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Re-Os molybdenite ages of granitoid-hosted Mo–Cu occurrences from central Anatolia (Turkey)

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ABSTRACT

The Central Anatolian Crystalline Complex (CACC), where many granitoids are emplaced and related ore occurrences/deposits occur, is tectonically located in the Alpine–Himalayan Belt. The CACC hosts numerous ore occurrences/deposits (Cu, Mo, Fe, Pb and Zn) that are spatially associated with granitoids. The calc-alkaline Karacaali, Baliseyh and Başnayayla granitoids that form the northern granitoid belt of the CACC host important Mo–Cu occurrences. In this paper, we document Re–Os isotopic age data in molybdenites to determine the timing of the granitoid-hosted mineralizations in the CACC.

The Re content of molybdenite in the Başnayayla is significantly higher (108.9–148.5 ppm) than molybdenites from the Karacaali (16.3–74.8 ppm) and Balışeyh (4.2 ppm). Two molybdenite samples from Karacaali and two samples from Başnayayla occurrences give Re–Os ages ranging from 73.8 ± 0.4 to 76.2 ± 0.4 Ma and 77.1 ± 0.4 to 78.0 ± 0.4 Ma, respectively. Furthermore, one molybdenite sample from Balışeyh gives a 73.6 ± 0.4 Ma Re–Os age. These ages are consistent with those of post-collisional granitoids and indicate close relationship between mineralization events and granitic magma differentiation–crystallization processes. The new Re–Os age data obtained from this study show that mineralization events developed earlier (78–77 Ma) in the East (Başnayayla) as compared with the West (76–73 Ma) (Karacaali and Baslışeyh) of central Anatolia. Moreover, one molybdenite sample from Karacaali gives 76.2 Ma, which is very close to the Başnayala ages (78 and 77.1 Ma). According to these data, one possible explanation is that older molybdenite ages in Karacaali and Başnayayla probably represent the mineralization period related to crystallization–differentiation processes. On the other hand, the younger molybdenite age (73.8 Ma) in the Karacaali may represent prolongation of the life of magmatic–hydrothermal processes/cycles and/or the remobilization of molybdenum within the solidified granitic system by the intrusion of the basic magma.

1. Introduction

The Central Anatolian Crystalline Complex (CACC), where many granitoids are emplaced and related ore occurrences/deposits occur, is tectonically located within the Alpine–Himalayan Belt (Boztuğ, 1998; Çemen et al., 1999; İlbeyli et al., 2004; Whitney et al., 2001; Yalınız et al., 2000) (Fig. 1). The CACC consists of metamorphic, ophiolitic, sedimentary and magmatic rocks. The most extensive magmatic rocks are granitoids that were emplaced during the Early to Late Cretaceous (Akıman et al., 1993; Aydın et al., 1998; Boztuğ, 1998; Düzgören-Aydın et al., 2001; İbeyli and Pearce, 2005; İlbeyli et al., 2004; Köksal et al., 2004; Otlu and Boztuğ, 1998; Tatar and Boztuğ, 1998; Yalınız et al., 1999).

Granitoids in CACC are mainly classified as syn- and post-collisional granitoids (Akıman et al., 1993; Aydın et al., 1998; Boztuğ, 1998; Düzgören-Aydın et al., 2001; İbeyli and Pearce, 2005; İlbeyli et al., 2004; Köksal et al., 2004; Otlu and Boztuğ, 1998; Tatar and Boztuğ, 1998; Yalınız et al., 1999). They have two emplacement peaks ranging between 110 and 84 Ma and 82–67 Ma (İlbeyli, 2005), which are identical to the timing of the collision between Pontide magmatic arc and the northern margin of the Touride–Anatolide continental plate and then the post-collisional period following the main collision event (Akıman et al., 1993; Boztuğ, 2000; Boztuğ et al., 2007a,b,cErler and Göncüoğlu, 1996; Göncüoğlu and Türeli, 1993, 1994; Göncüoğlu et al., 1991, 1992; İlbeyli, 2005; Otlu and Boztuğ, 1998; Türeli et al., 1993). As a result of the collision between Pontide magmatic arc and Touride–Anatolide continent, the slab break-off and lithospheric delamination led to extensional post collisional regime and emplacement of the post-collisional granitoids in the CACC (Boztuğ, 2000; Boztuğ et al., 2007a,b,c, 2009; Düzgören-Aydın et al., 2001; Köksal et al., 2001). This collision between Pontide magmatic arc and Touride–Anatolide continent and following post-collisional events resulted in the formation of different types of ore deposits/occurrences related to granitoids in CACC.

Ore deposits/occurrences related to granitoids in CACC can be classified into two groups: (1) Skarn- and (2) Vein-type (quartz–

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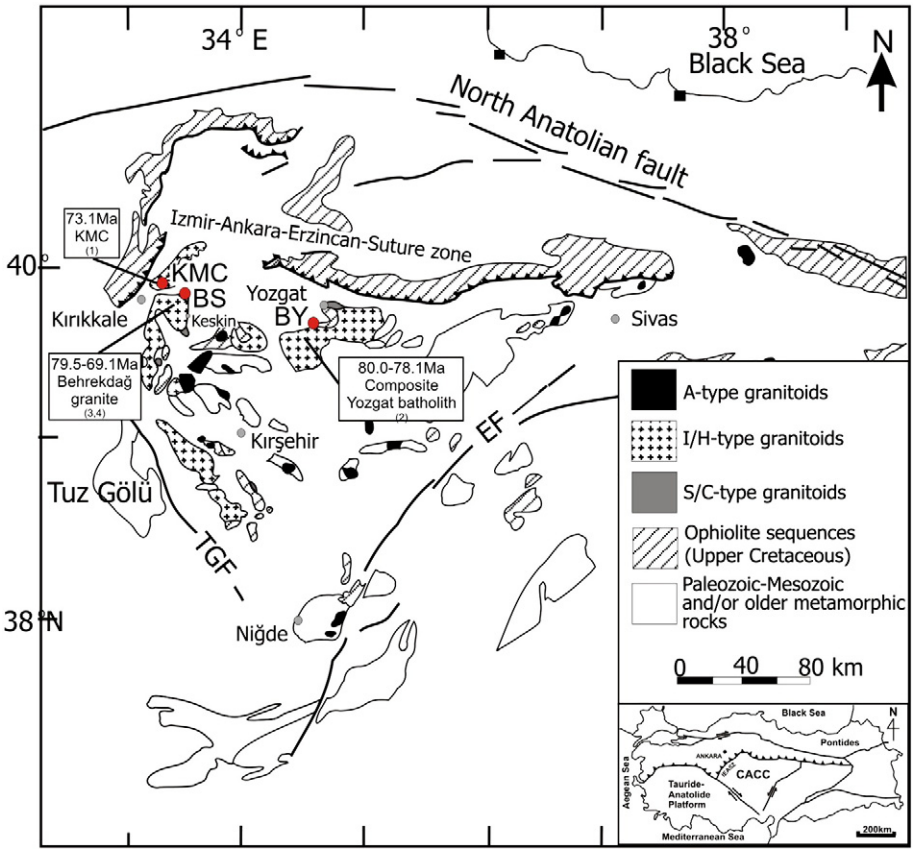

Fig. 1. Simplified regional geological map of Central Anatolia and location map of Karacaali Magmatic Complex, Balışeyh Granitoid and Başnayayla Granitoid in Central Anatolia. CACC, Central Anatolian Crystalline Complex; KMC, Karacaali Magmatic Complex; Balışeyh Granitoid; BS, Başnayayla Granitoid; BY, CAFZ: Central Anatolian Fault Zone. [Modified after Ketin (1961), Bingöl (1989); granitoids classification modified after Boztuğ (1998)] (1:Delibaş et al., 2011; 2: Boztuğ et al., 2009; 3: İlbeyli et al., 2004, 4: Tatar et al., 2003).

molybdenite, quartz–galena and fluorite–quartz veins) (Erler and Bayhan, 1998). These deposits are genetically related to Late Cretaceous post-collisional granitoids. The northern granitoid belt of the CACC hosts several vein-type Mo–Cu occurrences/deposits. The most important granitoid-hosted Mo–Cu deposits/occurrences, from west to east, are Karacaali (KMC), Balışeyh (BS) and Başnayayla (BY) (Delibaş, 2009; Delibaş and Genç, 2004; Karabalık et al., 1998; Kuşçu, 2002; Kuşçu and Genç, 1999; Sözeri, 2003) (Fig. 1; Table 1). The calc-alkaline Karacaali, Balışeyh and Başnayayla granitoids, the subject of the present study, are typical examples of Late Cretaceous post-collisional granitoids in the CACC. Mineral exploration and mining were conducted in Balışeyh between 1936 and 1940 by the General Directorate of Mineral Research and Exploration of Turkey (MTA) and Eti Mine. The estimated total reserves in 1937 were 6600 tons at a grade of 2.2% MoS_2 (MTA, 1965). The Balışeyh mine has been operated by numerous private mining companies after 1937. From this mine, 11,977 tons of ore with 1–1.5% Mo grades were extracted by the Turk Maadin Company in 1984 (Sözeri, 2003) and it was operated at certain times between 1984 and 2010 by numerous companies.

The Başnayayla occurrence in Yozgat was discovered by the MTA in 1993 as part of an exploration program that included geochemical explorations and five diamond-core drill sites. In total, 690 m of drillholes were conducted in the area to determine ore potential and reserves (9375 tons of measured + indicated reserves at 0.02% Mo; Kuşçu and Genç, 1999). On the other hand, the existence of nearly 3750 m^3 of ancient iron-ore slag in the Karacaali (North of Yarımca Hill) shows the ancient mining activities. Furthermore, MTA conducted 1825.20 m of drillholes in total for Fe and Mo–Cu mineralization in the area between 1999 and 2001 (the Cu, Mo, Pb, Zn and Fe-oxide contents are <1.4 wt.%, <0.4 wt.%, <0.1 wt.%, <0.2.wt% and 15–60 wt.%, respectively) (İşbaşarır, et al., 2002; Kuşçu, 2002) (Table 2).

The understanding of the evolution of these occurrences/deposits is critically based on the petrogenesis of the host rock granitoids and the exact timing of mineralization. In recent years, several scientific studies have been conducted, especially on the petrogenesis of the CACC granitoids, including studies on radiogenetic isotopic dating using various techniques (see below). However, the precise timing and genetic relations between the granitoids and ore occurrences/deposits in the CACC have not been clearly constrained up until now.

The present study aims to constrain the timing of the Mo–Cu occurrences/deposits and the relationship between ore formation and magmatic activity in the CACC. For this purpose, we have carried out Re–Os dating studies on molybdenites from the Karacaali (Kırıkkale), Balışeyh (Kırıkkale) and Başnayayla (Yozgat) occurrences. Based on the timing of the mineralizations, we aim to discuss the genetic relationships between the granitoids and Mo–Cu mineralization. This is the first study to present Re–Os age data for Central Anatolian molybdenites.

2. Regional geology

The Central Anatolian Crystalline Complex (CACC) (Göncüoğlu et al., 1991) is an important segment of the Alpine–Himalayan collision system (Boztuğ, 2000; Çemen et al., 1999; İlbeyli et al., 2004; Whitney et al., 2001; Yalınız et al., 2000). The CACC is located in the center of Turkey and bound by three main structural zones: the Izmir–Ankara–Erzincan Suture Zone to the North, the Tuz Gölü Fault to the west and the Ecemiş Fault to the East (Erler and Bayhan, 1995; Göncüoğlu et al., 1991, 1992, 1993; Yalınız et al., 1999; Fig. 1). The complex consists mainly of sedimentary, ophiolitic, magmatic and metamorphic rocks. Magmatic rocks intrude into both the ophiolitic and metamorphic rock sequences of the complex. They consist