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Short communication

Possible Carlin-type disseminated gold mineralization in the Mahakoshal fold belt, central India

Reddy V.R. Talusani *

Division of Earth Sciences, University of New England, P.O. Box U 21, Armidale, NSW 2351, Australia

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Abstract

The paper records the first occurrence of dolomite-hosted, disseminated gold mineralization at Barhi and Jhal, in a Late Archean-Early Proterozoic metavolcano-sedimentary belt (Mahakoshal fold belt) in central India. Gold mineralization is hosted by dolomite that occurs as discontinuous bands interbedded with phyllite. Hydrothermal alteration styles of the host rock include decalcification, silicification, and argillization. Pyrite is the most common sulfide, whereas stibnite and realgar are rare. Mineralization is characterized by persistent gold from 0.20 to 0.62 ppm and a consistent association of anomalous arsenic, antimony, and mercury with gold. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Gold deposits; Mahakoshal fold belt; Dolomites

1. Introduction

Gold deposits occur in a wide variety of geological environments and can form through numerous geological processes. Disseminated gold deposits have been attractive exploration targets since the early 1960s when the Carlin deposit in northeastern Nevada (USA) was discovered. Although most known Carlin-type, sedimentary rock-hosted gold deposits are located in the western United States (e.g., Radtke et al., 1980; Bagby and Berger, 1985; Tingley and Bonham, 1986; Arehart, 1996; Hofstra et al., 1999), similar deposits may be present in other parts of the world, including China (Cunningham et al., 1987) and Indonesia (Turner et al., 1994). This paper reports on a newly discovered gold occurrence from central India.

The Late Archean–Early Proterozoic Mahakoshal fold belt (MFB) in central India is a $\sim$500 km long, ENE-trending belt extending from Jabalpur in Madhya Pradesh in the west to Palmau in Bihar in the east. The exposed width of the belt varies from 5 to 40 km. Anomalous gold values in some samples from the eastern and western parts of MFB had been mentioned previously in the records of the Geological Survey of India (Khan et al., 1991; Sharma et al., 1992). During the course of geological and geochemical investigations in the central part of MFB, an interesting occurrence of gold mineralization was

* Tel.: +61-2-677-33121; fax: +61-2-677-33300.
E-mail address: vtalusan@hotmail.com (R.V.R. Talusani).

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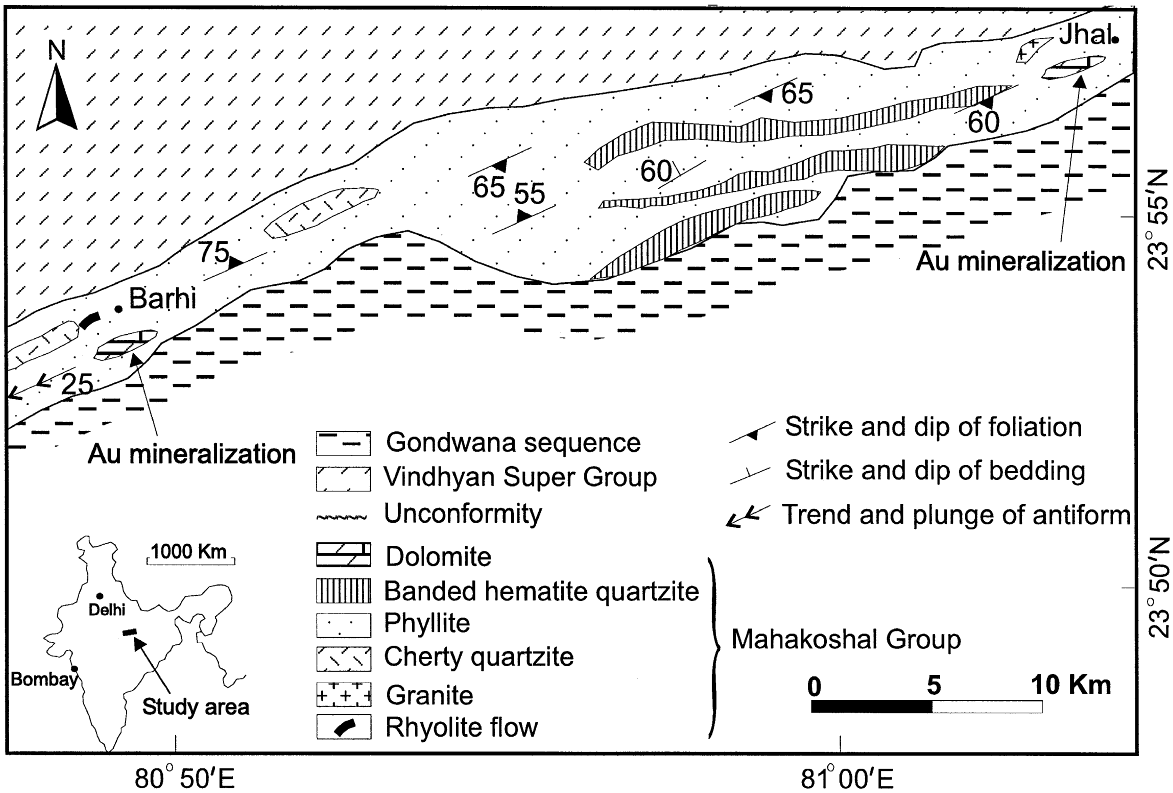

Fig. 1. Geology of the area around Barhi and Jhal, from the central part of the Mahakoshal fold belt, central India. The location of gold mineralization is indicated.

reported for the first time (Talusani, 1994) in dolomites near Barhi and Jhal (Fig. 1).

This paper presents a brief description of the geologic setting, ore petrography and geochemistry of gold mineralization at Barhi and Jhal.

2. Geologic setting

The geology, metamorphism and structural setting of the MFB are detailed in several previous studies (Ameta, 1990; Roy and Bandyopadhyay, 1990; Talusani, 1994; Nair et al., 1995). The metavolcanic and metasedimentary rock sequence of the Mahakoshal Group was developed in a rifted basin, which was bounded on the north by Archean gneisses and the overlying Vindhyan Supergroup (upper Proterozoic), and on the south by Archaean gneisses and the Gondwana Supergroup (Permo-Jurassic). Both the northern and southern boundaries are marked by the deep-seated faults. The structural setting of the MFB is complex, as the rocks have undergone three phases of folding and are traversed by several longitudinal high-angle thrust and transverse faults (Ameta, 1990). Periodic reactivation of the ENE-trending basin-bounding faults controlled later magmatism (Nair et al., 1988). Exposed rocks include a strongly deformed and weakly metamorphosed supracrustal sequence dominated by metasedimentary rocks (~ 80%), with subordinate metavolcanic rocks of basaltic composition. Intrusions include dikes of gabbro, diabase, ultramafic rocks, and granite. Rhyolite occurs as flows both within the MFB and in the upper Proterozoic Vindhyan sediments. They are undeformed and unmetamorphosed, and appear to have been formed due to later reactivation of MFB probably during Late Proterozoic, after the deposition of Vindhyan sediments (Talusani, 1994).

Rocks near the villages of Barhi and Jhal in the central part of the MFB consist of a volcano–sedimentary sequence that has been metamorphosed to the greenschist facies (Fig. 1). The main rock types include phyllite, quartzite, dolomite, and banded hematitic quartzite. The sequence is cut by quartz veins and intruded by granite and rhyolite. The rocks have undergone polyphase deformation and are traversed by ENE-trending thrust faults and minor north striking, high-angle normal faults. The mineralizing hydrothermal solutions likely gained access to favorable lithologies along these faults.

Gold occurrences are hosted by dolomite, which occurs as discontinuous bands interbedded with phyllites. The best exposures of these rocks in the MFB are encountered southwest of Jhal and south of Barhi. The dolomites are strongly folded, fine-grained, silicified, and thinly bedded.

3. Sampling

About 100 samples of dolomite were collected on a grid pattern covering 400×80 m and 600×80 m zones in the Barhi and Jhal areas, respectively. In addition, 30 samples of quartzite and banded hematitic quartzite were collected from areas adjoining the dolomite bands. Most samples were used for both petrographic study and geochemical analysis.

4. Alteration and mineralization

Petrographic evidence indicates that the carbonate rocks of the MFB near Barhi and Jhal have been hydrothermally altered by processes that include decalcification, silicification, and argillization. The intensity of alteration is locally variable and ranges from weak to intense. The metallic mineral assemblage consists of disseminated micron- to submicron-sized gold, realgar, orpiment, stibnite, cinnabar, and pyrite. Gold deposition occurred within pyrite late in the main stage (Fig. 2), followed by the formation of realgar, orpiment, stibnite, and cinnabar. Other hydrothermal minerals include quartz, kaolinite, sericite, barite, and calcite. Alteration of the host rocks is

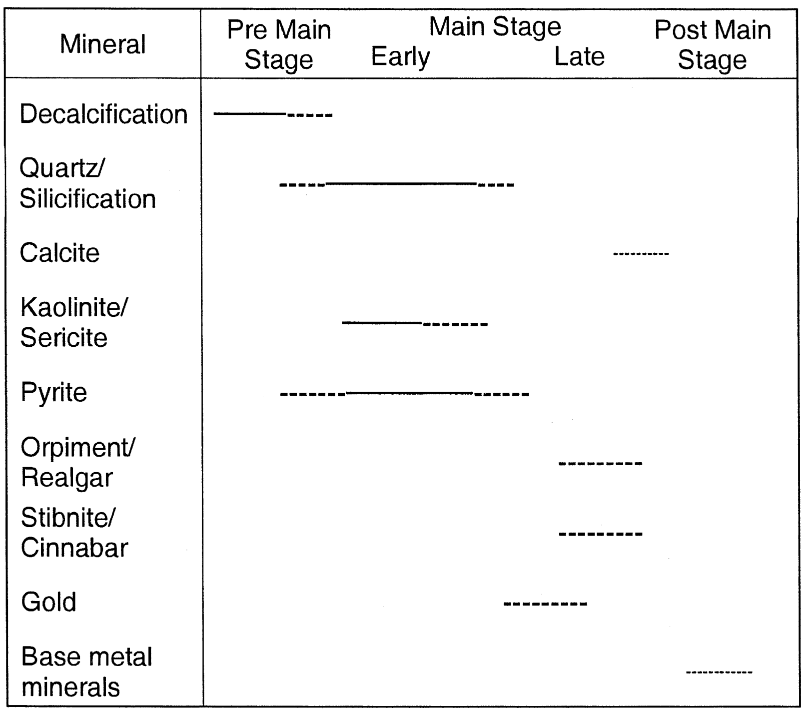

Fig. 2. Paragenesis of the Barhi and Jhal occurrences.

similar to other Carlin-type disseminated gold deposits but at lower alteration mineral abundances.

Decalcification involves the removal of calcite and dolomite from the sedimentary host rock. In the Barhi and Jhal areas, decalcification of dolomite resulted in loose dolomite rhombs that megascopically have the appearance of sand. Geologic evidence for volume decrease is widespread in the dolomites of Barhi and Jhal areas and is observable on hand specimen scale. The most strongly altered zones of early-stage alteration show evidence of volume decrease due to carbonate removal. Volume loss in silicified rocks is indicated by the destruction of calcite veins that predated this hydrothermal event and locally increased porosity. The bedding in some highly altered zones is disrupted and locally brecciated owing to this volume loss. Field and petrographic observations indicate a progressive increase in the intensity of brecciation with enhanced silicification and early pyrite deposition. Early removal of calcite is recognized as an important process in the preparation of the host rock for later gold mineralization within the Carlin-type deposits (Berger and Bagby, 1991). The importance of the early hydrothermal stage was to increase the porosity and permeability of the host rocks (Radtke, 1985) and thus to make them more favorable for replacement-style mineralization. Decalcification within the dolomites of MFB suggests early hydrothermal solutions were acidic; however, they were pre-gold stage and may have differed in composition from the mineralizing solutions.

Silicification is an important form of hydrothermal alteration, and includes formation of quartz overgrowths on detrital quartz and precipitation of structurally controlled small jasperoid bodies. The jasperoids are smoky gray, veined with quartz, and sometimes brecciated. The presence of jasperoids is a very good indication of gold mineralization as suggested by Romberger (1986).

Most of the hydrothermal alteration at the Barhi and Jhal occurrences took place during the main hydrothermal stage. During the main hydrothermal stage, fine-grained quartz, sericite and minor kaolinite, formed in the matrix of the carbonate rocks. Quartz replaced borders of corroded dolomite rhombs. Petrographic evidence and correlated chemical data suggest that most of the hydrothermal pyrite, together with gold, realgar, orpiment, stibnite, and cinnabar were introduced during the main hydrothermal stage. Pyrite is the major sulfide mineral and occurs as subhedral to anhedral grains (< 80 μm), and in clusters. Realgar and orpiment have a limited occurrence, and stibnite and cinnabar are rare. Gold has been identified by microprobe studies and is most commonly micron- to submicron-sized and occurs with arsenic-, antimony-, and mercury-bearing sulfides as coatings on surfaces and as fracture fillings in pyrite grains. Base metal sulfides include

Table 1
Selected element analyses of dolomites from Barhi and Jhal

Sample	Au	Cu	Pb	Zn	Ni	Co	As	Sb	Hg
BR-1	0.31	30	15	15	40	25	125	110	0.70
BR-8	0.44	10	20	25	60	15	140	80	0.58
BR-22	0.20	15	< 10	20	55	20	95	65	0.45
BR-27	0.28	25	30	40	25	25	90	85	0.64
BR-30	0.52	10	25	30	15	30	170	120	1.4
BR-34[a]	< 0.01	15	< 10	10	15	10	15	10	0.04
JL-4	0.60	< 10	10	15	15	40	175	140	1.2
JL-10	0.35	55	45	35	40	35	120	75	0.52
JL-16	0.39	20	20	30	30	20	105	80	0.54
JL-23	0.46	25	35	25	35	15	155	125	0.94
JL-31	0.48	30	40	25	20	15	140	115	0.90
JL-35	0.51	15	< 10	45	15	25	195	130	1.4
JL-39	0.62	40	30	20	15	20	185	150	2.2
JL-41	0.39	25	10	10	15	40	130	70	0.86
JL-45	0.28	65	25	15	25	15	80	65	0.38
JL-55[a]	< 0.01	10	10	< 10	< 10	5	10	5	0.02
Mean[b]	0.46	35	30	30	35	25	150	115	0.94
Mean[c]	< 0.01	10	10	15	15	5	10	8	0.03
Mean[d]	< 0.01	15	< 10	15	10	5	15	10	0.05
Min[e]	0.20	< 10	< 10	< 10	15	10	80	65	0.38
Max[f]	0.62	65	45	45	60	40	195	150	2.2

Note: Abundances are in parts per million (ppm). Samples BR-1 to 34 are altered dolomites from the Barhi area and samples JL-4 to 55 are altered dolomites from the Jhal area.

Methods and detection limits. Atomic absorption analysis: Au (0.01 ppm), Cu (10 ppm), Pb (10 ppm), Zn (10 ppm), Ni (10 ppm), Co (5 ppm), As (10 ppm), Sb (5 ppm); cold vapor atomic absorption: Hg (0.01 ppm).

[a] Unaltered dolomites.

[b] Mean composition of 80 samples of altered dolomite (including the 14 samples listed in the table).

[c] Mean of eight samples of unaltered dolomite (including the two unaltered dolomite samples listed in the table).

[d] Mean of 10 samples of quartzite (not listed in the table).

[e] Minimum concentrations of 80 samples of altered dolomite.

[f] Maximum concentrations of 80 samples of altered dolomite.

chalcopyrite and sphalerite, which are very rare and probably formed later in the paragenesis. The occurrence of base metal sulfides in late-stage barite veins suggests that they may have been formed during the late hydrothermal stage. This conclusion is supported by the lack of correlation between the base metal elements and those of the gold–arsenic–antimony–mercury suite. Gangue minerals include chalcedonic quartz, calcite and minor barite. The generalized alteration paragenesis is shown in Fig. 2.

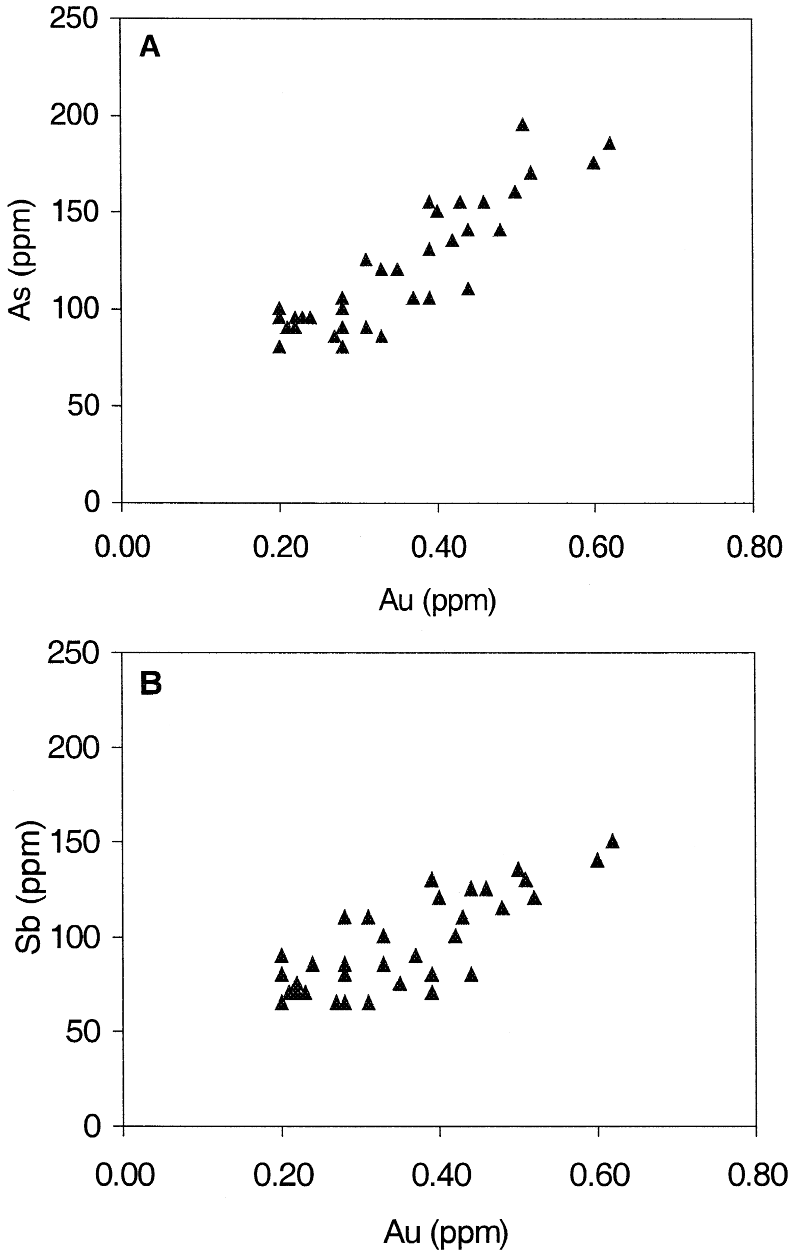

Fig. 3. Variation of As and Sb against Au for the Barhi and Jhal occurrences.

5. Geochemistry

Eighty rock samples of altered dolomite, eight of unaltered dolomite, and 10 of quartzite were analyzed for Au, Cu, Pb, Zn, Ni, Co, As, Sb, and Hg by atomic absorption spectrometry. The representative analytical results, mean composition, and minimum and maximum concentrations are presented in Table 1. Of the 80 analyzed samples, 52 samples contained gold, with contents ranging between 0.20 and 0.62 ppm. The sample with the maximum gold concentration (0.62 ppm) also contained the most significant mercury (2.2 ppm) and antimony (150 ppm) anomalies. The strong positive correlation, illustrated in Fig. 3, between Au and As (with correlation coefficient, 0.88) and Au and Sb (0.94) indicates that gold is associated mainly with realgar-orpiment and stibnite. The positive correlation between As and Sb (0.79) also shows the association of As and Sb as co-existing sulfide minerals.

Although the gold content is elevated (> 0.20 ppm) in more than half of these samples, the concentrations of Cu, Pb, and Zn are consistently at background levels. The average contents of the base metal elements are 35 ppm Cu, 30 ppm Pb, and 30 ppm Zn. The As, Sb, and Hg contents are consistently anomalous in the more gold-rich samples. The average abundances for these elements in the 80 samples are 150 ppm As, 115 ppm Sb, 0.94 ppm Hg, and 0.46 ppm Au. The Au–As–Sb and Hg signature is similar to that which characterizes Carlin-type disseminated gold deposits (Berger and Bagby, 1991; Arehart, 1996).

Chemical analyses of unaltered dolomites average 10 ppm As, 8 ppm Sb, and 0.03 ppm Hg. These values are considerably lower than those in the mineralized dolomites. The average gold content (< 0.01 ppm) and the average contents of base metals are also lower in the unaltered dolomites than in the mineralized dolomites. The mean concentrations of Au, As, Sb, Hg, and base metals in the quartzites are similar to those of the unaltered dolomites.

6. Conclusions

The newly reported dolomite-hosted, disseminated gold mineralization in the MFB of central India has many features in common with the Carlin-type gold deposits. Important structural features at Barhi and Jhal include ENE-trending longitudinal thrust faults and minor north-striking normal faults. Hydrothermal alteration of the host rock consists of decalcification, silicification and argillization. This style of alteration acted as a preparation for the deposition of pyrite, minor As-, Sb-, and Hg-bearing sulfides, and gold. The characteristic trace element suite of Au, As, Sb, Hg (with low concentrations of base metals) is consistent with Carlin-type hydrothermal systems in dolomitic sequences.

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