs occupying the gaps between the domal blocks of basement granitoids and the contact zone between these blocks and younger Kur Gudda and Tuppadahalli Formation (Chadwick et al 1988). Best known are the segments exposed in the vicinity of Masanikere, Tavarekere, Hanumalapur, Ubrani, Chickkamalali, all enclosing some of the very prominent and V-Ti magnetite seams. An examination of these for PGE mineralization has revealed that among the segments mentioned only Hanumalapur is the most important. Coincidentally only in this segment there is the association of V-Ti magnetite and chromitite; in all others only magnetite seams occur and no significant anomalies of PGE warranting a more detailed investigation are picked up.

The Hanumalapur block constitutes 0.3 km x 3.5 km tabular northern extension of Tavarekere segment. This layered extension comprises narrow gabbroic border zone on either side and a thick central zone consisting of fine grained chromite-chlorite rock (derived from dunite containing bands and lenses of chromitite) and coarse grained pegmatitic metapyroxenite. The contacts between the borders and the central zone are occupied by thick V-Ti magnetite seams and isolated pods/lenses of anorthosite.

Mineralogical and geochemical examination of more than 80 samples from the outcrops and a trench cut across the central zone has revealed that the PGE mineralization is lithologically and stratigarphically controlled, being localized to the fine grained chromite-chlorite rock forming 30 to 50 m of the central zone and to the chromiferous magnetite seam located in the eastern contact zone. Anomalous Pt-Pd values attaining ore level are recorded over the entire strike length of 3.5 km. Analysis of trench samples has further indicated that the mineralization is diffused over as much as 50-60 m wide zone. Exploratory drilling carried out so far has confirmed not only the stratigraphic localization but also the strike persistence of the mineralization for about 2 km. The mineralization is noted to include more of Pd-rich reefs than Pt-rich ones. This is the most important find of the present study and holds a very high promise of a commercially workable deposit.

Analyses of the representative rocks hosting PGE mineralization and also the typical platinum minerals in the Hanumalapur and Shankaragatta occurrences, the two locations where evidence of ore level PGE mineralization has been recorded, are presented in Tables 1 and 2.

Based on the experience of the present reconnaissance study, it is recommended that in a more detailed future exploration, the following targets can be selectively examined for location of PGE mineralization in the Shimoga and other late Archaean greenstone belts of Karnataka:

i. Layered Fe-Al rich complexes (also enriched in Ni, Cu and Zn and depleted in REE) hosting both magnetite and chromite seams i.e., comparable to Hanumalapur find (SJ- reef-type mineralization in Penicat layered intrusion, Finland, Alapieti and Lahtinen 1986).
ii. Nickeliferous sulphide zone in massive metadunite with no recognizable layering i.e., comparable to Shankaragatta find (Merensky-type mineralization, Campbell et al 1983).

Table 1. *Analyses of PGE mineralized rocks*

	1	2	3	4
	M5:96	M98:97	M93:97	192:97
SiO_2	14.93	9.56	8.2	35.03
TiO_2	1.55	2.86	2.5	0.06
Al_2O_3	11.84	11.33	5.5	0.9
Cr_2O_3	11.52	18.29	5.9	0.37
Fe_2O_3	40.05	46.46	70.18	11.85
MgO	14.42	10.04	5.17	36.5
(ppm)				
Ni	1511	1087	925	13601
Cu	306	85	254	73
Zn	710	933	502	38
PGE	(ppb)			
Pt	1200	860	930	223
Pd	3380	2080	630	813
Au	82	370	12	2700

1.Chromite-Chlorite rock, 2 & 3 Chromiferous magnetites : from Hanumalapur block
4. Ni-sulphide mineralized metadunite : from Shankaragatta

Table 2. *Chemical analyses of typical PGE minerals*

	1	2	3	4	5
	M5:96	M5:96	M98:97	M93:97	M192:97
Pt	51.18			25.73	
Pd	0.18	6769	63.57	1.21	9.13
Rh	1.02			15.28	
Ru				2.20	
Ir					
Sb		29.05	5.31		
Te			5.11		76.43
Bi			21.42		
Ni					11.99
Te					2.39
Cu		0.76	1.64		
S			8.06		
As	43.63	0.78		36.21	

1. Sperrylite 2. Merteiite-II 3. Keithconnite
4. Hollingworthite 5. Melonite –sample numbers correspond to PGE mineralized rocks in Table 1

The study has also brought to light that the mafic-ultramafic complexes containing only magnetite or only chromitite seams are not likely to prove as hosts of commercially important PGE mineralization -- incidentally most mafic-ultramafic complexes examined under the present reconnaissance study come under this non potential category.

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