Geoscience Frontiers 5 (2014) 877–892

Contents lists available at ScienceDirect

China University of Geosciences (Beijing)

Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf

Research paper

Tourmaline from the Archean G.R.Halli gold deposit, Chitradurga greenstone belt, Dharwar craton (India): Implications for the gold metallogeny

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A R T I C L E I N F O

Article history:
Received 20 September 2012
Received in revised form
27 November 2013
Accepted 3 December 2013
Available online 10 January 2014

Keywords:
Tourmaline
G.R.Halli
Orogenic gold deposit
Dharwar craton
Archean

A B S T R A C T

Tourmaline occurs as a minor but important mineral in the alteration zone of the Archean orogenic gold deposit of Guddadarangavanahalli (G.R.Halli) in the Chitradurga greenstone belt of the western Dharwar craton, southern India. It occurs in the distal alteration halo of the G.R.Halli gold deposit as (a) clusters of very fine grained aggregates which form a minor constituent in the matrix of the altered metabasalt (AMB tourmaline) and (b) in quartz-carbonate veins (vein tourmaline). The vein tourmaline, based upon the association of specific carbonate minerals, is further grouped as (i) albite-tourmaline-ankerite-quartz veins (vein-1 tourmaline) and (ii) albite-tourmaline-calcite-quartz veins (vein-2 tourmaline). Both the AMB tourmaline and the vein tourmalines (vein-1 and vein-2) belong to the alkali group and are classified under schorl-dravite series. Tourmalines occurring in the veins are zoned while the AMB tourmalines are unzoned. Mineral chemistry and discrimination diagrams reveal that cores and rims of the vein tourmalines are distinctly different. Core composition of the vein tourmalines is similar to the composition of the AMB tourmaline. The formation of the AMB tourmaline and cores of the vein tourmalines are proposed to be related to the regional D_1 deformational event associated with the emplacement of the adjoining ca. 2.61 Ga Chitradurga granite whilst rims of the vein tourmalines vis-à-vis gold mineralization is spatially linked to the juvenile magmatic accretion (2.56–2.50 Ga) east of the studied area in the western part of the eastern Dharwar craton.

1. Introduction

Tourmaline is an acentric rhombohedral borosilicate with a general formula expressed as $XY_3Z_6(T_6O_{18})(BO_3)_3V_3W$, where X = Ca, Na, K, vacancy; Y = Li, Mg, Fe^{2+}, Mn^{2+}, Zn, Al, Cr^{3+}, V^{3+}, Fe^{3+}, Ti^{4+}; Z = Mg, Al, Fe^{3+}, Cr^{3+}, V^{3+}; T = Si, Al, B; B = B, vacancy; V = OH, O and W = OH, F, O. The structure of tourmaline is characterized by six-membered tetrahedral rings (T sites) whose apical oxygen atoms point toward the (−) c-pole, producing the acentric nature of the structure. The tourmaline mineral group is chemically one of the most complicated groups of silicate minerals as its composition varies widely because of isomorphic replacement (solid solution).

Boron is an essential constituent of tourmaline. The source of boron can be from fluids or other boron bearing minerals and must be concentrated by geochemical processes in order to form tourmaline, as it is a trace constituent in the upper crust, lower crust and mantle. Formation of tourmaline is strongly influenced by boron content within the protolith and fluids interacting with crustal rocks during metamorphism (Henry and Dutrow, 1996). Tourmaline not only acts as a recorder of boron influx in the rock systems but also records large numbers of inter and intra-site substitution under pressure and temperature conditions ranging from diagenesis to granulite facies and crustal anatexis (Henry and

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Peer-review under responsibility of China University of Geosciences (Beijing)

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http://dx.doi.org/10.1016/j.gsf.2013.12.004

Dutrow, 1996). Therefore tourmaline is an unique mineral to document the mineral recrystallization events and fluid flow almost across the entire spectrum of metamorphism. Besides it is a typical accessory mineral in magmatic and sedimentary rocks. For many years, efforts are being made to utilize the tourmaline chemistry for exploration guide as a metallogenic indicator. Tourmaline are reported throughout the world as an important gangue mineral in metallic and non-metallic ore deposits where it occurs either as trace or minor mineral in the host litho-units or as major constituents (>15%) in concordant and discordant layers referred as tourmalinites. The presence of tourmaline is reported worldwide from various gold deposits and it forms an important mineral in many of the Archean orogenic and Proterozoic gold deposits. It also occurs as an accessory gangue mineral in several types of strata-bound gold deposits. Economically, the Au-tourmaline veins are the most valuable, as they form some of the largest and richest gold deposits of the world (Slack, 1996). Tourmaline bearing Au-quartz veins commonly occur within greenschist or amphibolite grade metavolcanic and metasedimentary rocks (and some metaplutonic rocks), especially in the Archean greenstone belts (Roberts, 1987; Hodgson, 1993; Hutchinson, 1993; Ram Mohan et al., 2008).

Tourmaline is spatially associated with greenstone volcanic as well as gold and other ore deposits of India across the geological period. Recently geochemistry of tourmaline is being utilized as a metallogenic indicator (Fareeduddin et al., 2010). Krienitz et al. (2008) reported the presence of tourmaline as minor but widespread constituent in the inner and distal hydrothermal alteration zones of Hira Buddini gold deposit in the Archean Hutti-Maski greenstone belt of the eastern Dharwar craton (EDC). Occurrence of tourmaline is also noted in Kolar gold deposit, Dharwar craton (Siva Siddaiah and Rajamani, 1989). Honnamaradi gold mineralization (nearly 22 km north of present study area) in the Chitradurga greenstone belt (CGB) is marked by intense development of tourmaline (Mohakul and Babu, 2001). Tourmaline occurs as a minor but important mineral in the alteration zone of Archean orogenic Guddadarangavanahalli (G.R.Halli) gold deposit in the CGB of the western Dharwar craton (WDC). No attempt has been made so far to characterize tourmaline for detailed petrography and chemical composition. This paper documents mineralogy and chemical composition of tourmaline and the new dataset is used to discuss the origin of tourmaline and its genetic link with gold mineralization.

2. Geological background

2.1. Regional geology

The Dharwar craton corresponds to a large tilted section of the Archean continental crust that exposes >3.0 Ga old tonalitic-trondhjemitic-granodioritic (TTG) gneisses (commonly known as Peninsular Gneissic Complex or PGC), two generations of greenstone sequences, potassic to calc-alkaline granitoids with synplutonic mafic dykes and mafic dyke swarms (Bhaskar Rao et al., 1992; Chadwick et al., 2000; Jayananda et al., 2000, 2006, 2008, 2013). The craton is divided into two sub-blocks i.e. the western Dharwar and the eastern Dharwar based upon the differences in the nature and abundance of the greenstones and in the degree of regional metamorphism (Swami Nath et al., 1976; Rollinson et al., 1981), plutonism and geochronological studies (Jayananda et al., 2006). The western block is dominated by old TTG (>3.0 Ga) with abundant greenstone sequences and discrete 2.62 Ga potassic plutons whilst eastern block contains younger gneisses with large remnants of old TTG (>3.0 Ga) with thin elongated volcanic dominated greenstone sequences and most voluminous 2.56–2.52 Ga granitoids/diatexites (Jayananda et al., 2013 and references therein). Recently a threefold subdivision is proposed for the Dharwar craton based upon U-Pb zircon ages and Nd isotope data i.e., the WDC with dominant old crust (3.4–3.2 Ga), the central Dharwar craton (CDC) with mixed old and younger crust (3.4–3.2 Ga and 2.56–2.52 Ga) and the EDC with mainly younger (2.7–2.52 Ga) crust (Dey, 2013; Peucat et al., 2013). In this paper we follow the two fold classification of the Dharwar craton.

The boundary between two cratonic blocks is marked by a 400 km long NW–SE trending mylonitic shear zone located on the eastern margin of the CGB (Swami Nath and Ramakrishnan, 1981; Drury et al., 1983; Chadwick et al., 1997) known as the Chitradurga eastern boundary shear zone (CBSZ). The intrusive granite plutons on both side of the CBSZ are entirely different with respect to their pristine and tectonothermal signature (Jayananda et al., 2006; Chardon et al., 2011). The WDC granitoids are emplaced around 2.62 Ga and synkinematic with respect to development of dome-basin patterns associated with D_1 deformation whereas the 2.56–2.52 Ga granitoid plutons in the EDC are emplaced during development of regional strike-slip shearing (Jayananda et al., 2006; Chardon et al., 2011). Late Archean tectono-plutonism between 2.56 and 2.50 Ga accompanied regional HT-LP metamorphism and ended with the formation of massive charnockites from gneisses and migmatites in the deepest exposed crust. The low temperature WDC with dominant development of Mesoarchean to Neoarchean granite greenstone terrains has presumably developed as a fore land over which high temperature EDC with profuse end Archean granitoids and linear greenstone belts are thrusted and amalgamated during the Dharwar orogeny (Chadwick et al., 2000).

2.2. Geology of the Chitradurga greenstone belt (CGB)

The N–S to NNW–SSE trending CGB (Sheshadri et al., 1981) extending for about 460 km long and 2–40 km wide (Fig. 1) is one of the most prominent Achaean tectonic features of the Indian Precambrian terrain. It comprises about 2–10 km thick sequence of metasediments and metavolcanics belonging to the Dharwar Supergroup. The Dharwar Supergroup is grouped into two subgroups viz. older Bababudan Group and younger Chitradurga Group (Swami Nath et al., 1976). The generalized litho-stratigraphic sequence of the eastern part of the WDC is presented in Table 1. The CGB shows a progressive increase in metamorphic P-T conditions from greenschist facies in the north to amphibolites facies in the south (Raase et al., 1986) which coincide with late D_1 and early D_2 events (Mukhopadhyay, 1986). The regional structure of the CGB has been described as second generation central anticline flanked by first generation synclines on either side (Mukhopadhyay et al., 1981; Mukhopadhyay and Ghosh, 1983; Mukhopadhyay and Baral, 1985). These structures are refolded along E–W trending warps formed during D_3 deformation (Mukhopadhyay and Baral, 1985). The D_2 deformation is related with the development of N–S sinistral shear zones within and at the margins of the schist belts (Chadwick et al., 2000) and these shear zones are known for hosting big and small gold deposits in the Dharwar craton. Twenty six gold incidences in different host rocks of the CGB are reported along the eastern extremity of the CGB and in proximity to the CBSZ (Radhakrishna and Curtis, 1999). Three most important gold deposits occurring along the close proximity of the CBSZ are Ajjanahalli, G.R.Halli and Gadag. The CGB, also known for its copper and iron mineralization, is interpreted to have formed as a result of collision tectonics and closure of a basin between two juvenile continental crust blocks (Naqvi, 1985).

2.3. Geology of the G.R.Halli gold deposit

The G.R.Halli (latitude 14°17′00″ N, longitude 76°24′00″ E) gold deposit is located at about 6.5 km north of the Chitradurga town in