ALTERATION CONTROLS ON LOCALIZATION OF PORPHYRY COPPER-GOLD MINERALIZATION IN THE YUBILEINOE DEPOSIT AREA, THE SOUTH URALS

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Summary

Based on results of combined petrographical and geochemical mapping of hydrothermally altered rocks of the Yubileinoe Cu-Au deposit area, the sequence of hydrothermal activity events have been reconstructed. Such an approach made it possible to determine the geochemistry of alteration zones related both to the mineralized granite porphyry stock and to pre-granitic volcanic and sedimentary units. The results can be used to evaluate the ore potential for alteration haloes associated with hidden granite porphyry stocks within the study area.

Introduction

The Yubileinoe deposit is situated in western Kazakhstan (Fig. 1), 200 km southeast from the city of Aqtobe, and lies in the Magnitogorsk-Mugodjar zone of the Urals (Zaykov *et al.*, 1996; Koroteev *et al.*, 1997). The Yubileinoe deposit is one of the largest porphyry gold deposits in the Urals. It has gold resource estimated at 45 t, with grades ranging from 6 to 10 g/t (Krivtsov, 1993). Copper grades vary from 0.5% in the upper parts of the deposit to 1.0% in the lower part. The ores also contain Mo and Ag with grades of economic interest. The deposit is associated with the plagiogranite porphyry stock, assumed to be related to a local cupola of the large hidden gabbrodiorite/granodiorite intrusion that presumably belongs to the Late Devonian–Early Carboniferous Airyuk Intrusive Complex (Rudenko and Gilmanov, 1980; Redkozub, 1991). The intrusion is exposed only in the northern part of the study area as a stock of 7.5 km^2 in size, whereas most of the intrusion is hidden and inferred from geophysical data to occur at the depth of more than 300–500 m (Fig. 2). It was emplaced into Silurian – Devonian volcanics and sediments that stratigraphically belong to the Mugodjar Group (mafic volcanics of tholeiitic affinity) which are overlain by island arc volcanics and sediments of the Mialyshy, Qundyzdy and Janghany Formations.

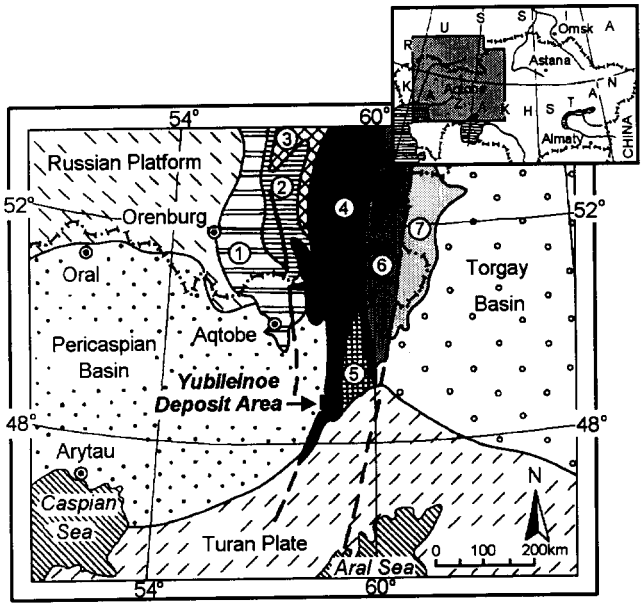

Fig. 1. Location map of the Yubileinoe deposit area.
Tectonic zones of the Southern Uralides (numbers in circles): (1) Pre-Uralian foredeep, (2) West-Uralian zone, (3) Central-Uralian zone, (4) Magnitogorsk-Mugodjar zone, (5) Central Mugodjar zone, (6) East-Uralian zone, (7) Trans-Uralian zone.

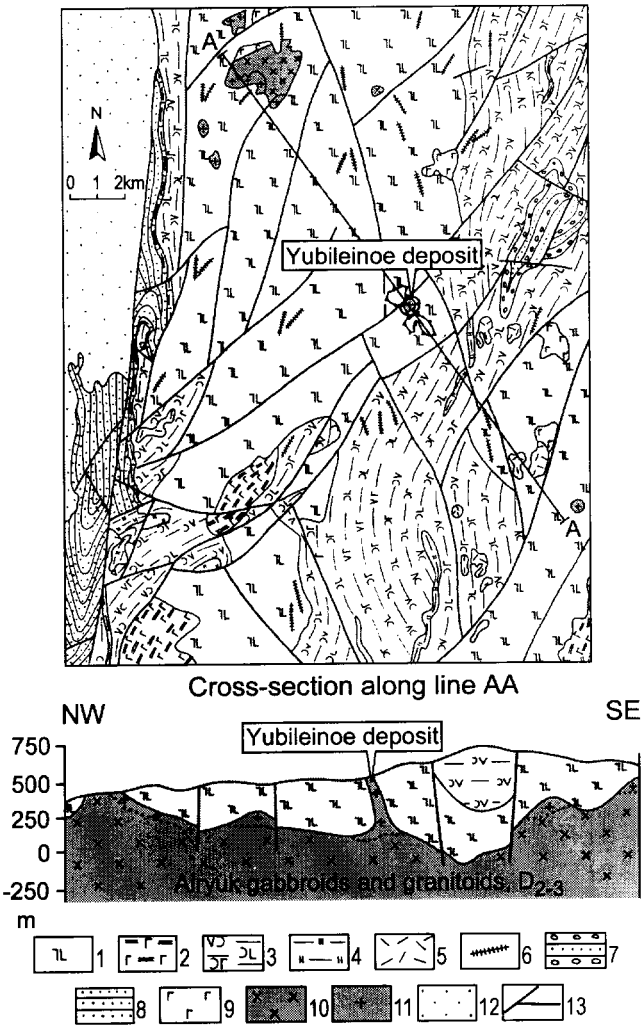

Fig. 2. Geology of the Yubileinoe deposit area (modified after Redkozub, 1991).
(1) *Mugodjar Group, S_2–D_1:* diabase, basalt, andesite; *Mialyshy Formation, D_2:* (2) basalt, (3) andesite, (4) chert, cherty siltstone, (5) dacite and rhyolite; (6) diabase dyke; (7) *Qundyzdy Formation, D_{2-3}:* conglomerate, graywacke and siltstone; (8) *Janghany Formation, D_3:* terrigenous flyschoid sequence; *Airyuk Intrusive Complex, D_3–C_1:* (9) gabbrodiorite, (10) diorite, granodiorite, (11) plagiogranite porphyry; (12) Mz–Cz sedimentary rocks; (13) fault.

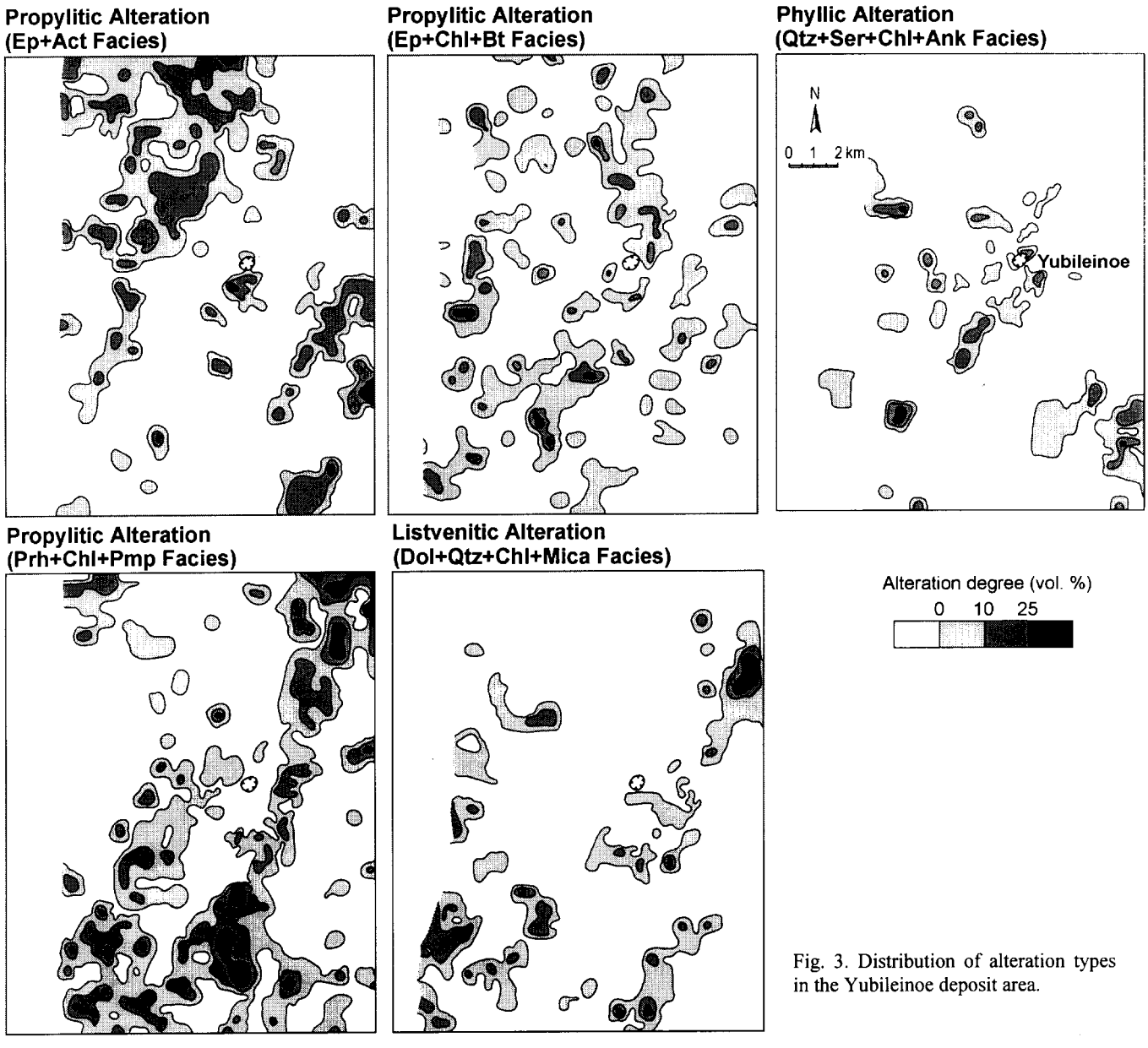

Fig. 3. Distribution of alteration types in the Yubileinoe deposit area.

The Cu-Au porphyry mineralization of the Yubileinoe deposit is associated with a plagiogranite porphyry stock, approximately 250–300 m in diameter. Ore mineralization, being of stockwork type in both granite porphyry and country mafic volcanics, is traced to a depth of more than 600 m from exploration drilling, with unknown deeper extension. The mineralization is accompanied by skarn, potassic and phyllic wallrock alteration formed during the emplacement and subsequent evolution of the Yubileinoe plagiogranite porphyry stock.

In this study, we discuss new data on the geochemistry and petrography of hydrothermally altered rocks from this area.

Sampling and analytical method

The combined petrographic and geochemical study of hydrothermal alteration was carried out during detailed field work at the beginning of the 90's. Surface and core samples were collected on an approximate 500 m grid over a 10×10 km area surrounding the deposit, the sample mass ranging from 200 to 500 g. In areas of intense hydrothermal alteration, the grid size was reduced to 250×250 m or even 100×100 m. All 1083 samples were analyzed by emission photospectrometry for trace elements and for Au. Analyses were normalized by Clarke values and by lithology using petrographic and lithologic data from the PC data set (Shatov and Moon, 1997). Thin sections were examined in order to obtain quantitative petrographic information on the main alteration types from the study area using point counting and chord methods. GIS based analysis of the data set utilized the PGD software package (Makedon *et al.*, 1993) to extract lithological information and the size both of alteration and geochemical haloes around the deposit. Plots showing the distribution of main alteration types and Au, Cu and Cr content are shown in Figs. 3 and 4.

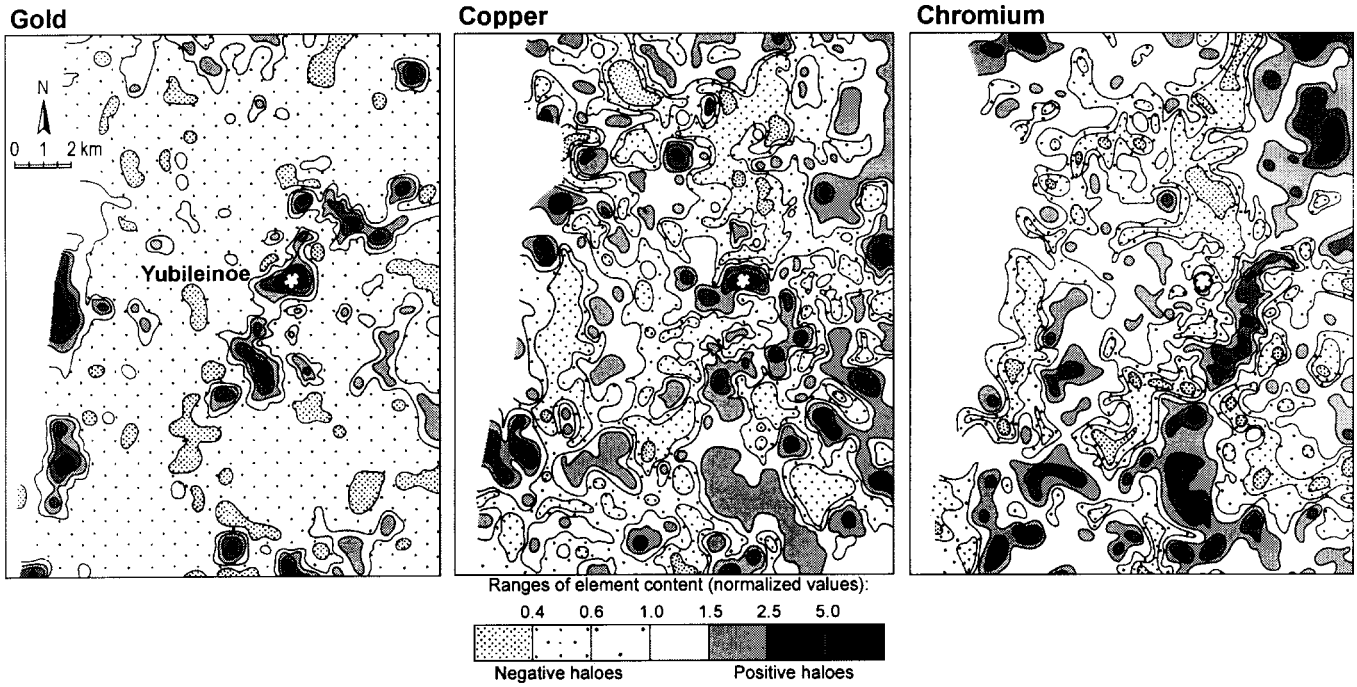

Fig. 4. Distribution of gold, copper and chromium positive and negative haloes in the Yubileinoe deposit area.

Sequence of alteration types

All lithological units of the study area underwent hydrothermal alteration of variable types and age that can be subdivided for the following two alteration systems:

(1) Pre-granitic volcanic-associated system represented by sodic (ab+qtz+chl), propylitic (prh+chl+pmp) and listvenitic (dol+ +qtz+chl+mica) alteration styles that are widespread to the west, southwest and northeast of the deposit (Fig. 3). These alteration types are of regional extent and closely associated with the Middle Devonian mafic, intermediate and felsic volcanics of the Mialyshy Formation that unconformably overlies tholeiitic basalt of the Mugodjar Group. The hydrothermally altered volcanic and sedimentary rocks of the Mialyshy Formation embody VMS Au-Cu mineralization of the Jenishke occurrence situated 16 km to the northeast of the Yubileinoe deposit.

(2) Granite-related system, comprising potassic (qtz+kfs+bt), skarn (grt+cpx+ep), ep+act and ep+chl+bt propylitic and phyllic (qtz+ser+ank+chl) alteration assemblages that occur mainly in the middle, north and southeast parts of the study area, where they form two large and zoned alteration haloes 92 and 47 km^2 in size, respectively (Fig. 3). Among alteration types of this system, propylitic and phyllic varieties prevail. Mostly affecting country volcanic and sedimentary units of Silurian and Devonian age, they are superimposed on earlier volcanic-associated sodic, propylitic and listvenitic alteration assemblages that makes the latter rather strongly masked. Phyllic alteration is much less widespread than propylitic and forms small occurrences within the propylitic alteration zone. Within the Yubileinoe deposit, the phyllic alteration is the main wallrock alteration style that controls the localization of disseminated Cu-Au porphyry mineralization.

Geochemistry

The distribution of Au, Cu and Cr in hydrothermally altered rocks of the Yubileinoe deposit area is demonstrated in Fig. 4.

The mass balance calculation undertaken for the above-described alteration types made it possible to assess quantitatively redistribution of large group of trace elements such as Au, Ag, Cu, Zn, Cr, Ni, V, Mn, As, Sb, W, Bi and Mo during the evolution of both pre-granitic volcanic-associated and granite-related alteration systems.

The pre-granitic alteration system is characterized by strong redistribution of Cr, Ni, V, Mn and Zn, and to a lesser extent of Au, Cu and Ag. The high depletion is typical for Cr, Ni, V, Mn and Cu in sodic altered mafic volcanics, whereas in prh+chl+pmp propylitic and listvenitic alteration zones these elements are highly enriched forming a positive geochemical halo. Compared to these elements, Au and Zn are weakly removed both from sodic and from propylitic alteration zones, whereas their slight enrichment is characteristic of listvenitic altered volcanics and sediments of the Mialyshy Formation in the northeast part of the deposit area.

In contrast with the above-described alteration system, the granite-related one is notable for strong redistribution mostly of Au, Ag, Cu, Bi, As, W, and Mo, and to a lesser extent of siderophile elements. The highest enrichment in Au, Ag, Cu, Mo and Bi is distinguished for phyllic and skarn altered rocks within the mineralized zone of the Yubileinoe deposit and its vicinity. Depletion of the above-mentioned elements in propylitically (ep+chl+bt facies) altered mafic volcanics and sediments is typical, as well as in albitized granodiorites and diorites of the Airyuk intrusion.

Conclusions

The combined petrographical and geochemical study of hydrothermal alteration undertaken for the Yubileinoe deposit area made it possible to reconstruct the sequence of hydrothermal events and determine the geochemistry of alteration zones related both to pre-granitic volcanic and sedimentary units and to the

mineralized granite porphyry stock.

The latter is a local cupola of the large diorite/granodiorite intrusion that seems to belong to the Airyuk Intrusive Complex of Late Devonian–Early Carboniferous age. Most of the intrusion is non-exposed and is inferred both from geophysical data and the

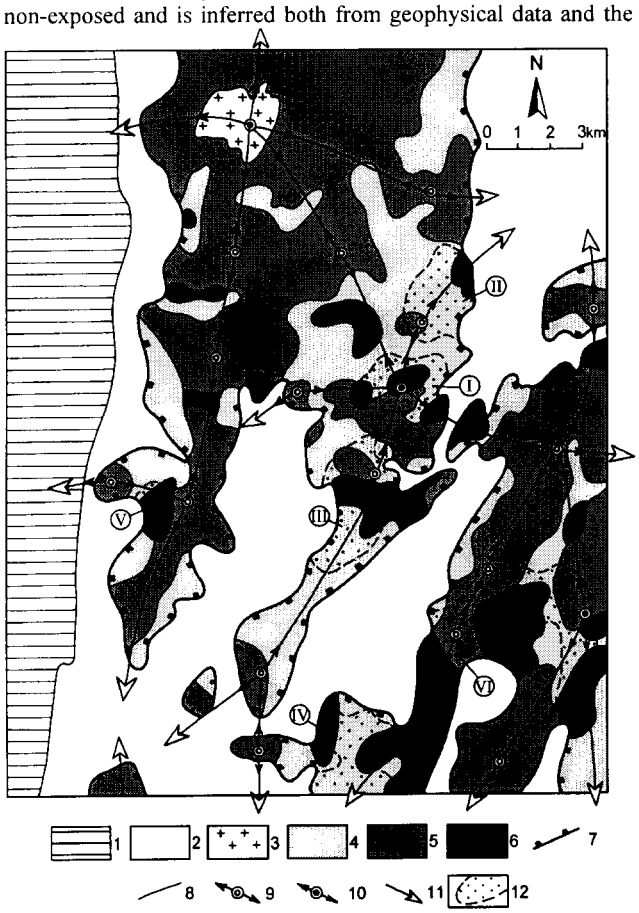

Fig. 2. Distribution of alteration types in the Yubileinoe deposit area

Fig. 5. Interpretative alteration zoning map showing the distribution of mineral prospecting areas of the Yubileinoe deposit type. (1) Pericaspian Basin cover; (2) pre-granitic volcanic-associated alteration system; *Yubileinoe granite-related alteration system:* (3) potassic, (4) propylitic of ep+chl+bt facies, (5) propylitic of ep+act facies with occasional skarn bodies, (6) phyllic; (7) outer limits of Yubileinoe alteration system; *morphological elements of the roof surface of the granitoid intrusion:* (8) crest line, (9) plunge of hidden local cupolas, (10) plunge of exposed local cupolas; (11) plunge of the intrusion roof surface; (12) summarized positive geochemical haloes of Au+Cu+Ag+Bi+W+Mo+As.

Mineral prospecting areas of the Yubileinoe deposit type (numbers in circles): I — Yubileinoe ore field, II — Sheqarabulak, III — Southwestern, IV — Ashlyasha, V — Aschesai, VI — Ayuly.

results of the present study. The interpretative alteration zoning map, illustrating the internal fabric of the granite-related mineralizing porphyry alteration system in the study area, is shown in Fig. 5. Regionally developed pre-granitic volcanic-associated sodic, prh+chl+pmp propylitic and listvenitic alteration zones occur 0.5 to 1.5 km away from the hidden granitoid contact. Incipient replacement of chlorite by biotite and pervasive dissolution of pumpellyite mark the outer limits of granite-related alteration zoning. Internal fabric of the latter is controlled primarily both by the morphology of the intrusion and by an erosion surface in the deposit area. Successive propylitic alteration of ep+chl+bt facies, ep+act facies and skarn zones are recognized with decreasing distance towards the granitoid. The ep+act propylitic and skarn alteration zones being the nearest to the granitoid contact indicate the local cupolas on the roof surface of the hidden granitoid intrusion, whereas the above-mentioned alteration styles in combination with phyllic alteration haloes point to the local cupolas complicated by presence of small granite porphyry stocks and dykes. The geophysical data show that cupolas of the Sheqarabulak and Southwestern mineral prospect areas are more close to the present-day surface than cupolas associated with the Ayuly, Ashlyasha and Aschesai mineral prospects. The depth to their roof reaches 300–500 m. These cupolas are assumed to be the deepest in the study area.

The zones of skarn and phyllic alteration are accompanied by positive geochemical haloes of Au, Cu, Ag and other trace elements, and reflect increasing degree of granite-related fluid-rock interaction. This petrographical-geochemical zoning pattern allows us to assess the prospecting and evaluation of ore potential of the study area. For example, the intense phyllic zones within the Sheqarabulak, Southwestern and Ayuly mineral prospects (Fig. 5) together with the positive haloes of Au+Cu+Ag+Bi+W+Mo+As can be taken as an indication of non-exposed porphyry Cu-Au mineralization of the Yubileinoe deposit type.

Acknowledgments

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