Identification of Sandur schist belt as a potential gold field

C. Manikyamba, S. M. Naqvi, R. H. Sawkar* and G.R. Group§

National Geophysical Research Institute, Hyderabad 500 007, India
*Hutti Gold Mines Co. Ltd., Hutti, India

Preliminary mineralogical and geochemical studies with a new approach over the Sandur schist belt indicate a strong possibility of this region becoming a new gold field of India. Gold concentrations ranging from trace to 2.9 gpt have been found at ten new different localities. Earlier workers have reported old workings from Lingadahalli only. Our studies have shown high gold values in the weathered surface rock samples of (i) banded iron formations of Taranagar, Joga and Vibhutigudda, (ii) quartz veins and volcanic rock samples of Papinayakanahalli and Sujigudda-Murutalegudda, and (iii) graywackes of Vibhutigudda. Traces are found in the graywackes of Deogiri also. Most of this gold is invisible and refractory. Detailed geochemical exploration at close interval has been taken up to estimate the economic potential of these deposits. The results of this study emphasize that adoption of new concept-based exploration methodology, in addition to the existing one, can go a long way for a better evaluation of the country's precious metal resources.

SANDUR schist belt (Figure 1) is made up of 2.6 Ga old volcanosedimentary sequences which have been laid down on a passive margin fore land basin and fore arc active basin, later juxtaposed and brought to its present geometry by convergent margin and thrust thickening process[1]. The belt is divided into eight blocks exhibiting lithological, structural and metamorphic discontinuities[1,2]. The structural and stratigraphic interpretations are debated[1-5]. Since this communication is addressed to the gold potential of the belt, these debates are not discussed here. Gold potential of this belt was realized and reported by us[6] and a project was submitted to DST in collaboration with HGML[7]. Subsequently, high Au potential of the belt has been suggested by other authors also[3,8]. Here we report the preliminary results of the work carried out during the last two years. Gold mineralization in the volcanic rocks of the Lingadahalli is known since long and has been reported earlier[3,8-10]. However, other localities (Figure 1) reported here are new finds.

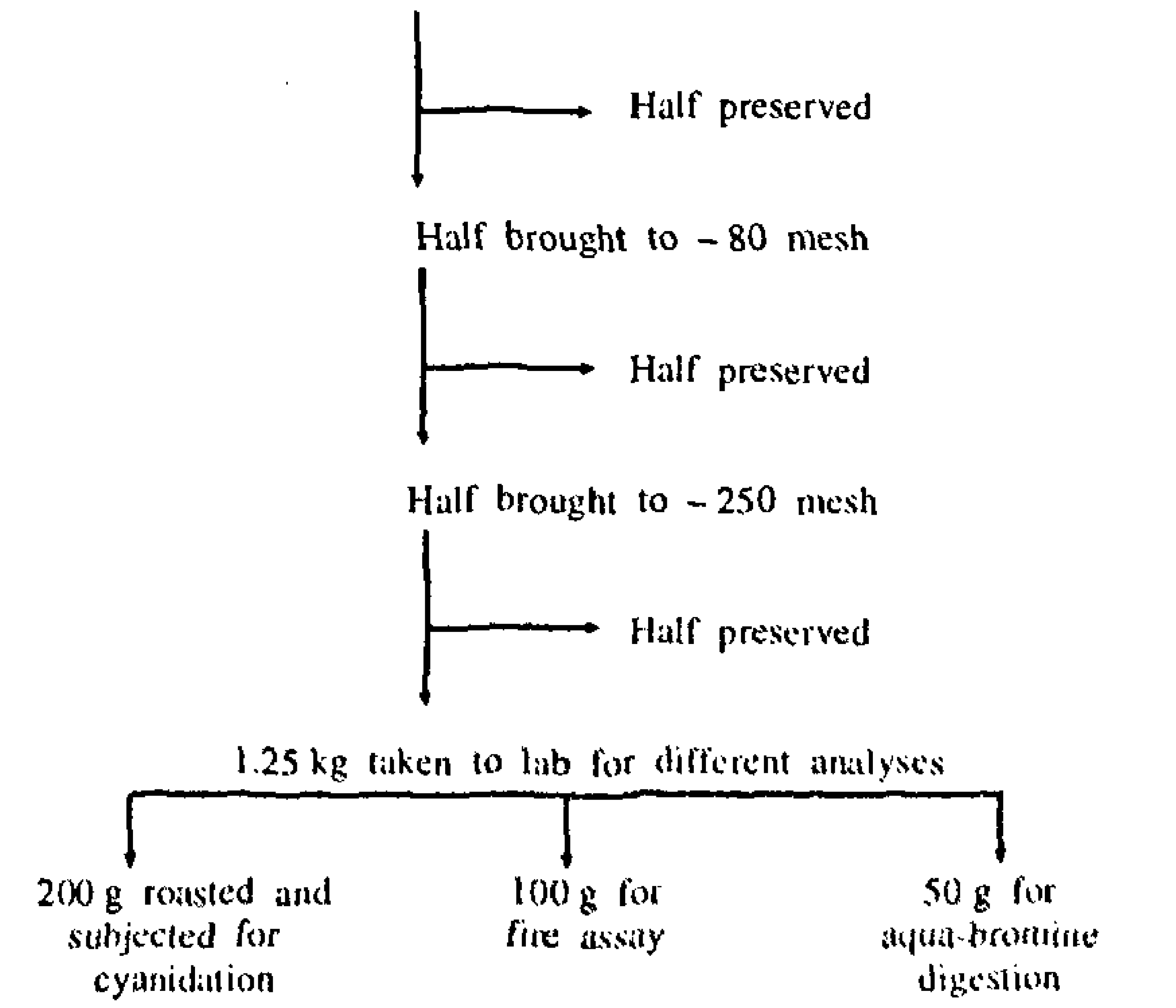
One of the major tasks for gold exploration is to identify new areas in greenstone belts where zones of anomalous gold are present. Such areas have been identified on the basis of a 14-point criterion. We propose that the region to be taken up for first-order bed rock bulk sampling should be tested for (1) presence of thick sequence of basic volcanic rocks, (2) sulphidic BIFs, (3) carbon phyllites, (4) emplacement of dykes, (5) greenschist to amphibolite facies metamorphism (200–400°C), (6) existence of acid volcanics along with metabasalts, (7) generation of fracture and shear system soon after peak metamorphism, (8) multiple ductile wet deformation, (9) emplacement of quartz veins across the schistosity, (10) presence of sulphides in quartz, (11) alteration haloes around quartz veins, (12) visible evidence of carbonatization, sericitization and chloritization, (13) multiple felsic intrusive activity, (14) presence of old workings.

All these characteristics are found in Sandur schist belt and thus we believe that this is one of the main areas which has been subjected to convergent margin processes, generation of secondary hydrothermal fluids, resulting in mineable gold mineralization along certain suitable zones. Along such zones where 10 or more characteristics mentioned above are found, first-order bed rock bulk sampling has been carried out.

Obtaining a representative sample and the procedure for its analysis are the two most important aspects for realistic estimation of the gold content of a prospect. Distribution of gold is inheritantly inhomogeneous. Size of the sample collected is the most important factor to avoid the nugget effect. Small samples generally lead either to over or underestimation of gold content of a given area. Therefore, the bulk sampling and analysis of a large amount of sample is essential to obtain reliable values. Since our petrographic examination under EPMA has shown that gold occurs in submicron size, we collected 10–15 kg sample from different localities and subjected them to sample reduction and analysis, as given in the flow chart below.

Procedure followed for the bed rock bulk sampling and analysis

10–15 kg sample at 50–100 m interval broken by hand and jaw crusher to 1–2 cm chips and divided into two equal parts by quartering and conning.



§G.R. Group – represents the entire team of gold project from NGRI and HGML.

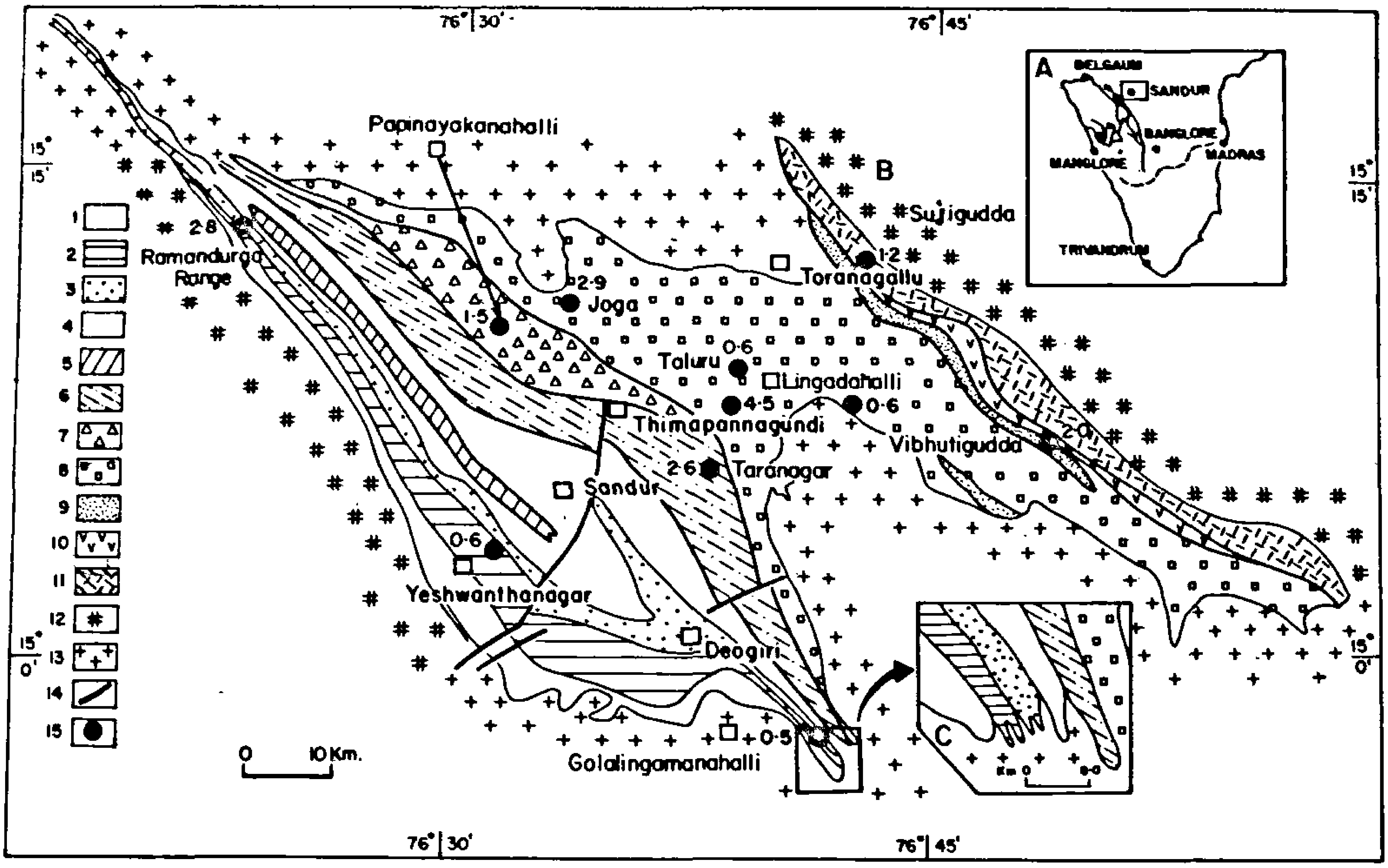


Figure 1. Geological map of Sandur schist belt showing the subdivision into different lithotectonic blocks and the accretion planes which a termed as layer parallel faults (LPF). 1. Yeswanthanagar volcanic block; 2. Deogiri block; 3. Western volcanic block (BIF block); 4. Cent volcanic block; 5. Graywackes in central volcanic block; 6. Eastern volcanic (BIF) block; 7. North central acid volcanic block (graywacke-co glomerate); 8. Sultanpura volcanic block; 9. Metasediments of eastern acid volcanic block; 10. Acid volcanic rock; 11. Amphibolites; 12. Grani gneiss; 13. Granites; 14. Faults; 15. Location of the areas studied for gold exploration.

Cyanidation of 200 g powder (– 250 mesh) for 24 h in the presence of H_2O_2 in an alkaline medium has yielded best results. Samples that yielded gold values of 0.5 gpt or more were analysed by fire assay at HGML and MSPL. Furthermore, these samples were also analysed by ICP-MS and AAS. Details of the analytical procedures developed and adopted at NGRI have been recently published[11]. Values obtained by cyanidation under air agitation are minimum compared to those obtained by aqua-bromine digestion of 50 g powder and analysis on ICP-MS. Cyanidation values compare well with the fire assay and cyanidation carried out at HGML and MSPL labs. An inhouse standard AGI has been made from the sample of gold ore of Ajjanahalli deposit. One 200 g aliquot of the AG-1 is run most of the time along with unknown samples. This standard has given a repeated value of 6.1 gpt Au. This indicates that the rapid cyanidation method can provide the trend of gold anomalies and lead us to narrowing down the area to take up further detailed work in small areas.

Cherty banded iron formation (CBIF) immediately west of Taranagar (Figure 1) is sulphidic and carbonaceous. This band is 50 m wide and 7000 m long in NE–SW direction with 80° dip towards north east. The band is highly fractured, brecciated and such planes are filled with sulphides (Figure 2). It rests on metabasal and is overlain by a 30 m thick carbonaceous phyllit Sulphides and oxides of iron and chert are the ma constituents. Gold is present in invisible form in sulphid and altered sulphides. Both silver and arsenic are ass ciated with Au. One hundred and ten bulk surfa samples were analysed from this zone by cyanidatic method, and gold specks thus obtained were weighe on a microbalance. Most of them contained gold tra amounts to 2.6 gpt. Large number of samples gave valu ranging from 0.5 to 2.6 gpt. Floatation separates sulphides yielding 6.0 gpt gold.

The most important locality of a possible mineab gold deposit is around/near Joga (Figure 1), where fi sulphidic BIF bands having E–W strike with a combin strike length of 20,000 m, are found. Each band is 4(50 m thick (Figure 3). Fifty bulk samples were draw and analysed from these bands. Gold content of the: bands varies from 0.3 to 2.9 gpt. These bands are host in metavolcanics which are interpreted to be Archae oceanic ridge basalts[1]. These metabasalts are classifie as Sultanpura volcanic block[1] and Taluru Formation The triple junctions of the pillows near sulphidic ban are also sulphidic and contain more than 0.6 gpt gol At the surface most of the sulphides are oxidized ar sulphur smell emanates at the freshly blasted outcrops (Figure 3). Thin argillaceous carbonate bands, probable equivalents of pelagic sediments are also associated. Gabbro, metapyroxenites and doleritic dykes are numerous and in close association. The entire sequence may be a relict Archaean oceanic ridge assemblage and a pseudoophiolite. The sulphidic deposits in these oceanic basalts most probably are partial analogue of modern ridge smoker deposits where high concentrations of gold is found[12]. Aplite, pegmatite and quartz veins of 0.5 to 1 m wide cut across these rocks near the granitic contact and those do not contain gold.

Micron size gold in these bands is locked in sulphides. Best values are obtained after roasting the – 250 mesh powder, which oxidizes the sulphur and releases gold, thus becoming amenable for cyanidation. Detailed sampling and analysis of this zone is in progress. Initial experiments show that with depth the grade of the ore may increase. Since these bands form hillocks, 30–60 m deep open cast mining is easily (spot 3) possible.

Oxide facies BIFs of the southern part of the belt near Golalingamanahalli also contain gold. The values obtained are not consistent. Further work is being carried out to examine the economic viability of this spot. Ramandurga range (Figure 1) in the western part of the belt[13] also contains gold, varying from traces to 2.8 gpt. The high Au content is found in the dolerite dyke and the sulphide-bearing quartz veins cutting across the oxide facies BIFs. However, most of the samples of oxide facies BIFs analysed so far have less than 0.2 gpt gold.

Sulphidic BIFs of the copper mountain also contain 0.1 to 2.0 gpt Au (Figure 1). Radhakrishna[8] and Vasudev[9] have reported old workings and traces to 1.2 gpt gold in the sulphidic ferruginous chert of this hill range.

Gold mineralization is associated with the network of quartz veins in the metagraywackes of the Deogiri and eastern acid volcanic block[1] (Figure 1). Four bulk samples were drawn from the graywackes of the Deogiri block which yielded between 0.1 and 0.6 gpt Au. This area needs more investigations as the deformation pattern of the metabasalts and graywackes shows generation and migration of considerable amount of fluids. On the other side, the graywackes of the eastern acid volcanic block[1] or the Vibhutigudda Formation[3], contain extensive blue quartz veins, with which pyrite, arsenopyrite and chalcopyrite are essentially associated (Figure 4). Forty-two bulk samples (more than 50 kg each) were first drawn from outcrops (Figure 1). These metagraywackes were found to be very promising as most of the samples gave positive results of Au content ranging from 0.1 to 2.0 gpt. The zone sampled is more than 100 m wide and 3000 m long. Detail sampling around the locations, giving more than 0.5 gpt Au will be carried out during coming field season. Radhakrishna[8] has also mentioned the occurrence of gold in the cherts of this region. This entire zone also appears to be suitable for open cast mining up to a depth of 60 m as it forms prominent hill range.

The volcanic rocks of the NCAVB[1] south of Papinayakanahalli (Figure 1), the conglomerate–graywacke bearing part which has been included in the Donimalai Formation[3], also has 40 m wide and 6000 m long acid-intermediate flow which contains 0.9 to 1.5 gpt gold in its surface samples. Ten samples were recently drawn from this flow and all of them gave positive values by cyanidation, fire assay and aquaregia solutions run on ICP-MS. The results from these three analytical procedures were within 10% error bar. Acid volcanic rocks and the blue quartz veins between Murutalegudda and Sujigudda (Figure 1) having abundant box work, after the alteration, and leaching of sulphides, contain 0.8 to 1.2 gpt gold. A thick zone of carbon phyllite and sulphidic BIF is associated with acid volcanics in this zone.

In addition to these locations where encouraging values

Figure 2. Sample showing the brecciated and fractured nature of the BIFs. Remobilization and deposition of sulphides along the fracture planes is visible.

Figure 3. Field photograph showing the sulphidic bands of Joga auriferous BIF.

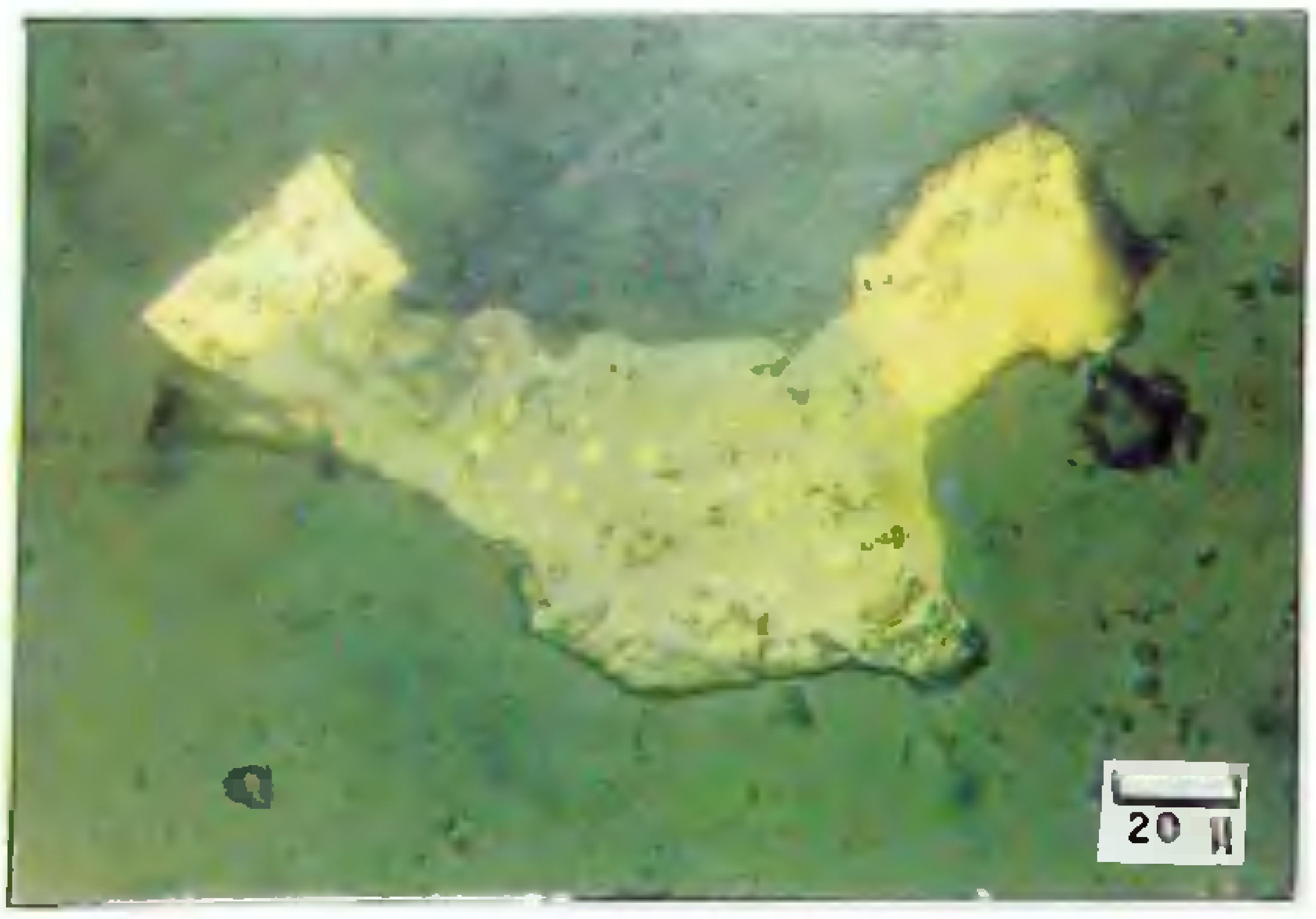


Figure 4. Microphotograph showing the invisible gold-bearing pyrite, arsenopyrite and chalcopyrite in Vibhutigudda.

have been obtained, there are zones such as southeast of Taluru (Figure 1) and southeast of Lingadahalli (Figure 1) where gold values from traces to 0.6 gpt have been found in the random reconnaissance sampling. The Geological Survey of India carried out extensive work around Lingadahalli old workings and reported gold content ranging from 2.5 to 4.5 gpt in acid volcanics and metabasalts[8].

Most of India's gold exploration programme has been revolving around the old workings, which are located on visible gold occurrences. Estimates of the reserves are made through shallow drillings[8]. We have been searching for the elusive Kolar's and Hutti's, which once produced 50 gpt Au[14]. It may be pointed out that only 3 to 4 ppm (gpt) is being mined from Hutti or 2–3 ppm (gpt) from Ajjanahalli. The values more than 0.5 gpt (ppm) are very significant. Total cost of open cast mining and extraction is covered by 0.6 gpt gold. Therefore, if we can identify zones of 1.5 gpt (ppm) then it becomes an economically viable region. Furthermore, studies at several places have shown that 0.2 gpt (ppm) gold concentration at surface, increases to more than 10 gpt (ppm) at depth. Therefore, these values are highly significant and may lead to some economic deposits. There are 800 values. Gold concentration of more than 10 ppb level is considered to be an anomaly in China, Canada and Australia.

A conceptual change in the approach for the gold exploration is needed. Surface bed rock bulk sampling and rapid analysis to prepare geochemical maps of the promising areas have yielded encouraging results. This procedure is more relevant for invisible refractory low-grade ores. Stream sediment surveys may not be successful due to the disturbance of soil through cultivation and construction of small bunds at each elevation change within short distance. The problem becomes more complicated owing to the micron size of the gold grain locked in sulphides and the secondary nature of the soil in most of the low-lying terrains. Recently, convergent margin and ridge subduction processes, resulting in accretionary prisms, have been recognized for generation of the gold deposits in several areas[1,15–17]. Therefore, we propose that all rock types of a suspected convergent margin, where secondary hydrothermal fluid generation and migration is evident should be surveyed by bulk bed rock sampling. After preparation of a large quantity of representative sample, it should be analysed by a combination of cyanidation, ICP-MS and other techniques. The results obtained represent a general trend of gold distribution in such areas. Sandur schist belt being a product of convergent margin processes superimposed on an earlier extensional setting with its highly evident generation and migration of fluids, is one of the most promising greenstone belts which may be transformed into an open cast mining gold field within a short time.

1. Manikyamba, C. and Naqvi, S. M., *Lithos*, 1997 (communicated).
2. Manikyamba, C. and Naqvi, S. M., *Curr. Sci.*, 1996, **71**, 476–479.
3. Chadwick, B., Vasudev, V. N. and Ahmed, N., *J. Geol. Soc. India*, 1996, **47**, 37–57.
4. Naqvi, S. M., *J. Geol. Soc. India*, 1997 (in press).
5. Mukhopadhyay, D. and Matin, A., *J. Struct. Geol.*, 1993, **15**, 309–322.
6. Naqvi, S. M., Hussain, T. S. M., Charan, S. N. *et al.*, *NGRI Annu. Rep.*, 1994–1995, pp. 29–30.
7. Department of Science and Technology, *Annu. Report*, 1995–96, pp. 19–20.
8. Radhakrishna, B. P., *Mineral Resources of Karnataka*, Geological Society of India, 1996, pp. 471.
9. Vasudev, V. N., Prabhakar, B. C., in *Brazil Gold '91* (ed. Ladiera, F. A.), Balkema, Rotterdam, 1991, pp. 735–741.
10. Foote, R. B., *Geol. Surv. India*, 1885, **25**, 216.
11. Balaram, V., Gnaneshwar Rao, T., Anjaiah, K. V., Ramesh, S. L. and G.R. Group, Preworkshop Volume on Gold Resources of India, 1996, pp. 231–239.
12. Hanington, M. D., Tivey, M. K., Larocque, A. C. L., Petersen, S., Rona, P. A., *Can. Mineral.*, 1995, **33**, 1285–1310.
13. Sawkar, R. H., Subba Rao, D. V., Charan, S. N. *et al.*, Preworkshop Volume on Gold Resources of India, 1996, pp. 60–63.
14. Radhakrishna, B. P. and Curtis, L. C., *Geol. Soc. India*, 1991, **3**, 160.
15. Manikyamba, C. and Naqvi, S. M., Proceedings of the National Symposium on Applied Geochemistry, Dept. of Applied Geology, University of Madras, 1994, pp. 16–17.
16. Haeussler, P. J., Bradley, D., Goldfarb, R., Snee, L. and Taylor, C., *Geology*, 1995, **23**, 995–998.
17. Barley, M. E., Eisenlohr, B. N., Groves, D. I., Perring, C. S. and Vearncombe, J. R., *Geology*, 1989, **17**, 826–829.

ACKNOWLEDGEMENTS. We thank Dr H. K. Gupta, Director, NGRI and Mr K. N. Srivastava, Chairman, Hutti Gold Mines Co. Ltd. for their keen interest, support and permission for publication of this paper. This work has been carried out under a DST support NGRI-HGML collaboration programme and we thank Dr K. R. Gupta of DST for his keen interest and support. We thank Mrs Rahana Naqvi and Mr Kiran for their valuable help in the field. Ms Nancy Rajan is thanked for her help in preparation of the manuscript.

Received 26 September 1996; revised accepted 18 February 1997