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Baddeleyite-apatite-spinel-phlogopite (BASP) rock in Achankovil Shear Zone, South India, as a probable cumulate from melts of carbonatite affinity

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Abstract

We report here the petrography, mineralogy and in-situ trace-element mineral geochemistry of a rare and hitherto unidentified baddeleyite-apatite-spinel-phlogopite (BASP) rock in Late Neoproterozoic Achankovil Shear Zone (ACSZ) in South India. The rock unit occurs as isolated outcrops and demarcates the western boundary of an ultramafic complex in ACSZ. The modal mineralogy of the BASP rock is baddeleyite < apatite < spinel < phlogopite. Baddeleyite is found as inclusions within spinel and phlogopite. The spinel is highly aluminous with copious inclusions of high-T melts, pure CO_2-fluids, magnesite and graphite. Apatite is the major carrier of halogens such as F and Cl, LREEs, U and Th, and phlogopite is the robust reservoir of Ba and Rb. The concentrations of REE in apatite are quite variable (ΣREE ~ 7646–13485 ppm), but the chondrite normalized patterns show a uniform negative sloped REE patterns with significant negative Eu anomaly, which is indicative of the crystallization of apatite in a reduced environment. The mineral assemblage of apatite–phlogopite–baddeleyite is typical of carbonatites from various carbonatite complexes. Moreover, the LREE enrichment and negative Eu anomaly of apatite, low Ti and Fe, and high Al, Mg, Ba and Rb of phlogopite, as well as actinide enrichment of baddeleyite relative to REEs, are characteristic signatures of carbonatites from various tectonic settings. Therefore, we argue that the BASP rock is probably formed by crystal precipitation from melts having carbonatite affinities derived from the upper mantle and emplaced into the lower crustal level during the extensional collapse of the orogen following the collisional assembly of the Gondwana supercontinent. The deep-rooted ACSZ acted as the pathway for the infiltrating melts.

Keywords: Baddeleyite; Apatite; Aluminous spinel; Phlogopite; Carbonatite; Achankovil Shear Zone

1. Introduction

Shear zones in high-grade metamorphic terrains often exert significant control over the exhumation history of continental deep crust, emplacement tectonics of igneous intrusives, and transfer of unusual fluids/melts from various depths (e.g. McCaig, 1997; Cartwright et al., 1999). They also serve as loci for a variety of mineralization (Mikuchi and Ridley, 1993). Among a suite of magmatic plutons associated with various shear zones in high-grade terrains, silica-undersaturated rocks are of particular importance since they offer windows into processes from the deep crust through crust–mantle

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interface to the upper mantle. The continental fragments derived from East Gondwanaland consist of a collage of high-grade metamorphic terrains, which are dissected by major transcrustal shear zones. The Late Neoproterozoic Achankovil Shear Zone (ACSZ) in southern India is an example, which is characterized by highly deformed granulite facies supra-crustal rocks and orthogneisses that are variously intruded by felsic plutons, mafic dykes and ultramafic bodies. In this paper, we report the results of petrography, and major- and trace-element mineral chemistry on an undeformed and unmetamorphosed, rare and unusual, baddeleyite-apatite-spinel-phlogopite (BASP) rock within the ultramafic complex of Achankovil Shear Zone (ACSZ), South India. This will contribute to the unraveling of a peculiar deep-seated process related to the behaviors of melts of carbonatite affinities that has never been documented.

2. Geological setting and outline of the ultramafic complex

The study area, around Perunthol village is located in the Kollam district of Kerala and lies within the Late Neoproterozoic Achankovil Shear Zone (ACSZ) in Southern Granulite Terrain (SGT) (Fig. 1a). ACSZ is widely recognized in the literature as a major transcrustal shear zone (e.g. Drury and Holt, 1980; Rajaram et al., 2003) and has received broad attention in Gondwana correlation studies (e.g. Windley et al., 1994; Kröner and Brown, 2005). The ACSZ is a dominant NW–SE trending strike-slip shear zone that appears as a major lineament in aeromagnetic and satellite images, and separates a vast supracrustal sequence of Trivandrum Block (TB) that lies in the south of the shear zone from predominantly granulite facies rocks of Madurai Block (MB) in North (Drury et al., 1984; Harris et al., 1994). All these blocks were subjected to polyphase ductile deformation, granulite facies metamorphism and crustal rejuvenations during the Pan-African Orogeny (Brandon and Meen, 1995; Braun et al., 1998; Braun and Kriegsman, 2003; Santosh et al., 2003, 2005; Cenki et al., 2004). The dominant rocks within ACSZ are represented by intensely deformed and migmatized garnet-biotite gneiss, khondalite, cordierite and quartzofeldspathic gneiss, charnockites and calc-silicates (Santosh, 1987, 1996 and references therein). They were intruded by partly to totally undeformed felsic rocks, such as granite, pegmatite, monzonites, quartz diorite and basic to ultramafic rocks like gabbro, dolerite and rare ultramafic rocks (Rajesh et al., 1996; Rajesh, 2004a,b; Rajesh et al., 2004a; Santosh et al., 2005). The metamorphic grade throughout the shear zone ranges from ultra-high temperature to high-temperature part in granulite facies (e.g. Nandakumar and Harley, 2000). The predominant granulite facies metamorphisms were dated back to be of the Pan-African period (e.g. Bartlett et al., 1998; Cenki et al., 2004). Most of the felsic intrusives were also dated to be Late Pan-African by various methods (Rajesh, 2004a; Santosh et al., 2005).

A comprehensive portrayal of the geological aspects of the rare rock units constituting the ultramafic complex in ACSZ is given in Rajesh et al. (2004a,b), and is briefly summarized here. The rarity of outcrops and thick soil cover hindered the direct observation of the relation of the BASP rock with the other rock units of ultramafic complex and the surrounding high-grade metamorphic rocks. This unique ultramafic complex is composed of spinel dunite (olivine + spinel + phlogopite + dolomite ± ilmenite ± rutile + serpentine), phlogopite dunite (olivine + phlogopite + dolomite ± ilmenite ± rutile ± brucite ± baddeleyite + serpentine), glimmerite (phlogopite ± ilmenite ± rutile), graphite-spinel glimmerite (phlogopite + spinel + graphite ± baddeleyite) and phlogopite-graphite spinellite (spinel + graphite ± zirconolite ± phlogopite) from SE to NW (Fig. 1b). Based on bulk rock and mineral chemistry, stable C and O isotopes, and fluid inclusion studies Rajesh (2004b) interpreted that the ultramafic complex was formed by the differentiation and crystallization of highly potassic and volatile (H_2O and CO_2) rich melts of probable upper mantle origin. Subsequently these melts were emplaced into lower crustal levels through the deep-rooted shear zone (which acted as the pathway for the infiltrating fluids) after the dominant Pan-African tectonothermal events. The complex was dated to be Early Ordovician by U–Pb electron microprobe ages of zirconolite and K–Ar ages of phlogopite (Rajesh, 2004b; Rajesh et al., 2004a,b, in press).

The investigated rocks are found in the northwestern limit of the ultramafic complex and occur as an isolated exposure in the streambed in close proximity to the phlogopite–graphite spinellite. The rock is medium-grained with interlocking texture and is melanocratic. Megascopically visible constituent minerals are randomly oriented with no perceptible deformations in the rock, which is in sharp contrast to the highly deformed nature of the surrounding high-grade metamorphic rocks. The rock appears to be very fresh meagascopically even though phlogopite forms the predominant mineral (Fig. 2). The spinel is almost colorless to pale violet, phlogopite is glittering pale black to dark brown and apatite is light greenish in color in hand specimen. At places, relatively coarse grains of apatite (~ 0.5 cm in