# STRATIFORM AND STRATABOUND ORE Mineralization OF SOUTH SEGMENT OF THE KOLYMA STRUCTURAL LOOP (NORTHEASTERN RUSSIA)

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**ABSTRACT**

Important stratiform and stratabound ore mineralization occurs in the central part of Northeastern Russia in the Kolyma River basin and Chersky mountain system. The main occurrences of stratiform and stratabound ores are closely associated with an extension zone at the juncture of Yana-Kolyma and Alaseya-Oloy fold systems which marks the suture between the ancient Eurasian continent and Paleo-Pacific Ocean (the Kolyma structural loop). Extreme lateral sedimentary and magmatic rock variations, complex folding and numerous thrusts characterize this zone. The polar sea coast of Chukotka, Wrangel Island belong to ancient North America and may represent the other side of this closed ocean basin. The following types of stratiform and stratabound mineral deposits are recognized and described for south segment of the Kolyma structural loop: sedimentary Fe, sedimentary Mn, sandstone- and shale-hosted Cu, carbonate-hosted Pb-Zn (Mississippi Valley type), volcanic-associated massive sulphide, bedded Pb-Zn-barite, scheelite-sulphide ores in greenschist(similar to Austrian Alps), and Cu-bearing basalts. The variety of deposits partly reflects the diversity of geodynamic environments and the large time interval represented. Tectonic settings include passive continental margins, volcanic island arcs and divergent plate boundaries. The stratigraphic range of stratiform and stratabound ore mineralization extends from Late Proterozoic to Late Jurassic. Mineralization is absent only from Triassic and Lower Jurassic sediments.

## INTRODUCTION

Important data has been the recently obtained on stratiform and stratabound ore mineralization for south segment of the Kolyma structural loop in the central regions of northeastern Russia, including the Kolyma River basin and northeastern spurs of the Chersky mountain system (Figure 1). Understanding of the metallogeny of these types of deposits in this remote region remains incomplete.

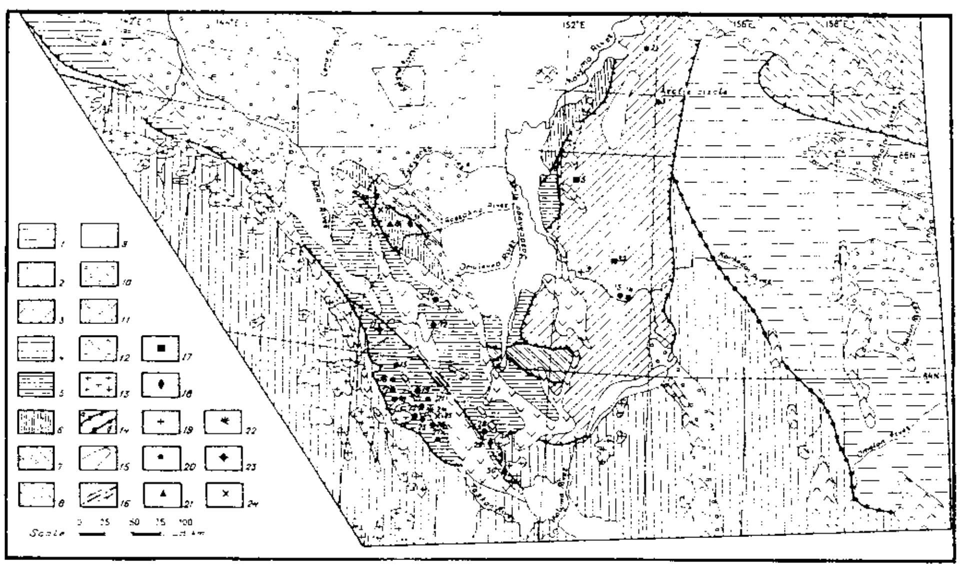

Fig. 1. The map of central regions of Northeastern Russia showing the location of tectono-stratigraphic terranes, post-accretionary structures and the main stratiform and stratabound deposits. *Eurasian paleocontinental margin terranes (Yana-Kolyma fold system)*: 1 - Omolon cratonal terrane; 2 - Inyali-Debin flysch terrane; 3 - Prekolyma shelf terrane; Chersky-Polousny superterrane: 4 - Tas-Khayakhtakh shelf terrane, 5 - Omulevka (Taskan) shelf terrane; *island arc, marginal-marine, and ophiolite accretionary terranes of Alazeya-Oloy ocean-marginal Paleo-pacific basin*: 6-7 - Rassokha terrane; 6 - Bulkut subterrane, 7 - Argatas subterrane; 8 - Oloy terrane; *post-accretionary*: 9 - Cenozoic sedimentary troughs, 10 - Late Jurassic-Early Cretaceous marine and continental deformed sedimentary troughs; 11 - Uyandina-Yasachnaya volcanic belt ($J_2$-$K_1$); 12 - Okhotsk-Chukchi volcanic belt ($K_{1-2}$); 13 - Granitoid bodies of Kolyma plutonic belt; 14 - terrane boundaries (a-thrusts, b-steeply dipping faults); 15 - stratigraphic and intrusive contacts, 16 - large post-accretionary wrench faults; *types of stratiform and stratabound deposits*: 17 - sedimentary Fe, 18 - sedimentary Mn, 19 - Cu sandstones and shales, 20 - carbonate-hosted Pb-Zn (Mississippi Valley type), 21 - massive sulphide volcanic-hosted Pb-Zn, 22 - bedded barites, 23 - green slate-hosted scheelite-sulphide ores (Austrian Alps type), 24 - Cu basalts.

The stratiform and stratabound ores are hosted by the Yana-Kolyma (Fig. 1:1-5) and Alazeya-Oloy (Fig. 1:6-8) fold systems, identified by Shilo et al.(1976). The Yana-Kolyma system represents the ancient margin of the

Eurasian continent and the Alazeya-Oloy system represents an ancient ocean basin herein called the Paleo-Pacific Ocean. Abrupt sedimentary and magmatic facies changes, complex folding, and numerous thrusts characterize the boundary between the two fold systems.

## TECTONIC FRAMEWORK OF THE TERRITORY

Northeastern Russia is comprised of a series of fault-bounded (primarily thrusts) tectono-stratigraphic terranes each of which is characterized by specific stratigraphy, magmatic suites, metallogeny and deformational history (Fig. 1). The ancient Eurasian continental margin includes several terranes which formed by Paleozoic rifting. Oceanic terranes represent the Paleo-Pacific Ocean and include elements of volcanic island arcs and the Alaseya-Oloy ocean floor. Analysis of composition of strata, paleofauna communities, and lateral facies changes has shown that most of the terranes influenced each other during the history of their geological development.

The oceanic terranes were accreted to the ancient margin of the Eurasian continent. The boundary between the continental and oceanic rocks forms a huge crudely triangular loop (the Kolyma structural loop) which can be traced northwestward almost to the mouth of the Lena River and then eastward to the mouth of the Kolyma River where it abruptly turns south. Most of the occurrences described here are near the southeastern corner of this loop where southeast-directed structures and south-trending structures intersect at an acute angle.

The following short description of terranes in order from the paleocontinent towards the paleo-ocean serves to define the tectonic environments in which the stratiform and stratabound deposits formed.

### *Omolon Terrane*

The Omolon cratonal terrane (Fig. 1:5) is divided into two structural complexes: Pre-Riphean crystalline basement and cover. Basement consists of strongly metamorphosed Archean rocks: crystalline schists, amphibolites, granulites and ferruginous quartzites. The cover consists of Riphean sedimentary and volcanogenic rocks; Ordovician carbonate shelf sediments; Devonian subaerial, mostly felsic volcanic rocks; and Permian, Jurassic, and Jurassic terrigenous shallow-water sediments. Relatively thin stratigraphic units (tens to hundreds of meters), numerous stratigraphic breaks and subhorizontal bedding characterize the cover (Terekhov et al, (1979) and distinguish the Omolon terrane from the other terranes described here, in which great thickness of sedimentation (up to several km) and lot of folds are typical.

### *Inyali-Debin terrane*

The Inyali-Debin terrane (Fig. 1:2) in Russian literature, is named after the Inyali-Debin synclinorium. It is a large arcshaped structure characterized by great thickness of flysh sediments up to 12 km thick and intense folding. They are represented mainly by thin-bedded terrigenous shale, siltstone, and argillite, but also include grit, sandstone, and tuff. Rhythmic flishoid bedding is common in the upper parts of this stratigraphic sequence and suggests that these sediments were deposited as turbidites in a deep marine environment, probably a riftogenic trough (Chekhov, 1990).

### *Prekolyma Terrane*

The Prekolyma terrane (Fig. 1:3) consists of the central and eastern parts of an uplift of the same name. Paleozoic rocks located to the west of the Prekolyma terrane are a part of the Prekolyma uplift according to accepted Russian tectonic terminology. The western terrane boundary is marked by a metamorphic belt which contains the most ancient rocks of the area (Shishkin, 1979). They are represented by schist and granitoid gneiss of Lower Riphean(?) age. Unconformable overlying them is a slightly metamorphosed series of shallow water sandstones, limestones and delimits about 5000 m thick and Middle-Upper Riphean in age. They are in turn overlain disconformably by unmetamorphosed clastic and carbonate sediments about 2200 m thick, and Vendian and Cambrian age. The Lower and Middle Ordovician and Devonian are represented by essentially calcareous, shelf sediments of 1000 m and 2500 m, thickness, respectively. The Upper Ordovician and Silurian are completely absent from the stratigraphic section. Sandstones, tuffs and cherty rocks are predominant in the Upper Devonian section. Rift-related basalts and tuffs also occur. The Permian, Triassic and Lower Jurassic deposits are mainly marine clastics: mudstones, siltstones and sandstones with a total thickness of about 1300 m. Upper Permian and younger deposits overlie the Devonian and Carboniferous rocks with small angular disconformity in the northeastern part of the terrane. The greater part of the Paleozoic and Early Mesozoic sequence was deposited as a passive margin to the Omolon cratonal block. This passive margin acquired characteristics of an active margin only at the Riphean-Vendian boundary, in Late Ordovician-Silurian, Late Permian and Late Mesozoic.

### *Chersky-Polousny Superterrane*

A chain of horst-shaped uplifts consisting of mainly Paleozoic shelf carbonates (Chersky-Polousny superterrane; Fig. 1:4-5) is located southwest of the southern end of the Prekolyma terrane. The Omulevka (Taskan) terrane (Fig. 1:5), first recognized as structural zones by Merzlyakov (1971), contains the most complete and typical sequence. A series of Ordovician, Silurian, and Devonian carbonates up to 1200 m thick overlies a basement of metamorphosed Riphean-Cambrian rocks. Ordovician and Silurian shelf carbonate strata change laterally to thinly bedded calcareous to argillaceous flysh and turbidites of the continental slope in the northeastern part of the terrane. Givetian sediments contain trachybasalt lava sheets of possible riftogenic origin. Upper Devonian to the Middle Jurassic sediments are mainly black argillaceous shales, cherty rocks, mudstones and siltstones locally alternating with carbonates and tuffs.

### *Omulevka terrane*

The stratigraphic character of the Omulevka terrane indicates that it was a passive miogeoclinal trough on the margin of the Siberian craton during the early Paleozoic. The region on the east of the Siberian craton underwent compression at the end of Ordovician and Late Silurian time. Consequently, redbeds, belts of dislocation, thermal metamorphism, stratigraphic breaks, and structural unconformities appeared. Significant rifting began in the Givetian (Middle Devonian) and continued until the end of the Early Mesozoic, resulting in considerable northeastward separation of Chersky-Polousny superterrane (including Omulevka) from the Siberian craton. By Late Mesozoic time the superterrane was displaced a considerable distance to the southwest as indicated by numerous Pre-Bathonian and later thrusts with northeastern dip.

### *Rassokha Terrane*

Rassokha terrane (Fig. 1:6-7) was described as a structural zone within the Alaseya-Oloy eugeosyncline by Merzlyakov (1971). Rassokha terrane as presently defined differs from the latter by the presence, in different parts of the sequence, of basaltic associated with both deep and shallow-water sediments. Cambrian ophiolitic clastic rocks were found as basement to the terrane (Shpikerman, Merzlyakov, 1988). Overlapping Ordovician sediments (5000 m thick) are composed mainly of black siliceous to argillaceous graptolitic shales and shoshonitic volcanic rocks. Silurian deposits are missing and marine Devonian carbonates and shales of 3800 m total thickness overlie the Ordovician sediments with angular unconformity. In the northeast part of the terrane, Devonian deposits are represented by deep-water volcanic basalt and rhyolite association. Sediments of Upper Paleozoic and Lower Mesozoic age up to 6000 m thick have a volcanogenic-siliceous-terrigenous composition in general. The differences between the southwestern and northeastern parts of the Rassokha terrane make it possible to define two subterranes, Bulkut and Argatas, respectively (see Fig. 1:6,7). The character of strata, magmatic associations and total terrane zonation allow a reconstruction of several environments, including marginal spreading sea (Cambrian), volcanic island arc (Ordovician and perhaps Silurian), passive continental margin shelf (Devonian), and riftogenic ocean (Devonian to Triassic).

The modern tectonic picture of the Rassokha terrane is defined as a series of imbricate slices, complicated by mainly isoclinal folds. Composition of slices shows that they are fragments of an ancient ocean margin and the oceanic Alazeya-Oloy basin within the Paleo-Pacific, emplaced by accretion. However, the accretion was not single stage. The existence of a pre-Devonian structural unconformity extending over part of the Omulevka terrane shows that separate oceanic elements were joined in Silurian time. The main accretionary stage occurred in the Late Mesozoic.

A sequence of Ordovician and Devonian beds similar to those described in the previous paragraph is exposed on the north bank of the Kolyma River. A large block of Upper Paleozoic sedimentary and volcanogenic strata is known in the Upper Yasachnaya River (See Fig.1). It is proposed herein that these blocks of Paleozoic rocks localized in the western part of Prekolyma terrane are mostly oceanic fragments of the Alazeya-Oloy oceanic paleobasin.

### *Oloy Terrane*

The Oloy terrane, located in the northeastern corner of the map in Fig. 1 (i.e. 1:8) is an element of the Alazeya-Oloy oceanic paleobasin. Folded Upper Devonian, Carboniferous, Permian, Triassic and Lower Jurassic chert, volcanogenic, and clastic deposits form the terrane.

### *Overlap Assemblages*

The folded strata of Archean to Lower Mesozoic age of all previously described terranes are overlain with sharp angular unconformity by Middle to Upper Jurassic and Cretaceous marine and continental deposits: mainly volcanic of various compositions, alternating with clastic sedimentary rocks. The Middle Jurassic-Early Cretaceous Uyandina-Yasachnaya volcanogenic belt is most important (Fig. 1:11). The rock associations in the belt indicate deposition in continental margin volcano-plutonic arcs, marginal seas and small riftogenic oceans. Regional magmatic zonation of belt appear to reflect, in part, substratum zonation. A possible tectonic environment similar to that of the modern California margin of North America is proposed.

## CLASSIFICATION AND DESCRIPTION OF DEPOSITS

The most important occurrences of stratiform and stratabound ore mineralization of central regions of northeastern Russia are in the Prekolyma, Omulevka, and Rassokha terranes, and in the Uyandina-Yasachnaya volcanogenic belt (Figs. 1,2). Studies by the author of geology and ore composition of stratified deposits established the distinction between the following types: 1 - sedimentary Fe, 2 - sedimentary Mn, 3 - Cu-bearing sandstones and shales, 4 - carbonate-hosted Pb-Zn (Mississippi valley type), 5 - volcanogenic massive Pb-Zn sulphides, 6 - bedded barite, 7 - scheelite-sulphides in greenschists (Austrian Alps type), 8 - Cu-bearing basalts. Representatives of each type are described below.

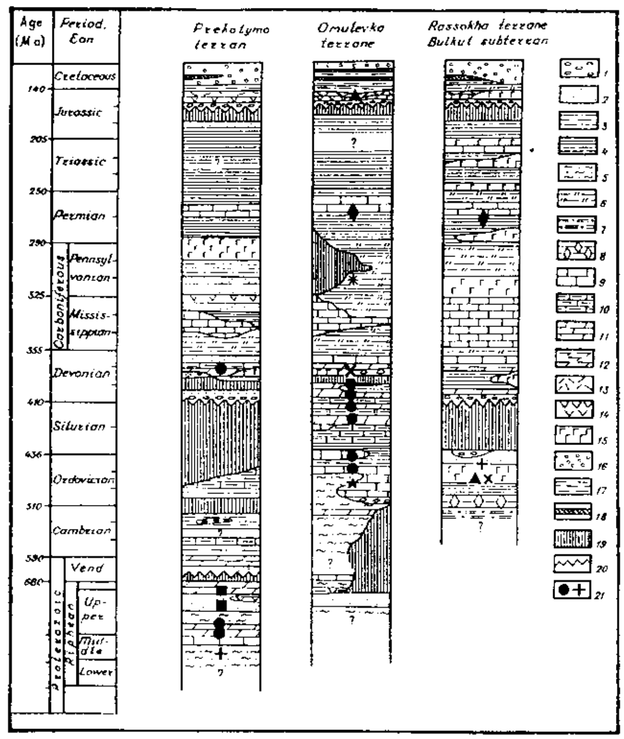


Fig.2 Chronostratigraphic and lithological position of stratiform and stratabound mineralization in some terranes of central regions of Northeastern Russia. *Marine sedimentary rocks*: 1 - conglomerates; 2 - sandstones; 3 - siltstones; 4 - shales; 5 - metamorphose siltstones, sandstones and shales (green slates); 6 - siliceous rocks; 7 - ophiolitic clastics; 8 - chaotic breccias (olistostrome sediments); 9 - limestones; 10 - argillaceous limestones; 11 - dolomites 12 - sulphate (gypsum and anhydride); *marine volcanogenic and volcanogenic-sedimentary rocks*: 13 - rhyolites, dacites and their tuffs; 14 - andesites and their tuffs; 15 - basalts and their tuffs; *subaerial sediments*: 16 - rudaceous; 17 - argillaceous; 18 - carbon-bearing; 19 - sediments eroded or did not accumulate; 20 - structural unconformities; 21 - types of stratiform and stratabound deposits (See Fig.1).

### *Prekolyma terrane*

Cu-bearing sandstones and shales in the Prekolyma terrane are known only in the most ancient metamorphosed rocks (Fig. 1:19 and Fig. 2). The Oroek deposit (9[1]) is confined to the formation of the same name of Middle Riphean(?) age. The Oroek Formation is about 3000 m thick and composed of metamorphosed quartz sandstones and greywacke, siltstones and red-colored mudstones, and minor basalt bodies and tuffs. Layers of copper-bearing rocks are mainly schistose metasiltstones and sandstones with thin disseminations and lenses of chalcocite and hematite. Small quartz lenses containing large aggregates of bornite are also common. Copper-bearing strata are 1 to 2 m thick; veins are 0.2 to 1.0 m thick. The copper content in is 2-6%.

Carbonate-hosted Pb-Zn ores (Mississippi valley type) occur at two stratigraphic levels within the Prekolyma terrane: in the Chebukulakh Formation of Middle-Upper Riphean age, and in the Yarkhodon Formation of Middle Devonian age (Fig. 1:20 and 2). The Chebukulakh formation is about 1000 m thick and consists mainly of stromatolitic limestone, delimits and carbonate-chlorite slates. The upper part includes quartzite interbedded with chlorite slates. The Chebukulakh ore occurrences (13) are confined to a stratum of gray, thinly laminated and brecciated delimits. The ore mineralization is mainly sphalerite and lesser galena. The sulphides impregnate

[1] Numbers in brackets correspond to the numbers of occurrences in Figure 1.

the matrix and clasts of dolomite breccias. The Romashka ore occurrences (14) occur in quartzite beds of the upper part of Chebukulakh Formation, and consist of galena and sphalerite-bearing carbonate-quartz veinlets.

The Yarkhodon Formation consists of dark grey delimits and dolomitic limestones with numerous fossils of Givetian brachiopods. It hosts Pb-Zn mineralization (2,3 and others) intermittently in the northern part of the Prekolyma terrane. Between one and seven concordant mineralized horizons with thickness from 0.4 to 10 m (Fig. 3) have been recognized in ore occurrences (Davydov et al., 1988). The ores usually are dolomite breccia with calcite-barite-sulphide matrix and sulphide impregnation in breccia clasts. The main ore minerals are galena, sphalerite and pyrite.

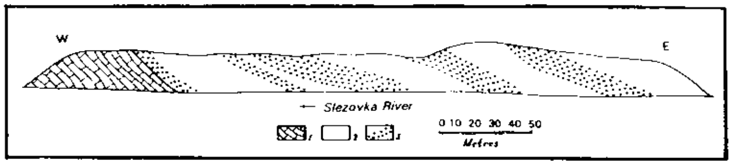


Fig.3 Schematic section of Givetian Yarkho-don Formation fragment on the north bank of Slezovka River (2) (according to the data of A.V.Artemov).
1 - limestones; 2 - delimits and dolomitic rhythmites; 3 - horizons with impregnated lead-zinc mineralization.

Sedimentary Fe deposits are widespread in the Prekolyma terrane (15, 32 and many others). They are hosted by the sediments of the Upper Riphean (Upper Proterozoic) Spiridonova Formation with total thickness of 2000 m. The formation is represented mainly by quartz and feldspar-quartz sandstones with clastic grains of hematite, magnetite, ilmenite and zircon attaining concentrations of 50-60. Some varieties of these deposits contain up to 12% $TiO_2$. The ferruginous sandstones formed in shallow water environments, as clearly indicated by cross-bedding and wave-cut ripple structures. Some authors distinguish tillites interbedded with these sediments (Furduy, 1968). However, reliable evidence of ancient glacial activity are absent. Delimits of the overlying Upper Riphean Gorbunova Formation locally contain hematite. Hematite cements the fragments of carbonate breccias and was probably derived from the underlying sedimentary deposits. Chemical-sedimentary carbonate ores also occur. Gelman et al.(1974) proposed that Archean ferruginous quartzites (jaspilites), which form the basement of the Omolon cratonal block, were the source of iron minerals in Riphean sediments.

### *Omulevka terrane*

Scheelite-sulphide ores in greenschists (Austrian Alps type) occupy the lowest stratigraphic levels in the Omulevka terrane (Fig. 1:23). They are confined to the Middle Ordovician Krivun Formation, which comprises rhythmically alternating carbon-bearing calcareous siltstones, limestones and calcareous argillites. The rocks are metamorphosed to greenschist facies. The famous Omulevka ore occurrence is located in the core of a large anticline (Fig. 4). The ore mineralization is mainly scheelite and pyrite, plus antimonial realgar, orpiment, galena, and chalcopyrite. Streaky ores are localized in thin, concordant bed-shaped deposits, which have undergone a complex dislocation together with host rocks. Magmatic rocks are absent in the occurrence with the exception of some small sills of metadiabase. Ore mineralization is proposed to have formed during metamorphism as a result of mobilization of host rocks with primary tungsten enrichment.

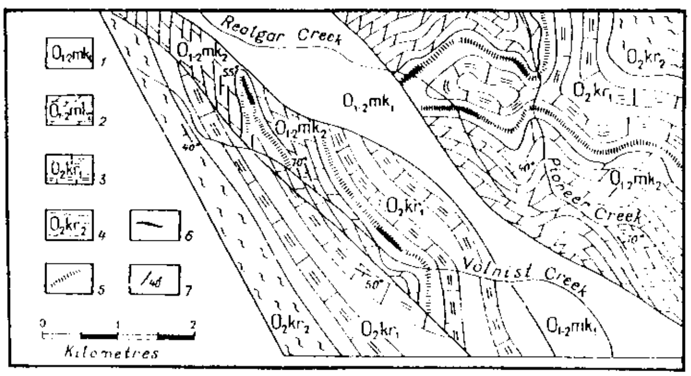


Fig.4. Schematic geologic map of Omulevka tungsten ore occurrence (11)
Mokry Formation of Lower-Middle Ordovician: 1 - lower band (phyllites, schistose siltstones and argillites), 2 - upper band (argillaceous limestones); Krivun Formation of Middle Ordovician: 3 - lower band (limestones, carboniferous argillaceous shales), 4 - upper band (marls, phyllites); 5 - horizons with sulphide-scheelite mineralization, 6 - zones with high grade scheelite, 7 - bed orientation.

Carbonate-hosted Pb-Zn (Mississippi Valley type) within the Omulevka terrane is represented by numerous deposits and ore occurrences (10, 12, 15-22, 26, 27 and others). At present, they are known at six stratigraphic levels (see Fig. 2): in the Minutka Formation of Llandeilian age(late Middle Ordovician), at the top of the Terekhtayakh Formation of Upper Ordovician age, in the upper parts of the Bizon Formation of Ludlovian age (early Late Silurian), in the Mirney Formation of Przidolian age (late Silurian), in Lower Devonian delimits of the Bitumen and Snezhnyi Formations (upper parts of Pragian and Upper Emsian stages). From one to six concordant mineralized horizons are established within each of the specified stratigraphic datums. In contrast to the similar Prekolyma terrane deposits, one of the main ore components is fluorite instead of barite.

The Bitum-Sdvig (16) deposit was studied in detail. Most of its orebodies are confined to a 240 m thick interval of Upper Emsian massive delimits (Fig. 5). From three to six ore horizons with thicknesses of several meters and with strike lengths of one kilometer or more were discovered by prospecting. They are bedding-concordant bodies which are steeply inclined (60 - 80°) at the fold limbs, and occupy fold cores. Rich ores form irregular lenses and pockets within lower grade disseminated mineralization. Average grades of high grade mineralization are 3.55% Pb, 3.90% Zn and 10 % Fl. Higher grade material contains germanium. Host rocks are dark gray thinly crystalline delimits of diagenetic origin. "Zebra-dolostones" and dolomitic breccias are widespread in the host rocks. The main ore minerals are galena, sphalerite, fluorite and rarely pyrite. They are commonly associated with coarsely crystalline calcite and anthraxolite. Quartz is rare. Ore morphology testifies to its epigenetic origin. Orebodies are accompanied by halos of dissemination in both footwall and hanging wall. The homogenization temperature of gas-fluid inclusions in fluorite and sphalerite is 100-260° C. The formation of mineralization probably is connected with hydrothermokarstic processes in a Paleozoic paleoartesian thermal oil-bearing basin.

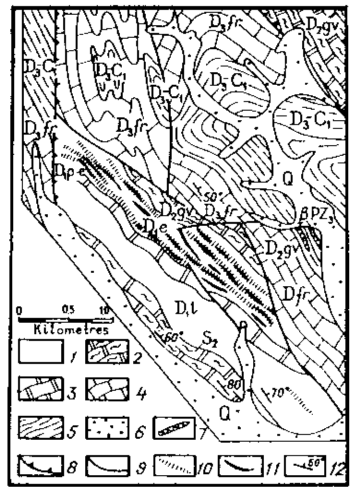


Fig.5. Schematic geologic map of the Bitum-Sdvig stratabound fluorite-lead-zinc deposit (16).
1 - diagenetic delimits of Lochkovian ($D_1$) and Upper Emsian ($D_1e$) 2 - dolomitic marls of Upper Silurian ($S_2$) and Givetian ($D_2gv$); 3 - partly dolomitized limestones of Pragian-Lower Emsian ($D_1p$-e); 4 - Frasnian limestones ($D_3$); 5 - siltstones, argillaceous and siliceous shales of Upper Devonian-Lower Carboniferous($D_3$-$C_1$); 6 - unconsolidated Quaternary sediments; 7 - diabasic sills of Late Paleozoic age($Pz_3$); 8 - thrusts; 9 - other faults; 10 - fluorite-lead-zinc-bearing horizons; 11 - lenses of high grade fluorite-lead-zinc; 12 - bed orientation.

Cu basalts (Fig. 1:27) within the Omulevka terrane are insignificant and known only at the bottom (200 m thick) of the Givetian Mylga Formation. Cu-bearing basalts as well as red colored marls and sandstones were deformed into simple folds. Disseminated bornite, chalcocite and covellite are confined to the tops of subalkaline amygdaloidal basaltic lava flows. Mineralized flow-tops are 1-3 m thick. Cu grades are 1.5-3.5%. Metasomatic changes in mineralized basalts are represented mainly by epidosites. Silver and barium are associated with the copper.

Bedded barite (Fig. 1:22) deposits are known within Carboniferous siliceous rocks and black shale of the Bat'ko and Kiprey Formations. The Prizovoye deposit (24) is a steeply dipping bed of massive white barite 30 m wide with extent of more than 300 m. Relict bedded occurs in the center of the barite body, but textures at the margin indicate lit-par-lit metasomatic replacement of host rocks. Barite-bearing siliceous shales and siltstones are strongly deformed, contain numerous interbedded bodies of Late Paleozoic diabase, and are characterized by anomalously elevated geochemical backgrounds of manganese, zinc, copper, silver, barium and phosphorus. The barite strata probably represent the distal facies of sedimentary exhalative Ba-Pb-Zn-Ag deposits ("Red Dog" type) in siliceous shales. The latter are not yet recognized within the Omulevka terrane.

Sedimentary Mn ores (Fig. 1:18) (29,30) are confined to lower parts of the Upper Permian Turinsk Formation in the southern part of the Omulevka terrane. The formation is 400-750 m. thick and composed of biogenic limestones, shales, cherts, tuffaceous sandstones. The Mn-bearing interval is 150-200 m thick and consists of varicolored (raspberry, green, black) shales and cherts, interbedded with siltstones, tuffaceous sandstones and biogenic limestones. According to the data of L. I. Belyayev, who conducted the prospecting of the deposit in 1943-1944, orebodies form concordant lenses up to 5 m thick, and 7 m. The lenses occur at several horizons. The structure of the ore is bedded, and locally oolitic and spherulitic. Rhodochrosite (up to 63%) is the main ore mineral; pyrolusite, rhodonite, ankerite and barite occur in lesser amounts. Near Late Mesozoic granitoid intrusions, the manganese-bearing sediments are metamorphosed and contain piedmonite, apatite and quartz. Pyrolusite, psilomelane, vernadite and limonite are developed in oxided supergene zones. The content of MnO in primary ores is 2.5 to 65%; in oxidized ores it reaches 57%.

*Rassokha terrane*

Volcanic-associated massive sulphide Pb-Zn ores in the Rassokha terrane are known in the Bulkut Formation of Llandeilian age (Merzlyakov and Shpikerman, 1985). The formation, with a thickness of 1000 m, is composed of submarine tuffs, tuff-breccias and lavas of trachybasalts and trachytes with interbeds and lenses of conglomerates, argillaceous and siliceous to argillaceous graptolitic slates and siltstones. Numerous beds and veins are located near the well-studied Dogor ore occurrence (8). Several contiguous small beds of massive sulphide ores occur between blue trachyte tuffs. Quartz-carbonate-sulphide veins 2 cm to 1 m thick cross trachyte flows which are located stratigraphically above the blue trachyte tuffs. The main ore minerals are pyrite, galena, sphalerite, marcasite and pyrrhotite. Chalcopyrite and magnetite are less common. Typical grades are 4-10% Pb, 1.3-3% Zn, and 0.0014-0.0028% Ag. The ore formation had two stages: iron sulphide aggregates with a kidney-like colloform texture predominate in early mineral assemblages of bedded ore bodies; galena and sphalerite predominate in late mineral assemblages. The classification of this mineralization as volcanogenic massive sulphide is problematic since their associated volcanic rocks are shoshonites. Possibly a new variety of this type deposit is involved.

Cu basalts of the Rassokha terrane grade laterally into basaltoids of the same age associated with the massive sulphide lead-zinc ores described above. The Bulkut Formation of Llandeilian age is represented in the Agyndza copper-bearing region by shallow-water facies consisting of red-colored potassium trachybasalts, trachyandesite-basalts and trachytes. Lava flows with thickness of 10-30 m alternate with tuffs, limestones, red-colored conglomerates and sandstones. The sedimentary rocks, particularly the sandstones are also Cu-bearing throughout the sequence (Fig. 6). Thus, copper sandstones are present in the Ordovician sediments of Rassokha terrane in association with Cu basalts. The total thickness of Cu-bearing strata is about 1000 m.

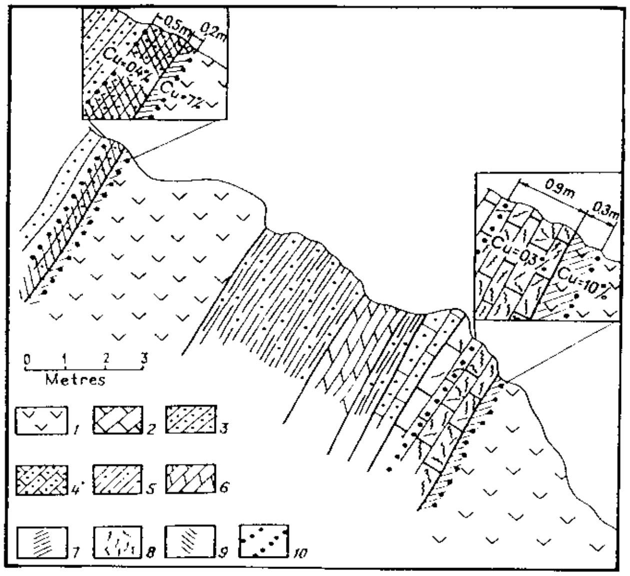


Fig.6. Partial section through the Agyndzha deposit (?) showing stratigraphy and Cu concentration.
1 - amygdaloidal trachybasalts; 2 - limestones; 3 - volcanomictic sandstones; 4 - calcarenites; 5 - red-coloured siltstones; 6 - green-colored marls; types of sulphide mineralization: 7 - bornite impregnations in matrix and amygdules of trachyandesitic basalts; 8 - veinlets in limestones; 9 - cuprous sandstones; 10 - conventional boundaries of mineralized strata.

Copper in basaltic lavas occurs in several forms. Disseminated ores in amygdaloidal trachybasalts are the most widespread. Cu sulphides (mainly bornite) are localized in the upper part of lava flows, 1 to 1.5 m from the top. They are dissemination in the matrix and partly fill amygdules. In some cases Cu minerals are also in volcaniclastic rocks. In trachyte flows streaky disseminations of bornite and chalcopyrite occur in and adjacent to numerous calcite veinlets. Streaky, disseminated mineralization, according to the data of A. P. Kropachev et al. (1988) is also present in subvolcanic syenite porphyry intrusions. In addition, Cu-bearing calcite-quartz-sulphide lodes are also widespread in the Agyndzha region. In summary, shoshonitic magmatic rocks contain copper mineralization both in basaltic flows and in subvolcanic porphyries.

Cu-bearing sandstones commonly overlie Cu-bearing basalts and form composite stratified orebodies (see Fig. 6). The main volume of Cu sandstone is in the upper part of the Ordovician Cu-bearing series. Some mineralized strata attain thickness of 28 m, however, the Cu contents in sandstones are typically 0.3-0.6 %. As in the basalts, the ore mineral assemblage is bornite, chalcopyrite and chalcocite. The sulphides are localized as veinlets and massive aggregates. Clastic fragments of Cu sulphide and mineralized rocks also occur.

Sedimentary Mn in the Rassokha terrane occurs at the same Upper Carbonaceous-Permian stratigraphic horizon as in the Omulevka terrane and in the same tuffaceous-siliceous-shaly series. Only a few occurrences (31 and others) are known, and descriptive data are lacking.

### *Uyandina - Yasachnaya volcanogenic belt*

Volcanic-associated massive sulphide Pb-Zn ores are the only type of stratiform mineralization known in the Uyandina-Yasachnaya volcanogenic belt. They are associated with a series of Late Jurassic bimodal basalt-rhyolite marine volcanic rocks. The Khotojdokh deposit (4) is in Upper Jurassic sedimentary and volcanic rocks. Ore-bearing strata, 450m thick, are composed of black argillaceous shales interbedded with rhyolite and basalt flows and lesser horizons of tuffs and cherty rocks. Subvolcanic rhyolite bodies are also present. Massive barite sulphide lenses, up to 15 m thick, are concordant with underlying rhyolite and overlying tuffs and argillites (Fig. 7). The most important lens consists of fine-grained sphalerite, pyrite, barite and galena aggregates with lesser amounts of chalcopyrite and quartz. Grades of >10 % Zn, 3% Pb, 2%Cu and anomalous more 100 g\t. Thin-bedded structures are characteristic of the ores. All these features are representative of Kuroko type deposits.

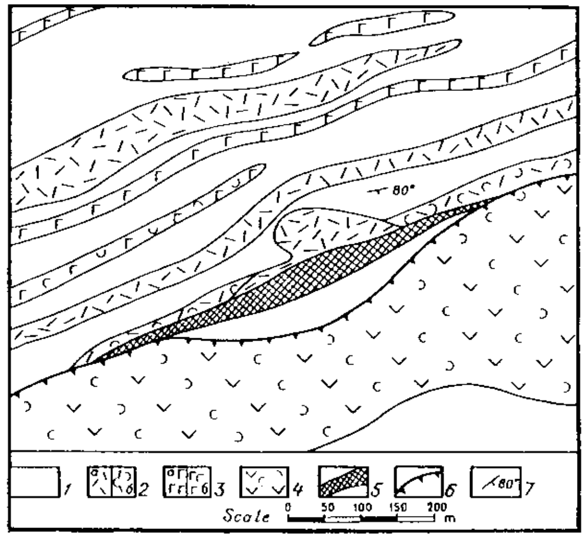


Fig. 7. Geological map of the Khotoidokh deposit 4) (according to the data of S.A.Zuyev and E.F.Dylevsky unpublished data):
Volcanites and sedimentary rocks of Upper Jurassic age: 1 - argillaceous shales, flints, siltstones; 2 - rhyolites (a) and their tuffs (b); 3 - basalts (a) and their tuffs (b); 4 - andesitic tuffs; 5 - massive sulphide lens; 6 - thrusts; 7 - bed orientation.

## CONCLUSIONS

1. Stratiform and stratabound deposits of central parts of Asia Northeast formed in three different geodynamic environments: passive continental margin, volcanic island arcs, and incipient divergent plate boundaries.
2. The deposits range in age from Middle Proterozoic to Upper Jurassic, inclusive. They are absent only in Triassic and Lower Jurassic sediments.
3. The variety of stratiform and stratabound deposits reflects the different tectonic environments and considerable time interval of formation.

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