DISCUSSION


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We appreciate the efforts of the authors in bringing out the PGE mineralization of the Hanumalapur segment of the Channagiri mafic-ultramafic complex. The authors have estimated 'an approximate combined Pt+Pd reserves of 7500 kg', 'assuming a strike persistence of 2.5 km and depth persistence down to 100 m'. However, they have omitted the information on the assumptions made on the average persistence down to 100 m'. It is stated that 'the reefs show strike persistence from 10 metres to a couple of hundred metres'. If so, how the three reefs with 3.7 gm, 5.0 gm and 4.0 gm with thickness of 20 cm, 30 cm and 35 cm respectively could be expected to extend for 2.5 km. Though, the authors have mentioned about the persistence PGE mineralization in 8 boreholes, only 7 boreholes have been shown in the map (Fig.2) over a strike length of <2 km. The authors have not provided information on the grades and thickness of mineralization in any other boreholes. From the map and the description, it is inferred that there is only one trench closer to the BH-1 profile in the entire area and there are no other surface controls of mineralization. Though, there are indications of a number of zones of PGE mineralization in the trench, it is not known which one of them is correlatable with the reefs intersected in the BH-1. It would be beneficial to the readers, if these information are also provided. In the absence of the same, it can only be presumed that the grades and thickness of the reef intersected in BH-1 has been extended for the entire length and the figure of 7500 kg of combined Pt+Pd may be considered only as resource potential rather than 'reserve'.

It has been stated that 'only the central fine-grained ultramafite and the chromiferous lenses in the eastern magnetite seem to host PGE mineralization of commercial interest with Pt+Pd values ranging from 1.5 to 6 ppm' (p.535, abstract). However, it may be noted that the richest mineralization is not on the eastern side but on the foot wall (western side) of the magnetite band (Fig.5). The fine-grained ultramafite (chromite-chlorite schist) is considered as meta-dunite with variable proportions of chromite, while the coarse-grained ultramafite as equivalent of meta-pyroxenite with variable proportions of Fe-Ti oxides. Extreme variations of the rock corresponding to chromitite and chlorite schist have been reported in the fine-grained ultramafite. The chromitite bands are also shown in borehole log of BH-1 (Fig.5). The scale used for plotting the Cr values is logarithmic. It starts with 0.01 followed by 0.1 and the next value should be 1% instead of 10%. Even if it is correct, it is surprising that none of the samples analyse more than 10% chromium. The single grain data of chromite (JS-159; Table 6) also shows a Cr₂O₃ value of about 30% and FeO ranging from 19.44 to 34.56% (total FeO ranges from 49.73 to 61.87%) with Cr/Fe ratio of 0.43 to 0.55. The Cr₂O₃ content of all the fine-grained ultramafites are less than 17.03% (Table 7). More than 70 bore hole and surface samples analysed by XRF method have indicated values in the range of 0.03 to 0.06% except for one sample with 9.44%. The EDS and EPMA studies carried out by us have shown that the oxide grains are found to be magnetite and chromiferous magnetites and there is no chromite sensu stricto. Thin section samples of the ultramafic units of the complex did not reveal presence of any relict olivine. Presence of chlorite do not confirm that the parent rock was dunite. Moreover, no serpentinisation is seen which is common in other ultramafic complexes. The EPMA studies have confirmed relict pyroxene (hypersthene, diopside and augite). So, the host for the fine-grained ultramafite can also be a pyroxenite as in the case of coarse grained ultramafite.

The authors have attempted a correlation of the PGE mineralization of Hanumalapur segment with that of the UG2 chromitite of Bushveld Complex. It is like comparing mole hill with mountain. The UG2 chromitite layer with 0.5 to >1.0 m thickness and extending for hundreds of kilometers has a chrome content of 43.5% Cr₂O₃ and a Cr/Fe ratio of 1.26 to 1.4 (Schurmann et al. 1998).

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The authors have mentioned ‘it is not clear how the thick heterogeneous PGE mineralized zones in the Hanumalapur segment were formed. But, the evidence gathered so far suggests something other than a traditional orthomagmatic model. Such an opinion derives support by the general lack of base metal association in favour of chromite and silicates’ (p.543). However, the main reefs in the borehole BH-1 are located in (metamorphosed) clinopyroxenite with picrite and websterite inter bands and the entire picrite layer’. The so-called chromite bands just happen to be associated with these pyroxenites. Association of sulphides have also been reported with the leaner PGE mineralization. The log of BH-1 (Fig.5) also indicates association of sulphides in the main reef zones with nickel and copper more than 1000 ppm. Our studies also confirm presence of base metal sulphides such as pyrrhotite, chalcopyrite and pentlandite in all the ultramafic units. All these only suggest that the PGE mineralization is associated with silicates and sulphides but not with the oxides as suggested by the authors.

The usage of the term ‘reef’ may not be appropriate for this area as the mineralized layers are not as continuous as observed in Bushveld complex as the authors themselves recorded.

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We are thankful to S. Balakrishnan and others for their appreciation of our efforts to provide with whatever data base we have been able to gather based on a prolonged period of almost fifteen years study of the Hanumalapur PGE mineralization i.e. the same since it was discovered by us way back in 1993. We offer the following clarifications for several of the points raised by them:

1. **2.5 km persistence?** The intervals of bore holes drilled by the State Department of Geology in support of our investigation varied from about 200 to almost 900 meters. The actual strike distance from BH 06 (located at northern end) to BH 08 (at the southern end) is 2.2 km. Additional 0.3 km strike persistence is extrapolated. Actually, based on analysis of outcrop samples, persistence of mineralization over a strike length of 3.5 km has been recorded. Detailed core logging of samples from the main ore zone in bore holes 01 and 03 (the two are 290 m apart) has brought to light remarkable similarity in both levels of Pd-Pt concentrations and also depths of intersection of ore zones/reefs in the two bore holes.

2. **Only seven bore holes locations shown in the map?** Bore holes 04 and 02 are essentially on the same line and direction. BH 02 is about 20 m east of BH 04. BH 02 was abandoned after drilling to a depth of about 70 m for reasons such as collapse. For the same reason BH 02 is not separately shown. BH 04 is drilled to a depth of nearly 200 m.

3. **Only one bore hole is fully logged?** Mainly because of paucity of adequate funds we could not log fully drill cores of all the bore holes. However, core samples from the main five meter ore zone of BH 03, intersected at depths of 97 to 102 m, have been continuously logged. In addition, the intersection of the PGE mineralized layers in the other drill holes is confirmed, although no continuous logging has been carried out and the levels of PGE concentrations recorded are not the same.

4. **‘Reserves’?** By labeling our estimations as ‘approximate reserves’ we actually meant ‘resource potential’ in the strict sense.

5. **Main ore zone follows essentially the zone occupied by fine-grained ultramafite shown in our enlarged map of the mineralized Hanumalapur segment (Fig. 2).**

6. **Only one trench?** Although four trenches (two 50–52 m long and the other two 20–30 m long) were made, once again because of paucity of funds, we were able to obtain serial analyses of samples collected from only one trench (Fig 4).

7. **‘Richest’ mineralization is in the western foot wall side!** Right, the main PGE ‘ore’ zone is in the western foot wall side, closely interlinked with what we have described as fine-grained (meta) ultramafite. However, for clarification we might add here that PGE mineralization recorded in the eastern magnetite seam is minor and limited to narrow chromiferous lenses located within it. We have not been able to assess the proportion/frequency of these PGE mineralized chromiferous lenses. Our intention of referring to this is to stress the fact that we have PGE mineralization associated with the eastern magnetite seam too.

8. **Mistake in the core log plotting of Cr?** There is no mistake. While the mean Cr value of 16 outcrop samples containing relatively high proportion of Fe-Cr oxides (refer our Table 6, analysis 1) is 9.16 wt % Cr (or 13.4 wt % Cr₂O₃) and more one hundred core samples of BH 01 analysed contain a maximum or 8.32 wt % Cr. The same is reflected in our logarithmic plotting of Cr data.

9. **Iron-rich composition of chromite:** Yes, the Fe-Cr oxide occurring in the PGE mineralized fine-grained
ultramafite has a very high iron content and corresponds to 'feritchromit/ferrian chromite' to 'chromian magnetite-magnetite'. We have highlighted this chemical characteristic of the mineral on page 845 and Table 6 of our paper and also in greater detail in our earlier publication dealing with 'Chemistry of Cr-spinel.....' published in the June issue of the JGSI (Devaraju et al, 2007, pp. 1161-1175). Some memories of the original chromite compositions are, however, preserved in the cores of the occasionally recorded zoned chromite crystals (refer Table 5 of our paper and also our earlier publication).

10. Relict pyroxenes? Our detailed study of more than 130 high quality polished thin sections of core samples covering the 250 m long core of BH 01, and utilizing the excellent microprobe facilities of the Oulu University have not revealed the existence of any relics of pyroxenes (or olivine)! We have, however, recorded epidote, amphibole, biotite and plagioclase in the fresh looking core samples collected from below 30 m depth. A similar detailed probe examination of a large number of outcrop samples has indicated that the PGE mineralized fine-grained ultramafite is virtually chloride-Cr-Fe-Ti oxide rock with amphiboles and carbonates assuming importance only in places.

11. Fine-grained ultramafite can also be pyroxenite! Our interpretation that fine-grained ultramafite is metadunite with chromite bands/pods/disseminations is based especially on the extremely low CaO (both outcrop and core samples analyse less than 0.05 wt%) in the whole rock analysis and absence of relics of pyroxenes.

12. Correlation with UG2 chromitite? We are fully aware that the PGE mineralization at Hanumalapur and the Channagiri mafic-ultramafic complex are no match to either the Bushveld Complex or the Great Dyke. The smaller complexes of Sompujarvi and Ala Pennika forming a part of Penikat intrusion in Northern Finland (Halkoaho, 1994) are better examples for comparison in several respects.

13. Base metal association? The main PGE 'ore' zone of Hanumalapur segment intersected at depths of 97 to 102 m (in BH-1) is sulphide free/poor. The ore contains abundant silicates and some portions include significant proportions of Fe-Cr oxide. However, in the thicker (about 40 m thick) diffused and leaner PGE mineralized zone intersected between 36 and 76 meters of the bore hole there is typical base metal sulphide association. This zone has high Cu (up to 1.8 wt%) and Ni (up to 0.23 wt%) contents too. Please refer to our recent publication in "Mineralogy and Petrology" (Alapieti et al. 2008, pp.99-128) where fuller details of mineralogy, ore types and also geophysical and ore beneficiation data are presented.

14. Considerable scope for further investigation! As pointed out in our reply to earlier received comments of Dr. K.T.Vidyadharan (see Feb 2008 issue of this Journal, pp. 290-291), there is indeed considerable scope for further investigation of the prospect. We need to establish the three dimensional geometry of the PGE ore zone over the entire strike length of 3.5 km. It is also crucial to verify that the 'ore' is amenable for beneficiation and ultimate commercial exploitation. Geological Survey of India is indeed a competent organization with all the resources needed to carryout the investigation to the logical end. We, however, have the satisfaction of having brought to light, with reliable data base, the existence of what looks like a commercially potential Pd-Pt deposit.

References


