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Contrasting fluid inclusion characteristics of staniferous and non-staniferous pegmatites of Southeast Bastar, Central India

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Abstract

Tin and rare metal-bearing granitic pegmatites in the Bastar–Malkangiri pegmatite belt of Central India are hosted by metabasic and metasedimentary country rocks. Fluid inclusion studies were conducted in spatially associated two-mica granite and the staniferous and non-staniferous pegmatites to characterize the physicochemical environment of mineralization, to distinguish different pegmatites in terms of their fluid characteristics and to envisage a possible genetic link between the pegmatites and spatially associated granite. Three different types of primary inclusions were identified. The type-I, aqueous bi-phase (L + V) inclusions are the most abundant and ubiquitous. Type-II polyphase (L + V + S) inclusions are rare. Type-III, monophase (L) and metastable aqueous inclusions, though less abundant than type-I inclusions, are ubiquitous. The fluid evolution trends indicate that mixing of two different fluids of contrasting salinities, one of high salinity (20–30 wt% NaCl equivalent) and another of low salinity (0–10 wt% NaCl equivalent), was responsible for precipitation of the bulk of the cassiterite. This mixing is the single most important characteristic that distinguishes the staniferous pegmatites from their non-staniferous counterparts. The non-staniferous pegmatites, on the other hand, are typified by the presence either of a high saline or a low saline fluid that evolved through simple cooling. The minimum pressure–temperature of entrapment, estimated from the intersections of the halide liquidus with the corresponding inclusion isochores of type-II inclusions, range between 2.1–2.2 kb and 300–325 °C. The similar *P–T* range of fluid entrapment of the staniferous and non-staniferous pegmatites indicates that they were possibly emplaced within a similar physical environment. Type-I inclusions from granite recorded only the high salinity fluid, the salinity of which compares well with that of the highly saline fluid component of type-I inclusions in the pegmatites. This is a possible indication of a genetic link between the pegmatites and spatially associated granite.

Keywords: Pegmatite; Tin; Fluid inclusion; Exploration; Bastar; Malkangiri; Central India

1. Introduction

The Bastar–Malkangiri Pegmatite Belt (BMPB) is one of the important pegmatite belts in the country, well known for its rich tin mineralization. Tin mineralization in this belt was first reported by Fermor and Kellerschon (1909). Preliminary geological investigations in BMPB and adjoining areas were initiated back in the nineteenth century (Ball, 1877; King, 1881; Greisbach, 1899, 1900; Fermor, 1935; Heron, 1937; Crookshank, 1963). A large amount of work on field relations, mineralogy and geochemistry of granites and pegmatites have been carried out in this pegmatite belt (see Pal et al., 1998, 2001 for references). Pal et al. (1998) carried out fluid inclusion studies in the Malkangiri sector of the BMPB. The present communication addresses the issue of fluid characteristics of the BMPB as a whole, combining fluid inclusion data from both the Malkangiri and Bastar sectors. The transport-depositional mechanism of Sn, vis-à-vis contrasting trends of fluid evolution in the staniferous and non-staniferous pegmatites, has been discussed.

The role of hydrothermal fluid in the transport and deposition of Sn and some rare metals is well known. It has also been experimentally demonstrated that Sn has a tendency to partition into the saline fluid phase in a melt-fluid system. A detailed characterization of the fluid is therefore warranted in order to understand the magmatic and late stage processes responsible for tin mineralization. Three granite plutons, namely Palim, Darba and Katekalyan, are exposed along the BMPB. Geochemical characterization and trace element

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modeling (Pal et al., 2001) on the evolution of the granites of the study area (Palim pluton in particular) strongly indicate that the granites are Sn-bearing and have the potential to generate Sn-bearing pegmatites. Hence, a genetic link between the granites and the pegmatites stands as a priori assumption. In this paper, we also attempt to characterize the late stage fluid in the granite and aim at working out the possible genetic link of the pegmatites with the granites on the basis of the characteristics of the end stage fluid in granite and the fluid regime in pegmatite, through fluid inclusion studies. In this paper, the term staniferous/mineralized pegmatites are broadly used to include those pegmatites which have visible tin mineralization and which have been exploited for the recovery of tin. On the other hand, the non-staniferous/non-mineralized pegmatites are those that do not show any visible mineralization.

2. Geology of the study area

The Bastar (Chattisgarh)–Malkangiri (Orissa) pegmatite belt is located on the southwestern part of the Bhandara Craton in the Indian Peninsula and is surrounded by the Eastern Ghat granulitic terrain on the east and southeast, high-grade metamorphic rocks of the Sukma Group in the south, and the Bailadila Iron Ore Group in the west (Fig. 1). The different rock units that are exposed along the Bastar–Malkangiri tin province include Archaean to Lower Proterozoic Bengpal metasediments, Middle Proterozoic basic extrusive, intrusives and acid magmatic rocks and Upper Proterozoic cover sediments of the Indravati Group (Babu, 1994). Fig. 1 is the lithological map of the study area showing the locations of the important Sn and rare metal mineralization in the Sn-belt (inset). The Bengpal metasedimentary rocks include sericite–quartzite, quartz–muscovite–schist, andalusite–sericite–biotite–schist, and brecciated ferruginous quartzite. A large part of the study area is occupied by the mineralogically and chemically heterogeneous Palim Granite, the eastern margin of which is chemically more evolved (Ramesh Babu, 1999; Pal, 2000; Pal et al., 2001). Pal et al. (2001) suggested that the chemical heterogeneity of the pluton could be explained by 31–33% assimilation fractional crystallization of an initial I-type melt to produce granite with many characters akin to S-type granites. The basic/intermediate rocks are medium to fine grained and bear distinctly different mineral assemblages. Although, the original igneous mineral assemblage is mostly obliterated, retention of the pristine igneous textures and relict of original igneous minerals (viz. plagioclase, hornblende, pyroxene) are observed. Basic intrusives east and northeast of the Palim pluton experienced pervasive fluid-induced alteration resulting in almost complete obliteration of the primary igneous mineralogy and they are now represented by clinozoisite/zoisite + epidote + tremolite + opaque ± plagioclase ± quartz ± chlorite ± hornblende in different proportions. In contrast, the basic/intermediate rocks on the northern and western sectors are less altered and commonly retain the original igneous texture and are presently represented by actinolite + plagioclase + tremolite + clinozoisite/zoisite + opaque minerals ± epidote ± chlorite ± hornblende ± pyroxene ± quartz. The pervasive fluid induced alteration of the rocks located east and northeast of the Palim Pluton is a possible indication of fluid flux from crystallizing granite towards the east and northeast.

Pegmatites occur within Bengpal metasediments, metabasics and also in Palim granite. The pegmatites are concentrated on the northeastern and eastern parts of the study area (Fig. 1) and generally follow an E–W trend in the Malkangiri sector and NW–SE or NNW–SSE trend in the Bastar sector. Unzoned pegmatites are present in all rocks present in the study area. However, zoned staniferous pegmatites occur mostly in a metabasic host. The zoned pegmatites are generally characterized by a discontinuous quartz core, intermediate zone of blocky K-feldspar/perthite and a boarder zone consisting of fine-grained quartz, K-feldspar and muscovite. Varying degree of albitization and greisenization partially replace the different units, particularly the core and the intermediate zone of the pegmatites. This indicates the fluid saturated condition of pegmatitic melt towards the end stage of pegmatite formation. Tin mineralizations in the form of cassiterite concentrate at the quartz core, the intermediate zone or at the core intermediate zone boundary and are often closely associated with the zone of albitization and greisenization. Veinlets of cassiterite sometimes occur in the quartz core. During the course of the present investigation, six mineralized pegmatites located at Dhuramagurah, Mundval, Govindpal, Mundaguda, Haladikunda and Bacheli and 22 non-mineralized pegmatites covering the entire study area were investigated. The first three pegmatites are well within the metabasic country rocks, whereas the Mundaguda pegmatite intrudes the metabasic and the metasedimentary country rocks. The Haladikunda pegmatite, which is mineralogically homogeneous and poorly mineralized, occurs within mica schist and the Bacheli pegmatite is hosted by quartzite.

3. Fluid inclusion studies

3.1. Fluid inclusion petrography

Fluid inclusion studies were conducted in quartz from the quartz cores of zoned pegmatites, pegmatitic quartz of the unzoned pegmatites and quartz from quartz veins and granites. Cassiterite was found to be unsuitable for fluid inclusion studies because of poor optical clarity. Sixty-six doubly polished wafers of 0.30–0.50 mm thickness were prepared from 28 pegmatites, 10 quartz veins and two-mica granite for fluid inclusion petrography and microthermometric experiments. One sample was studied from the two-mica granite in the eastern part of the Palim pluton (Fig. 1). After carefully studying all the wafers, only 24 wafers were selected for fluid inclusion petrography and subsequent microthermometric experiments.

Inclusion petrography was conducted with the help of a Leitz Laborlux D petrological microscope, fitted with a 100 W illuminator. Only the primary and pseudo-secondary inclusions, following the criteria of identification outlined by Roedder (1984) and Shepherd et al. (1985), were considered for microthermometric experiments. The inclusions range in size from 6 to 30 μm (dia/length in the direction of elongation),