1 Geological Background

The Late Mesozoic Mo–Cu porphyry Zhireken deposit is located within the eastern segment of the Central Asian Orogenic Belt, bordering the northern margin of the Mongol-Okhotsk suture zone (Fig. 1). The Zhireken deposit was formed in the intraplate setting resulted from the closure of the Mongolo-Okhotsk ocean and collision between the Siberian and Mongolia-North China continents. Collision of the Siberian and Mongolia-North China plates and the complete closure of Mongol-Okhotsk Ocean in its western part (in the territory of present Transbaikalia) happened at the Lower-Middle Jurassic boundary (Zorin et al., 1997).

The deposit includes rocks of two magmatic complexes: the precursor plutonic Amanan and the ore-bearing Porphyry complexes. SHRIMP U–Pb zircon dating yielded ages of 162.6±1.4 Ma for the Amanan granites, while the Porphyry complex showed ages of 159.0±1.6 and 157.5±2.0 for the fine-grained leucogranites and monzonite porphyries, respectively. Mineralization is temporally and spatially associated with granitic porphyry stocks (Porphyry complex), which intruded J2 granitoids of the Amanan complex.

The Amanan and Porphyry complexes at Zhireken are represented by a series of high-K calc-alkaline rocks similar in composition. The Amanan complex is dominated by coarse-grained biotite granites and fine-grained leucogranites, with rare gabbro. The subvolcanic Porphyry complex is mainly consists of granite porphyries with subordinate monzonite- and quartz monzonite porphyries. Mafic rocks are rare and occur mainly as remnants among granitoid rocks. Both Amanan and Porphyry complexes include adakite-like rocks with geochemical characteristics of K-adakites associated with high-K calc-alkaline granitoids with typical arc-type characteristics.

Recent studies on geology and geotectonics of Eastern Transbaikalia (Yarmolyuk et al., 2000; Zorin et al., 2001) together with geochronological data (Ponomarchuk et al., 2004; this study) are consistent with the emplacement of the Amanan complex at the final stages of the collisional regime in the region; the formation of the Porphyry complex may have overlapped with a transition to extension. In general, the Zhireken deposit is similar in many respects to porphyry Cu–Mo deposits from the Tibet–Himalayas and North-Chinese craton–Yangtze collisional zones.

2 Discussion

Major, trace and REE element data indicate that the rocks of both complexes share much in common. In general, they are characterized by high contents of LREE, lowered medium REE (MREE) and low HREE.

High Sr, low Y and HREE contents and high Sr/Y, (La/Yb)N and (Tb/Yb)N=1.9-2.06 ratios in mafic Zhireken rocks imply that basaltic magma was derived from a source at pressures high enough to stabilize garnet. The
primitive mantle-normalized trace element patterns for gabbro samples are characterized by enrichment in LREE and depletion in HREE, and show positive Pb, Sr and negative Nb, Ta, P anomalies, suggesting the involvement of a subduction component in the process of magma generation. Considering that these magmas were not associated spatially and temporally with subduction, it is likely that arc geochemical signature resulted from mantle metasomatism related to an earlier subduction of the Mongol-Okhotsk Ocean plate beneath the Siberian continent.

Relatively low $\varepsilon_{\text{Nd}}(\text{T})$ values (-1.4 and -1.8) and $(^{87}\text{Sr}/^{86}\text{Sr})_0 = 0.70501$ in gabbroic rocks from the Amanan complex probably imply the involvement of old continental crust in the source. Fig. 2a shows an isotope correlation diagram ($\varepsilon_{\text{Nd}}$ vs. initial $^{87}\text{Sr}/^{86}\text{Sr}$) for the studied rocks. Data for gabbro from the Amanan complex fall close to the mantle array between the metasomatized mantle end-member and lower crust. Interaction between basaltic magma and crustal material probably took place at the mantle level as a result of magma injection into the crust or lithosphere delamination during collision.

The gabbroic samples from the Amanan complex show relatively high MgO=4.87-9.26 wt.%, Ni, Cr, V and Sc contents (up to 101, 216, 360 and 52 ppm, respectively). They are mainly metaluminous (A/CNK=0.64–0.75) and exhibit high-K calc-alkaline features. Geochemical and isotopic characteristics of gabbroic samples suggest that they were probably originated from differentiated basaltic melt.

Both mafic and granitoid rocks from the Zhireken inherited petrogeochemical characteristics of the preceding subduction magmatism; their primitive mantle-normalized trace element patterns are similar. The Zhireken granitoid samples from the Porphyry complex show $\varepsilon_{\text{Nd}}(\text{T})$ values close to CHUR, Sr and Pb isotopic compositions close to mantle values (Fig. 2a, b), suggesting the involvement of mantle component in felsic magmas. However, limited occurrence of mafic rocks and relatively low Ni, Cr, MgO contents and Mg# values in felsic samples imply that granitoid rocks of both complexes could not be generated from a parental basaltic magma. Therefore, it is reasonable to suggest the involvement of juvenile crust, formed by underplating of mantle-derived basaltic magmas generated in subduction settings in Late Paleozoic-Early Mesozoic. Relatively elevated initial $^{87}\text{Sr}/^{86}\text{Sr}$ values for the Zhireken granitoid rocks reflect a crustal component in magma generation. Additionally, Nd model ages ($T_{\text{DM}-1st}$) for felsic Zhireken rocks ranging from ~0.8 to 1.5 Ga suggest significant involvement of Precambrian continental crust in their source. These data, as well as variations in Pb isotopic composition point to mixing between juvenile crust and old crust partial melts during granitoid magma generation.

Taking into account widespread occurrence of adakitic rocks at Zhireken, their K$_2$O/Na$_2$O $\approx$ 1, it is suggested that K-adakitic melts were probably generated at depth of at least 55 km (Xiao and Clemens 2007). Relatively low contents of compatible elements and MgO imply that K-adakite magma can not have interacted significantly with mantle rocks. They were likely derived from the base of the crust thickened by collision or from delaminated adakite protolith located near the base of the crust. Zhireken magmas, lacking adakite-like signatures were probably generated at shallower levels of lower crust.

The granitoid rock samples from the Amanan and Porphyry complexes show some differences in the Nd isotopic composition. The Amanan granites are characterized by low $\varepsilon_{\text{Nd}}(\text{T})$=-10.3; in granitoid rocks from the Porphyry complex it ranges from -3.7 to +1.0. Nd model age ($T_{\text{DM}-1st}$) show 1.5 Ga in granites from the Amanan complex and 0.8 – 1.1 Ga in granitoid rocks from
the Porphyry complex. The higher $\varepsilon_{Nd}(T)$ values and lower $T_{DM-1st}$ ages of the porphyry rocks relative to the plutonic series imply stronger contribution of juvenile mantle-derived material to the fertile magmas of the Porphyry complex.

3 Conclusion

Ore-bearing porphyry samples show zircon U–Pb ages of 159.0±1.6 and 157.5±2.0 Ma. A slightly older age of 162.6±1.4 Ma was obtained for the precursor granites from the Amanan complex. Geological and geochronological data are consistent with the emplacement of the Amanan complex at the final stages of the collisional regime in the region; the formation of the Porphyry complex may have overlapped with a transition to extension. The regional geological, geochemical and Sr-Nd-Pb isotopic data indicate that mixed sources consisting of old Precambrian continental crust and mafic juvenile crust contributed to the origin of the Zhireken rocks. Variations in $\varepsilon_{Nd}(T)$ are probably caused by incorporation of Precambrian crustal components in variable proportions in the magma source. Isotopic data imply stronger contribution of juvenile mantle-derived material to the fertile magmas of the Porphyry complex. Relatively low contents of compatible elements and MgO imply that K-adakitic magmas were most likely derived from the base of the crust thickened by collision or from delaminated adakite protolith located near the base of the crust.

References