TUNGSTEN MINERALISATION IN RAJASTHAN, INDIA

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The Aravalli craton constitutes an important segment of the Precambrian metallogenic provinces in the Indian shield. It consists of Mid- to Late Archean basement represented by Banded Gneissic Complex, which is successively overlain from east to west by rocks of Early Proterozoic Aravalli fold belt and Mid Proterozoic Delhi fold belt (Fig. 1). The Aravalli fold belt hosts several Pb-Zn deposits, including a world class deposit at Agucha (120 Mt ore having 13% Zn, 1.5% Pb, 50 g/t Ag, 200 g/t Cd), large deposits of stromatolytic phosphorite and world class marble deposits. The volcano-sedimentary sequence of Delhi fold belt hosts several Cu deposits.

During Late Proterozoic period (900-700 Ma) the Aravalli craton witnessed several episodes of acid magmatism. Some of these Late Proterozoic granites emplaced along the western margin of Delhi fold belt are associated with world class skarn wollastonite deposit at Belka, greisen tungsten deposits at Degana, Balda and Sewariya areas, and in many instances these granites themselves qualify as valuable deposits of building stone. The present discussion is focused on the geological characteristics of tungsten mineralisation associated with these Late Proterozoic granites in Rajasthan.

Degana Tungsten Deposit

The Degana pluton consists of three different intrusions of porphyritic granite (Fig. 2), of which the older medium- to coarse-grained granite is emplaced within phyllite and the two younger intrusions, namely coarse grained porphyry and fine grained porphyry, are emplaced within the older granite, accompanied by intense brecciation of intruded rocks (Fig. 3). Large number of aplite dykes, formed during two distinct stages, intrude into these granites and phyllite. Magmatic-hydrothermal
activity, which followed the emplacement of granite and aplite, has resulted in extensive fracturing of all these rocks and the development of greisen veinlets (Fig. 4), greisen-bordered lodes (Fig. 5) which are labelled as A, B, C etc. in Fig. 2, and breccia fill (Fig. 6), consisting of quartz-zinnwaldite/muscovite-topaz-fluorite-wolframite. Field relationship of various rocks and ore bodies shows that there were two consecutive cycles of magmatic to magmatic-hydrothermal events which produced granite followed successively by aplite, greisen veinlet and wolframite mineralized lode/breccia fill during each cycle.

The granitic rocks of Degana are peraluminous with A/CNK ratio in the range of 2.03 to 2.16, enriched in Rb (650-1070 ppm) and depleted in Sr (8-22 ppm), as a result of which Rb/Sr ratio is abnormally high (such value in non-mineralised granites is less than 4, (Tauson and Kozlov, 1973) Abnormally high concentration of Li and F in the granites, greisen and tungsten ore bodies is indicated by the presence of Li-mica, topaz and fluorite. Analysis of one sample of unaltered granite at IGEM, Moscow in the year 1972 showed 510 ppm Li and 9500 ppm F, whereas average abundance of Li and F in granite is 30 ppm and 800 ppm respectively (Krauskopf, 1979).

Wolframite lodes commonly show crustification with zinnwaldite/muscovite lining the vein walls (Fig. 7) and quartz occupying bulk of the veins along with disseminated topaz, fluorite and wolframite of ferberitic composition (Mn/Fe ratio from 0.02 to 0.33). The granites and aplites are greisenised adjacent to the lodes as well as thin greisen veinlets, the width of alteration zone varying from few cm to several metres, and composed of grey quartz, dark green zinnwaldite and minor amount of topaz, fluorite and wolframite. Chemical analysis of wallrock granites show enrichment of Li and F close to the ore body. K-Ar radiometric dating of zinnwaldite and muscovite from wolframite lodes, carried out at IGEM in the year 1972, has indicated ages of 860±25 Ma and 870±25 Ma respectively.
From thermometric analysis of primary fluid inclusions in quartz, fluorite and topaz, Jaireth et al. (1984) inferred that the wolframite-bearing quartz veins formed in the temperature range of 110 to 460°C from hypersaline (20 to 42 wt.% NaCl eq.) aqueous solution that underwent recurrent boiling. Wolframite deposition is inferred to have occurred before fluorite at temperature above 203°C. We have recognized three types of primary inclusions in quartz from the lode: aqueous bi-phase inclusions with salinity 4.3 to 22.4 wt % NaCl eq, aqueous inclusions containing halite crystals with salinity 30 to 50 wt%. NaCl eq., and aqueous-carbonic inclusions. Intersection of isochors of saline aqueous inclusions and aqueous-carbonic inclusions indicate P-T condition of 200-312 bar and 200°C during precipitation of quartz in the lode.

Balda Tungsten Deposit

Metasediments of Delhi Supergroup constitute the major rock unit of this area, intruded by an older, deformed biotite granite gneiss (Erinpura granite) and a younger, massive tourmaline leucogranite (Balda granite) (Fig. 8) which is the source of hydrothermal activity and tungsten mineralisation in this area (Chattopadhyay et al., 1982). Erinpura granite has yielded Rb-Sr whole-rock isochron age of 830 Ma (Choudhary et. al. 1984). Balda granite is medium grained consisting of quartz, alkali feldspar and muscovite as the major minerals and biotite, tourmaline, topaz, fluorite and ilmenite as accessories. Tourmaline in this granite is schorl showing dichroism (brown to colourless) in thin section.

In Balda area several shear zones are located along the intrusive contact between Balda granite and argillaceous metasediments (Fig. 9). These shear zones are occupied by wolframite bearing quartz veins (Fig. 10). Nine such mineralised veins, ranging in length from 50 to 600 m and in width from 1.5 to 20 m have been located over a strike length of 2.5 km (Geological Survey of India, 1982). Wolframite in these ore bodies is ferberitic in composition with Mn/Fe ratio varying between 0.08 to 0.12 (Banerjea et. al., 1979). Greisenisation of wallrock phyllite and granite adjoining the W mineralized quartz veins is prominent, with the appearance of tourmaline along with muscovite, fluorite and apatite (Fig. 11 and 12). There are also few fluorite rich veins (containing less quartz) occurring within the leucogranite.

Chemical composition of Erinpura granite is comparable with normal granites. Balda granite is peraluminous and geochemically specialised with enrichment of Li, Rb, W, Sn and Nb, and depletion of Sr and Ba. The W content of Balda granite varies from 71 to 128 ppm with an average value of 97 ppm (Singh and Singh, 2001). B and F contents are also high in Balda granite as it contains significant amount of tourmaline and fluorite.

Presence of poly-phase hypersaline, CO₂-bearing, and low saline liquid rich aqueous inclusions have been observed in quartz from W-mineralized quartz veins of Balda, and thermometric studies
have indicated that these veins formed in the temperature range of 200 to 470°C from dense (1.25 to 0.5 g/cm³) and saline (4 to 60 wt. % NaCl eq.) aqueous solution at a pressure of 700 bar (Sharma et al. 1994). We have also recognized three types of primary inclusions in quartz from the W mineralized vein: aqueous bi-phase inclusions with salinity 4.3 to 22.4 wt. % NaCl eq., aqueous inclusions containing halite crystals with salinity 30 to 50 wt%. NaCl eq., and aqueous-carbonic inclusions. Laser Raman analysis of some of the aqueous carbonic inclusions indicate the presence of methane and graphite in addition to CO₂ in these inclusions. Intersection of isochores of saline aqueous inclusions and aqueous-carbonic inclusions indicate P-T condition of 200-312 bar and 200°C during precipitation of quartz in the lode.

**Sewariya Tungsten Deposit**

In Sewariya-Govindgarh area (Fig. 13), a medium to coarse grained tourmaline leucogranite (known as Govindgarh granite, GG) is emplaced as small stocks and dyke swarms intruding into
metasediments and metavolcanics of Delhi Supergroup and a biotite granite gneiss (known as Sewariya granite, SG) (Fig. 14). While Sewariya granite shows effects of ductile, brittle-ductile and brittle shearing (Fig. 15), such deformation are not recorded in Govindgarh granite Two types of tourmaline leucogranite are found in this area: (1) an older, medium grained granite, which at many places shows magmatic layering defined by tourmaline, and (2) a younger, coarse grained granite which appears to be the product of pegmatite stage. Both these rocks have a common mineral assemblage of quartz, microcline, sodic plagioclase, tourmaline, muscovite, garnet and apatite.

![Fig. 13: Geological map of Sewariya W deposit](image1)

![Fig. 14: Dykes of Govindgarh granite](image2)

![Fig. 15: (L to R) Pseudotachylite in Sewariya granite (SG), brittle deformation in SG; brecciated ultramylonite in SG](image3)

![Fig. 16: W mineralised veins in mica schist and SG](image4)

Quartz-tourmaline veins are commonly found along the contact zone between SG and metasediments (Fig. 16). Geological Survey of India recognised wolframite mineralisation in these veins occurring near Kalni, Motiya, Pipiliya, Richmaliyan and Kotariya. The W mineralized veins have formed during magmatic hydrothermal stage which followed the emplacement of tourmaline leucogranite (GG). Wolframite from these veins is ferberitic in composition with average Mn/Fe ratio of 0.36.
Tourmaline occurring in various rocks of the area is black coloured schorl variety. As primary mineral in GG it shows a characteristic colour zoning in thin section: blue coloured with a thin greenish yellow rim in medium-grained leucogranite to dominantly greenish yellow with a small blue coloured core in coarse-grained leucogranite (Fig. 17). Mica schist and Sewariya granite contain metasomatic tourmaline near to intrusive contact of GG and W-bearing veins. Tourmaline from W-bearing veins and the altered wall rocks shows dominant yellowish brown colour studded with irregular patches of blue and greenish yellow (Fig. 17). Electron probe microanalysis of tourmaline grains from all the litho-units corresponds to that of schorl variety. From the variation in concentration of Fe and Li within (core to rim) tourmaline grains and its correlation with colour zoning, it is inferred that Li rich zone assumes blue colour and Li poor zone shows greenish yellow colour.

Fig. 17: (L to R) Plane light microphoto of tourmaline in coarse leucogranite (top), medium grained leucogranite (3 photos), and in mineralised vein (middle); tourmaline formed by hydrothermal alteration in Sewariya granite (right to middle) and in mica schist (right most). Width of each photo = 1.35 mm.

Both Sewariya granite and Govindgarh granite are peraluminous. Large differences exist in the concentration of Rb, Nb, Zr and Y between GG and SG, with all these 4 elements enriched in SG as compared to GG. W concentration in both the varieties of leucogranites (average 4 ppm in medium grained leucogranite, and 5 ppm in coarse grained leucogranite) match with metallogenetically specialized granites reported by Tischendorf (1977).

Thermometric studies on primary fluid inclusions in quartz from W-mineralized quartz veins of Sewariya, have indicated that these veins formed in a P-T range of of 373 to 417°C and 250 to 350 bar from aqueous fluid showing a continuum in fluid density from 0.2 to 0.85 g/cm³ which experienced boiling, followed by increase in salinity of the aqueous fluid to 32.5 to 42.5 wt.% NaCl eq. (Sharma et al 2003).

Exploration and Mining History

Degana tungsten deposit, the largest of the three deposits, was discovered in 1913 and has been periodically mined until 1995. So far the lodes alone have been mined partially. Stockwork mineralization (porphyry type?) has been proved in the entire granite pluton and associated phyllite. Presently mining operation is abandoned due to high cost of production. Balda tungsten deposit was discovered in 1978. Detailed exploration and exploratory mining was carried out during next 15 years. The prospect is yet to be mined. Sewariya tungsten deposit was discovered in 1987. Detailed exploration was carried out for 7 years following its discovery. This prospect is also not yet mined.
References


