SHORT COMMUNICATION

Gold in Chromite Ore of South Kaliapani Mines, Sukinda Ultramafic Belt, Jajpur District, Orissa

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Abstract: Gold in the form of cuprian grains is reported based on Electron Probe Micro Analyzer (EPMA) study of a sample received from the chromite tailing dumps of South Kaliapani mines, Sukinda Ultramafic Belt, Jajpur district, Orissa The cuprian gold grains vary in size from 3 microns to 10 microns and are found as disseminations within the chromite host-phase Chromite is one of the earliest minerals to form whereas hydrothermal process is characteristic of gold The association of chromite and gold grains is therefore unusual and highly interesting Textural features suggest that the gold grains are more likely to be genuine primary inclusions within the host chromite rather than being late stage hydrothermal products filling up cavities or open spaces A preliminary account of characterization studies of gold grains involving back-scattered electron imaging, X-ray element 'dot' mapping, and qualitative elemental scanning are presented

Keywords: Cuprian Gold, Chromite, Sukinda Valley, Kaliapani mines, Jajpur district, Orissa

INTRODUCTION

Conservation of mineral wealth of our country through beneficiation is one of the foremost functions of the Indian Bureau of Mines During the course of detailed mineralogical characterization studies on the samples received for beneficiation test work from chromite tailing dumps of South Kaliapani mines, Sukinda Ultramafic Belt, Jajpur district, Orissa, the authors came across an interesting case of gold mineralisation in the form of cuprian gold grains (gold containing minor proportions of copper) within chromite Even though Platinum Group of Minerals (PGM) and "invisible" gold values have been reported from time to time from the Baula Nuasahi chromite ultramafic complex of Keonjhar district (e g Mondal and Baidya, 1997, Auge et al 2002), Orissa, there was no *mineralogical information* of gold and other precious metals from the nearby chromite bearing Sukinda ultramafic belt in the Jajpur district The presence of Au (in ppb) in chromitites and limonites of Sukinda Ultramafic Belt has however been reported (Pattanaik, 1988) Recently, incidence of Au-PGM in the breccia zone of Katpal chromite quarry of the Sukinda Ultramafic Belt from the neighboring Dhenkanal district has been recorded (Sarkar et al. 2003). The main purpose of this communication is to report the observed gold mineralisation and to present mineralogical characterization studies carried out on gold grains by using an Electron Probe Micro Analyzer (EPMA)

GEOLOGICAL SETTING

The chromite bearing Sukinda ultramafic belt (Fig 1) is one of the largest chromite deposits of India with significant reserves of lateritic nickel ore (Srinivasachari, 1979, Chakraborty and Chakraborty, 1984, Sahu and Venkateswaran, 1989) The Sukinda ultramafic belt is intruded into the Precambrian metamorphites and has a width of 2-5 km and extends for about 20 km in a ENE-WSW direction from Kansa (21°04' 85°57'E) in the east to Maruabil (21°02'· 85°43'E) in the west (Fig 1) It essentially consists of highly serpentinised dunite, peridotite and subordinate amount of pyroxenite Younger gabbro-diorite, granite and dolerite have intruded the ultramafics Lateritic cappings are also conspicuous in the entire belt Detailed geology of the belt has been carried by a number of workers (e g Banerjee, 1972, Chakraborty et al 1980)

MINERALOGY

The studied sample was received, for mineralogical characterization, in the form of fines of -70# size Detailed

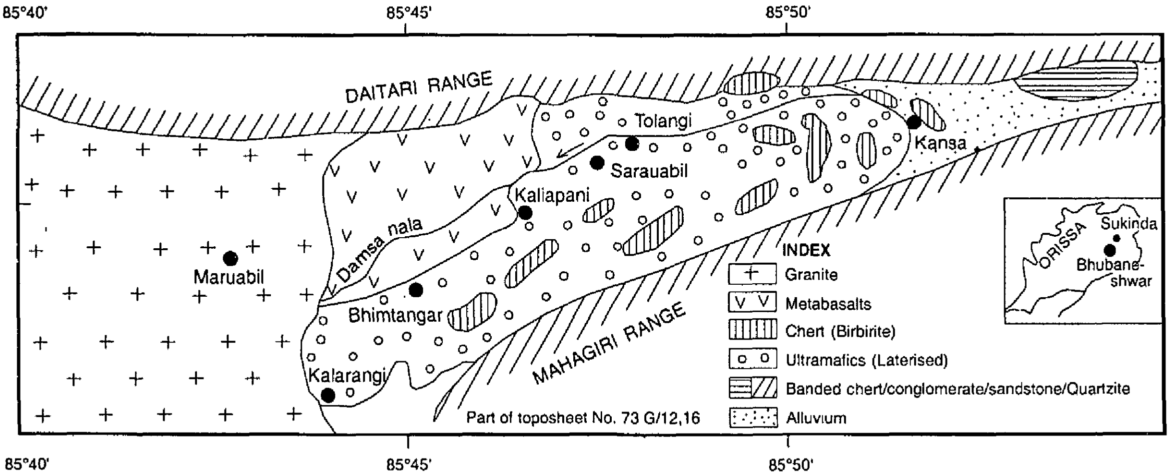

Fig.1. Location of Kaliapani mines in the Sukinda ultramafic belt, Jaipur district, Orissa (adopted from Sahoo, 1995).

mineralogical studies of the sample were carried out by transmitted and reflected light microscopy as well as by Electron Probe Micro Analyzer (EPMA). These studies revealed that the sample contained chromite, serpentine (mostly antigorite), talc, iron oxides (haematite and magnetite), iron hydroxides (goethite and limonite), sulphides (pyrite, pyrrhotite and arsenopyrite), clay (kaolinite), quartz and gold grains. Ore microscopic studies reveal that the chromite grains exhibit idiomorphic habit and contain fractures and veinlets. Some of these fractures/veinlets are occupied by serpentine and rarely by talc. However, no metallic phases were found confined to the fractures/veinlets. Microscopically, gold grains are characterized by very high reflectivity, bright yellow colour and are feebly anisotropic under crossed nicols. Their extremely fine size (up to 10 micron size) however come in the way of their precise characterisation by conventional instrumental techniques. Electron Probe Micro Analyzer (EPMA) played a major role in the characterization of the gold grains.

The mineral chemistry of individual chromite (chrome-spinel) grains studied by EPMA revealed that they have extensive substitution of Mg and Al in their structure and have the following composition: Cr_2O_3 = 64.40-66.21 wt%; FeO= 9.10-11.26 wt%; MgO= 13.32-14.76 wt%; Al_2O_3 = 9.93-10.87 wt% and NiO= 0.02-0.15 wt%.

Characterization of the Gold minerals by EPMA

The gold grains were characterized by CAMECA SX100 Electron Probe Micro Analyzer (EPMA). Back-Scattered Electron (BSE) Imaging, qualitative analyses, X-ray element 'dot' mapping and quantitative analytical techniques were employed for this purpose using wave-length dispersive (WDS) analytical techniques. PEAK SIGHT on line software program developed by CAMECA was used to acquire and process the data. For generating Back Scattered Electron (BSE) images an acceleration voltage of 20 kV, beam current of 15nA and a beam diameter of 1 micron were used. For qualitative spectral scan on individual grains an acceleration voltage of 25 kV, beam current of 25nA, beam diameter of 1 micron and three WD spectrometers having PET, TAP and LLIF crystals were used.

X-ray mapping of gold grains was carried out for Au Lα (on LIF crystal), Au Mα (on PET crystal), Cu Kα (on LLIF crystal) and CrKα (on LIF crystal) using a 25 kV, beam current of 30nA and a collection time of 10 minutes. Quantitative analyses were carried out only for those elements of interest which were detected during the qualitative spectral scan. For quantitative analyses, an acceleration voltage of 20 kV, beam current of 20nA, beam diameter of 1 micron, a counting time of 30 secs and three WD spectrometers having LIF, PET and LLIF crystals were used.

A list of standards (natural as well as synthetic) used for elemental peak calibration along with the X-ray emission lines used for quantitative analyses are provided: Chromium-Cr_2O_3, Kα; Iron- pure Fe, Kα; Magnesium – MgO, Kα; Aluminium – Al_2O_3, Kα; Gold- native Au, Mα and Copper-native Cu, Kα. The generated data was corrected by using an on-line PAP-correction program. After repeated analyses of respective standards listed above along with the minerals of interest, it was observed that error on the elements was less than 1%.

Back Scattered Electron (BSE) Images clearly depict the intimate association of the gold grains within the chromite host (grey; Fig. 2 A and B). Gold grains (white)

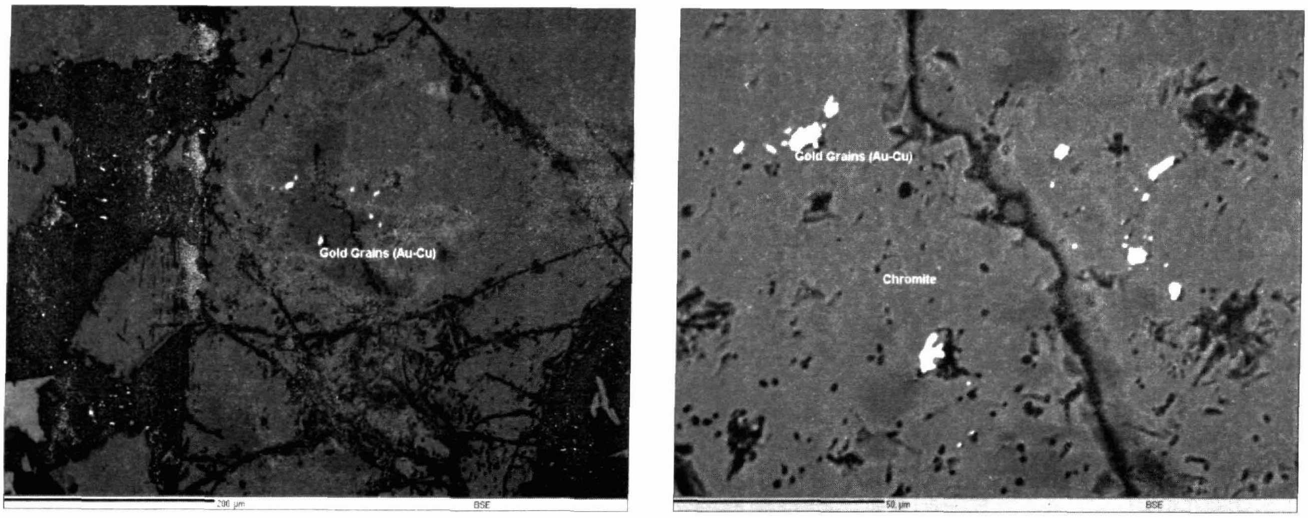

Fig.2. (**A**) Back scattered Electron (BSE) image showing gold grains (white) (Au-Cu in composition) occurring as fine disseminations within chromite grain (grey) (magnification x550 times). (**B**) Same image of (A) at higher magnification (x2200 times).

are of 3-10 microns size of amoeboid, oval, rounded and tabular shape. Chromite is one of the earliest minerals to form whereas gold mineralisation is predominantly controlled by late-stage hydrothermal fluids. Therefore, the association of chromite and gold is most unusual and extremely rare not only in the Indian scenario but also world-wide (*see* Gasparrini, 1993). A close look at the BSE indicates that gold grains are more likely to be genuine primary inclusions within the host chromite rather than being late stage hydrothermal products filling up cavities or open spaces. This is also supported by the lack of any metallic phases in the fractures/veinlets of chromite grains. However,

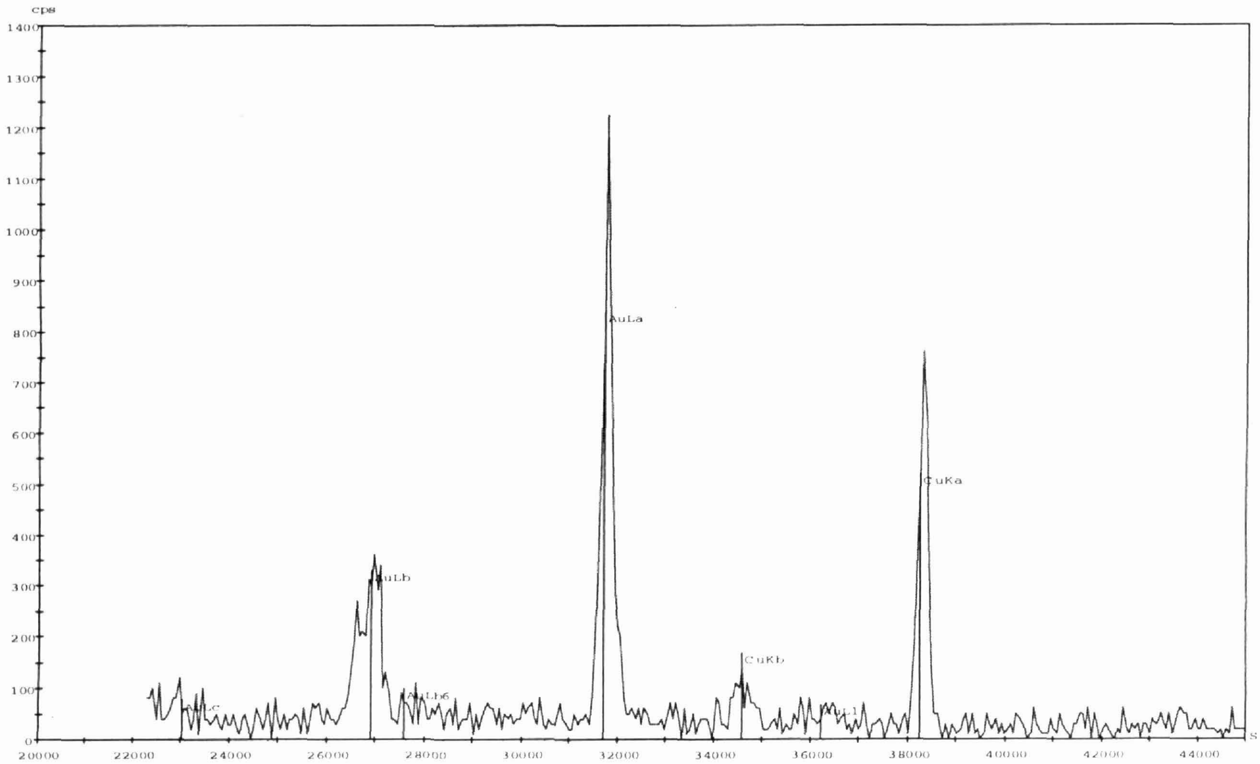

Fig.3. Qualitative X-ray scan of individual gold grains on a LLIF crystal depicting that they essentially consist of Au and Cu. Abscissa refers to Sinθ positions of X-rays of elements of mineral under study whereas ordinate referes to their counts per second (cps).

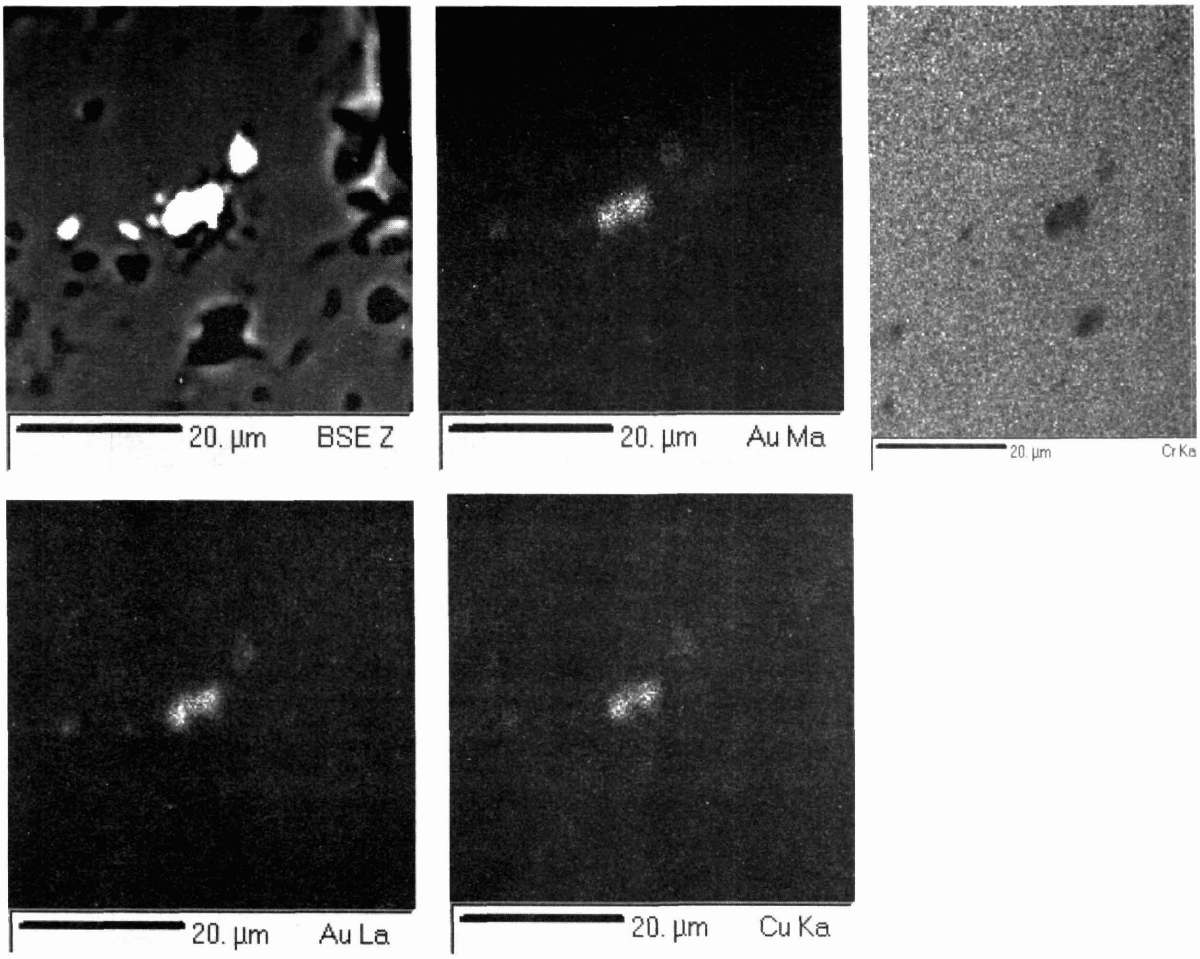

Fig.4. X-ray element 'dot' mapping of individual gold grains (white colour in BSE image) using AuLα, AuMα and CuKα X-ray emission lines. X-ray element 'dot' map of host chromite is also presented using CrKα which clearly shows absence of Cr counts in the gold grains.

there is no evidence to suggest that gold grains could be exsolved phases during the cooling of host chromite.

Qualitative X-ray scan on individual gold grains (Fig. 3) reveal that they essentially consist of Au and Cu. No other elements, including Pt, Pd, Bi and As, were detected. The qualitative X-ray peak positions of Au and Cu on LLIF crystal are in excellent agreement with those of theoretical values (AuLα=0.31700; AuLβ=0.26910; CuKα=0.38261; CuKβ=0.34577). Apart from the above, X-ray element 'dot' mapping carried out for various X-ray emission lines of Au, Cu and Cr to understand the distribution of these elements in individual gold grains and also in the host chromite is presented along with the BSE image (Fig. 4). X-ray element 'dot' mapping demonstrates (i) the confinement of Au and Cu elements to the gold grains but not to the host chromite and (ii) the absence of elemental Cr in the gold grains. Even though semi-quantitative and quantitative analyses (see below) carried out for the gold grains reveal that the Au content predominates over that of Cu, apparently dense Cu X-ray element 'dots' in Fig.4 are interpreted to be due to more excitation of CuKα lines compared to that of AuLα and AuMα lines in a collection time of 10 minutes.

Semi-quantitative analyses (performed by using a PEAKSIGHT software version 3.4.2 provided by CAMECA) making use of X-ray peaks of Au and Cu obtained by qualitative analyses suggests Au content of the individual gold grains to be up to 80 wt% whereas their Cu content is up to 20 wt%. Our in-house results of semi-quantitative analyses performed on various minerals suggests that this method has an accuracy within 15%. Extremely small grain size of the gold grains under study and their setting within a chromite host phase (which itself is compositionally complex with varying substitutions of other elements such as Mg, Al and Ni apart from Cr and Fe – as discussed above) contributed significant background X-ray peaks thereby necessitating adequate background corrections whilst quantitative analyses after calibrating the respective peaks of elements in the standards The maximum content of Au in the individual grains by quantitative analyses was found to be up to 92 57 wt% whereas that of Cu is up to 11 24 wt%

DISCUSSION

Gold occurs in a variety of geological settings in India (Radhakrishna and Curtis, 1999 for an overview) viz , (i) Lode gold associated with quartz-carbonate veins e g Kolar (Karnataka), (ii) Banded Iron formation e g Chitradurga schist belt (Karnataka), (iii) Disseminated gold in intrusives and volcanics e g Malanjkhand (Madhya Pradesh), (iv) Polymetallic sulphide deposits e g Khetri (Rajasthan) and Rakha (Bihar), (v) Placers e g Subarnarekha (Bihar) and Subansiri (Assam) rivers, (vi) Laterites e g Nilambur valley, Kerala

There is published information available regarding the presence of gold in chromite bearing ultramafic complex at Sukinda up to a maximum of 550 ppb (Pattanaik, 1988) However, the mode of occurrence of gold from the area of investigation has not been reported The present study clearly indicates the presence of discrete gold bearing minerals in the South Kaliapani chromite mines of the Jajpur district

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