Role of pathfinder elements in gold exploration in Chitradurga Schist belt

Elements such as gold (Au), silver (Ag), copper (Cu), lead (Pb), zinc (Zn), cobalt (Co), nickel (Ni), arsenic (As), antimony (Sb), tellurium (Te), selenium (Se) and mercury (Hg) serve as geochemical pathfinders in the exploration for gold[1]. The Archaean gold ores are typically enriched in gold with variable enrichments in Ag, As, tungsten (W), Sb, bismuth (Bi) and (Pb)[2–4]. If the anomalies of a good number of these coincide to substantiate the geological evidence, there appears to be reasonable chance of locating gold. In the recent exploration for gold in India geochemical methods have not been used much, except in a few cases, in comparison to a large number of areas that have received attention by trenching and drilling. Arsenic is widely distributed in sulphide minerals in certain types of polymetallic mineral deposits, especially those containing copper, mercury, bismuth, silver, vanadium, molybdenum and gold–silver arsenide. Arsenic, antimony, tellurium, tungsten and bismuth in rocks, ores, alluvium and groundwater have also been used in the prospecting for gold. In addition, knowledge of the chemistry of transport and deposition of arsenic, antimony, silver, thallium and tellurium, which are frequently associated with gold, enhances our understanding of the processes involved. A comprehensive interpretation of noble metal geochemistry is usually more complete, if additional abundance data of these pathfinder elements are also available. Gold continues to enjoy the reputation of being one of the most sought-after metals. As the demand for gold has increased many folds, its search, using modern exploration and mining techniques, has also intensified. The main objective of this communication is to present the results on the effective use of pathfinder elements in mineral exploration studies for gold at the Chikkasiddavanahalli (C. S. Halli) area, Chitradurga Schist belt, Western Dharwar Craton.

The 450 km long Chitradurga Schist belt extends from Gadag in the north to Srirangapatanam in the south with a NNW–SSE trend and shows greenschist to amphibolite facies metamorphism[5]. The Chitradurga Super group is made up of the Vanivilas, Ingaldhal and Hiriyur formations, in ascending stratigraphic order. The Ingaldhal Formation is made up of basic, intermediate acid lavas, pyroclastics, associated MSOBIF and Fe-rich shales[6]. The ~1.2 km long and ~250 m wide C. S. Halli (Figure 1) hill range constitutes the lithology of MSOBIF and Fe-rich shales, overlies carbonated schistose and massive metabasic volcanics[7]. In stratigraphic succession, they represent the Ingaldhal Formation that is an integral part of the Chitradurga Schist belt. The general strike trend of the above lithological sequence in the C. S. Halli area varies from N–S to N 340° with vertical to steep easterly dips (in the northern parts) to 70–75° westerly dips (central portions). In relatively less deformed portions[8], the average width of the banded iron formations (BIFs) and the Fe-shales is 5 and 12 m. In Ajjanahalli gold mineralization is localized to sheared sulphidic facies BIF of 10–30 m width and extend up to nearly 35 km in length. The BIF strikes NNW–SSE and dips 50–70°E. The quartz veinlets traverse the BIF measuring 2 cm to 1 m in width and varying up to 10–70 m length. The BIF shows profuse emplacement of quartz–carbonate veins, with wall-rock alteration (sercitization, chloritization, pyritization) and gold mineralization. Petrography studies show that BIFs are medium-grained comprising alternate bands of recrystallized chert, iron oxides and sulphide-bearing bands with refractory gold (gold locked in sulphides). In sheared BIF samples, the thin quartz–calcite-rich veins cutting across these bands show stretching, with chert-rich bands. The mineralized sulphidic and oxide facies BIFs exhibit cummingtonite–grunerite, hornblende and chlorite mineral assemblage.

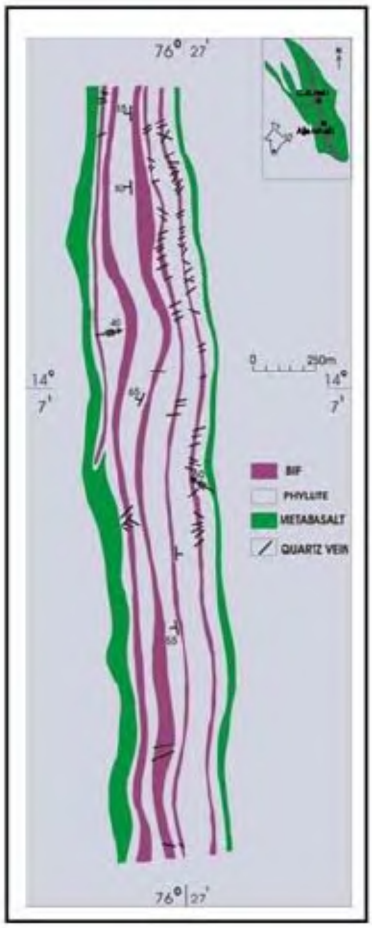

Figure 1. Geological map of C. S. Halli (modified after Charan *et al.*)[7].

Table 1. Pathfinder data for Ajjanahalli and C. S. Halli areas

Element	Maximum	Minimum	Average
Ajjanahalli $N = 50$ samples			
As	5845.00	358.00	2137.56
Mo	4.10	1.52	5.48
Pd	38.00	0.04	10.49
Ag	1.37	0.01	1.75
Cd	3.21	0.01	3.94
Sb	58.53	0.01	12.99
Te	1.46	0.03	0.93
W	1.30	0.01	0.97
Pt	0.04	0.01	0.05
Au	35.00	0.05	13.45
Tl	0.49	0.01	0.46
Bi	1.13	0.11	0.64
C. S. Halli $N = 50$ samples			
As	2042.19	182.21	633.96
Mo	6.91	0.84	2.57
Pd	0.44	0.01	0.10
Ag	1.32	0.03	0.41
Cd	BDL	BDL	BDL
Sb	81.76	0.61	12.57
Te	7.95	0.07	1.05
W	1.39	0.01	0.48
Pt	0.18	0.01	0.06
Au	3.22	0.23	1.08
Tl	7.95	0.07	1.05
Bi	0.83	0.01	0.15

BDL, Below detection limit.

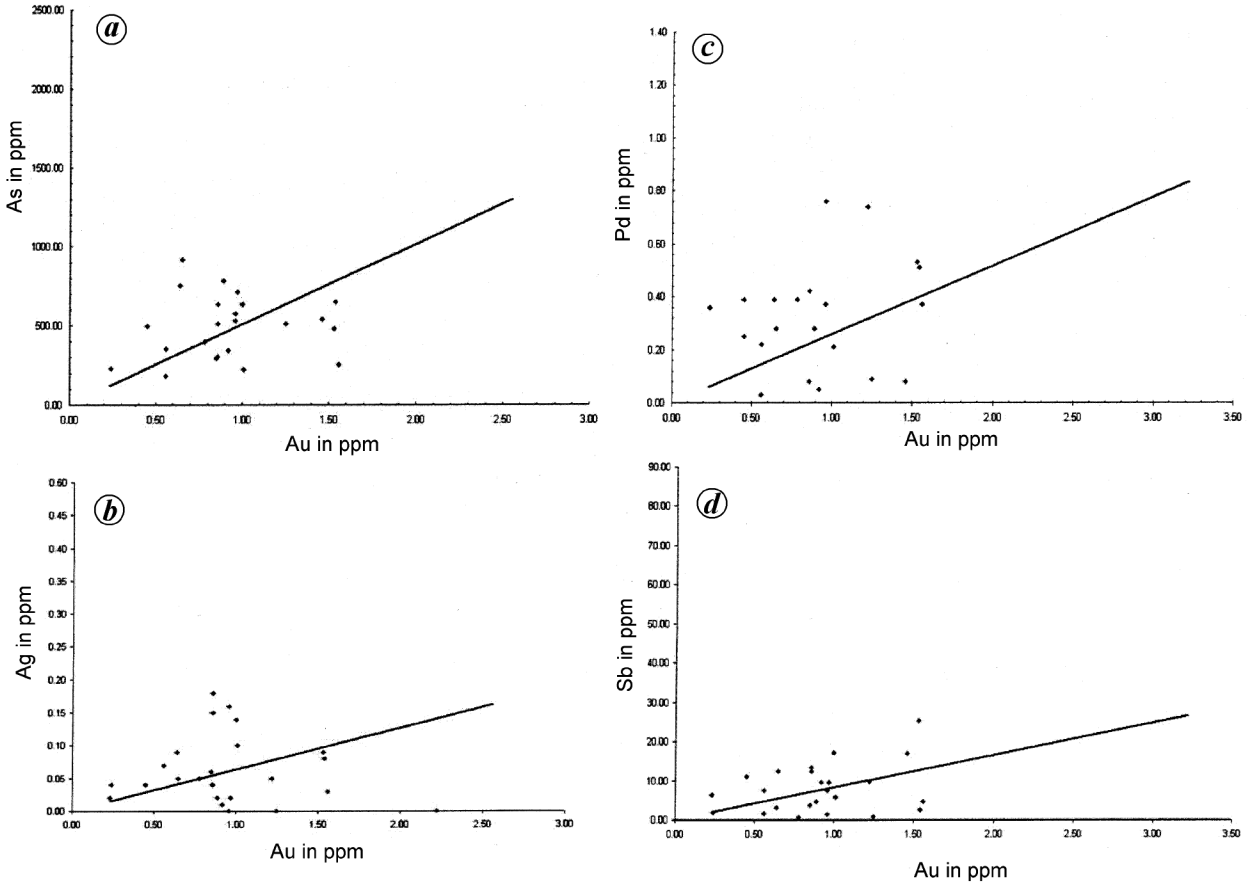

Figure 2. Binary diagram of Au vs As (*a*), Au vs Pd (*b*), Au vs Ag (*c*) and Au vs Sb (*d*).

For the present study, a Model SpectrAA 220 flame atomic absorption spectrometer was used. Details about the instrument with precision and accuracy of elements are discussed elsewhere[9,10]. The instrumental parameters were optimized for maximum absorbance and readings were taken between 0.1–0.4 absorbance. For this study fifty representative samples were selected. The results for C. S. Halli show that W enrichment is 1.30, Pt 0.20, Au 3.22, Te 7.95 and Ag 1.32 ppm (Table 1). The values are well corroborated in the chip samples from twenty-three trenches across the strike direction. In C. S. Halli, As (average 630 ppm) is positively correlated with gold. For example, in Con mine at Yellowknife, the gold-mineralized zones were discovered on the basis of arsenic content vs gold. Tungsten is a rare element with average background abundance of 0.4 ppm in oceanic basalts[11], but common as scheelite within gold-bearing veins and also as anomalous concentrations in sedimentary rocks[11]. At C. S. Halli, gold shows positive correlation with arsenic (Figure 2 *a*), palladium (Figure 2 *b*), silver (Figure 2 *c*) and antimony (Figure 2 *d*). Wherever samples show higher concentrations of these elements, gold anomalies are also found. Hence they are used as a direct tool for identifying gold-bearing zones. Our studies have shown that the average abundance of silver to gold is 2 : 1. In Ajjanahalli, sulphidic BIF with intense wall-rock alteration contains maximum concentration of gold (12 ppm). Gold also shows positive correlation with arsenic and palladium, and negative correlation with Mo, Ag, Cd, Sb, Te, W, Pt, Ti and Bi. The concentration of gold from the surface to a depth of 80 m along the mineralized zone increases from 0.2 to 12.0 ppm. This increase in the grade of ore with depth may be due to unoxidized nature of sulphides at greater depth.

In C. S. Halli, systematic reconnaissance sampling (close-grid sampling) and pathfinder elements correlation with gold helped identify gold anomalies up to Tekalvatti village (3 km). The development of shears and the emplacement of gold sulphides bearing thin quartz veins, especially in the eastern most BIF bands in C. S. Halli area, appear to have been due by regional compression accompanied by limited alteration zones and base metal-bearing metavolcanics, similar to the gold mineralization episodes in other Late Achaean greenstone–granite terrains.

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