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Results of pilot Re–Os dating of sulfides from the Sukhoi Log and Olympiada orogenic gold deposits, Russia

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ABSTRACT

The pilot study with Re–Os dating of sulfides from Sukhoi Log and Olympiada gold deposits revealed early Paleozoic ages of the auriferous sulfides from the two largest orogenic gold systems in the Neoproterozoic orogens of the Baikalides framing the Siberian craton. The age-dating results indicate that gold mineralization is therefore epigenetic. The formation of the dated orogenic gold deposits is synchronous with some regional metamorphic events in the Baikalides, at least in case of the Sukhoi Log deposit. The metamorphic events occurred in the rear parts of the early Paleozoic magmatic arcs, where coeval subduction-related magmatism produced porphyry copper–(molybdenum) mineralization.

1. Introduction

Sukhoi Log and Olympiada are the two largest orogenic gold deposits in Eurasia and some of the largest in the world, with resources of 96 Moz Au (Migachev et al., 2008) and 60 Moz Au (Wardell Armstrong, 2011), respectively. Both deposits occur within the Neoproterozoic orogens at the southern and western periphery of the Siberian craton (Fig. 1; Yakubchuk et al., 2005).

The opinion on age of gold mineralization at Sukhoi Log is currently ranging from Neoproterozoic (Buryak, 1982; Buryak and Khmelevskaya, 1997) to middle Paleozoic (Goldfarb et al., 2001; Laverov et al., 2000). Rundqvist et al. (1992) and Laverov et al. (2000) showed that the main metamorphism is early Paleozoic (516 ± 22 Ma), whereas their Rb–Sr dating of quartz from Sukhoi Log gave a middle Paleozoic (320 ± 16 Ma) age. Dating of granitoids (Rundqvist et al., 1992) and alteration (Goldfarb et al., 2001) revealed an age for both of 370–350 Ma. These ages are similar to the age of the large Barguzin batholiths, occupying most of Transbaikalia (Kuz'min et al., 2006).

At the Olympiada deposit in the Yenisei Ridge, previous attempts to date the mineralization employed K–Ar and Rb–Sr techniques. Novozhilov and Gavrilov (1999) dated muscovite from quartz-vein selvages of the earliest (pre-ore) alteration as 890 to 842 Ma (K–Ar ages). However, the sericite–quartz–carbonate altered rocks yielded ages of 794 ± 15 Ma (Rb–Sr) for early hydrothermal alteration, and 615 ± 15 Ma for late stage events (Novozhilov and Gavrilov, 1999). Serdyuk (2002) reported 754, 765, 811 Ma ages based on K–Ar data. The results of dating using the K–Ar and Rb–Sr methods appear to be controversial. These dates are complemented by similar Neoproterozoic estimates for some smaller Sb–Au deposits nearby (Distanov et al., 1975; Novozhilov and Gavrilov, 1999), generally believed to be 847 to 605 Ma old (Sazonov et al., 2010). The age of >3 Moz Sovetskoye orogenic gold deposit, another large deposit in the Yenisei Ridge, is constrained based on ^{40}Ar–^{39}Ar data on 900–850 Ma metamorphic slate micas and 830–820 Ma to 730–720 Ma for ore-related metasomatism (Tomilenko et al., 2008).

These uncertainties are a critical problem when attempting to establish a genetic model for the deposits and, specifically, in determining how mineralization relates to regional tectono-magmatic evolution. In order to resolve some of the uncertainties of the previous geochronological work, we collected samples from Sukhoi Log and Olympiada gold deposits to assess whether the Re–Os technique could provide a more robust estimate of age of mineralization (e.g., Stein et al., 2000). Sulfides are principal hosts of gold and are considered to be coeval with gold at Sukhoi Log (Buryak, 1982) and Olympiada (Genkin et al., 1994). This provides an opportunity of direct dating the mineral event. However, several generations of sulfides have been reported for both deposits (Buryak, 1982; Distler et al., 2004; Genkin et al., 1994; Large et al., 2007; Novozhilov and Gavrilov, 1999), suggesting a potentially complex isotopic history.

2. Geological setting

2.1. Sukhoi Log deposit

The Sukhoi Log deposit is hosted within the more than 15,000-m-thick deformed and metamorphosed Meso- to Neoproterozoic passive

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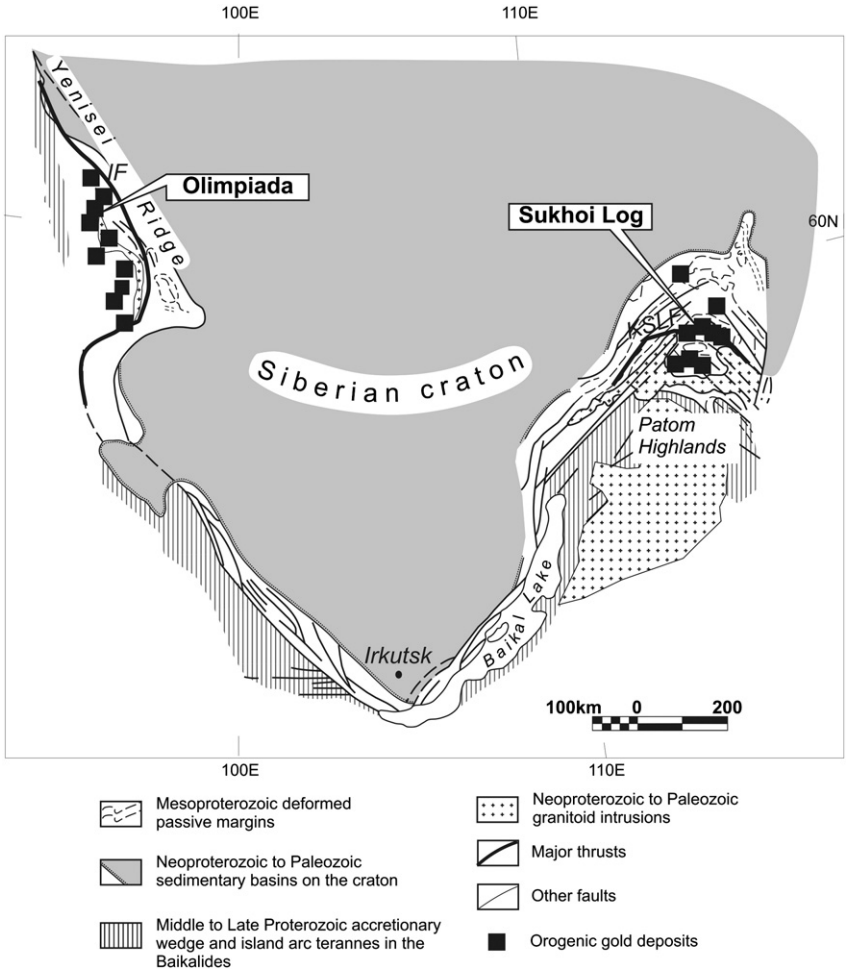

Fig. 1. Position of the Sukhoi Log and Olympiada orogenic gold deposits in the Neoproterozoic orogens of the Patom Highlands and Yenisei Ridge relative to the Siberian craton (modified after Yakubchuk et al., 2005). IF—Ishimba fault, KSLF—Kadali–Sukhoi Log fault.

margin rock sequences in the Patom Highlands (Buryak, 1982; Buryak and Khmelevskaya, 1997; Distler et al., 2004). Lithologically, gold mineralization of Sukhoi Log occurs within carbonaceous shales (Khomolkho Formation), part of the 1500-m-thick carbonate–shale sequence of the Nigry Group (Distler et al., 2004), forming most of the Chuya–Tonoda anticlinorium whose core occurs several dozen kilometers to the north of the deposit towards the Siberian craton. In the core of the anticlinorium is the exposed Paleoproterozoic basement (Buryak and Khmelevskaya, 1997).

The Nigry Group package is overturned to the south and thrust along the Kadali–Sukhoi Log fault onto the 2500-m-thick predominantly clastic-shale sequence of the Bodaibo Group, part of the Mama–Bodaibo synclinorium (Fig. 2A), suggesting that the Kadali–Sukhoi Log fault zone can be viewed as a major structural divide in the Patom Highlands. The fault zone also seems to control position of the middle Paleozoic granitoids of the Konkuder–Mamakan Complex that intruded the already deformed package (Rundqvist et al., 1992). Near Sukhoi Log, it is represented by the Konstantinovskiy stock, exposed just 6 km southwest of the deposit (Fig. 2B). On the basis of the geophysical data, it is interpreted as an exposed part of the larger and deeper intrusion (Distler et al., 2004).

At the deposit level, the shales of the Khomolkho Formation, sandwiched between otherwise marble–carbonate formations of the Nigry Group, form a parasitic anticlinal fold on the southern limb of the Chuya–Tonoda anticlinorium. Locally, gold mineralization outcrops as the discrete Zapadnoye and Sukhoi Log orebodies (Fig. 2C), which however merge at depth. Within the anticlinal fold, gold distribution is controlled by an axial cleavage (Fig. 2C, D).

Owing to the complex geological history, Buryak (1982) proposed that the Sukhoi Log deposit has a metamorphogenic origin, with remobilization of auriferous fluids from syngenetic sulfides and their entrapment into the anticlines. Buryak (1982) and Buryak and Khmelevskaya (1997) recognized the earliest sulfides at Sukhoi Log as syngenetic. Syngenetic sulfides were partly to completely recrystallized in the ore zones, often with fibrous-columnar quartz pressure-fringes during metamorphism. The post-metamorphic mineralization in the form of quartz and quartz–calcite veinlets was proposed to link genetically with the Konstantinovskiy stock, as part of a third introduction (or remobilization) of gold into steeper-dipping Au–quartz veins and additional recrystallization of cleavage-controlled disseminated sulfide minerals.

Buryak's three main sulfide events were confirmed by Large et al. (2007), who, however, identified six sulfide phases, further subdividing the three phases of Buryak (1982).

2.2. Olympiada deposit

The Olympiada gold deposit also occurs within the Neoproterozoic (Late Riphean) quartz–mica carbonaceous schists, but in the Yenisei Ridge on the western flank of the Siberian craton (Fig. 3A). In its west is the Isakov island arc terrane (700–630 Ma), which is tectonically transposed eastward along the Yenisei thrust fault onto the Central Angara terrane (Vernikovsky et al., 2003). The latter consists of the Ribnaya–Panimba ophiolite belt in the east, with 1050–900 Ma Ar–Ar ages of amphibole and plagioclase from gabbro–amphibolite. This is inferred to reflect the time of their accretion to the Siberian craton