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N. S. Askarova,
orcid.org/0000-0002-2103-6198,
A. T. Roman,
orcid.org/0000-0003-3489-9475,
V. S. Portnov,
orcid.org/0000-0002-4940-3156,
A. N. Kopobayeva,
orcid.org/0000-0002-0601-9365

Karaganda Technical University, Karaganda, the Republic of Kazakhstan, e-mail: kazakh.7979@mail.ru

FEATURE SPACE OF THE ATASU TYPE DEPOSITS (CENTRAL KAZAKHSTAN)

Purpose. Studying geological formations of the Atasu type deposits to identify prospecting criteria.

Methodology. Analysis of literature and fund materials, comparative analysis of geological factors characteristic of stratiform ores, stage formation and metamorphism.

Findings. The main features characteristic of the deposits of the Atasu type have been formed: their belonging to the lower strata of the Upper Famennian, Upper Devonian to the Visean stage of the Lower Carboniferous; complex composition of ferromanganese and polymetallic ores formed in three hydrothermal stages (sedimentary, metasomatic and vein ones), stratiform, lenticular, localized near volcanic edifices.

Originality. The main geological criteria have been established that determine the belonging of the Uspensky ore belt in Central Kazakhstan deposits to the stratiform deposits of the Atasu type formed at different depths in continental rift valleys. The criteria include the age interval of the formation of ore deposits of the stratiform type, hydrothermal staging of mineralization (sedimentary, metamorphic, metamorphic (hydrothermal, dislocation multistage and dynamothermal)); localization of folded and post-folded subvolcanic intrusions near former volcanic edifices.

Practical value. The main prospecting geological criteria (features) established for the Atasu type deposits can be used to form a feature space for predicting the areas of mineral deposits localization of the Uspensky ore belt of Central Kazakhstan formed in close time periods, in similar geological-geochemical, thermodynamic and geodynamic conditions.

Keywords: *Uspensky ore belt, Famennian-Tournaisian era, iron-manganese, polymetallic ores, stratiform bodies, stages of mineralization and metamorphism*

Introduction. Establishing the formational belonging of deposits is one of the stages of ore formation analysis used to predict the areas of localization of mineral deposits formed in close time periods, in similar conditions, combined into one large geological structure (volcanic-plutonic belt, ancient rift zone, and so on).

The identification of the ore formation is based on a detailed study on the geological structure of folded and fractured structures, regularities in the mineral composition distribution of ore bodies, textural and structural characteristics of ores, the scale of mineralization, paragenetic associations, and the nature of near-ore changes.

The results of geological studies obtained at various stages of geological exploration and exploitation of deposits, form a feature space, whose criteria serve to solve the problem of the formational belonging of deposits to one or another type. This problem has a probabilistic nature and is solved using the maximum possible number of reliable geological features that characterize this type or formation.

Previously, pattern recognition methods were used in geology as a method of analogies [1]. A higher level assumes the use of this method, as a result of the development of the problem of recognition: probabilistic and deterministic. The probabilistic approach is based on the statement that a given object is more likely to belong to this class of objects than to another class.

Let us analyze the established and reliable geological criteria of the feature space to determine the belonging of certain deposits to the Atasu type deposits, to highlight the exploratory criteria.

Analyzing the feature space. A common characteristic of deposits (of the Atasu type) is their location within the Atasu region of the Uspensky ore belt of Central Kazakhstan. These are stratiform lenticular and sheet-like accumulations of iron-manganese and lead-zinc ores in interbedded argillite-siliceous-limestone packs, with hydrothermal-metasomatic zinc-lead-barite mineralization [2, 3].

The time of the Uspensky Belt ores formation is determined by the interval from the lowermost Upper Famennian of the Devonian to the Lower Carboniferous. The total duration of the metallogenic epoch, from the beginning of the first stage of mineralization to the end of the second one, is estimated at 15–20 million years.

Deposits of the Atasu type of the Famennian-Tournaisian and other epochs of ore formation include iron-manganese deposits: Karazhal, Bolshoi Ktai, Tur, Zhomart, Bogach, Kamys, Kentobe, Ushkatyn, Shointas, Tarsai, Atabay, and others; polymetallic one: Zhairem, Karagailly, Bestyube, Zhalair, Akzhal, Kuzhal Ushkatyn, Kairakty, and so on (Fig. 1).

In the Uspenskaya shear zone, the analogs of barite-polymetallic deposits of the Zhairem group are the deposits of the Karagailinsky ore cluster; in Akzhal and the Akbastau zone polymetallic deposits Akzhal, Uzunzhal, and so on; the de-

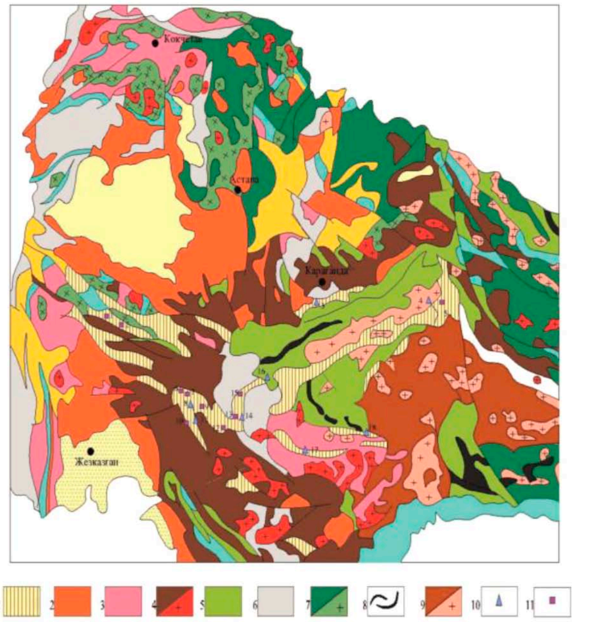

Fig. 1. Distribution pattern of Late Famennian – Early Carboniferous rift-induced structures of Central Kazakhstan [2–4]:

1 – rift-induced structures (D_3-C_1); 2 – geological complexes of the inland sea basin (D_3-C_1); 3–7 – pre-Middle Devonian continental crust: Precambrian sialic massifs (3); Devonian runway (4); marginal sea basin (S_1-D_2) (5); passive continental margin (∈-O_3) (6); island arcs (∈-O_2) (7); tectonized ophiolite zones (8); Late Paleozoic runway (9); deposits: polymetallic (10): Zhalair (3); Karagaily (4); Zhairem (8); Rifovy (11); Bestobe (14); Kuzhal (16); Uzunzhal (17); Akzhal (18); ferromanganese (11): Tur (1); Bogach (2); Kentobe (5); Kamys (6); Arap (7); Ushkatyn (9); Zhomart (10); Karazhal (12); Bolshoi Ktai (13); Keregetas (15) [2–4]

posits of ferromanganese ores of the Kentobe belong to the Togai group. Alongside with this, in other areas there are deposits heavily altered by post-ore processes, which makes it difficult to recognize them. The establishment of their formational belonging to the Atasu type of deposits allows approaching the solution of controversial problems of the genesis of similar deposits in other ore regions, according to G. N. Shcherba (1964). It was found that according to the data of G. N. Shcherba (1964), a common characteristic of such deposits was the location of ore fields on the wings, or in the crestal parts of small isometric folds of the volcano-tectonic type in the Zhailminskaya, Kairaktinskaya and Uspenskaya synclinoria [2–4].

The section of the Upper Famen-Tournai Formation (Fig. 2), in which the ore deposits of the Atasu type deposits are located, consists of light, gray and pinkish limestones with a variable role of interlayers of siltstones, yellowish gray sandstones, silicites and tuffites with a total thickness of up to 400 m. The rocks often contain carbonaceous substance, pyrite, iron and manganese minerals.

These are shallow marine sediments typical of stagnant depressions in which terrigenous material is usually absent, and volcanic rocks are represented by tuffites, tuffs and effusive deposits, chemogenous and organogenous limestones and silicites (Fig. 2).

The rocks of the productive formation of the Upper Famennian (D_3fm_1)-Tournai (C_1t) cover deposits of nodular-layered limestones, clay-siliceous-carbonate rocks, basalts, tuffites, siltstones, beds and lenses of lead-zinc, hematite-magnetite and manganese-siliceous ores, argillaceous-carbonate rocks and pyrite rhythmites (Fig. 2).

The deep-water deposits of this suite ($D_3fm_1^a - C_1v_1$) with the total thickness of 810 m are represented (Fig. 3) by light, dark and gray, pink organogenous limestones, yellow-gray sandstones with the total thickness about 400 m.

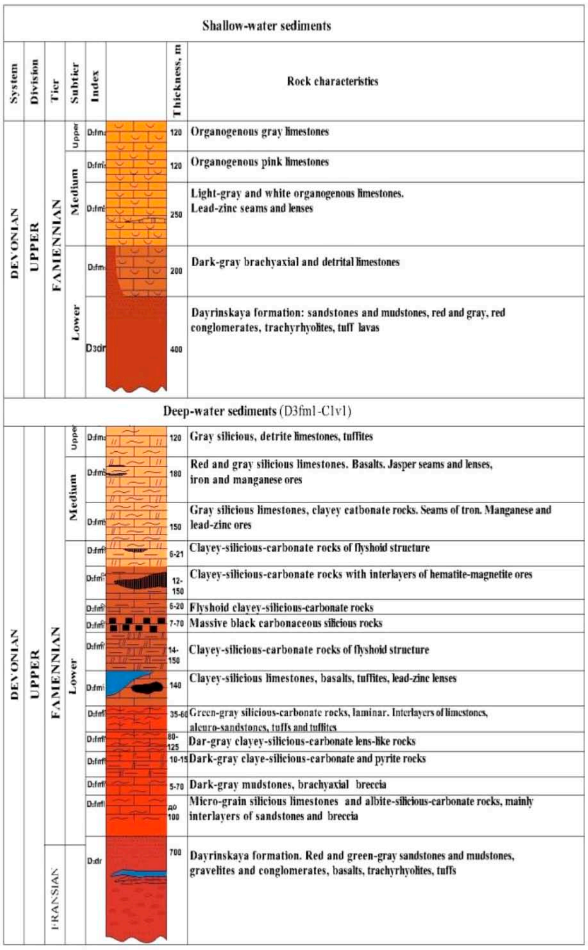

Fig. 2. Section of the productive formation of shallow and deep-water ores of the Atasu type [2, 3]

Analyzing the Atasu type genesis. In continental rift valleys (Fig. 3) limited by a series of deep-seated faults (D_2žv-D_3f), thick strata of molasse were accumulated, in association with scattered volcanic sheets, dyke-like and sill-like bodies of normal and moderately alkaline rhyolites and dacites. Local and volcano-plutonic masses of moderately alkaline igneous rocks, localized in the outer most uplifted zone of the rift valley, often arose.

At the later stages (D_3fm-C_1t-v_1) the opening of rift-induced systems took place in the conditions of the Famennian-Tournaisian inland sea. At this stage, the continental sediments of the rift valley gradually, without significant structural rearrangements were replaced by carbonate and terrigenous-carbonate sediments of moderate depths (Fig. 2), and in the axial zone of the rift by deep-sea sediments, in places in paragenesis with fractured eruptions of normal and moderately alkaline and alkaline basalts and picrobasalts, less often picrites accompanied by linear deposits of parallel dikes and sills of alkaline picrites, dolerites and picrodolerites (Fig. 2). In paragenesis with them in the ore fields of the Karazhal and Zhairem groups, various pelagic sediments are found: pelitomorphic limestones, clay-carbonaceous-siliceous rocks, ore and barren jasper. This association is a newly formed oceanic type crust.

According to G. N. Shcherba (1964), the average composition of petrogenic elements, rift-induced magmatic formations in the petrochemical characteristics, belongs to the moderate and high potassium series [2, 3].

The axial zones of rift-induced structures of the Atasu ore cluster are characterized by a sharply increased thickness of the basalt layer (up to 33 km) and the presence of a large volume of mantle material at its base and, accordingly, a reduced thickness of the granite layer (10–12 km) [3, 4]. The central

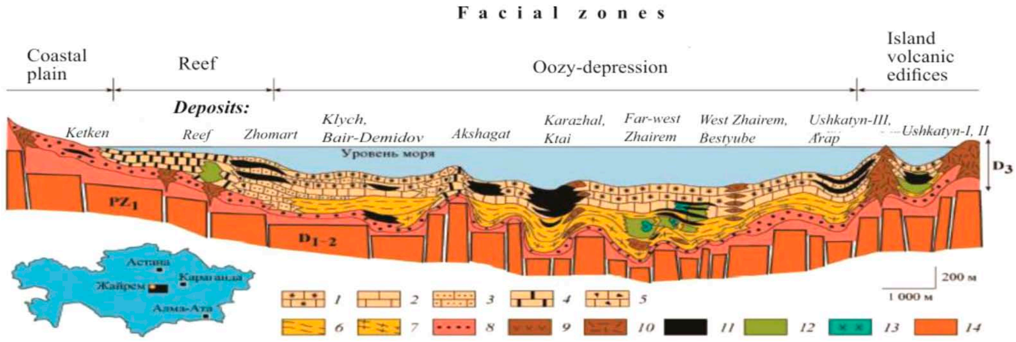

Fig. 3. Lithological-facies setting of Famennian sedimentation and ore deposition in the Atasu rift basin (according to L. L. Rozhnov (1982) with simplifications):

1–13 – Upper Devonian sediments: 1–5 – limestones: 1 – siliceous nodular-layered red-colored; 2 – the same, gray-colored; 3 – organogenic-detrital; 4 – organogenic-algal reef; 5 – sedimentary breccia; 6, 7 – clay-siliceous-carbonate rocks: 6 – flyschoid; 7 – lenticular-layered; 8 – conglomerates, sandstones, siltstones; 9, 10 – volcanic rocks: 9 – basalts and trachybasalts; 10 – trachyrhyolites; 11–13 – ores: 11 – iron-manganese; 12 – lead-zinc; 13 – barite and barite-lead; 14 – terrigenous-volcanic deposits of the Lower-Middle Devonian and metamorphosed volcanogenic-terrigenous strata of the Lower Paleozoic with granite intrusions [8, 9]

part of the structure is characterized by a high degree of fragmentation of the basement, which predetermined the increased permeability and mobility of thermo- and hydrofluidic flows, which eventually led to the formation of powerful ore stratiform deposits of ferromanganese and barite-base metal ores (Zhairem, Ushkatyn, Karazhal, Karagaily, Kentobe, and so on), present day rifts [2, 3].

Complex stratiform ores of iron, manganese, barite, lead and zinc occur mainly in deep-water siliceous-argillaceous-carbonate and carbonaceous-carbonate-siliceous rocks (Fig. 2), less often in reefogenic limestones, and are localized at the junctions of longitudinal (rift-induced) and transverse (transform) faults expressed in the present day tectonic structure by zones of intense folded and ruptured deformations.

The Atasu region of stratiform iron-manganese and polymetallic mineralization is confined to the Zhailma Famennian paleorift and is one of the elements of the Central Kazakhstan intracontinental paleorift system [6, 7].

According to Kh. A. Bespaev (1999), the Central Kazakhstan paleorift system was characterized by powerful ore-forming processes that formed large stratiform deposits of Pb, Zn, Mn, Fe and Ba. An important role in these processes was played by the flows of reduced mantle fluids enriched in carbon, which transported alkalis, chlorides, salt melts, and brines of metals from the depths of the mantle. The Famennian ore-bearing strata are represented by marine sedimentary deposits (facies of shallow water, open sea, turbidity flows, silt depressions) and in subordinate amounts, by covers of trachybasalts, trachyrhyolites and tuffaceous material (Fig. 4) [6].

The Zhailma paleorift was formed at the intersection of the system of near-latitudinal-northeastern faults with an even more powerful system of deep-seated fractures of the near-meridian-north-western direction [5].

According to L. V. Shabalina (2003), the formation of the rift system was associated with the introduction of mantle plume diapirs into the central part of the Kazakhstan continent in the Early Paleozoic and the activation of these processes in the Middle Paleozoic, which led to the disintegration of the continent into many microplates and the establishment of rift depressions [11].

The Famennian ore-bearing strata of the Zhailminskaya trough is filled with argillaceous-siliceous-carbonate deposits of the axial part of the paleorift; there are basalt and diabase bodies (Fig. 3) there. Ore formation was associated with the flow of hydrothermal solutions to the bottom of the trough, bearing metal components, and the deposition of the latter in

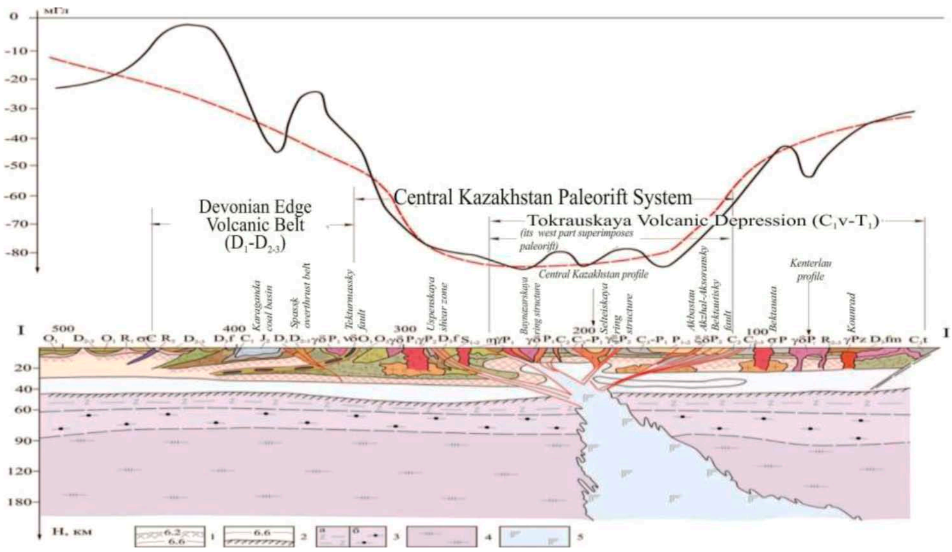

Fig. 4. Geological model of the lithosphere structure of the Central Kazakhstan paleorift system (according to L. V. Shabalina). Deep layers of the lithosphere:

1 – granite-metamorphic; 2 – granulite-basic. The upper mantle (depth facies): 3 – harzburgite, plagioclase-peridotite alpine-type (a)); spinel-peridotite (b); 4 – garnet-lherzolite; 5 – gabbro-pyroxenite the bottom reducing conditions. The formation of deposits of the Atasu type took place at two stages: the first (hydrothermal-sedimentary) stage was the formation of iron-manganese ores and, possibly, poor lead-zinc mineralization; the second (hydrothermal-metasomatic) stage was the formation of barite-polymetallic ores [11, 12].

The base of the Zhailma graben-syncline (trough) is heterogeneous. In the gravitational field, local linear positive and negative anomalies and the zone of high gravity gradients separating them correspond to it (Figs. 4, 5). The positive anomaly characterizing the eastern half of the trough fixes the hidden part of the Atasu uplift, the negative one restites of deep foci of palingenic granite formation and granite intrusions of Devonian age [7].

In metallogeny of the Paleozoic of Central Kazakhstan, an important role is played by geological complexes formed in the geodynamic conditions of continental Late Devonian-Early Carboniferous rifting. They are associated with the largest deposits of manganese (third in the world), barite (30 % of the world's resources), lead and zinc [7].

Based on studying [11] the features of the deep structure, it can be seen that the Central Kazakhstan metallogenic province was formed as a long-functioning supra-plume system. Polymetallic and iron-manganese mineralization [12] is associated with intracontinental rifting, rare metal – with granite

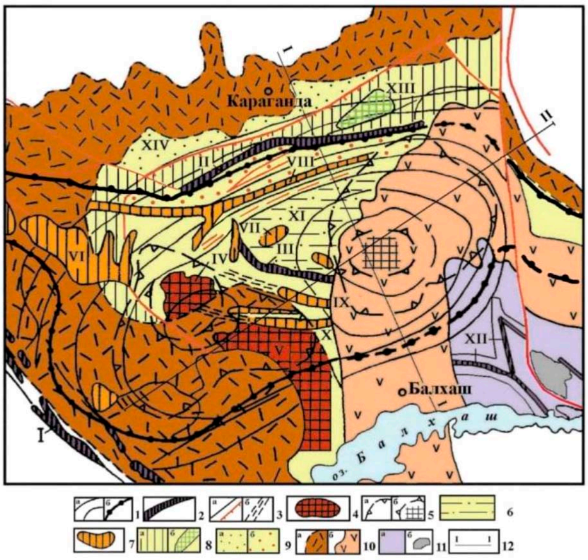

Fig. 5. Tectonic pattern of the Central Kazakhstan paleorift system [11]:

1 – Central Kazakhstan regional gravity minimum: isolines of equal values of Δg (a), line corresponding to the border of the paleorift system (b); 2 – tectonic seams controlling ophiolite and siliceous-basalt rock associations (I – Zhalair-Naimansky, II – Tekturmas, III – Taldyespetau-Tkenektinsky, XII – Kazyk-Itmurundinsky); 3 – the largest faults (a), shear zones (b); 4 – outcrops of Precambrian rocks (IV – Aktau-Mointinsky, V – Kyzylaspinsky anticlinoria); 5 – hidden relics of granite-gneiss domes in the basement: outer contours (a), non-granitized outliers (b); 6 – flyschoid deflections on the sialic base destroyed by destruction; 7 – Famennian-Early Carboniferous depressions of rift-induced origin (VI – Zhailminskaya, VII – Kayraktinskaya, VIII – Uspenskaya, IX – Akzhal-Aksoranskaya, X – Akbastau); 8 – Spassky continental margin belt of riftogenic (D_1-D_2gv), island-arc (D_2gv) origin (a), outcrops of basement rocks in the Matakskу horst (b); 9 – deflections: inter-arc (a), pre-arc (b); 10 – terrestrial volcanic belts: Central Kazakhstan Devonian (a), Balkhash-Ili Middle-Late Paleozoic (b); 11 – Kenterlau-Mataiskaya zone of diffuse spreading without dissection (a), Sayakskaya trough (b); 12 – the lines of sections characterizing the model of the deep structure of the paleorift system, along the Balkhash-Temirtau profiles – I–I, Central Kazakhstan – II–II. Other structures: anticlinorium: Zhaman-Sarysuisky – XI; synclinoria – Karasorsky – XIII, Nurinsky – XIV

formation at the stage of collisional compression of the paleorift system.

The considered rift-induced structures of Central Kazakhstan were formed on the pre-Middle Devonian continental crust from the Upper Givetian to the Early Visa inclusive, i.e. in less than within 40 million years (Fig. 2) [7].

At the end of the Famennian time, the rift mode was replaced by a stage of thermal subsidence. In the formed vast sea basin from the Late Famennian, up to and including Namur, carbonate and sandy-clayey sediments accumulated [2].

Analyzing the tectonic conditions of the deposit formation. The main tectonic factor in the formation of barite-lead and polymetallic mineralization of the Atasu type is the northeastern and northwestern faults, due to which mineralization is fixed at a considerable distance from the sources of ore-bearing solutions, and for ferromanganese and polymetallic mineralization, the northeastern faults 4 are not very promising [five].

One of the signs of barite-lead mineralization is its location at a considerable distance from the source of ore-bearing solutions, while rare metal mineralization is associated with faults. The connection of rare-metal mineralization with leucocratic granites of the Atasu district gives grounds to believe that rare-metal mineralization will be traced in the supra-intrusive and intra-intrusive zones of intrusions composed of leucocratic granites.

The activation of tectonic movements led to the formation of folded and post-folded small intrusions of the subvolcanic type localized near the former volcanic edifices. This is a very important petrometallogenic feature of the Atasu type deposits [4].

The removal of ore components coincided basically with the stage of attenuation of the effusive-explosive activity of volcanic edifices, with the activation of exhalations and solfatars, in conditions of watering of the upper parts of porous volcanic edifices.

Ore deposits are formed in ore plumes, which is caused by the pulsation of hydrothermal solutions coming from cracks into the aquatic environment forming multi-storey deposits, alternating ores of different composition (Fig. 3).

There are three distinguished stages [2–4] of mineralization formation of the Atasu type deposits.

The first one is hydrothermal-sedimentary, during which sedimentary iron and manganese, as well as poor lead-zinc and barite ores are formed. The ores of the first stage are predominantly ferromanganese and are synchronous with the formation of the enclosing rocks. The formation of ores is associated with the volcanism of the Lower Devonian, and then the Givetian-Frasnian time. Ore deposits contain volcanic bombs and lapilli of dacitoliparite or keratophyric composition. Iron and manganese, silicon are excess products of magmatic differentiation of basaltoid magmas, which carried them through volcanic cracks into the sea basin [4, 5]. Manganese ores with brownite, hausmanite, and, less commonly, jacobsite, are confined to the deep-water facies of the Famennian. They are firstly replaced by relatively rich, and then by poor iron ores, then by ferruginous jaspers and weakly mineralized red-colored nodular-layered limestones.

Lead, zinc, copper, barium of the first stage of mineralization passed from basaltoid magmas into solutions before the elimination of acid differentiates from them, and after splitting off acidic lavas and the formation of iron and manganese ores, basaltic (andesitic) lavas appeared and again solutions released zinc, lead, copper, and others (G. N. Shcherba, 1964).

In the second hydrothermal-metasomatic stage, due to remobilization, regeneration and redistribution of ore components of the first stage and the input of barium, post-sedimentary hydrothermal-metasomatic ores of lead, zinc, barium are formed. With this post-folding stage associated with the activation of tectonic movements, the appearance of deposits and stocks of diabase and andesite composition is synchronized, followed by subvolcanic intrusions of acid composition. At the same time, a large amount of excess calcium (chemogenous limestones) passed into the solution. In addition, arsenic, antimony, bismuth, etc., halides, potassium were also isolated, as well as sodium.

In the third, hydrothermal-vein stage, small lenticular accumulations, veins and lenses of lead, copper and copper-barite ores were formed.

Analyzing the mineralization characteristic of the Atasu type deposits. Zinc-lead-barite ores are represented by barite, sphalerite, galena and pyrite, less often chalcopyrite, antimony and arsenic sulfosalts of lead, copper and silver. Associated components are copper, sulfur, mercury, cadmium, silver, antimony, thallium, indium (A. A. Rozhnov, 1988).

These ores are characterized by the following stages of mineralization:

- the first stage that is associated with the accumulation of argillite-calcareous facies with the formation of layer-by-layer dissemination of iron, zinc, and less often lead and copper sulfides occurs in the Zhairem section, between the iron-manganese strata 50 and 80 m apart in the deposits of the upper Famennian lying stratigraphically somewhat lower than the iron-manganese ores (20–200 m). This mineralization is synchronous with the accumulation of sediments and is associated with the removal of elements by underwater volcanic fluids [2–4]. Ores together with rocks underwent folded deformations, including micro-folding (N. M. Mitryaeva, A. A. Rozhnov, G. N. Shcherba, 1962; N. M. Mitryaeva, 1979);

- at the second hydrothermal-metasomatic stage, complex sulfides of copper, lead, arsenic and others are added to the minerals of the first stage, with the predominant development of barite and galena. Ore bodies form lenticular deposits, sometimes spatially separated by stratal mineralization of the first stage. The ore is dispersed along cracks that cut through fine folding; ore veins cut also subvolcanic bodies of gabbro-diorites and gabbro-monzonites, deposits of diabase porphyrites. The superposition of hydrothermal-metasomatic processes was accompanied by the introduction of Ba, Zn, Pb, Cu, As, Bi, Ag, Ni, Co and other elements, as well as volatile components on sedimentary iron-manganese and lead-zinc ores and rocks (N. M. Mitryaeva, M. M. Kayupova). Spatially, ores are located in carbonate facies, and tend to the areas where volcanic rocks are manifested: tuffites, tuffs, subvolcanic bodies [13].

For polymetallic deposits of the Atasu type, metasomatic zoning is characteristic (from the center to the periphery): quartz-pyrite metasomatites are replaced by the monobarite zone, in places with chalcopyrite mineralization; then sequentially – galena-barite, galena-sphalerite-barite, galena-sphalerite zones, and the latter are replaced by zones of dispersed sedimentary lead-zinc and essentially zinc [3, 4].

Iron and manganese mineralization. Ore-bearing accumulations of iron and manganese of the Atasu district depending on the location relative to the sources of ore genesis, change from hydrothermal-metasomatic, through chemogenic-sedimentary, to normal sedimentary with a gradual change in mineral parageneses in the direction of $Fe \rightarrow Fe + Mn \rightarrow Mn$ (G. N. Shcherba, 1964).

A. G. Betekhtin, D. Sapozhnikov, V. I. Kavun, and others believed that Fe, Mn entered the sea basin from eroded land. N. A. Shtreis, N. L. Cheruvimova, E. A. Sokolova considered that the source was iron and manganese ores, which form concordant and sub-concordant stratus and lenticular deposits, whose centers coincide with the tectonically most complex areas where hydrothermal processes are intensely developed.

Thus, iron-manganese mineralization, as well as lead-zinc mineralization, is confined to the rocks of the Famennian stage, and the former occurs in different facies conditions, and the latter occurs only in deep-water sediments of silt depressions (Figs. 2, 3), where it forms large deposits of Zhairemskaya, Ushkatynskaya and Bestobinskaya groups.

Iron-manganese and zinc-lead-barite and barite-polymetallic ores are located among volcanic-sedimentary (mainly sedimentary) rocks that are metamorphosed marine sediments with interlayers of volcano-clastic and volcano-chemical deposits (tuffites, silicites, travertines, and others) of the Upper Famennian.

Analyzing the stage of metamorphism. In addition to the phenomena of diagenesis, three stages of metamorphism are distinguished in the Atasu type ores.

The first group of signs of hydrothermal metamorphism in time has not been established at all deposits. It took place simultaneously with the formation of metasomatic polymetallic ores, into rocks, ferromanganese and polymetallic ores of the first syngenetic sedimentary stage. At the same time, oxide, hydroxide compounds and sulfides were metamorphosed, recrystallized, and oxide-nitrous compounds began to predominate in the composition of ores. Alkaline metasomatism with new formations of albite, microcline, barite, sulfides, minerals with boron, fluorine and chlorine is characteristic. Alongside with recrystallization of sedimentary ores, there was a partial movement of ore matter, metasomatic enrichment of ore layers and lenses, the appearance of intersecting hydrothermal veinlets of metasomatite bodies (G. N. Shcherba, 1964).

The intensity of hydrothermal metamorphism is not the same and depends on the distance of sedimentary deposits from the centers of the second-stage hydrothermal fluids inflow gravitating towards the middle parts of volcano-tectonic structures. This fact is one of the most important search criteria.

The second stage of dislocation multistage metamorphism is associated with volcanic folding: movements during the formation and destruction of volcanic edifices.

The third stage of metamorphism (dynamo-thermal) was manifested only in deposits that fell into the areas of deformations and temperature fields of late intrusions.

Conclusions. Feature space of the Atasu type deposits.

Based on the detailed study on the Atasu type deposits carried out in different years by G. N. Shcherba, A. A. Rozhnov, B. I. Buzmakov, A. B. Weimarn, V. I. Shchibrik, R. M. Antonyuk and V. I. Lyubetsky and others, the following signs have been formed:

1. Deposits of the Atasu type are located within the Uspensky ore belt of Central Kazakhstan and are formed from the upper Famennian to the Vizean:

1.1. A narrow age interval of ore formation (lower part of the Upper Famen to visa).

1.2. The ore "stratiformity" (consistent occurrence of ore bodies among marine carbonaceous-clay-carbonate sediments, concentration of mineralization in the lithological horizons of the Famennian stage).

2. Spatial relationship of polymetallic mineralization with ferromanganese mineralization:

2.1. Complex iron-manganese and lead-zinc-barite composition of ores of deposits: Karazhal, Bolshoi Ktai, Zhumart, Kamys, Shointas, Tarsay, Atabay, and so on; polymetallic: Zhairem, Bestobe, Ushkatyn, Kairakty, and others.

3. Stages of mineralization formation: hydrothermal-sedimentary, hydrothermal-metasomatic, hydrothermal-vein:

3.1. The bed form of ore bodies of the first hydrothermal-sedimentary stage of iron-manganese ores and lead-zinc mineralization, their horizontal extent, the absence of significant near-ore changes.

3.2. Lenticular form of ore bodies of the second hydrothermal-metasomatic stage with apophyses, near-ore alteration of rocks, confinement of barite-base metal ores to tectonically complicated areas according to A. K. Mazurov and Kh. A. Bespayeva, (2002); Yu. S. Parilova (1999).

4. Stage zoning of metamorphism.

5. Localization of folded and post-folded small intrusions of the subvolcanic type near the former volcanic apparatuses.

The formed attribute space will make it possible to use the mathematical apparatus of pattern recognition in geology, in fairness, in the analysis of materials of hydrothermal-metasomatic mineralization of silicified dacites of the Murzashoky volcano; iron-manganese ores of the southeastern foot of the Targyl volcano (North-Western Balkhash region) of the Kamys deposit, and others (G.N. Shcherba, 1964).

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Ознаковий простір родовищ Атасуйського типу (Центральний Казахстан)

Н. С. Аскарова, А. Т. Роман, В. С. Портнов, А. Н. Копобаєва

Карагандинський технічний університет, м. Караганда, Республіка Казахстан, e-mail: kazakh.7979@mail.ru

Мета. Вивчення геологічних формацій родовищ Атасуйського типу для виділення пошукових критеріїв.

Методика. Аналіз літературних і фондових матеріалів, порівняльний аналіз геологічних факторів, характерних для стратиформних руд, стадійного формування й метаморфізму.

Результати. Сформовані основні ознаки, що властиві родовищам Атасуйського типу: приналежність до низів верхнього фамена, верхнього девону до візейського ярусу нижнього карбону; комплексний склад залізо-марганцевих і поліметалічних руд, сформованих у три гідротермальні стадії (осадова, метасоматична й жильна), що залягають стратиформно, лінзоподібно, локалізованих поблизу вулканічних апаратів.

Наукова новизна. Встановлені головні геологічні критерії, що визначають належність родовищ Успенського рудного поясу Центрального Казахстану до стратиформних родовищ Атасуйского типу, сформованих на різних глибинах у континентальних рифтових долинах. Критерії включають віковий інтервал формування рудних покладів стратиформного типу, гідротермальну стадійність зруденіння (осадова, метасоматична, жильна та стадийна зонального метаморфізму (гідротермальний, дислокаційний багатоетапний і динамотермальний)); локалізацію складчастих і післяскладчастих інтрузій субвулканічного типу поблизу колишніх вулканічних апаратів.

Практична значимість. Головні пошукові геологічні критерії (ознаки), встановлені для родовищ Атасуйського типу, можуть бути використані для формування ознакового простору задля прогнозування районів локалізації родовищ корисних копалин Успенського рудного поясу Центрального Казахстану, сформованих у близьких часових періодах, у подібних геолого-геохімічних, термодинамічних і геодинамічних умовах.

Ключові слові: *Успенський рудний пояс, фамен-турнейська епоха, залізо-марганцеві, поліметалічні руди, стратиформні тіла, стадії зруденіння й метаморфізму*

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