ISSN 1075-7015, Geology of Ore Deposits, 2024, Vol. 66, No. 1, pp. 21–41. © Pleiades Publishing, Ltd., 2024.

Porphyry Copper and Epithermal Gold–Silver Mineralization of the Baimka Ore Zone, Western Chukotka, Russia

A. F. Chitalin[a, *], **I. A. Baksheev**[b, **], **and Yu. N. Nikolaev**[b, ***]

[a] *Institute of Geotechnologies, Moscow, 119234 Russia*

[b] *Moscow State University, Moscow, 119991 Russia*

**e-mail: a.chitalin@igeotech.ru*

***e-mail: baksheev@geol.msu*

****e-mail: nikolaev@geol.msu.ru*

Received July 24, 2023; revised October 26, 2023; accepted October 28, 2023

Abstract—The results of modern studies of the Baimka Ore Zone (BOZ) in Western Chukotka obtained during prospecting and exploration in 2008–2016 are summarized, and the main features of its structure and development are shown. The porphyry–epithermal ore systems of the BOZ were formed within the NW-trending regional-scale dextral strike-slip fault in the Early Cretaceous time. Meridional extensional structures and diagonal strike-slip faults in the strike-strip fault zone controlled the position and morphology of intrusive bodies of monzonites and paragenetically related with them ore stockworks with porphyry copper and gold–silver epithermal mineralization. Ore stockworks were traced to 700-m depth by drilling, and, accordingly to the geophysical data, mineralization is forecasting deeper. The zoning of soil anomalies and the primary geochemical zoning of the Peschanka deposit and the Nakhodka ore field are described. An erosion levels of deposits are different. For the Peschanka deposit, an upper-middle erosion level has been established. For the deposits of the Nakhodka Ore Field, the erosion grade changes from the upper to the lower level. New prospects have been identified within the BOZ, where economical porphyry copper and gold–silver epithermal mineralization is predicted.

Keywords: Baimka ore zone, shift zone, ore stockwork, porphyry copper mineralization, gold–silver epithermal mineralization, geochemical zoning, Peschanka deposit, Nakhodka ore field

DOI: 10.1134/S1075701524010033

INTRODUCTION

The Baimka Ore Zone (BOZ) is located in the west of the Chukotka autonomous district in the southeastern part of the Anyui Highlands, within low mountains dissected by watercourses of the drainage basin of the middle reaches of the Bolshoi Anyui river, 180 km southwest of the city of Bilibino (Fig. 1). It extends in a north-northwest direction for more than 150 km with a width of 30–50 km and includes porphyry copper and epithermal gold–silver deposits and occurrences. The most studied is the Peschanka porphyry gold–molybdenum–copper deposit, which is included in the list of the largest porphyry copper deposits in the world.

In 1960–1990, the BOZ was studied by many specialists (Volchkov et al., 1982; Gulevich, 1974; Kaminsky, 1987, 1989; Migachev et al., 1984, 1995; Migachev and Shishakov, 1988; Shavkunov, 1973; Shapovalov, 1985, 1990). Industrial gold placers were discovered, large porphyry copper objects Peschanka and Nakhodka, the Vesenny epithermal gold–silver deposit were identified, and promising prospecting areas were established.

In 2008, the Baimskaya Mining Company (GDK Baimskaya) resumed prospecting, assessment and exploration work in the BOZ. The Peschanka deposit was further explored, and its reserves were put on the state balance sheet; additional exploration of the Nakhodka ore field was carried out, new promising areas were identified (Chitalin et al., 2013a; Chitalin and Nikolaev, 2014).

The authors of this article directly participated in prospecting, evaluation, and exploration at the Peschanka deposit, Nakhodka ore field, and other areas of the Baimka zone in 2008–2016. The huge new factual material collected together with our colleagues was analyzed and reflected in a report on search and evaluation work (Chitalin and Nikolaev, 2014), three candidate dissertations, and numerous publications. Based on the results of prospecting and assessment work, the resource potential of the central part of the BOZ was estimated at 22.9 Mt Cu, 1976.6 Au, 9124 t

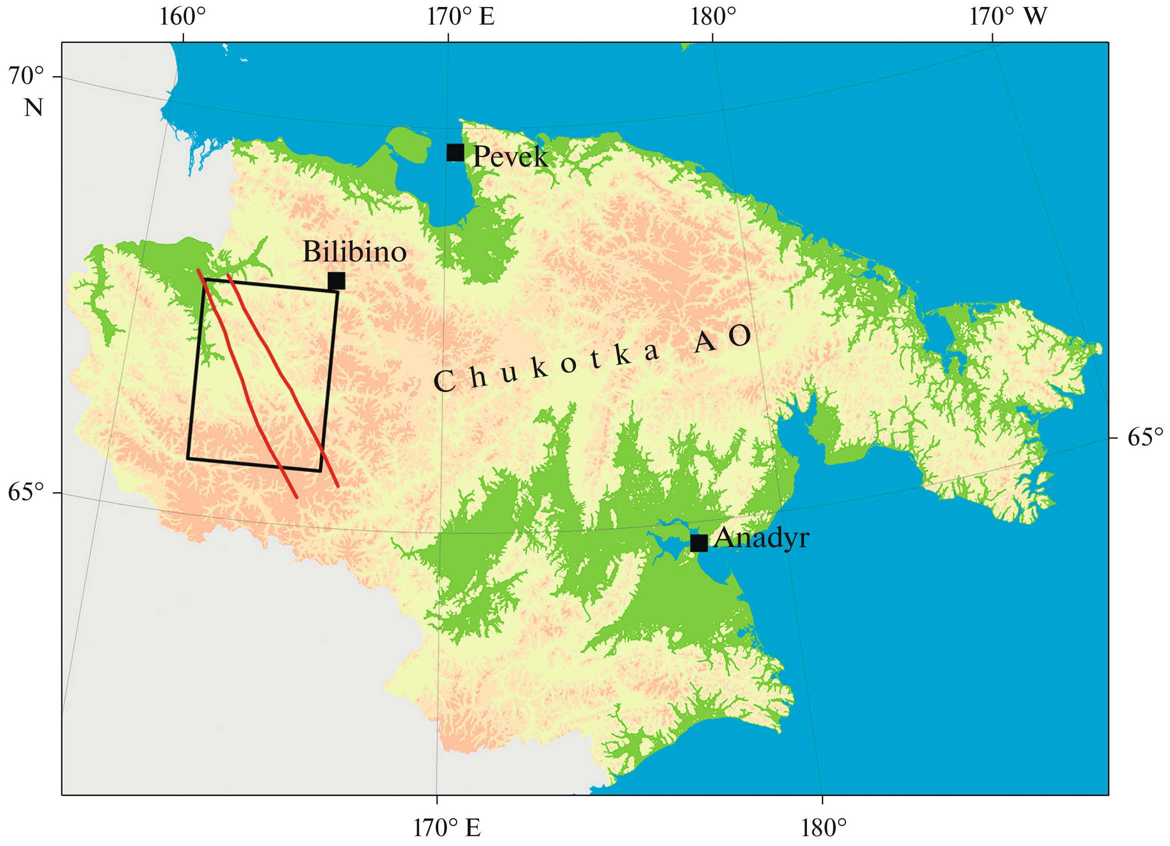


Fig. 1. Geographical location of the BOZ. The red lines show the contour of the BOZ. The black rectangle shows the contour of the geological scheme in Fig. 2.

Ag, and 325.3 kt Mo (Chitalin and Nikolaev, 2014; Chitalin et al., 2016).

In 2019, the Baimka license area was acquired by KAZ Minerals, which completed exploration of the Peschanka deposit and is preparing it for development.

This article summarizes the results of many years of research in the BOZ and shows the main features of its structure and development.

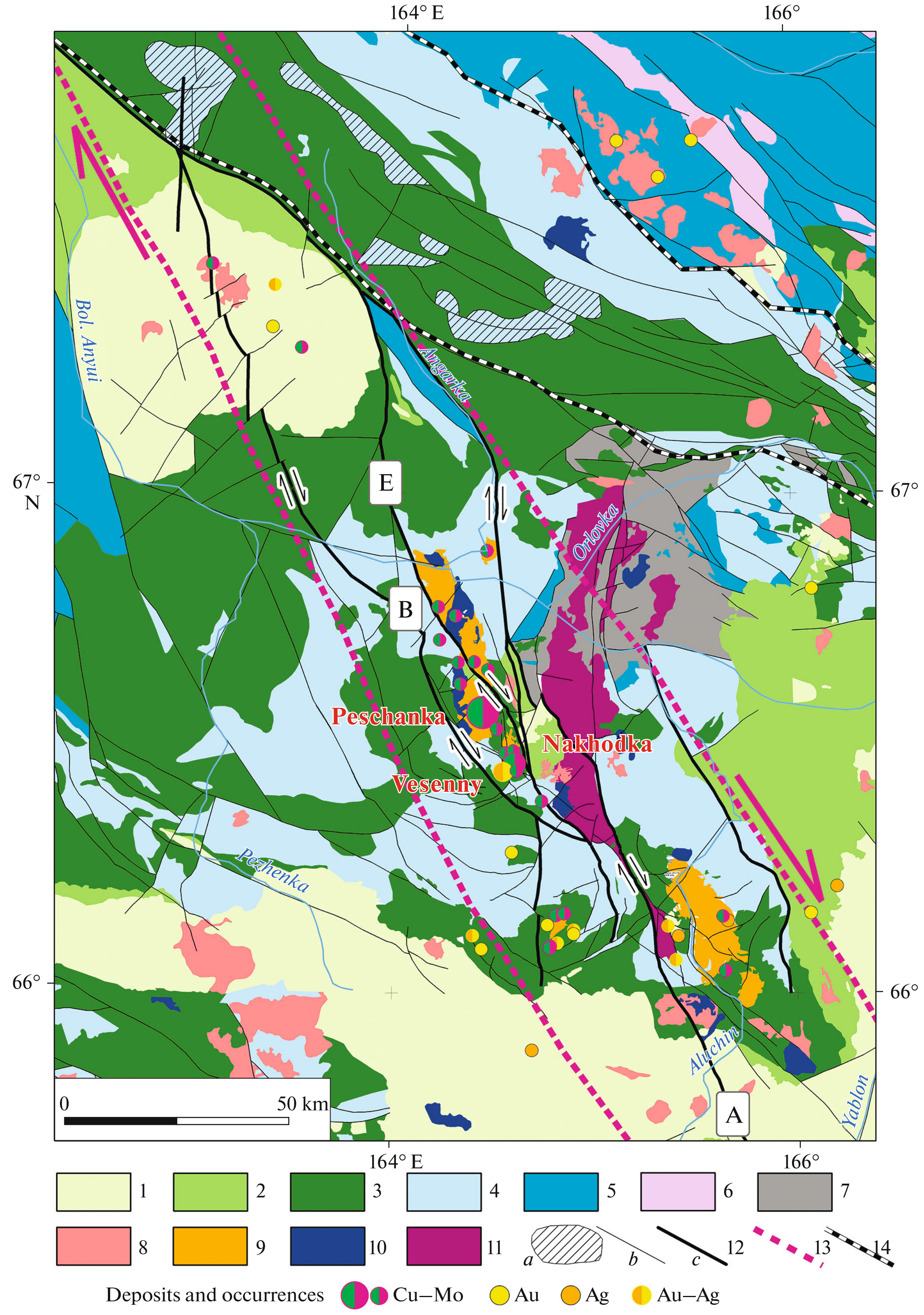
TECTONIC POSITION OF THE BAIMKA ORE ZONE

The BOZ belongs to the Oloy tectonic zone of the Alazeya-Oloy folded region (Volkov et al., 2006). The Oloy zone comprises the Triassic to Lower Cretaceous arc volcanic, volcano-sedimentary, and terrigenous sequences, folded into NW and nearly EW-trending linear and brachomorphic folds. The complex pattern of folds in plan is due to the cross folding of two deformation stages. This folded structure forms an Early Mesozoic complex, which includes blocks of deformed Paleozoic volcanic and terrigenous sediments and Late Paleozoic ophiolites (ultramafic and mafic rocks and plagiogranites). Fractures belong to different types and generations—reverse faults, thrusts, normal faults, and strike-slip faults.

The age of the Early Mesozoic structural complex is Late Jurassic to Neocomian (pre-Albian). In its composition, based on angular unconformities, structural floors are distinguished that correspond to individual episodes of the folded stage of deformation. The

→

Fig. 2. Geological sketch map of the BOZ and its surroundings. (1) Upper Albian volcanics; (2) Upper–Lower Albian to Lower Albian coal terrigenous sediments; (3) Tithonian to Neocomian volcanoterrigenous sediments; (4) Middle–Upper Jurassic volcanoterrigenous sediments; (5) Lower–Upper Triassic terrigenous sediments; (6) Lower–Middle Triassic terrigenous sediments; (7) Middle Devonian to Permian volcanic–terrigenous–carbonate sediments; (8) Early Cretaceous (Neocomian) intrusions of the Egdygkych and Vesenny complexes; (9) Late Albian granitoids; (10) Late Jurassic and Cretaceous gabbro; (11) Late Paleozoic ophiolites (ultamafic rocks, gabbro, plagiogranites); (12) faults: (*a*) allochthons of tectonic nappes; (*b*) faults of various kinematics; (*c*) large dextral strike-slip faults of the Baimka: the names of the strike-slip faults are indicated in the rectangles: A—Aluchin, B—Baimka, E—Egdygkych; (13) contour of the Baimka dextral strike-slip zone (half-arrows show the strike-slip kinematics); (14) contours of the South Anyui zone.


164° E
166°
67° N
67°
66°
66°
164° E
166°
Bol. Anyui
Angarka
Orlovka
Pezhenka
Aluchin
Yablon
E
B
A
Peschanka
Nakhodka
Vesenny
0
50 km
1
2
3
4
5
6
7
8
9
10
11
a
b
c
12
13
14
Deposits and occurrences
Cu–Mo
Au
Ag
Au–Ag

folds are intruded by Late Jurassic to Early Cretaceous shallow intrusions, with individual intrusions healing the folded ruptures. Early Cretaceous stocks of monzonite porphyriy, porphyritic diorite, and granodiorite porphyriy are associated with occurrences of copper, gold, and base metals. The folded-fault structure and ore-bearing intrusions with erosion and structural unconformity are overlain by Upper Aptian to Lower Albian continental terrigenous coal and volcanic sequences, filling the superimposed depressions of the outer zone of the Okhotsk–Chukotka Volcanic Belt (OCVB). The Early Mesozoic complex and superimposed structures are intruded by numerous stocks of Late Albian granitoids and are complicated by faults of predominantly strike-slip kinematics (Fig. 2).

The BOZ is confined to a system of large northwest-trending faults of predominantly dextral kinematics of Early Cretaceous age, which reflect a deep-seated strike-slip zone of 20–50 km wide. Associated with the main strike-slip faults are meridional faults and detachments controlling the stockworks of porphyry copper deposits and NE-trending sinistral strike-slip and normal and faults, as well as low-angle thrusts (Chitalin et al., 2013a, 2016).

The Baimka strike-slip zone in the north at an angle of 20° intersects the South Anyui zone with superimposed dextral deformations. This suture marks the subduction zone of the Late Jurassic to Early Cretaceous oceanic basin and the Early Cretaceous collision of the Kolyma–Omolon and Anyui–Chukchi terranes (Sokolov et al., 2015). To the south, dextral strike-slip faults of the Baimka zone attenuate within the OCVB.

GEOLOGY OF THE BAIMKA ORE ZONE

The BOZ with porphyry copper and epithermal gold–silver mineralization is controlled by a deep fault of polychronous development, which at the ore stage in the Early Cretaceous was a dextral strike-slip fault. We first identified the Baimka deep-seated dextral fault based on an analysis of regional geological and geophysical maps and a detailed study of its structure during the search, assessment, and exploration of ore objects. The basis for identifying a regional shift zone was the presence of a system of NW-trending extended en-echelon dextral strike-slip faults (Riedel shear system R) and associated transverse short NE-trending sinistral strike-slip faults (system R') and an en-echelon location of submeridional linear Early Cretaceous intrusions and associated linear porphyry copper stockworks of predominantly meridional strike, which marked areas of local horizontal latitudinal extension in the dextral strike-slip zone at the ore stage (Chitalin et al., 2012, 2013a).

The Early Cretaceous syenite–monzonite Egdygkych plutonic complex was formed under the conditions of an island volcanic arc of Late Jurassic-Early Cretaceous age (Volkov et al., 2006). The complex consists of three intrusion phases: 1) monzodiorites, 2) monzodiorite and quartz monzodiorite porphyries, and 3) syenites and quartz syenites. Porphyry copper–molybdenum mineralization is spatially associated with stocks and large dikes of the second and third phases (Volchkov et al., 1982; Kaminsky, 1987; Migachev et al., 1995; Chitalin, and Nikolaev, 2014).

According to geochemical and mineralogical characteristics, the monzonitoids of the BOZ were formed from water-saturated, high-potassium calc-alkaline shoshonite magmas with a high degree of oxidation (Soloviev, 2014). This is proven by the abundant magmatic and hydrothermal magnetite in monzonitoids, the presence of numerous gypsum and anhydrite veins and veinlets in ore stockworks, and high Fe_2O_3/FeO and V/Sc ratios in rocks of up to 1.27 and up to 21.9, respectively. Ratios of $Eu/Eu^* \geq 1$ also characterize potassium melts with high oxidation states. Abundant amphibole and biotite phenocrysts, as well as high Sr/Y ratios of up to 225, in the rock indicate significant water saturation of the parental magma (Chitalin et al., 2021).

The radiometric age of ore-bearing porphyritic diorite of the Vesenny and monzonitoids of the Egdygkych complexes, according to U/Pb dating of zircon, is 139–143 Ma (Komarova et al., 2015). Radiometric ages of altered wall-rocks and molybdenite from quartz veinlets and veins, determined by Rb/Sr and Re/Os methods, respectively, are over the range of 137–142 Ma (Moll-Stalcup, 1995; Kotova et al., 2012; Komarova et al., 2014, 2015; Baksheev et al., 2014). The resulting datings correspond to the time interval from the Late Berriassian to the Early Valanginian, inclusive. Obviously, this is the time of synore dextral deformations in the zone of the Baimka deep fault, expressed by meridional en-echelon structures of local horizontal latitudinal extension. In these structural traps, intrusive bodies were localized and linear ore stockworks were formed. Crystallization and cooling of stocks of porphyritic diorites and monzonites under shear conditions were accompanied by the formation of magmatic breccias, as well as blastomylonite zones—viscous “hot” tectonites (Chitalin, 2019a).

The width of the Baimka Shear Zone increases from 20 km in the north to 50 km in the south. In the southeast, it is overlain by Upper Cretaceous OCVB volcanics and intruded by comagmatic bodies. Individual NW-trending low-amplitude dextral strike-slip faults displace Late Cretaceous volcanics and intrusions, which indicates the activation of deep-seated displacements in the Late Cretaceous (see Fig. 2).

Ore-bearing intrusions of the Early Cretaceous Vesenny and Egdygkych complexes intruded the folded volcanosedimentary sequences of the Upper Jurassic–Lower Cretaceous. The Late Aptian terrigenous coal Ainakhkurgen Formation at the northern flank of the Peschanka deposit unconformably, with basal conglomerates at the base, overlays eroded mineralized monzodiorites and monzodiorite porphyries of the Egdygkych Pluton (Chitalin and Nikolaev, 2014f[1]).

In the northwest, within the Baimka zone, there is the Mangazeya volcanoplutonic structure of Albian age, which is also associated with porphyry copper and epithermal gold–silver occurrences.

In the bedrock outcrops within the BOZ, structural parageneses of sinistral and dextral strike-slip faults of various ages were identified, which formed at different stages of deformation. Early pre-ore sinistral strike-slip paragenesis of detachments and associated shears, filled with quartz veinlets, was established in cleaved Upper Jurassic siltstones in the southern part of the Baimka zone in the zone of the Anyui–Aluchinsky fault in the Lux gold prospect. A later dextral paragenesis of detachments and fractures healed by gold-bearing quartz–carbonate veinlets was also identified there. These veinlets cut dikes of Early Cretaceous porphyritic diorite and andesites.

In the suture zones of NW-trending large dextral strike-slip faults, drag folds with vertical hinges are noted—shaliness and associated viscous SC-tectonites formed as a result of sinistral strike-slip faulting are folded (Chitalin, 2019a).

The development of the Late Jurassic sinistral strike-slip faults along the NW-trending Egdygkych fault is also proven by the rupture and displacement along the fault in terms of an intense linear magnetic anomaly and the linear intrusion of the Late Jurassic Baimka Complex that caused it. The sinistral strike-slip fault was then healed by the Early Cretaceous Egdygkych linear intrusion of monzodiorites, and later—at the ore stage in the Early Cretaceous—was activated as a dextral strike-slip fault, displacing this intrusion (Chitalin, 2019).

In the Egdygkych strike-slip zone, drilling in the Egdygkych location (immediately north of the Peschanka deposit) revealed a low angle thrust of carbonaceous–terrigenous sediments of the postore Ainakhkurgen Formation onto ore-bearing monzodiorites. The thrust becomes steeper with depth and is associated with a vertical dextral strike-slip fault. Relatively different (?) tectonites are noted at the branch lines—viscoplastic blastomylonites and brittle cataclasites (Chitalin, 2019a).

Thus, large NW-trending faults of the Baimka Shear Zone are polychromous—they were formed during folding at the pre-ore stage as sinistral strike-slip or reverse faults, and at the ore and postore stages they were activated in a reverse mode as dextral strike-slip faults.

The ore-controlling faults and strike-slips of NS trending (Peschanka fault) are associated with thick zones of crushing and shearing and subvolcanic and hydrothermal bodies: stockworks, veins, small bodies of explosive hydrothermal breccias. Zones of increased fracturing adjacent to these faults host linear Cu–Mo porphyry stockworks.

At the Nakhodka and Pryamoy sites of the Nakhodka ore field, drilling revealed subhorizontal thick zones (up to 50–100 m) of unmineralized "dry" cataclasites and kakirites, associated with horizontal en-echelon gypsum veinlets filling tensional fractures (Chitalin et al., 2016). These low-angle zones of cataclasis and veining cut copper stockworks, linear bodies of mineralized hydrothermal breccias, and epithermal gold-bearing veins and are probably associated with the Cenozoic (?) thrusts.

The structural evolution of the Baimka Shear Zone was modeled using an analog tectonophysical model with heterogeneities in the form of longitudinal strike-slip faults and intrusive bodies (Frolova et al., 2019). Modeling made it possible to identify the origin and distribution over the area of potentially fluid-permeable zones of extension and decompression. Comparison of the model with the geological map of the Baimka zone showed that the extension areas on the model correspond well to known deposits and occurrences, as well as promising areas in fault junction zones, overlapped by the alluvium of large valleys. Gold placers are known in the valleys, and zones of altered rock and porphyry copper and gold–base metal mineralization have been identified in the outcrops on the slopes of the valleys. These valley sites deserve exploration to identify ore mineralization covered by alluvium (Frolova et al., 2019).

ORE STOCKWORKS OF THE PESCHANKA DEPOSIT AND THE NAKHODKA ORE FIELD

Ore bodies of the Peschanka deposit and the Nakhodka ore field (NOF) are localized in meridional linear quartz–sulfide stockworks—structures of horizontal latitudinal tension in the Baimka deep strike-slip zone. The position of the stockworks is controlled by a system of meridional faults and dextral strike-slip faults. The stockworks are obliquely intersected by extended NW-trending dextral strike-slip faults and associated with the later short NE-trending sinistral strike-slip faults and faults. Later epithermal gold-bearing quartz–carbonate veins and linear NOF stockworks form en-echelon rows in conjugate meridional and latitudinal strike-slip zones (Fig. 3).

Hydrothermal ore deposition within the BOZ occurred over a wide range of temperature (594–104°C) and pressure (1200–170 bar) from aqueous

---

[1] Chitalin A.F., Nikolaev Yu.N. "Report on the Results of Prospecting and Assessment Work for Copper and Gold within the Baimka Promising Area (Chukotka Autonomous District) Carried out in 2009–2014 with Assessment of Reserves and Predicted Resources"/Rosgeolfond; ChTFGI for Chukotka Autonomous District; OOO GDK Baimka; OOO Geokhimpoiski SV. M: 2014f.

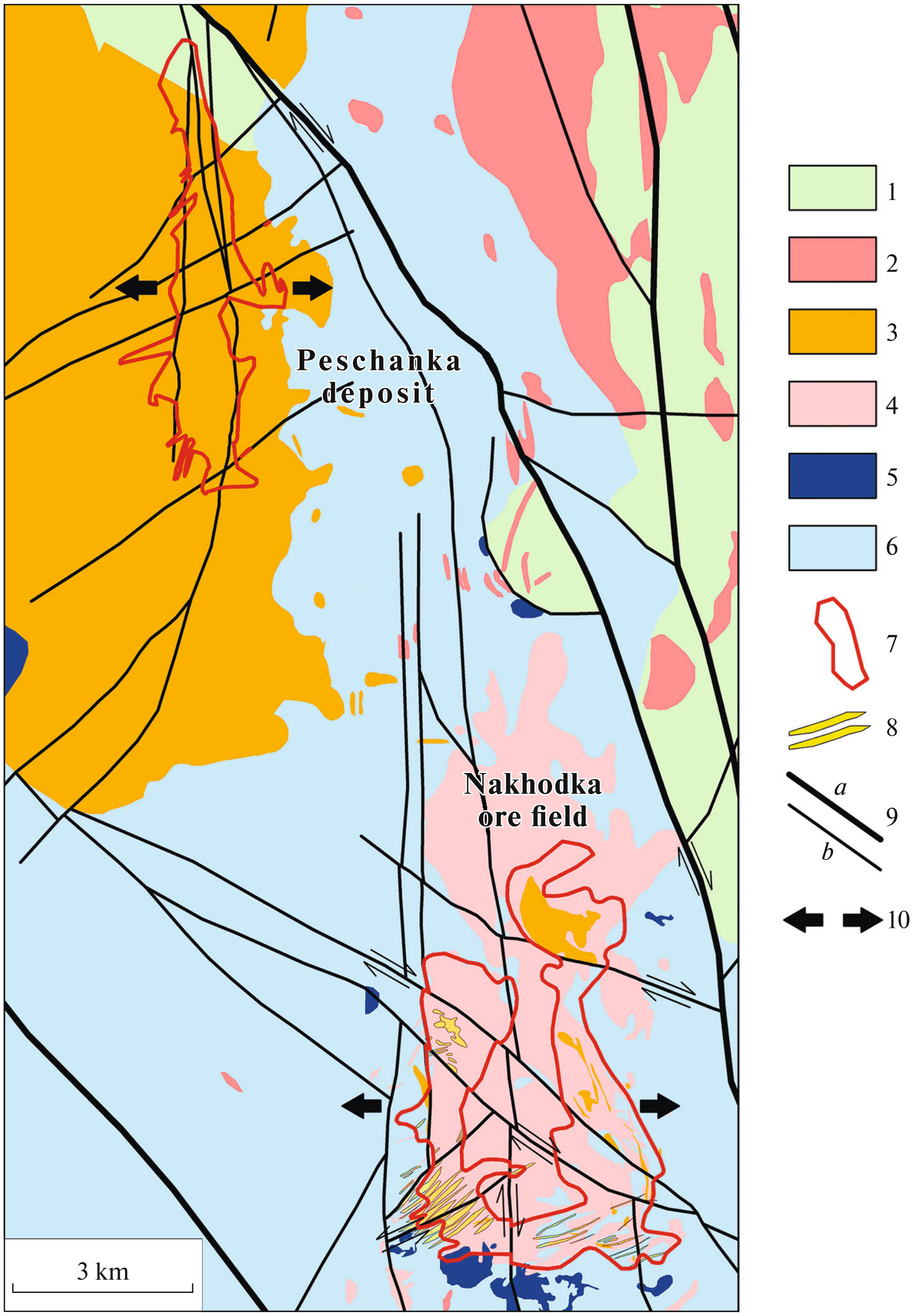


Fig. 3. Structural position of the Peschanka deposit and the Nakhodka ore field in the Baimka Shear Zone (after Chitalin et al., 2022, with modifications). (1) Postore coal terrigenous sediments of the Ainakhkurgen Formation; (2–4) Early Cretaceous intrusions: (2) Late Albian granitoids, (3) monzonitoids of the Egdygkych Complex, (4) porphyritic diorites of the Vesenny Complex; (5) Late Jurassic gabbro of the Baimka Complex; (6) Upper Jurassic volcaniclastics; (7) projection of the contour of copper mineralization; (8) linear stockworks and veins of epithermal gold–silver mineralization; (9) strike-slip faults and normal faults: (*a*) large; (*b*) others; half arrows show the kinematics; (10) direction of horizontal extension in the Baimka Shear Zone at the stage of porphyry copper stockworks.

fluids with highly variable salinity: porphyry copper at depths of 0.8–4.4 km, subepithermal at depths of 1.0–1.7 km, and epithermal at a depth of about 0.7 km (Nikolaev et al., 2016b).

Peschanka Deposit

The Peschanka copper–molybdenum–gold porphyry deposit is a linear multistage stockwork 7 km long and up to 1 km wide separated into three parts

(Main, Central, and Northern stockworks) by postore normal faults. The JORC resources of Peschanka (after completion of detailed exploration in 2017) are 9.9 Mt Cu with an ore grade of 0.39% and 16.6 Moz (516 t) Au with an ore grade of 0.21 g/t (https://www.kazminerals.com). The Peschanka deposit is comparable in reserves to the large Malmyzh porphyry copper–gold deposit recently discovered in Khabarovsk krai (balance reserves 8.3 Mt Cu and 347.4 t Au, https://www.rosnedra.gov.ru/), located in the zone of dynamic influence of the Central Sikhote-Alin fault (Chitalin et al., 2013b; Soloviev et al., 2019; Chitalin, 2021; Petrov et al., 2023).

Mineralized stockwork (veined–disseminated quartz–sulfide mineralization) was formed after altered monzodiorites of the first phase and monzodiorite porphyries of the second phase (Marushchenko et al., 2015; Chitalin et al., 2021, Fig. 4). The ore bodies are steeply dipping toward west and south thic plates which in some sections close together in the form of an arch in the axial part of the deposit. Below the oxidation zone (30–150 m) and inside it, a weak zone of secondary sulfide enrichment (chalcocite, covellite) is distinguished.

According to deep geophysics data (audio–magnetic–telluric sounding), the mineralized stockwork of the Peschanka deposit can be traced to a depth of 1 km, that was verified by deep drilling. The stockwork is mapped by an intense induced polarization anomaly, a low apparent resistivity anomaly, and a negative magnetic anomaly. The magnetic minimum is due to the demagnetization of rocks—the replacement of primary magmatic and secondary hydrothermal magnetite by hematite (Chitalin and Nikolaev, 2014).

At the Peschanka deposit, classical ore zoning is established. Toward the margins, there are a rich bornite core, an intermediate chalcopyrite zone, and an outer pyrite shell coinciding with propylitic altered rocks (Fig. 5). The relationship between the alteration and mineralization in plan (according to development stages) is shown in Fig. 6. Mineralization is located in the contour of biotite–K-feldspar–quartz alteration, which are replaced at the flanks of the deposit by epidote–chlorite–actinolite propylitic rocks along monzodiorites and host hornfelsed volcanic–sedimentary rocks of the Upper Jurassic.

According to the data of predecessors and our observations (Chitalin et al., 2012), numerous mineralized different-scale linear quartz–sericite zones (D-veins) form a metasomatic stockwork superimposed on biotite–K-feldspar–quartz alteration and partially on propylic altered rocks. The stockwork is dominated by NE-trending steeply dipping zones and, to a lesser extent, NW-trending zones; flat zones are rare. Quartz–sericite rocks have deformation–metasomatic banding; they developed as strike-slip-type shear fractures that first controlled early potassium feldspar and then later quartz–sericite metasomatism and veinlet-disseminated mineralization. At the flanks of the deposit, in the pyrite shell, zones of quartz–sericite metasomatites with only pyrite or not containing ore minerals are observed. The presence of unmineralized altered rocks probably indicates their formation before the deposition of ore minerals. Often, quartz–sericites, and later tectonic breccias with kaolinite cement, are observed, in which large undeformed cubic crystals of pyrite of a late stage of mineralization are observed. In the axial part of the stockwork in quartz–sericite zones, quartz alteration ("secondary quartzites") are locally noted.

Quartz–sericite and biotite–K-feldspar–quartz altered rocks are intersected by quartz and sulfide–quartz veinlets, which also form stockworks. Quartz in veins is light gray, sometimes fine-banded dark gray due to dustlike molybdenite clusters. Sulfides (bornite, chalcopyrite, pyrite, molybdenite, fahlore) are superimposed on quartz veinlets, concentrating in their selvages, as well as in cracks and microzones of crushing cutting the vein quartz and host rocks, where they are frequently associated with later white quartz cementing fragments of gray quartz.

Based on the volume of vein quartz in a quartz stockwork, lenticular core parts are distinguished with the thickness of quartz veinlets reaching several centimeters and total volume of quartz veinlets of 10% or more are identified. Usually, core parts of quartz stockwork are unmineralized or extremely depleted in ore materials. There are up to four systems of quartz veinlets of the same generation, forming a reticulate framework of the stockwork; second-generation quartz veinlets cutting them are rare. Meridional vertical veinlets predominate, filling sinuous tension fractures. Zones of abundant bornite and chalcopyrite in such veinlets are irregular throughout the stockwork and form copper-rich zones and lenses, usually steeply dipping and often en-echelon laterally.

The meridional steep gold-bearing (up to 5 g/t) sulfide veins filling tension fractures in the axial zone of the stockwork are the latest. These veins probably development at the subepithermal stage of the ore system. The stages of development of the ore stockwork of the Peschanka deposit are shown in Fig. 6.

At the substage of the "porphyry" stage, wall-rock alteration took place: propylitic alteration at the flanks of the structure, and biotite–K-spar–quartz, quartz–sericite, and strong-silica alteration (secondary quartzites) in the structure core. At the second substage, a quartz stockwork was formed; its structure is dominated by meridional subvertical veinlets filling tension fractures. At the third, actually ore, substage, multistage sulfide mineralization of the veinlet-disseminated type was formed, superimposed on pre-ore alterations and quartz veinlets. Meridional steeply dipping zones of rich bornite–chalcopyrite mineralization inherit zones of intense and abundant quartz veining in horizontal extension structures, and also

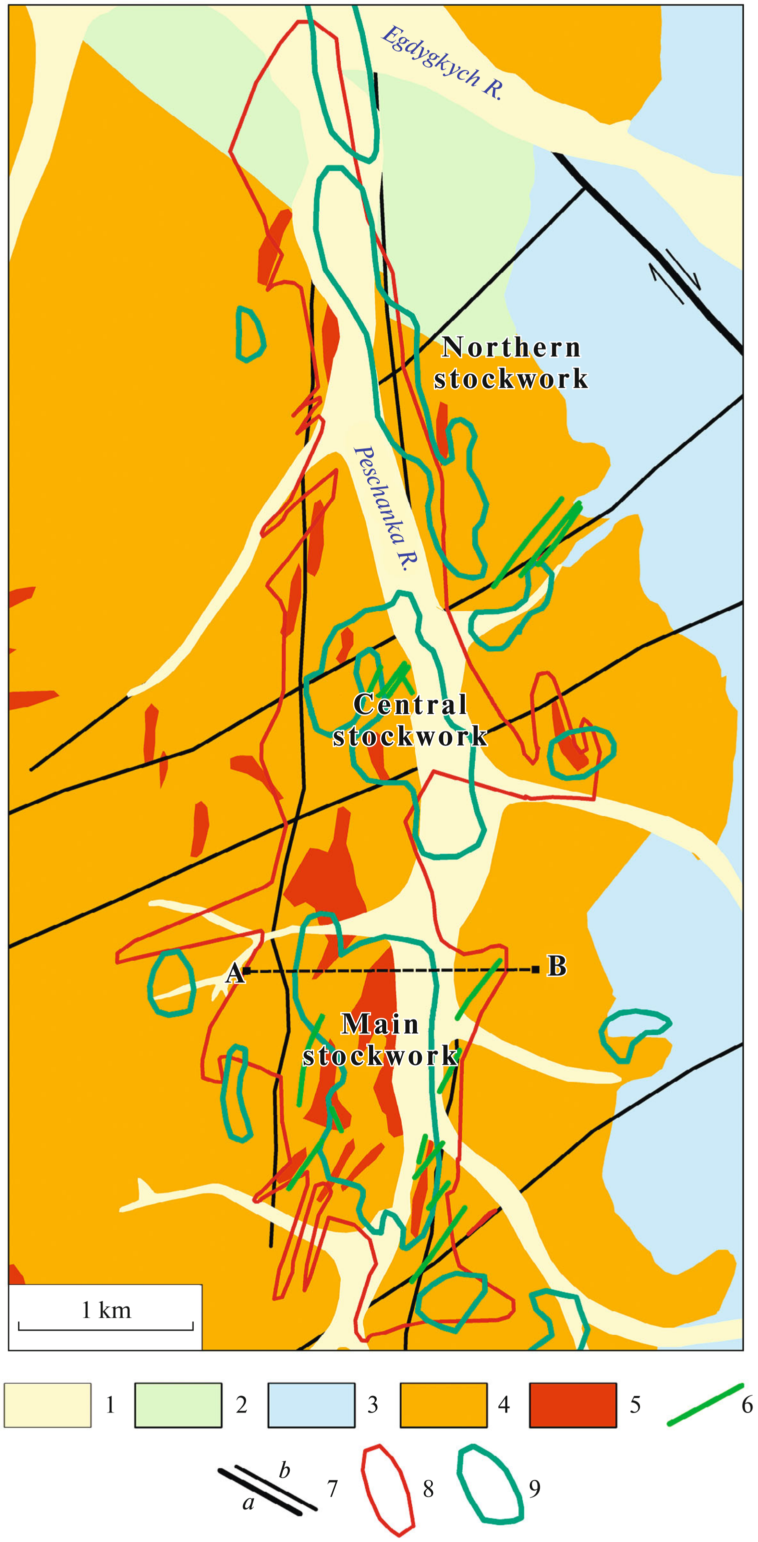


Fig. 4. Geological sketch map of the Peschanka deposit, modified after Chitalin et al (2021) and Dzhedzheya and Sidorina (2019). (1) Quaternary alluvium; (2) Lower Cretaceous Ainakhkurgen formation coal-terrigenous sediments; (3) Upper Jurassic volcaniclastics and terrigenous sediments; (4–5) Egdygkych Complex: (4) monzodiorites of the first phase, (5) quartz monzonite and quartz monzodiorite porphyries of the second phase and quartz syenite porphyries of the third phase; (6) Late Cretaceous andesite dikes; (7) faults: (*a*) Egdygkych dextral strike-slip fault; (*b*) strike-slip and normal faults; (8) projected contour of copper mineralization; (9) cores of anomalous geochemical fields. The dotted line shows the cut line in Fig. 5.

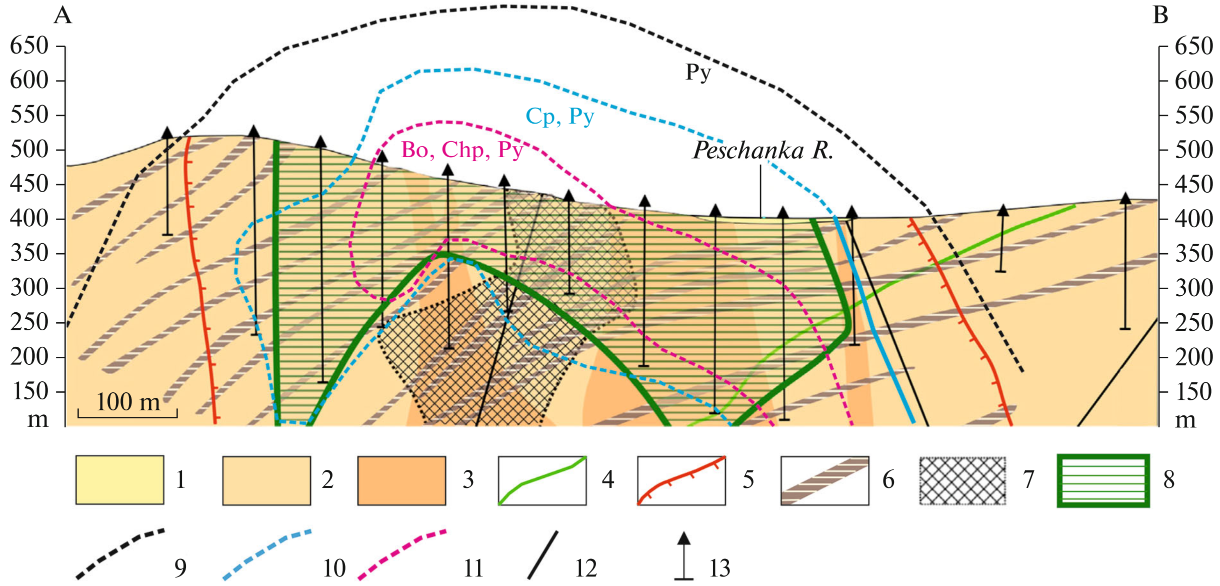


Fig. 5. Geological sketch map of the Main stockwork of the Peschanka deposit, modified after Chitalin et al. (2021). The section line is shown in Fig. 4. (1) Quaternary alluvium; (2) monzodiorites of the first phase; (3) quartz monzonite and quartz monzodiorite porphyries of the second phase; (4) Late Cretaceous andesite dikes; (5) contour of biotite–K-feldspar–quartz alteration; (6) subvertical zones of quartz–sericite alteration (*gently sloping zones are apparent due to oblique section*); (7) quartz stockwork; (8) zone of Cu mineralization with CuEq 0.2%; (9–11) contours of mineral zones of ore zoning: (9) pyrite (Py), (10) chalcopyrite (Chp), (11) bornite (Bo); (12) faults; (13) drill holes.

form en-echelon local structures in zones of strike-slip deformation within the stockwork. At the fourth (late ore) substage, gold-bearing sulfide–quartz veins of the subepithermal type were formed in the axial part of the stockwork. At the postore stage, Late Cretaceous (?) andesite dikes healed fractures and faults of the previous stages.

A structural–kinematic model of the Peschanka deposit (Chitalin et al., 2012, 2020; Chitalin, 2019a, b) reflects the long-term structural evolution of a mineralized linear stockwork. The meridional linear stockwork is a horizontal extension structure in the zone of the large Peschanka fault, which kinematically was a dextral strike-slip. The ore-localizing structures in the stockwork are pre-ore structures: zones of quartz–sericite alteration along predominantly NE-trending shear fractures (sinistral strike-slip faults), as well as quartz veins and veinlets that fill tension fractures of predominantly meridional strike. Lenticular zones of rich copper mineralization in the stockwork localized in structural traps—steeply dipping extension structures—also have a meridional strike. The ore stockwork and the associated strike-slips were formed in an environment of latitudinal horizontal extension and meridional horizontal compression in the dextral strike-slip zone along the Baimka deep fault (see Fig. 3).

Nakhodka Ore Field

The Nakhodka ore field (NOF) is located on the western flank of a large porphyry–epithermal system of the same name with eroded gold–silver epithermal mineralization in the central part and noneroded on the flanks.

The porphyry copper ores reserves and resources of the Nakhodka, Pryamoi, and Vesenny 3 sites of the Nakhodka ore field as of January 1, 2014, were as follows: category C_2 reserves, 4.7 Mt Cu, 75.6 kt Mo, 345 t Au, and 1576 t Ag; category $P_1 + P_2$ resources, 1.6 Mt Cu, 36.1 kt of Mo, 121 t Au, and 512 t Ag (Chitalin and Nikolaev, 2014).

The NOF includes the southern part of the weakly eroded Verkhne-Baimka hypabyssal stock of diorite porphyrites of the Early Cretaceous Vesenny Complex. The stock intrudes Upper Jurassic volcanosedimentary sequences and Late Jurassic gabbroics and is broken by strike-slip and normal faults with amplitudes of up to 1 km (Fig. 7).

The Verkhne-Baimka stock is composed of medium-grained diorite porphyry of the first phase intruded by dikelike bodies of large-porphyry diorite porphyry and quartz diorite porphyry of the second phase. The rocks of both phases are intruded by small bodies of Early Cretaceous monzonitoids of the Egdygkych Complex, which are associated with porphyry copper mineralization. The U–Pb zircon age of quartz diorite and monzodiorite porphyries is the same—139–141 Ma (Nagornaya, 2013; Chitalin et al., 2013a, 2016, 2019). This fact suggests that the diorite porphyries can be attributed to the Egdygkych Complex rather than the Vesenny Complex.

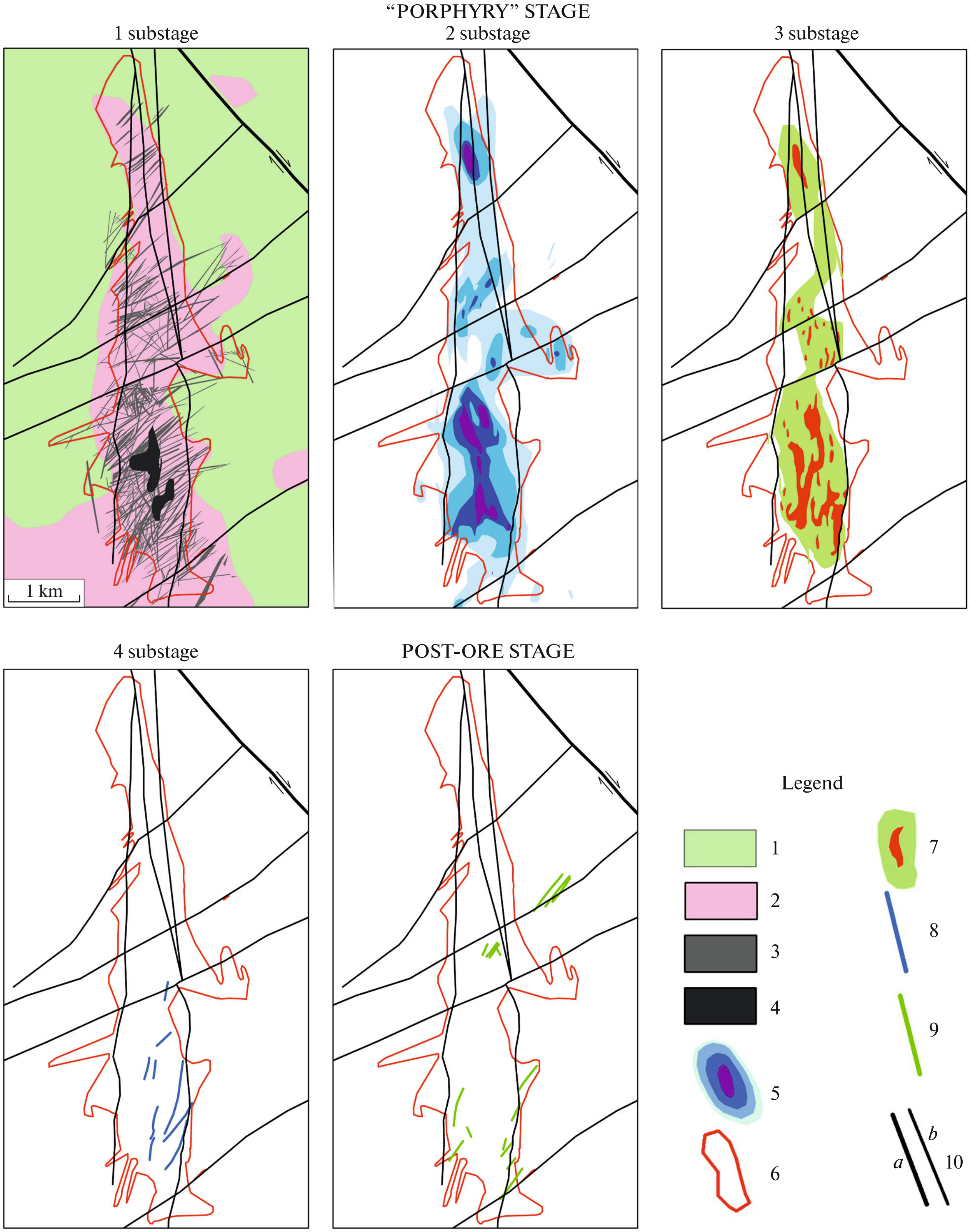


Fig. 6. The main stages of mineralized stockwork of the Peschanka deposit, modified after Chitalin (2021). See text for explanation. Legend: (1–4) alterations: (1) propylitic, (2) biotite–K-feldspar–quartz, (3) quartz–sericite, (4) strong silica; (5) volume percentage of vein quartz in stockwork (isolines 0.1, 1, 5, 10%); (6) projection of the contour of copper mineralization; (7) ore body with the cutoff grade of 0.2% Cu Eq (green) and high-grade lenses with the cutoff grade of 0.6% Cu (red); (8) gold-bearing sulfide veins; (9) postore dikes of basaltic andesites; (10) faults: (*a*) Egdygkych dextral shift; (*b*) strike-slip and normal faults.

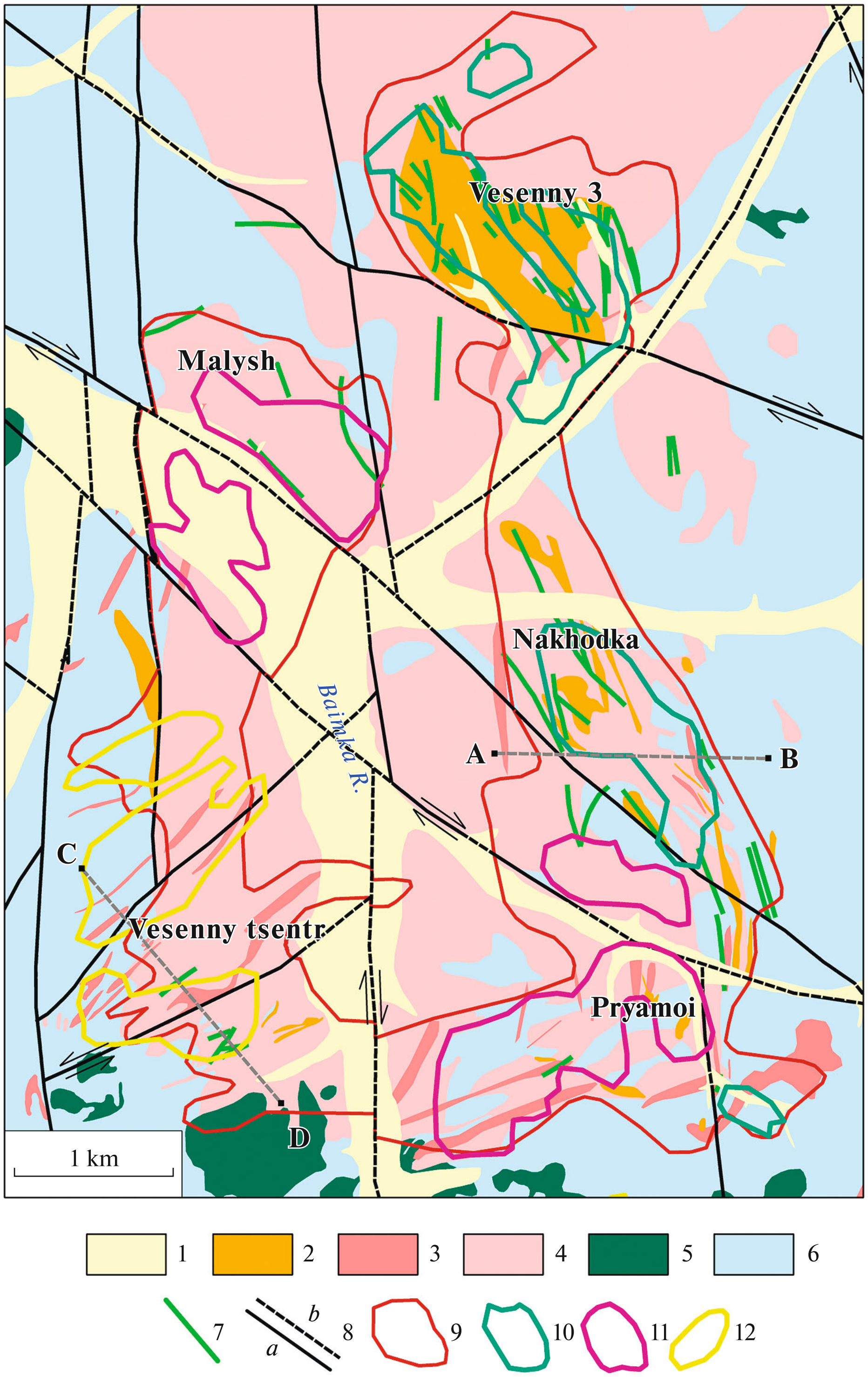


Fig. 7. Geological sketch map of the Nakhodka ore field, modified after Chitalin et al. (2022) and Sidorina (2015, 2016). (1) Quaternary alluvium, (2–4) Early Cretaceous intrusions: (2) monzodiorites and quartz monzonite porphyries of the Egdygkych complex, (3) quartz diorite porphyries of the second phase of the Vesenny complex, (4) quartz diorite porphyries of the first phase of the Vesenny complex; (5) Late Jurassic gabbrodiorites; (6) Upper Jurassic volcano-sedimentary sequences; (7) Late Cretaceous andesite dikes; (8) gaps: (*a*) reliable, (*b*) supposed to be under Quaternary deposits; (9) projection of the contour of copper mineralization on the day surface; (10–12) core parts of anomalous geochemical fields: (10) porphyry copper, (11) porphyry copper–molybdenum, (12) gold–silver. A–B, C–D—lines of sections shown in Figs. 8 and 9.

The projection on the day surface of the area of veinlet-disseminated gold–molybdenum–copper mineralization generally corresponds to the near-contact zone of the Verkhne-Baimka stock. Economic mineralization as closely spaced linear stockworks of mineralized quartz veinlets and hydrothermal breccias, as at Peschanka, is developed in quartz–sericite alteration, mainly in the eastern part of the stock, where diorite porphyries are intruded by small linear bodies of monzodiorites of the Egdygkych Complex. Three sites are distinguished here (Vesenny 3, Nakhodka, and Pryamoi), within which exploration drilling to a depth of 600 m has delineated several near-meridional lenticular en-echelon ore bodies with a steep dip and a thickness of up to 150 m. At the Nakhodka area, copper mineralization is completely delineated neither to the depth nor at the flanks, and so it is possible to identify new ore bodies within the mineralized stockwork.

In NOF copper-ore stockworks, in addition to steeply dipping ore veinlets, there are low-angle and subhorizontal veinlets filling contraction (?) fractures, which were slightly open and mineralized during horizontal compression. Therefore, the stockworks contain not only near-vertical, but also subhorizontal, zones of high-grade hypogene copper mineralization (Chitalin et al., 2016, 2019).

It has been established that the earliest is the copper–molybdenum-porphyry mineralization identified at the Malysh area and on the western flank in the Pryamoi area. It predates porphyry copper–gold mineralization. The Re–Os age of molybdenite of 137.9 ± 0.3 Ma is consistent with the U–Pb age of magmatic zircon and supports the paragenetic association of hydrothermal mineralization with monzonitoids of the Egdygkych Complex (Nagornaya, 2013).

The contour of copper mineralization is horseshoe-shaped (a parallelogram not closed in the north, the sides of which correspond to the axes of linear mineralized stockworks). Within the stockworks, northwestern, northeastern, and less frequent EW and NS zones of quartz-sericite alteration are abundant. The altered rocks are banded probably due to deformation; slickenslides of strike-slip type are observed along the banding. The length of quartz–sericite zones varies from tens to hundreds of meters, and the thickness ranges from several centimeters to a few meters. Quartz–sericite zones are developed both in intrusive rocks and propylitic altered country volcanosedimentary rocks. In the axial parts of thick quartz–sericite zones, tectonic breccias are frequent and consist of acute-angled or weakly rounded fragments of quartz–sericite rock cemented by kaolinite. This cement contains undeformed large crystals of late pyrite.

Within the NOF, in the contour of copper mineralization, numerous linear bodies (lenses) of strong silica alteration (“secondary quartzites”), which predated quartz–sericite zones and quartz stockwork, have been mapped. Lenses of strong silica alteration have a predominantly meridional, less often northeastern, strike; they heal small faults and fractures. “Secondary quartzites” are very dense, low-permeability rocks and practically do not contain ore minerals, with the exception of areas where they are intersected by later mineralized fractures and veinlets.

Hydrothermal breccias, often ore-bearing, are widespread throughout the NOF. They form lenticular bodies of predominantly meridional strike, often inheriting linear quartz–sericite zones. Breccias contain mainly fragments of host altered intrusive rocks, often cut by quartz–sulfide veinlets; fragments of allochthonous rocks—basaltic andesites—are less common. Breccia cement is represented by hydrothermal minerals: quartz, carbonate, hematite, magnetite, sulfides (chalcopyrite, pyrite, bornite). The identified “fragment within a fragment” texture indicates the multievent formation of hydrothermal breccias. Sometimes hydrothermal breccias inherit intrusive breccias in diorite porphyries. According to the classical model (Sillitoe, 2010), hydrothermal breccias are characteristic of the upper level of the porphyry copper system. Hydrothermal breccias are intersected by epithermal quartz–carbonate veins and veinlets, as well as postore andesite dikes.

At the Nakhodka site, the Cu–Au ± Mo stockwork is up to 600 m wide and extends 2000 m in the NNW direction. Ore zoning characteristic of porphyry copper deposits has been established (Lowell and Guilbert, 1970): a bornite core with high-grade ores is overlapped by a chalcopyrite zone and then a pyrite shell. Two spatially close spaced bornite cores are identified at Nakhodka (Fig. 8); they consist of meridional high-grade zones, which are en-echelon in plan. These zones coincide with linear quartz stockworks, in which the volume of veinlets reaches 10% or more. Copper–sulfide veinlet-disseminated mineralization is superimposed on quartz veinlets and earlier alterations. Quartz–sulfide linear stockworks are structures of horizontal EW extension.

The western and southern parts of the Nakhodka ore field are characterized by intense epithermal veined and veinlet-disseminated gold–silver mineralization superimposed on strongly silicified diorite porphyries and country Upper Jurassic andesites and their tuffs. Gold-bearing banded quartz–carbonate veinlets and veins intersect quartz–copper sulfide veinlets and porphyry copper-stage hydrothermal breccias.

At the Vesenny site, where predecessors discovered the vein gold–silver deposit of the same name, as a result of our work, large-volume stockwork mineralization with low-grade ores was established. The total P2 + P1 resource of large-volume epithermal vein-stockwork mineralization is estimated at 359 t of gold and 3099 t of silver. The resource base of the Vesenny

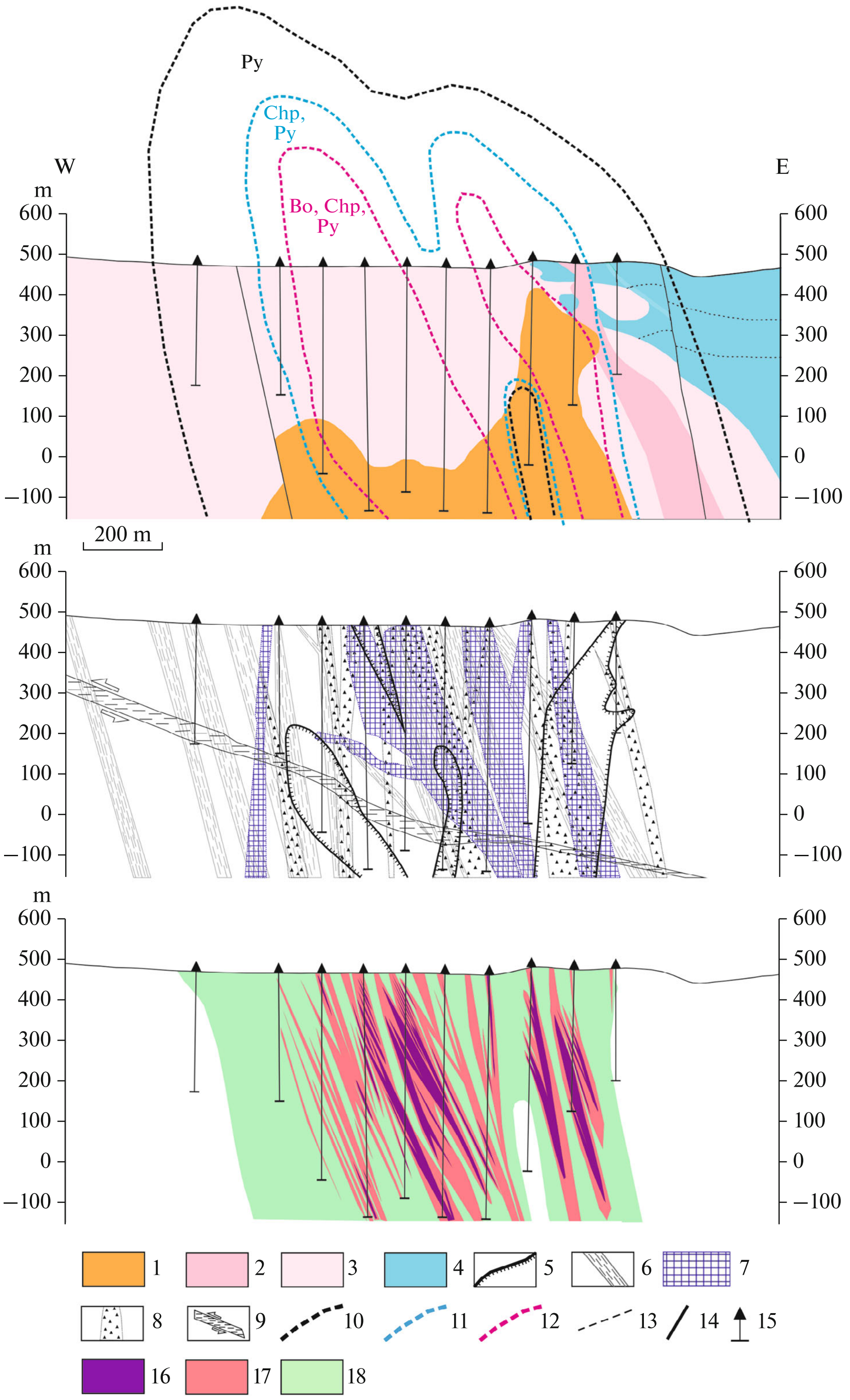


Fig. 8. Geological section of the Nakhodka site, modified after Chitalin et al. (2022). Section line A–B shown in Fig. 7. (1) Monzodiorites, quartz monzonite porphyries of the Egdygkych Complex; (2–3) Vesenny intrusive complex: (2) quartz diorite porphyries of the second phase, (3) quartz diorite porphyries of the first phase; (4) Upper Jurassic volcanosedimentary sequences; (5) K-spar contour; (6) zones of intense quartz–sericite alteration; (7) quartz stockwork; (8) hydrothermal breccias; (9) postore thrust zones with horizontal gypsum–calcite veinlets filling tension fractures; (10–12) contours of mineral zones of ore zoning: (10) pyrite (Py), (11) chalcopyrite (Chp), (12) bornite (Bo); (13) layering; (14) faults; (15) drill holes; (16–18) ore zones with copper grade, %: (16) >0.5, (17) 0.3–0.5, and (18) 0.1–0.3.

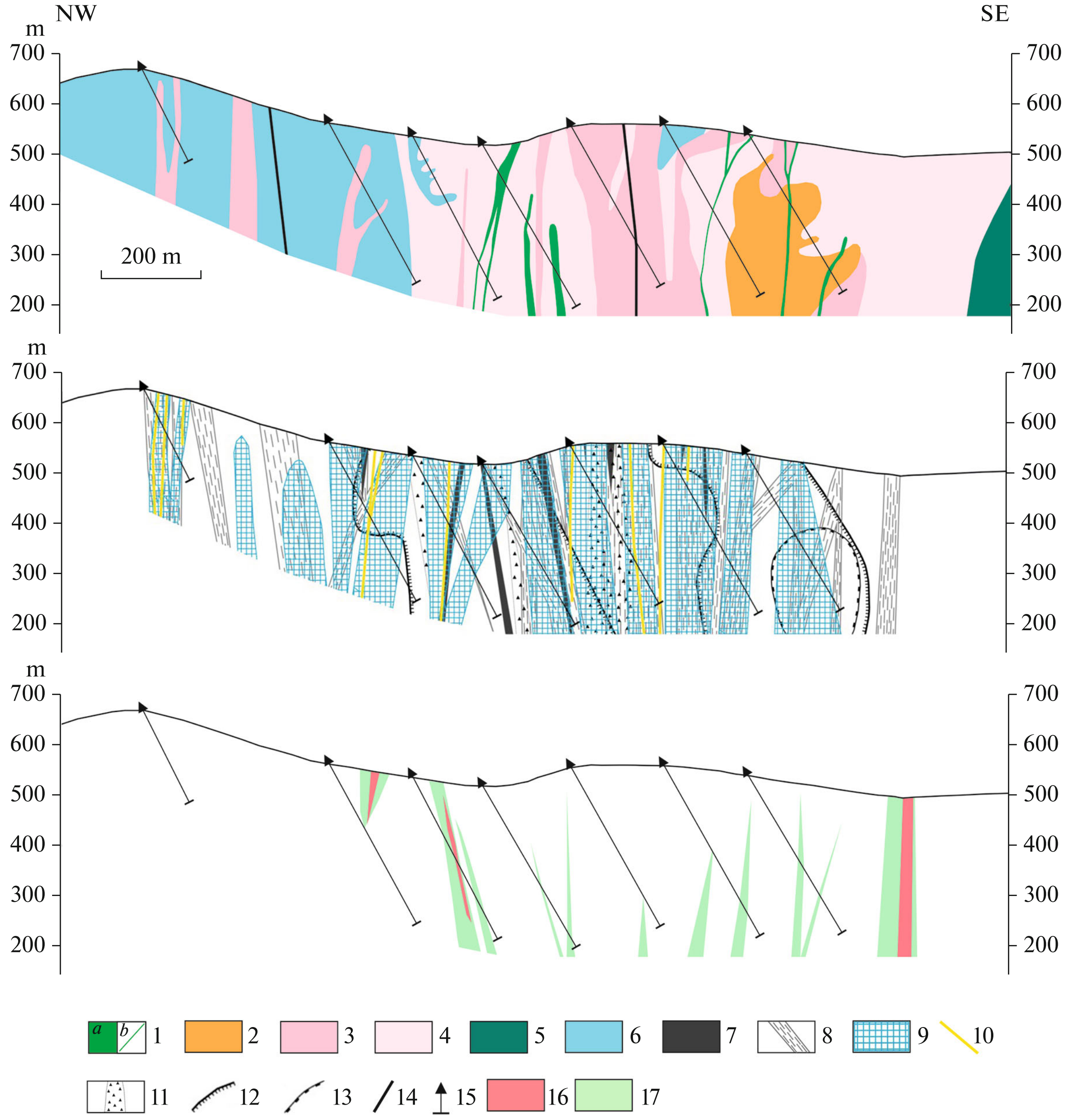


Fig. 9. Geological section of the Vesenny site, modified after Chitalin et al. (2022). Section line C–D shown in Fig. 7. (1) Subvolcanic (*a*) bodies and (*b*) dikes of Late Cretaceous andesites; (2) monzodiorites, quartz monzonite porphyries of the Egdygkych Complex; (3–4) Vesenny intrusive complex: (3) quartz diorite porphyries of the second phase, (4) quartz diorite porphyries of the first phase; (5) gabbroics of the Late Jurassic Baimka complex; (6) Upper Jurassic volcanosedimentary; (7) strong silica alteration ("secondary quartzites"); (8) zones of intense quartz–sericite alteration; (9–10) epithermal gold-bearing quartz–carbonate (9) stockworks and (10) veins; (11) hydrothermal breccias; (12) contour of K-spar alteration; (13) contour of biotite alteration; (14) faults; (15) drill holes, (16–17) ore zones with copper grade, %: (16) 0.3–0.5 and (17) 0.1–0.3.

site can be at least 500–600 t of gold with an average grade of 1.0–1.5 g/t (Chitalin et al., 2019).

According to the exploration data, banded steeply dipping ore bodies are mineralized zones, including areas of brecciation with lenses of quartz metasomatites ("secondary quartzites") and rhodochrosite–quartz dilution veins. The elevated gold content is associated with cataclazed quartz–sericite altered rocks and "secondary quartzites," which are intersected by hydrothermal breccias with sulfide–quartz–carbonate cement, carbonate–quartz veins, and zones of vein silicification. Ore bodies in quartz–carbonate stockworks and veins are delineated according to sampling data and have a northeast-trending lens shape in plan. The length of the ore bodies exceeds 800 m, and the width reaches 80 m (Fig. 9). Epithermal veins and stockworks intersect mineralized structures of the porphyry copper stage: quartz–sericite zones, quartz–

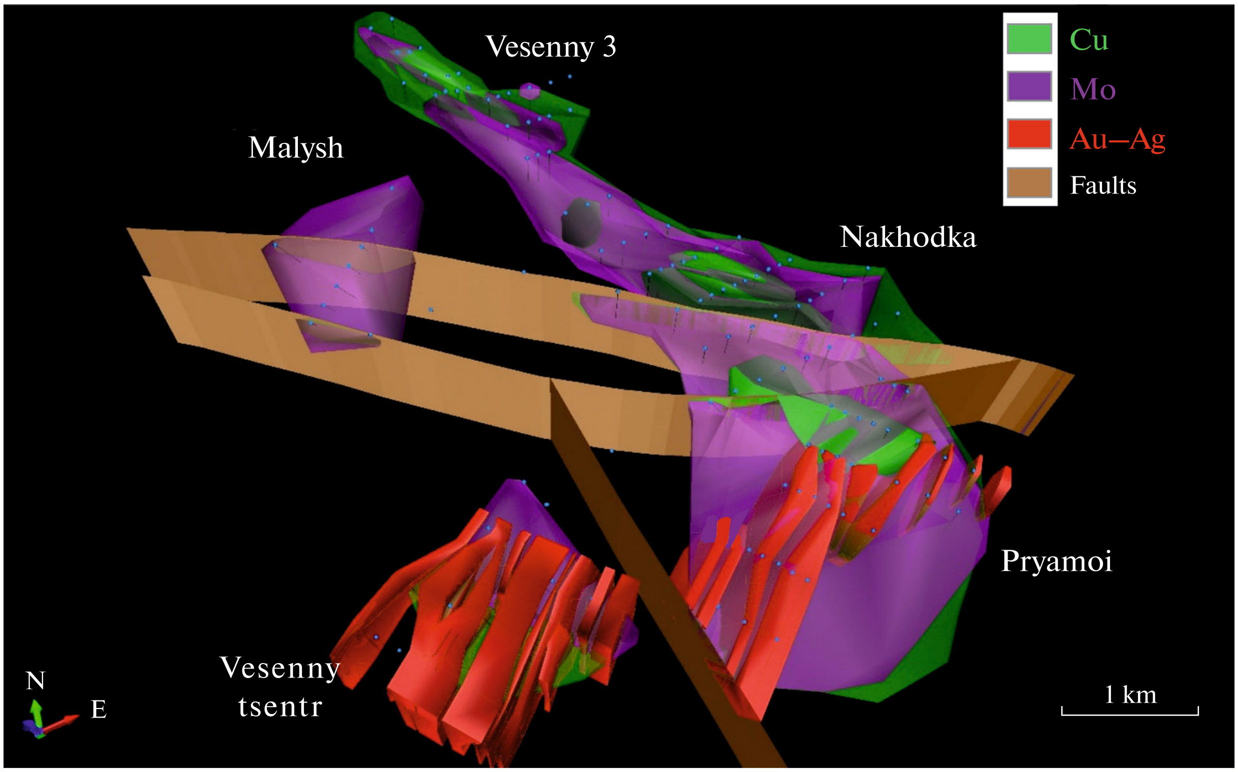


Fig. 10. Volumetric model of ore deposits of the Nakhodka ore field (Chitalin et al., 2016, modified). See text for explanation.

sulfide stockworks, and hydrothermal breccias. The drill cores show that epithermal banded veins intersect and replace sulfide–quartz veinlets.

Epithermal mineralization was formed as a result of repeated tectonic movements and the opening of fracture structures and early veinlets. Many veins are characterized by a complex internal structure, with traces of repeated dilation. Structural stereograms of the poles of fractures and small faults, as well as quartz–sericite and quartz veinlets, constructed according to the ditch documentation by geologists of ZAO Sibgeokonsalting, show the predominance in the Vesenny area of steeply dipping NE-trending structures, for which sinistral strike-slip kinematics of displacements have been established (Chitalin et al., 2016).

A volumetric model of the identified ore deposits of the Nakhodka ore field is shown in Fig. 10. There is a shift of molybdenum-porphyry mineralization to the inner zone of the copper stockwork and the superposition of epithermal gold–silver linear stockworks on molybdenum and porphyry copper stockworks. The unmineralized western flank of the NOF in the model is explained by its poor exploration of drilling. Based on geological, structural, mineralogical, and geochemical data, we predict the discovery of economic epithermal and porphyry copper (at depth) mineralization at the northern flank of the Vesenny site. Prospecting and verification drill holes at some secondary gold anomalies intersected steeply dipping gold-bearing epithermal quartz–carbonate veins and linear stockworks, which serve as extension structures—tension and slightly open shear fractures (Sidorina, 2015, 2016; Nikolaev et al., 2011, 2013; Chitalin et al., 2016, 2019). The stages of evolution of the Nakhodka ore field are shown in Fig. 11.

Stockwork mineralization of the mesothermal "porphyry" stage includes three substages (1 alteration, 2 quartz stockwork, 3 sulfide mineralization), which generally coincide with those at the Peschanka deposit. The fourth substage, hydrothermal breccias, is also common in the NOF, completing the "porphyry" stage itself. The stage of gold–silver epithermal mineralization is identified separately. The postore stage is characterized by the intrusion of postore andesite dikes of Late Cretaceous (?) age, the formation of conjugate sinistral and dextral strike-slip faults, and the activation of pre-ore and synore ruptures. Presumably, in the Cenozoic, low-angle thrusts formed, accompanied by "dry" cataclasites (kakirites) and subhorizontal en-echelon gypsum–anhydrite veinlets filling tension fractures.

According to the developed structural–kinematic models of porphyry copper and epithermal mineralization of NOF, metasomatic zones, quartz–sulfide stockworks, and hydrothermal breccias of the porphyry stage were formed in local meridional structures of horizontal latitudinal extension and in strike-slip structures—dextral NW-trending and sinistral NE-

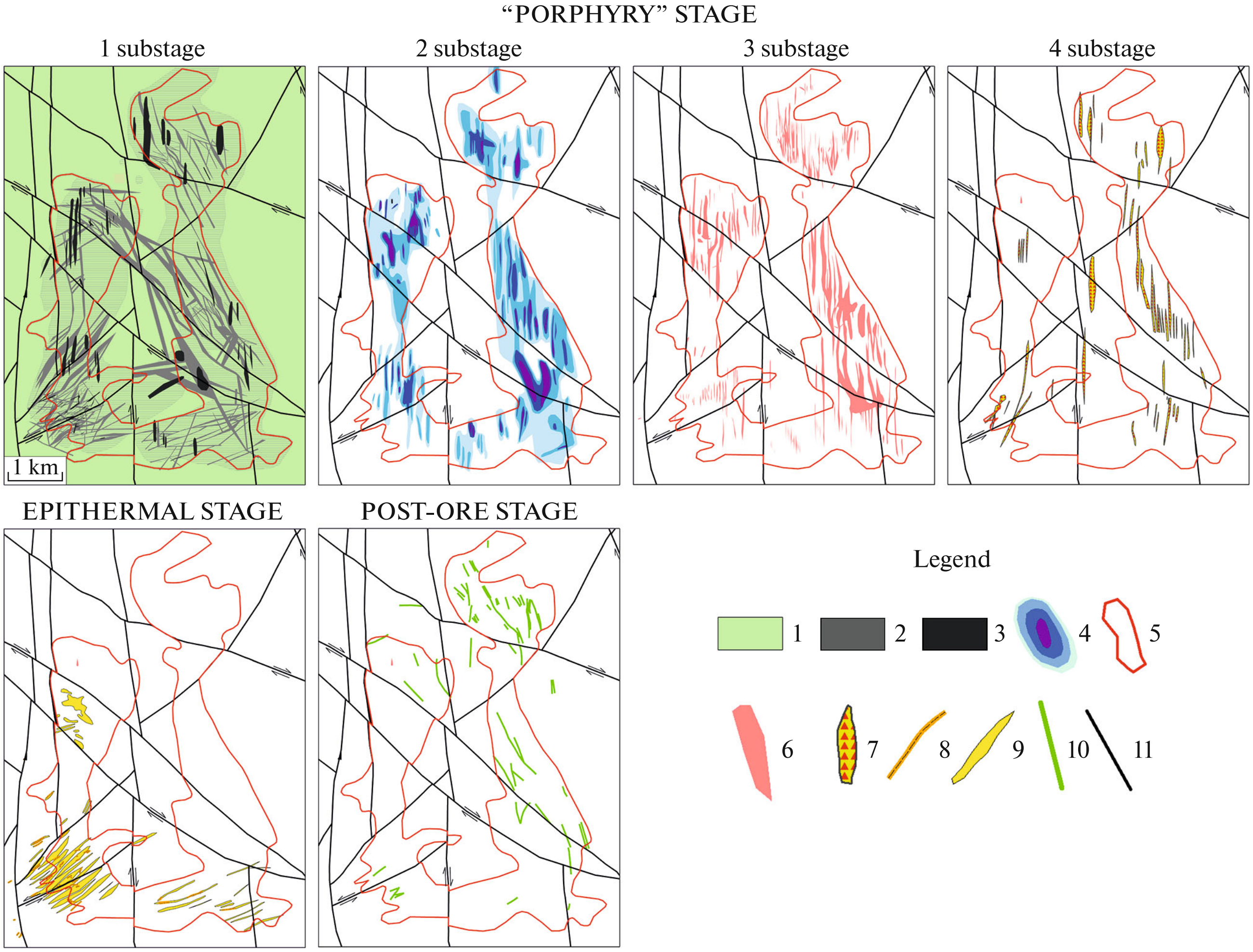


Fig. 11. Mineralization stages of the Nakhodka ore field, modified after Chitalin et al. (2019, 2022). See text for explanation. Legend: (1–3) alterations: (1) propylitic, (2) quartz–sericite, (3) strong silica; (4) volume percentage of vein quartz in stockwork (isolines 0.1, 1, 5, 10%); (5) projection of the contour of copper mineralization; (6) high-grade lenses with the cut-off grade of 0.6% Cu; (7) hydrothermal breccias; (8–9) epithermal gold-bearing carbonate–quartz formations: (8) veins, (9) stockworks; (10) postore dikes of basaltic andesites; (11) strike-slip and normal faults (half-arrows show kinematics).

trending. This paragenesis of ore-controlling structures formed in the zone of the deep dextral–lateral Baimka strike-slip fault. The formation of later vein-stockwork Au–Ag mineralization of the epithermal type was controlled by en-echelon shear structures of NS and EW strike (Chitalin 2019a; Chitalin et al., 2012, 2016, 2019, 2022).

GEOCHEMICAL FIELDS OF ORE OBJECTS

In the process of geochemical searches, extensive factual material was collected on the geochemistry of secondary dispersion halos forming anomalous geochemical fields (AGCFs) in the central part of the BOZ (Fig. 12). This material was supplemented by the results of ICP-OES analysis of core samples and a mineralogical description of the core from the drill holes of the Peschanka and NOF deposits (performed by geologists of OAO Sibgeokonsalting). The data obtained made it possible to identify the geochemical zoning of the objects under consideration. Since the established patterns of geochemical zoning are discussed in detail in papers (Dzhedzheya and Sidorina, 2018; Dzhedzheya, 2019; Nikolaev et al., 2011, 2013, 2014, 2016a, 2016b; Sidorina, 2015, 2016; Chitalin et al., 2013a, 2016, 2019; Chitalin and Nikolaev, 2014), here we will limit ourselves to only the main conclusions.

AGCFs consist of a core and intermediate and outer zones, reflecting geochemical associations of varying intensity. In the AGCF contours, most secondary geochemical anomalies of copper, molybdenum, gold, and other elements have mainly linear outlines and are elongated in the meridional, northwestern, and northeastern directions, along ore-controlling faults. The most intense and large anomalies coincide with meridional tension ruptures—faults

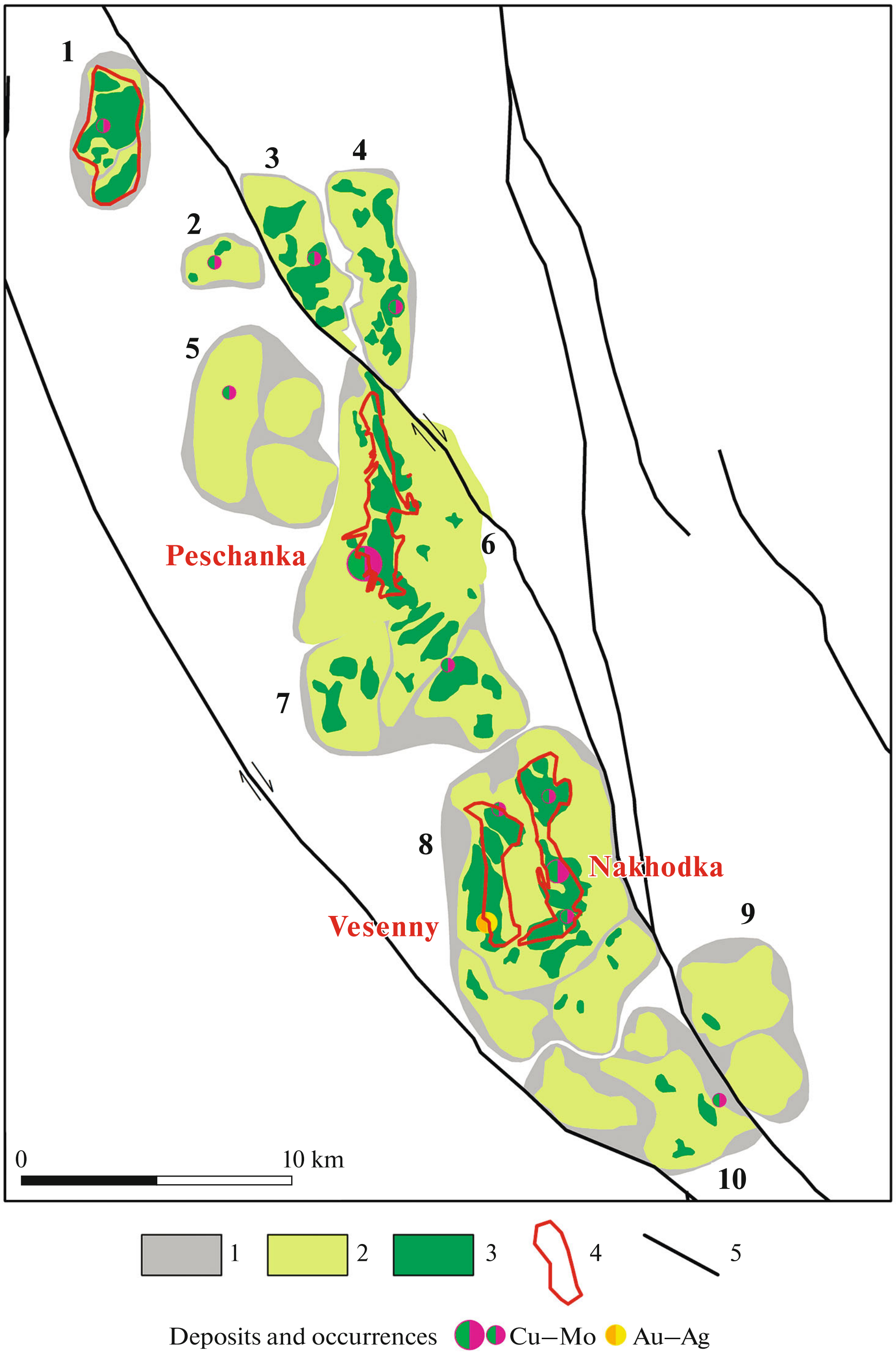


Fig. 12. Anomalous geochemical fields in the central part of the BOZ, modified after Sidorina (2016) and Dzhedzheya (2019). (1) Porphyry–epithermal systems; (2) AGCF external zone; (3) AGCF intermediate and core zones combined; (4) contours of copper-porphyry stockworks according to geological exploration results; (5) large dextral strike-slip fault of the Baimka Shear Zone (half-arrows show kinematics). The numbers indicate porphyry–epithermal systems: (1) Yuryakh, (2) Top', (3) Egdygkych, (4) Kust, (5) West Peschanka, (6) Peschanka, (7) Tallakh, (8) Nakhodka, (9) Omchak, (10) Svetly.

and strike-slips—that control ore stockworks. NE- and NW-trending anomalies coincide with faults and zones of shear-type fracturing. The contours of the explored porphyry copper stockworks of the Peschanka deposit, NOF, and smaller ore occurrences coincide with the contours of the core and intermediate zones of the AGCF.

In the BOZ, porphyry copper and associated epithermal mineralization form porphyry epithermal ore systems (PESs) (see Fig. 12). The main features of the structure of the PES are consistent with the "classical" model of a porphyry system, in the core of which Cu-porphyry mineralization is localized, while in the upper part Au ± Ag ± Cu ores are, and on the periphery of Zn–Pb–Ag–Au vein systems (Sillitoe, 2010). These types are combined differently in the BES of the Baimka zone, which is reflected in the composition and structure of their AGCF.

According to geochemical data, the Peschanka deposit is slightly eroded (Dzedzheya, 2019). The prospects for continued mineralization to depth are the highest for the Main Stockwork, moderate for the Northern and Central Stockworks. These conclusions are supported by the results of studies of fluid inclusions in quartz from various mineral associations of ore veinlets and fluorite of late veinlets of the Peschanka deposit (Nikolaev et al., 2014). Deep exploration wells on the Main Stockwork intersected economic mineralization at a depth of 700 m (Chitalin and Nikolaev, 2014).

Within the Nakhodka ore field, erosion of the Nakhodka occurrence is of medium-ore level. For the Pryamoi occurrence, an upper-middle ore erosion level is assumed. The least-preserved porphyry–epithermal system is in the area of the Third Vesenny occurrence, the erosion level of which corresponds to the lower ore one. At the Vesenny deposit, on the contrary, the upper part of the porphyry–epithermal system is widely expressed (Sidorina, 2015, 2016).

To the south of the NOF, within the Svetlinskaya PES (see Fig. 12), new promising areas have been identified where weakly eroded industrial mineralization of porphyry copper and gold–silver epithermal types is likely to be discovered. One of these areas is the Pravy Svetly occurrence, where complex lithogeochemical anomalies of copper, molybdenum, and gold were identified, and a porphyry copper stockwork with high-grade and run-of-mine ores was discovered in the true bottom of a gold placer.

CONCLUSIONS

The formation of polychronic ore mineralization of the BOZ occurred in the Early Cretaceous in the zone of NW-trending deep-seated dextral shift. The shear nature of the ore zone determined the meridional orientation and en-echelon arrangement of linear stockworks and high-grade ore lenses of deposits and occurrences in porphyry copper and porphyry–epithermal ore systems.

En-echelon extension zones in shift areas usually have a subvertical occurrence and can be traced to great depths. At the Peschanka deposit, industrial mineralization has been traced to a depth of 700 m and, based on a complex of structural–geological, geochemical, and geophysical data, is predicted to a depth of 1 km. In the Nakhodka ore field, the discovery of industrial ore bodies in blind occurrence cannot be ruled out, which is proven both by the structure of primary geochemical halos and the zoning of anomalous geochemical fields, as well as the presence of blind conductivity anomalies that may be associated with ore stockworks.

Hydrothermal ore deposition within the BOZ occurred over a wide temperature range (594–104°C) at different depths: porphyry copper 4.4–0.8 km, subepithermal 1.0–1.7 km, and epithermal ~0.7 km.

The erosion level of deposits and manifestations is different. For the Peschanka deposit, an upper-middle ore level has been established; for NOF manifestations, the erosion level varies from upper ore to lower ore. The combination of porphyry copper and epithermal types of mineralization at one deep level (Pryamoi and Vesenny sections of the Nakhodka ore field) probably indicates the uplift of the territory and erosion of the upper part of the ore system in the process of its evolution.

Prospects for the discovery of new deposits of porphyry copper ores are associated with insufficiently studied areas of the southern flank of the central part of the BOZ, where, within the Svetlinskaya PES (see Fig. 12), weakly eroded economic mineralization of porphyry copper and gold–silver epithermal types is likely to be detected.

There are areas at the junction of large shifts in the central part of the BOZ, covered by the alluvial cover of river valleys. According to the analogue tectonophysical model of the Baimka zone, zones of extension and decompression develop in areas where faults are connected, in which ore stockworks can form.

To the north of the Peschanka deposit in the Top', Egdygkych, Kust, and Luchik areas, according to drilling prospecting and evaluation works, only low-grade copper mineralization was established in linear stockworks (Chitalin and Nikolaev, 2014). However, in the Top' and Luchik areas, where gold–silver epithermal mineralization is established, industrial porphyry copper mineralization may be detected at depth (Yusupova et al., 2020).

The BOZ is comparable to the known porphyry copper zones (trends) in shift structures—Oyu Tolgoi and Erdenet in Mongolia, Pebble in Alaska, Kerman in Iran, Srednegorye in Bulgaria, etc.—within which large, giant, and supergiant gold–molybdenum–copper-porphyry deposits are concentrated. In the linear zone of the dynamic influence of the Central Sikhote-Alin, shift there is also the above-mentioned large Malmyzh porphyry gold–copper deposit, which was recently discovered in the northern part of the Sikhote-Alin orogenic belt and is comparable in reserves to the Peschanka deposit.

It appears that it was the presence of deep shift that contributed to the formation of large porphyry copper and porphyry–epithermal systems. Deeply penetrating vertical en-echelon structures of extension and shear, combined with transverse shifts, are present in the form of channels—structural traps for magmas and hydrothermal ore fluids, determining the position and shape of polychronous ore stockworks. According to some geodynamic models, large and giant porphyry copper deposits and epithermal gold deposits associated with high-K magmas are controlled by intracrustal shears formed during postsubduction or postcollisional extension of the lithosphere. Deposits are usually grouped into linear belts (trends) transverse or oblique to the subduction–collision zone and to the strike of the magmatic belt (Richards, 2009; Sillitoe, 2010; Farrar et al., 2023).

The Baimka ore-controlling shear zone was formed in the context of the completion of the Early Cretaceous subduction and collision of the Kolyma-Omolon and Anyui-Chukchi terranes. Together with the South Anyui suture, it forms a structural paragenesis of NE–SW horizontal compression.

ACKNOWLEDGMENTS

The authors are grateful to the anonymous reviewers for their comments and suggestions on the manuscript, which undoubtedly contributed to its improvement.

FUNDING

This work was supported by ongoing institutional funding. No additional grants to carry out or direct this particular research were obtained.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

REFERENCES

Baksheev, I.A., Nikolaev, Yu.N., Prokof'ev, V.Yu., Marushchenko, L.I., Nagornaya, E.V., Chitalin, A.F., Sidorina, Yu.N., and Kal'ko, I.A., Gold–molybdenum–copper porphyry epithermal system of the Baimka ore zone, West Chukotka, *Metallogeniya drevnikh i sovremennykh okeanov 2014: Mater. 20-i nauch. molodezhnoi shkoly* (Metallogen. Ancient and Modern Oceans, Proc. 20th Youth School), Miass: IMin UrO RAN, 2014, pp. 108–112.

Chitalin, A.F., Structural parageneses and ore mineralization of the Baimka shear zone, Westn Chukotka, *Rossiiskaya tektonofizika. K 100-letnemu yubileyu M.V. Gzovskogo* (Russian Tectonophysics. On 100th Anniversary of M.V. Gzovsky), Apatity: RIO KNTs RAN, 2019a, pp. 333–349.

Chitalin, A.F., Geological structural interpretation of geophysical and geochemical anomalies of the Bain ore zone, West Chukotka, *Sbornik tezisov Mezhdunarodnoi geologo-geofizicheskoi konferentsii i vystavki "GeoEvraziya 2019. Sovremennye tekhnologii izucheniya i osvoeniya nedr Evrazii"* (Proc. International Geological-Geophysical Conference and Exhibition GeoEvraziya 2019), Tver': PoliPRESS, 2019b, pp. 961–966.

Chitalin, A.F., Structure of stockworks of porphyry copper systems, *Trudy IV Mezhdunarodnoi geologo-geofizicheskoi konferentsii i vystavki "GeoEvraziya-2021. Geologorazvedka v sovremennykh realiyakh"* (Proc. 4th International Geological-Geophysical Conference and Exhibition "GeoEvraziya-2021. Geological Prospecting in Modern Realities"), Tver': PoliPRESS, 2021, Vol. 2, pp. 171–176.

Chitalin, A., Fomichev, E., Usenko, V., Agapitov, D., and Shtengelov, A., Structural model of Peschanka porphyry Cu–Au–Mo deposit, western Chukotka, Russia, *Structural Geology and Resources-2012. Bull. No. 56-2012. Symposia,* KALGOORLIE WA, 2012

Chitalin, A.F., Usenko, V.V., and Fomichev, E.V., Baimka ore zone as cluster of large non-ferrous and precious metals on the western Chukotka Autonomous Area, *Mineral. Res. Rossii. Ekon. Upravl.,* 2013a, no. 6, pp. 68–73.

Chitalin, A.F., Voskresenskii, K.I., Ignat'ev, E.K., Efimov, A.A., and Kolesnikov, A.G., Malmyzh—a new world-class large gold–copper porphyry system in Sikhote-Alin (Khabarovsk Krai, Russian Far East), *Mineral. Res. Rossii. Ekon. Upravl.,* 2013b, no. 3, pp. 65–69.

Chitalin, A.F., Nikolaev, Yu.N., Bakseev, I.A., Prokof'ev, V.Yu., Fomichev, E.V., Usenko, V.V., Nagornaya, E.V., Marushchenko, L.I., Sidorina, Yu.N., and Dzhedzheya, G.T., *Porphyry epithermal systems of the Baimka ore zone, West Chukotka, Smirnovskii Sbornik* (Smirnov's Collection of Papers), Moscow: Maks-Press, 2016, pp. 82–115. http://www.geol.msu.ru/news/smirnov_2016.pdf.

Chitalin, A.F., Agapitov, D.D., Shtengelov, A.R., Usenko, V.V., and Fomichev, E.V., Prospects of the discovery of the large gold–silver deposit at the Vesennii site of the Baimka ore zone, West. Chukotka, *Mineral. Res. Rossii. Ekon. Upravl.,* 2019, no. 2, pp. 22–29.

Chitalin, A.F., Baksheev, I.A., Nikolaev, Y.N., Djedjeya, G.T., Khabibullina, Yu.N., and Muller, D., Porphyry Cu–Au±Mo mineralization hosted by potassic igneous rocks: implications from the giant Peschanka porphyry deposit, Baimka Trend (North East Siberia, Russia), *Lamprophyres, Lamproites and Related Rocks: Tracers to Supercontinent Cycles and Metallogenesis,* Krmíček, L. and Chalapathi Rao, N. V., Eds., Geol. Soc. London: Spec. Publ., 2021. https://doi.org/10.1144/SP513-2020-178

Chitalin, A.F., Baksheev, I.A., Nikolaev, Y.N., Nagornaya, E.V., Khabibullina, Y.N., Nikolaeva, I.Yu., Kalko, I.A., and Muller, D., Porphyry-epithermal Cu–Mo–Au–Ag mineralization in the Nakhodka ore field, Baimka Trend, Chukotka, Russia: a geological, mineralogical and geochemical perspective, *Mineral. Deposita,* 2022, vol. 58, no. 1, pp. 287–306. https://doi.org/10.1007/s00126-022-01122-2

Dzhedzheya, G.T., Geochemical Zoning of the Peschanka Deposit and Criteria for Assessment of Erosion Level of Porphyry Copper Objects in the Baimka Copper District (West Chukotka), *Extended Abstract of Candidate's (Geol.-Min.) Dissertation,* Moscow, 2019.

Dzhedzheya, G.T. and Sidorina, Yu.N., The geochemical zoning of the Peschanka porphyry–epithermal system in the west of the Chukchi Peninsula, *Moscow. Univ. Geol. Bull.,* 2018, vol. 73, no. 3, pp. 254–261.

Farrar, A.D., Cooke, D.R., Hronsky, J.M.A., Wood, D.G., Benavides, S.B., Cracknell, M.J., Banyard, F., Gigola, S., Ireland, T., Jones, S.M., and Jose J. Piquer, A model for the lithospheric architecture of the Central Andes and the localization of giant porphyry copper deposit clusters, *Econ. Geol.,* 2023, vol. 118, no. 6, pp. 1235–1259.

Frolova, N.S., Kara, T.V., and Chitalin, A.F., Physical modeling of shear zones of different complexity for revealing areas of elevated fluid permeability, *Dinamik. Geol. Elektron. Nauchno-Obrazovat. Zh.,* 2019, no. 1, pp. 29–47.

Gulevich, V.V., Subvolcanic rocks and mineralization in the Bainka River basin, *Materialy po geologii i poleznym iskopaemym Severo-Vostoka SSSR* (Geol. Mineral. Resour. Northeast SSSR), Magadan, 1974, vol. 21, pp. 108–116. http://www.geol.msu.ru/news/smirnov_2016.pdf.

Kaminsky, V.G., Porphyry copper mineralization of the central part of the Baimka metallogenic zone, *Sov. Geologiya,* 1987, no. 6, pp. 49–54.

Kaminsky, V.G., Complex geological-prospecting model of the porphyry copper Baimak zone, *Sov. Geologiya,* 1989, no. 11, pp. 46–56.

Komarova, Ya.S., Kostitsyn, Yu.A., Nikolaev, and Yu.N., Age of porphyry molybdenum–copper mineralization of the Peschanka deposit, Chukotka, *VII Sibirskaya nauchno-prakticheskaya konferentsiya molodykh uchenykh po naukam o Zemle (s uchastiem inostrannykh spetsialistov): Mater. konf.* (Proc. 7th Siberian Scientific–Practical Conference of Youth Scientisis on Earth's Sciences (with Participation of Foreign Specialists), Novosibirsk: RITs NGU, 2014, pp. 138–139.

Komarova, Ya.S., Anosova, M.O., Kostitsyn, Yu.A., Nikolaev, Yu.N., and Baksheev, I.A., U-Pb age of the magmatic complexes of the Baimka ore zone, *Izotopnoe datirovanie geologicheskikh protsessov: novye rezul'taty, podkhody i perspektivy: Mater. VI Rossiiskoi konf. po izotopnoi geokhronologii* (Isotope Dating of Geological Processes: New Results, Approaches, and Prospects. Proc. 4th Russian Conf. Isotope Geochronol.), St-Petersburg: IGGD RAN–Sprinter, 2015, pp. 116–118.

Kotova, M.S., Nagornaya, E.V., Anosova, M.O., Kostitsyn, Yu.A., Baksheev, I.A., Nikolaev, Yu.N., and Kal'ko, I.A., Dating Metasomatic process and ore-bearing granitoids of the porphyry copper deposits of the Nakhodka ore field (Western Chukotka), *Geokhronometricheskie izotopnye sistemy, metody ikh izucheniya, khronologiya geologicheskikh protsessov: Mater. V Rossiiskoi konf. po izotopnoi geokhronologii* (Geochronometric Isotope Systems, Methods of their Study, Chronology of Geological Processes. Proc. 5th Russian Conference on Isotope Geochronology), IGEM RAN. M.: IGEM RAN, 2012, 181–184.

Lowell, J.D. and Guilbert, J.M., Lateral and vertical alteration-mineralization zoning in porphyry ore deposits, *Econ. Geol.,* 1970, vol. 65, pp. 373–408.

Marushchenko, L.I., Baksheev, I.A., Nagornaya, E.V., Chitalin, A.F., Nikolaev, Yu.N., Kal'ko, I.A., and Prokof'ev, V.Yu., Quartz–sericite and argillic alterations at the Peschanka Cu–Mo–Au Deposit, Chukchi Peninsula, Russia, *Geol. Ore Deposit,* 2015, vol. 57, no. 3, pp. 213–225.

Migachev, I.F., Shishakov, V.B., Sapozhnikov, V.G., and Kaminsky, V.G., Ore-metasomatic zonin of porphyry copper deposit at the Northeast USSR, *Geol. Rud. Mestorozhd.,* 1984, no. 5, pp. 91–94.

Migachev, I.F. and Shishakov, V.B., Geological–prospecting model of porphyry copper deposit, *Tr. Tsentr. Nauchn.-Issled. Geologorazved. Inst. Tsvet. Blagorod Metallov,* 1988, Vol. 223, pp. 47–53.

Migachev, I.F., Girfanov, M.M., and Shishakov, V.B., Peschanka porphyry copper deposit, *Rudy Met.,* 1995, no. 3, pp. 48–58.

Moll-Stalcup, E.J., Geochemistry and U-Pb-geochronology of arc related magmatic rocks, northeastern Russia, *Abstr. Progr. GSA,* 1995, vol. 27, no. 5, p. 65.

Nagornaya, E.V., Mineralogy and Zoning of the Nakhodka Porphyry Molybdenum–Copper Ore Field, Chukotka, *Extended Abstract of Candidate's (Geol-Min.) Dissertation,* Moscow, 2013, pp. 171.

Nikolaev, Yu.N., Dzhedzheya, G.T., Sidorina, Yu.N., and Kal'ko, I.A., Geochemical zoning of the Peschanka porphyry epithermal system (West Chukotka), *Razved. Okhr. Nedr,* 2016a, no. 11, pp.41–46.

Nikolaev, Yu.N., Baksheev, I.A., Prokof'ev, V.Yu., Nagornaya, E.V., Marushchenko, L.I., Sidorina, Yu.N., Chitalin, A.F., and Kal'ko, I.A., Gold–silver mineralization in porphyry–epithermal systems of the Baimka Trend, Western Chukchi Peninsula, Russia, *Geol. Ore Deposits,* 2016b, vol. 58, no. 4, pp. 284–307.

Nikolaev, Yu.N., Chitalin, A.F., Kal'ko, I.A., Baksheev, I.A., Sidorina, Yu.N., and Nagornaya, E.V., New geological, mineralogical, and geochemical data on the Nakhodka porphyry molybdenum–copper–system, *Electron. Sb. Mater. Mezhdunar. Molodezh. Nauchn Foruma "Lomonosov-2011"* (Electron. Proc. International Youth Scientific Formum "LOMONOSOV-2011). http://geo.web.ru/db/msg.html?mid=1186049&uri=nikolaev.html.

Nikolaev, Yu.N., Prokof'ev, V.Yu., Baksheev, I.A., Chitalin, A.F., Marushchenko, L.I., and Kal'ko, I.A., The first data on the zoned distribution of fluid inclusions in the ore-forming system of the Peschanka gold-copper porphyry deposit (northeast Russia), *Dokl. Earth Sci.,* 2014, vol. 459, no. 2, pp. 1615–1618.

Nikolaev, Yu.N., Sidorina, Yu.N., Kal'ko, I.A., Apletalin, A.V., Prokof'ev, V.Yu., and Chitalin, A.F., Geochemical fields of porphyry epithermal systems, their interpretation, and assessment of modern geological and genetic concepts, *Razved. Okhr. Nedr,* 2013, no. 8, pp. 45–50.

Petrov, O.V., Shatov, V.V., Khanchuk, A.I., Ivanov, V.V., Zmievskii, Yu.P., Shpikerman, V.I., Petrov, E.O., Snezhko, V.V., Shmanyak, A.V., Molchanov, A.V., Khalenev, V.O., Shatova, N.V., Rodionov, N.V., Belyatsky, B.V., and Sergeev, S.A., On prospects of discovery of the new Malmyzh type porphyry gold–copper deposit, Lower Amur region (Russian Far East), *Regional. Geol. Metallogen.,* 2023, no. 94, pp. 75–112.

Richards, J.P., Post-subduction porphyry cu-au and epithermal Au deposits—products of remelting of subduction modified lithosphere, *Geology,* 2009, vol. 37, pp. 247–250.

Shapovalov, B.C., Composition and Conditions of Formation of the Gold–Silver and Copper–Molybdenum Mineralization of the Baimka Area (West Chukotka), *Extended Abstract of Candidate's (Geol.-Min.) Dissertation,* Irkutsk: Irkutskii Politekhn. Inst., 1985.

Shapovalov, B.C., Some geochemical features of ores of the Baimka cluster, *Rudnye Formatsii Severo-Vostoka SSSR* (Ore Formations of Norheast USSR), Magadan: SVKNII DVO AN SSSR, 1990, pp. 162–170.

Shavkunov, B.N., Application of geophysical and geochemical data on outlined ore fields within the Baimka gold cluster, *Geokhimicheskie metody poiskov mestorozhdenii zo-*

lota po vtorichnym oreolam rasseyaniya (Geochemical Methods of Searching Gold Deposits Based on the Secondary Dispersion Haloes), Chita: Zabaikal. fil. geograf, ob-va SSSR, 1973, vol. 88.

Sidorina, Yu.N., Geochemical Criteria for Revealing and Assessment of Porphyry Copper Mienralization in the Baimka Copper Ore Zone (West Chukotka), *Extended Abstract of Candidate's (Geol.-Min.) Dissertation,* Moscow, 2016.

Sidorina, Yu.N., The geochemical zoning of the Nakhodka porphyry–epithermal system (west Chukotka), *Moscow Univ. Geol. Bull.,* 2015, vol. 70, no. 2, pp. 152–158.

Sillitoe, R.H., Porphyry copper systems, *Econ. Geol.,* 2010, vol. 105, pp. 3–41.

Sokolov, S.D., Tuchkova, M.I., Ganelin, A.V., Bondarenko, G.E., Layer, P., Tectonics of the South Anyui suture, Northeastern Asia, *Geotectonics,* 2015, vol. 49, no. 1, pp. 3–26.

Soloviev, S.G., *Metallogeniya shoshonitovogo magmatizma* (Metallogeny of Shoshonite Magmatism), Moscow: Nauchnyi mir, 2014.

Soloviev, S.G., Kryazhev, S.G., Dvurechenskaya, S.S., Vasyukov, V.E., Shumilin, D.A., and Voskresensky, K.I., The superlarge Malmyzh porphyry Cu–Au deposit, Sikhote-Alin, eastern Russia: igneous geochemistry, hydrothermal alteration, mineralization, and fluid inclusion characteristics, *Ore Geol. Rev.,* 2019, vol. 113, paper 103112, pp. 1–27.

Volchkov, A.G., Sokirkin, G.I., and Shishakov, V.F., Geological structure and composition of the Anyui porphyry copper deposits of Northeast USSR, *Geol. Rudn. Mestorozhd.,* 1982, no. 4, pp. 89–94.

Volkov, A.V., Savva, N.E., Sidorov, A.A., Egorov, V.N., Shapovalov, V.S., Prokof'ev, V.Yu., and Kolova, E.E., Spatial distribution and formation conditions of Au-bearing porphyry Cu–Mo deposits in the northeast of Russia, *Geol. Ore Deposits,* 2006, vol. 48, no. 6, pp. 448–472.

Yusupova, A.V., Baksheev, I.A., and Koshlyakova, N.N., Metasomatites and ore mineralization of occurrences of the northern flank of the Baimka ore zone (West Chukotka), *Geol. Razved.,* 2020, vol. 63, no. 4, pp. 27–37. https://doi.org/10.32454/0016-7762-2020-63-4-27-37