SHORT COMMUNICATION

INCIDENCE OF GOLD IN SUBGREENSCHIST TO GREENSCHIST FACIES
METABASALT OF BHOWALI, NAINITAL DISTRICT, UTTARANCHAL

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Mesoproterozoic metavolcano-sedimentary sequence in and around Bhowali-Khairna area, Uttarakhand, constitute mostly metabasalts with quartzites, phyllites and variegated slates, referable to Bhimtal Formation. Our study was centred on metabasalts and the rocks occurring in close spatial association with them. Detailed petro-mineralogical and SEM-EDS studies have revealed the presence of gold which we report here for the first time. Of the two types of metabasalts viz., massive, crudely foliated type and foliated type, both showing mineralogical assemblages of subgreenschist facies and greenschist facies respectively, gold is commonly found in the foliated type and rarely in the massive type. Presence of gold as tiny grains in disseminated fashion suggest that widespread hydrothermal activity caused precipitation of gold after the rocks had witnessed peak metamorphism.

INTRODUCTION

The Bhowali (29°23′10″N: 79°30′50″E) metabasalt and associated quartzite with subordinate grit, phyllite and slate constitute the Bhimtal Formation. The metabasalts occupy the core of a distorted anticline trending NW-SE (Varadarajan, 1974; Raina and Dungrakoti, 1975; Pal and Merh, 1974; Shah and Merh, 1976). With a view to developing a logical petrogenetic model of evolution of these metabasalts and understanding the effects of associated hydrothermal processes, detailed petrographic studies coupled with mineral chemistry, whole rock chemistry (major, trace by XRF, AAS and REE by NAA methods) were carried out on rocks exposed between Khairna (29°29′42″N: 79°28′55″E) and Naukuchiyatal (29°19′35″N : 79°35′00″E). To understand the detailed mineral chemistry, selected samples of metabasalts were analysed by electron microprobe (using Cameca SX 51 electron microprobe) followed by SEM-EDS (using LEO S-440 scanning electron microscope). EDS analyses were done using Oxford Link ISIS system at an accelerating voltage of 20 kV and filament current of 5mA.

The purpose of the present paper is to report the incidence of gold in the metabasalts of Bhowali for the first time and propose a probable mechanism by which gold was deposited.

PETROLOGY

Within the limits of study area (Fig. 1), the rock types encountered are: (1) dark greenish, predominantly massive, compact and rarely crudely foliated basalt with vesicles, (2) greenish, aphanitic, often foliated basalt, (3) dark greenish, well foliated tuff, often appearing as chlorite schist and (4) quartzite with pebbles at places, subordinate grit, phyllite and variegated slate. Late stage quartz-calcte-epidote veins are conspicuous in these basalts and occasionally these veins produce anastomosing patterns.

The massive, crudely foliated basalt (hereafter called CMB) comprise albite with minor oligoclase, amphibole (actinolite-ferroactinolite, following IMA nomenclature, Leake et al. 1997), clinopyroxene (mostly augite to diopside augite, following IMA nomenclature, Morimoto et al. 1988), chlorite, epidote, quartz, pumpellyite, calcite, magnetite, hematite, pyrite, occasional chalcopyrite and rare prehnite as replacement of augite (Varadarajan, 1974) and calcic plagioclase (this study).

In aphanitic foliated basalt (hereafter called AFB), the mineralogical assemblages are albite, chlorite, amphibole (actinolite-ferroactinolite with rare ferroactinolitic hornblende, following IMA nomenclature, Leake et al. 1997), epidote, calcite, quartz, sphene, muscovite, pyrite, magnetite with rims of titanomagnetite, occasional biotite and stibnomelane. Pumpellyite and prehnite are characteristically absent in this rock. Epidote composition (pistacite, Fe2+/Fe3++Al) usually range from 0.28-0.35 in AFB rocks whereas in CMB rocks the same range from 0.18-0.32, a feature similarly observed in the prehnite-pumpellyte (0.18-0.32) and greenschist (0.21-0.35) facies metabasites of Smartville Complex, California (Springer et al. 1992).
In both CMB and AFB, very minute grains of monazite (usually 2-5 μm) and zircon (maximum up to 10 μm) in the groundmass were detected through SEM-EDS studies. Minor jarosite is present in these rocks and it has been confirmed also through detailed XRD studies.

The tuffaceous rocks essentially comprise dominant chlorite, which impart a foliation to the rock, along with cryptocrystalline to cherty silica, tiny streaks of brownish ferruginous clayey material and small anhedral quartz grains occurring in random fashion. The brownish clayey material present in this rock may result from alteration of original volcanic ash or release of Fe-oxide during late stage deuteric alteration of tuffs.

While carrying out SEM-EDS analysis on samples of metabasalts, we have found specks of gold, mostly in AFB. Gold occurs as dissemination in the groundmass, interstitial to mafic and felsic silicates and also in close association with pyrite. Altogether 13 selected samples (mostly metabasalts and one each of quartzite and intrusive Amritpur granite) were studied by SEM-EDS and presence of gold
was confirmed only in two samples of AFB from Ratighat (sp. no. RTG-71) and Naukuchiyatal (sp. no. NKT-24) and one sample of CMB from Bhimtal (sp. no. BMT-27).

DISCUSSION

In most orogenic belts, subgreenschist and greenschist facies metamorphic rocks are widespread. The assemblages of minerals in metabasites are sensitive indicators of metamorphic grade. The low-temperature mineral equilibria (Liou et al. 1985, 1987; Frey et al. 1991) of these rocks have provided a useful petrogenetic grid for metamorphism of model basaltic system at low-temperature (Powell et al. 1993).

The mineralogical assemblages in CMB rocks, represent a high pressure series and correspond to pumpellyite-actinolite facies without prehnite and prehnite-pumpellyite facies with prehnite corresponding to high-P and low-P bathozones in the system CaO-MgO-Al,O,-SiO,-H,O (Powell et al. 1993). Phillips and Brown (1987) have shown that in the greenschist facies, metabasites have typical assemblage of actinolite + chlorite + epidote + albite + calcite + quartz + pyrite. The mineralogical assemblage in AFB of Bhowali thus clearly indicate that the rocks had undergone greenschist facies of metamorphism.

In the background of transition of burial metamorphic (subgreenschist facies)- to regional metamorphic (greenschist facies) rocks at Bhowali we have recorded the

Fig.2. Representative BSE image showing (a) specks of gold as interstitial to felsic silicates (scale bar = 1 μm) and (b) disseminated gold grains in groundmass silicates (left, scale bar = 20 μm) and the same magnified image (right, scale bar = 10 μm).

Fig.3. Showing energy dispersive spectral lines of gold grains as shown in Fig.2(a) and (b).
presence of gold mostly in AFB-domain whereas in the CMB-domain the same is relatively minor in proportion (Fig.2). The representative EDS analysis of elemental abundance (%) is presented above along with energy dispersive spectral lines (Fig. 3) of the gold grains as shown in Fig.2. The fact that the analysed gold grain in AFB (sp. no. RTG-7/1) show presence of W and Mo is because of induced effects from the adjoining monazite grains, as evidenced from their chemistry.

Studies on numerous gold deposits in various provinces (e.g. Archaean greenstones, Archaean Witwatersrand, Palaeozoic slate belt, Cenozoic epithermal deposits, etc.) have established a positive relationship between gold and sulphur. The gold is nearly (but not always) closely associated with pyrite, including where the pyrite replaces pre-existing Fe-rich minerals. Pande et al. (1991) and Phillips and Powell (1993) have shown that the essential feature common to gold provinces is metamorphic devolatilisation to produce a low salinity fluid capable of transporting gold as reduced sulphur complex and abundant generation of such fluids that occur at the greenschist to amphibolite facies transition. Deuteric alteration/autometamorphism that adds sulphur to the volcano-sedimentary pile may account for subsequent gold deposition. While temperature plays an important role on gold deposition, a low geothermal gradient would result in small temperature changes over a large vertical column and the gold deposit will be spread out over great depths (Phillips and Powell, 1993). This scenario would indicate that at subgreenschist and greenschist metamorphic terrains, minor gold deposits will form, in contrast to terrain with high geothermal gradient and attendant giant gold deposits. In case of Bhowali metabasalt which have imprints of subgreenschist to greenschist facies metamorphism, gold occurs as tiny disseminated grains.

The metabasalts of both types at Bhowali have experienced widespread alteration as evidenced by ubiquitous presence of chlorite. Their nature and textural characteristics (as tiny specks and elongated patches) indicate that majority are alteration products of clinopyroxene or glassy material, although second generation primary crystallized chloride is common and usually occurs as infillings in the vesicular cavities. Uralitisation of clinopyroxene is common, apart from independent amphibole crystals. Epidote occurs as patches, discrete grains, veins and sometimes in the vesicular cavities and are intimately associated with chlorite/uralite. Albiteisation of calcic plagioclases in these rocks is pronounced and breakdown of calcic plagioclase to pumpellyte and sericite are conspicuous. Tiny monazite (with 19.61-25.89 P_2O_5, 20.82-28.20 Ce_2O_3, total (REE)O_3 (including Ce_2O_3) ranging from 46.38-60.34 and 5.16-7.63 WO_3) grains in the groundmass of albited CMB- and AFB-rocks are the result of hydrothermal activity. Similar hydrothermal monazite (Ce) in gold deposits from albited rocks is reported from Sudbury Complex, Ontario, Canada (Schandl et al. 1994). Presence of jarosite in these rocks indicates that there were widespread hydrothermal activity. The common association of jarosite with gold is usually seen in hydrothermal environment. Thus, the presence of disseminated gold and its relationship with associated minerals suggest that widespread hydrothermal activity caused precipitation of gold after the rocks had witnessed peak metamorphism.

The Palaeoproterozoic (1880±40 Ma, K-Ar age; Varadarajan, 1978; 1888±46 Ma, Rb-Sr age; Trivedi and Pande, 1993) and Mesoproterozoic (1330± 40 Ma, K-Ar age; Varadarajan, 1978) episodic granitic rocks of Amritpur and the Palaeoproterozoic (1860±65 Ma, Rb-Sr age, Trivedi et al. 1982) rocks of Ramgarh Group which occur spatially close to rocks of Bhimtal Formation (Fig. 1), contain a number of late-stage quartz veins that show the presence of gold. Particularly around Chalthi (Southeastern part of the area), the quartz veins, occurring along the contact of rocks of Ramgarh Group and Bhimtal Formation, contain up to 5 gm/tonne of gold (Mangla Prasad, pers. comm., 2001). Detailed field and laboratory studies led Mangla Prasad et al. (1994) to conclude that hydrothermal activity played a significant role in the genesis of gold in these silicified veins. Presence of auriferous sulphide veins at Kimkhet and sulphidic hydrothermal breccia at Galpakot are some other evidences of hydrothermal activity in the area.

Our study on the incidences of gold in metabasalts of Bhowali is in a preliminary stage and further detailed work will be taken to assess its potentiality. In this context, our prediction is that the similar volcano-sedimentary sequence with imprints of low grade metamorphism within the Garhwal Group will show incidences of gold—the possibility of which was not thought of earlier.
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References


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