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Concordant U–Pb SHRIMP ages of U-rich zircon in granitoids from the Muruntau gold district (Uzbekistan): Timing of intrusion, alteration ages, or meaningless numbers

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ABSTRACT

For decades, the U–Pb isotope system of zircon is routinely used in geosciences for the determination of intrusion ages of felsic magmatic rocks. It is, however, well-known that zircon and the related U–Pb isotope system may be influenced by secondary hydrothermal alteration and new (hydrothermal) zircon growth. As a result, age determination may yield meaningless or alteration ages. An example is given here for intensely altered late Paleozoic granitoid rocks from the Muruntau area, Central Kyzyl Kum, Uzbekistan. Pb–Pb single grain evaporation and U–Pb SHRIMP isotope systematics of zircon from six granitoid rocks yield roughly consistent results defining ages ranging between 288 and 303 Ma. At first glance, these ages may be understood as intrusion ages of the magmatic rocks hosting the zircon. However, there is an apparent contradiction between the sequence of the measured U–Pb SHRIMP ages and the relative age sequences established in the field. Evaluation of data from comprehensive mineralogical and petrological studies reveals that the U–Pb system of magmatic zircon is complicated by inheritance in I-type granitoids, recrystallization, new hydrothermal zircon growth, and subsequent secondary alteration. Widespread albitization of the granitoids led to the formation of new, U-rich, hydrothermal zircon forming overgrowths on older grains or even new whole single crystals. Later alteration events caused direct and (apparent) reverse U–Pb isotope discordances. These late disturbances of the U–Pb system are mainly due to widespread sericitization. Consequently, precise concordant U–Pb zircon SHRIMP ages around 290–294 Ma defined for U-rich, largely undisturbed crystal areas constrain the timing of albitization rather than that of the intrusion. The reliability of the concordant U–Pb SHRIMP ages measured on U-rich zircon is confirmed by a U–Pb SHRIMP age of hydrothermal monazite (292 ± 8 Ma). This monazite associates with extremely U-rich zircon (U–Pb SHRIMP age: 291 ± 3 Ma) in a sample of the Murun granite recovered beneath the giant Muruntau gold deposit by super-deep drilling. Obviously, detailed mineralogical studies are important for a correct interpretation of zircon ages when hydrothermal alteration and late re-mobilization of zirconium and uranium were significant as often observed in areas with intense ore mineralization. The extensive Au mineralization found at Muruntau is similar in age to albitization but apparently somewhat younger. Likewise, the intrusion age of Permian granites is at least somewhat older than the hydrothermal zircon ages confirmed by U–Pb ages of monazite. It is, however, difficult to constrain further granite intrusion ages based on presently available data.

1. Introduction

The U–Pb system of zircon is routinely used for geochronology of acid magmatic rocks (e.g., Hanchar and Hoskin, 2003 and references therein; Harley et al., 2007; Nemchin et al., 2013). However, the situation appears ambiguous when hydrothermal formation or re-equilibration of zircon cannot be excluded a priori (Fu et al., 2009; Kusiak et al., 2009; Lisowiec et al., 2013). Such processes may further complicate the U–Pb system of single crystals in addition to the common occurrence of old cores overgrown by younger magmatic rims. Grant et al. (2009) described a case, where three discrete events (two magmatic and one hydrothermal-metamorphic) could be dated by SHRIMP in single zircon grains from metamorphosed trondhjemite and tonalite.

Problems arising in the definition of reliable zircon intrusion ages are further illustrated here by an example of late Paleozoic (Hercynian)

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zircon from granitoids in the Muruntau area, Uzbekistan displaying a complex formation and alteration history. Pb–Pb single-grain evaporation technique and U–Pb SHRIMP analysis were used to constrain the genetic relationships between late Paleozoic magmatism and extensive gold mineralization in the Muruntau area, Uzbekistan. The latter point is a matter of considerable debates concerning the genesis of the Muruntau deposit (Kempe et al., 2004b; Morelli et al., 2007; Wall et al., 2004). Based on the results of extensive petrological and mineralogical studies, we demonstrate that the undisturbed, concordant U–Pb SHRIMP zircon ages of U-rich zircon from the altered granitoids are meaningful and reflect albitization ages rather than that of the intrusion. This conclusion is confirmed by a SHRIMP U–Pb monazite age for one sample with associated hydrothermal monazite. Interpretation of U–Pb zircon ages from these granitoids is complicated by effects of inheritance, formation of overgrowths, subsequent hydrothermal alteration, and generally high U contents. It is demonstrated that Pb–Pb and U–Pb zircon ages should be interpreted with caution when widespread hydrothermal alteration is present. In particular, this applies to areas where significant uranium and/or zirconium remobilization is obvious.

2. Geological setting and sampling

The Tian Shan orogenic belt formed during late Paleozoic collision between the Kazakhstan continent to the north and the Karakum-Tarim continent to the south. The Muruntau area under study is located in the western part of the Bukantau-Kokshaal domain of the Southern Tian Shan collisional system which comprises complex fault and thrust structures (Biske and Seltmann, 2010). This gold-rich region formed just south of a suture zone between the Karakorum and the Kazakhstan-North Tian Shan masses (Drew et al., 1996). In the area, rocks of the Paleozoic Taskazgan and Besapan suites, which were metamorphosed in lower amphibolite to lower greenschist facies, are strongly deformed and overthrust by Devonian and Carboniferous marbles from the north (Drew et al., 1996; Kempe et al., 2001). The Paleozoic metamorphic rocks host late Paleozoic granites and hydrothermal gold deposits. The former are exposed within several tectonic windows (e.g., Drew et al., 1996; Kempe et al., 2001; Kraft and Kampe, 1994; see Figs. 1 and 2). Outcrops of late Paleozoic granitoids in the Muruntau area are few in number. However, it is assumed based on geophysical data that acidic magmatic rocks form a significant part of the crust in this region (Shayakubov and Dalimov, 1998). Some concealed granite bodies were revealed by drilling, in particular by the super-deep drill hole SG 10 about 1 km southeast of Muruntau ("Murun granite"; Fig. 2) and by exploration bore holes penetrating the Meso-Cenozoic platform cover about 15–25 km southeast and south-southeast from Muruntau ("Sardarin pluton" and "Kurukkuduk granite").

The Muruntau area hosts numerous important gold deposits including the giant deposit of Muruntau (Fig. 1). Recently, there have been numerous publications that have contributed to the understanding of the genesis of the world-class Muruntau gold deposit (Central Kyzyl Kum, Uzbekistan). However, there is an ongoing debate on this matter (e.g., Berger et al., 1994; Bierlein and Wilde, 2010; Graupner et al., 2001; Graupner et al., 2006; Kempe et al., 2001; Morelli et al., 2007; Wilde et al., 2001). Field work and petrographic studies provide evidence for widespread hydrothermal activity in this region that resulted in the formation of Au and W ore deposits during late Paleozoic times.

However, the possible role of granite magmatism in the formation of late Paleozoic ore deposits has not been explored adequately although several authors have proposed that the formation of gold deposits in the region is closely related to magmatic activity (Konstantinov et al., 2000; Kotov and Poritskaya, 1991; Palej and Sher, 1970; Rakhmatullaev, 1980; Shayakubov and Dalimov, 1998; Sher, 1970; Wall et al., 2004; Yudalevich and Levchenko, 1981). Reconstructions of the late Paleozoic magmatism can significantly improve our understanding of the tectonic conditions and processes leading to the formation of this important ore deposit and other adjacent gold occurrences (Kempe et al., 2004b).

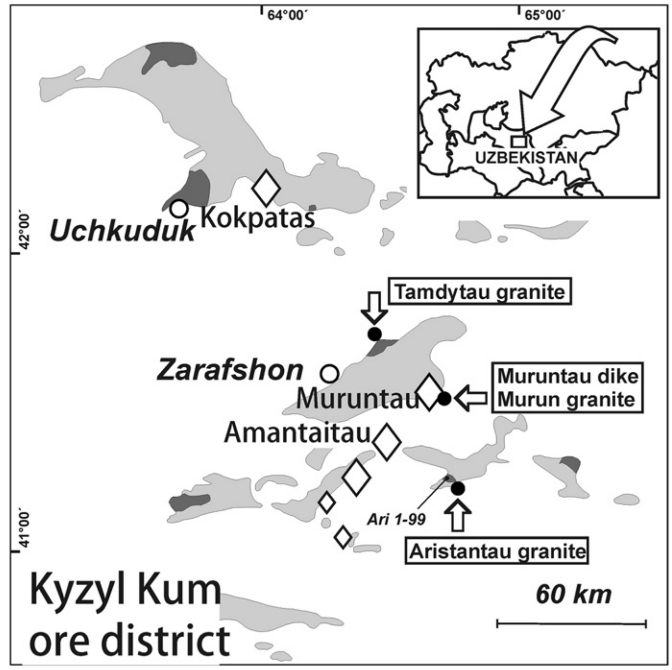

Fig. 1. Paleozoic tectonic windows (gray) with outcrops of Hercynian granitoids (dark gray) in the vicinity of the Muruntau Au deposit in the Central Kyzyl Kum desert, Uzbekistan. Locations of sampling areas are shown by arrows. Important Au deposits are marked by diamonds, important settlements by circles. Locations of hidden plutons are omitted for clarity (Sardarin pluton, 15 km to the southeast from Muruntau and Kurukkuduk granite, 30 km to the south southeast, not studied here).

The composition of the suite of late Paleozoic intrusive igneous rocks at Muruntau varies over a wide range from diorite to leucogranite (Shayakubov and Dalimov, 1998). Contacts of the granitoids with the host rocks are always intrusive. Thermal aureoles can be traced over widths of several hundreds of meters. However, some of the stocks and dikes are deformed, especially along their contacts with the host rocks (Shayakubov and Dalimov, 1998) indicating that intrusion took place during a late orogenic event. None of such obviously deformed rocks were included in the present study.

Of the twenty samples collected for this study, six were selected for further zircon isotope age determination (cf. Figs. 1 and 2): (1) one medium-grained, melanocratic quartz monzonite from the Aristantau pluton located about 50 km south of Muruntau (Ari 1-99; has been affected by sericitization); (2) three samples representing three varieties of granite from the Tamdytau pluton 30 km northwest of Muruntau, which are also variably affected by albitization and sericitization (MT 45, 44, and 43): (a) a seriate coarse- to medium-grained melanocratic granite (MT 45); (b) a seriate porphyritic medium-grained mesocratic granite (MT 44); and (c) a medium-grained leucocratic granite (MT 43). According to field relations, the latter two granites are geologically younger than the former one; (3) one weakly porphyritic, fine-grained sample from a dike in the Muruntau ore field (MT 168; strongly altered by various overprinting hydrothermal processes); and (4) one fine-grained, leucocratic sample (super-deep drill hole SG 10 at a depth of 4077 m; strongly albitized) from the Murun granite (MT 42318). The latter sample was also used for U–Pb SHRIMP age determination of hydrothermal monazite associated with zircon.

3. Methods

Polished thin sections of rock samples were studied by means of optical (OM) and scanning electron (SEM) microscopy. For SEM investigation, a Jeol JSM 6400 equipped with backscattered electron (BSE),