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PECULIARITIES OF THE FORMATION OF THE ZHAILMA VOLCANO-TECTONIC DEEP

Purpose. Studying the features of the Zhailma volcano-tectonic depression formation, as well as the principles and factors affecting this structure's ore formation.

Methodology. Analysis of the results of isotope dating of rocks, critical analysis of literature and fund materials, analysis of the genesis and specificity of the Zhailma structure mineralization, features of the volcano-tectonic depression formation.

Findings. The Zhailma graben syncline formation is associated with subsidence after ejections of significant masses of acidic magmatic material from stratovolcanoes concentrated on the Zhailma structure. The initiation and development of the graben-syncline is closely related to the processes of tectonomagmatic evolution of the Devonian volcano-plutonic belt.

Originality. The search model for stratiform deposits of the Atasu type has been revised, taking into account the original theory of the volcano-tectonic origin of the structure, formed at the final stages of the formation and development of the Devonian volcano-plutonic belt. The genesis of the Atasu-type deposits is considered as sedimentary-hydrothermal one, associated with the processes of diagenesis and catagenesis occurring within sedimentary basins. The presence of two large volcanoes on the northern side of the caldera structure was substantiated: North Zhairem and Ustanynzhal.

Practical value. It is recommended to carry out predictive metallogenic and, accordingly, prospecting work for deposits of the Atasu type within the graben-synclines of the Sarysu-Teniz segment of the Devonian volcanic belt, where such deposits of ferromanganese ores as Tur, Bogach and Karaadyr are already being developed in the Aydagarly graben-syncline.

Keywords: *volcanic graben syncline, isotopic analysis, Devonian volcano-plutonic belt, Atasu ore district, continental rifts*

Introduction. The issues of the Zhailma trough genesis, which is unique in terms of ore saturation developed in the middle of the last century, are the subject of constant discussions. In most scientific publications, the structure is considered as “the western flank of the latitudinal Uspensky rift zone, the Karakengir-Uspensky riftogenic trough”. In the paper, the authors consider the Zhailma trough alternatively as a volcanic depression, whose initiation and development is associated with intense manifestations of the rhyolitic Middle Devonian volcanism that later on, under conditions of gradual subsidence, was filled with volcanic products of the Middle-Late Devonian, the final stage of magmatism, and then carbonate and carbonate-terrigenous sediments of the Famennian-Early Carboniferous transgressive series.

The main reserves of complex ferromanganese, barite-polymetallic and barite ores of Central Kazakhstan are concentrated in the Atasu ore district. The main ore-controlling structure covering almost the entire territory of the Atasu ore district, is the Zhailma graben-syncline.

Results. For the first time, ferromanganese ores in the valley of the Atasu River were noted in the report of Kozyrev A. A. (1911); in 1927 Yagovkin I. S. described the Small and Big Ktai and Kentyube ore deposits. Already in 1930, exploration of iron ore deposits in the region began (Kheruvimova N. L., Konev A. K., et al.). In the periods of 1957–1970 and 1975–1981 a large amount of regional geological survey work was carried out in the area (Dvoychenko N. K., Kerensky M. E., Mikhailov A. E., Kavun V. I., Kazbagarov K. A., Korobova L. N., Kolesnik A. P., Gridina N. M., and others). In 1976, (Buzmakov E. I., Shchibrik V. I., Taranushich F. F.) a new lithological-stratigraphic scheme for the division of the Famennian and Carboniferous formations was developed.

The existing ideas of geology, tectonics, genesis, mineralogy, morphology of ore deposits have developed as a result of long service of many researchers: Rozhnov A. A., Bigaliyev B. B., Buzmakov E. I., Sereda V. Ya., Stroiteleva A. V., Rozhko M. N., Shchibrik V. I., Mitryaeva N. M., Kayupova M. M., Muratova D. N., Shcherba G. N., Puchkov E. V., and others.

The results of this work are covered in numerous publications. Most of them that deal with the issues of the trough genesis and consider it as a “riftogenic depression” confined to the extended linear graben-like riftogenic Karakengir-Uspensky trough [1]; to the Uspensky paleorift (Shcherba G. N., 1964, 1970), and others.

In works [2, 3], the Uspenskaya zone is considered as an integral part of the larger Tekturmas polycyclic geotectonogenic; trough structure (paleorift), and the Zhailma depression as the western flank of the Uspenskaya zone formed by the Early Hercynian rifting processes.

However, Borsuk B. I., et al., 1972, while characterizing the Uspensky part of the Atasu-Uspensky synclinorium, notes that it is a highly compressed linear structure complicated by a system of small, sometimes calm folds with slope of wings 40–500, often steeper and thrown back to the north. It is broken by numerous longitudinal ruptures that caused the thrusting of the older rocks on the young ones [4].

According to seismic exploration (Sherubay-Nurinsky DSS profile) [5], the Moho surface within the Uspenskaya zone (Popov A. A., 1967) forms a trough with an amplitude of up to 5 km. According to the results of DSS, MTS and interpretation of gravimagnetic anomalies, the Uspensky profile and its western continuation in the Zhailma graben-syncline at depths of 6–7 km corresponds to a trough-like depression that expands to the west and narrows to the east. In the Moho surface, against the background of general regional sagging, it corresponds to a depression, where the depth of the Moho surface reaches 52–53 km, both structures have increased thickness of the earth's crust.

According to geophysical data, the thickness of the crust under the continental rifts decreases and a corresponding rise of the Moho surface takes place. The thickness of the crust under the Baikal rift decreases to 30–35 km, under the Rhine rift to 22–25 km, under the Kenyan rift to 20 km, and to the north, along the Afar valley, it reaches 13 km, and then under the axial part of the valley there appears the oceanic crust [6].

If we consider similar parameters of the Moho surface troughs in the Central Kazakhstan "paleorift system", Agadyr-Vishnevsky 50 km and Kenkuduk-Karagaily 47.5 km, then the thickness of the crust under the rift is significantly greater than in modern rifts. In the mantle ledge under the rift, the rocks are usually decompacted (the velocities of longitudinal waves vary in the range of 7.2–7.8 km/s (Kenyan), and the central Kazakhstan paleorift is characterized by the longitudinal waves velocity that is equal to 8.2 km/s [7].

One of the undoubted achievements in the geology of the past and the beginning of the 21st century is the development of ideas of the rifting processes (Milanovsky E. E. 1976, 1987, 1988; Sengor, Burke, 1978; Sengor, 1995, etc.), which allows giving an objective assessment of the validity of classifying the Zhailma trough and the Uspenskaya shear zone as "riftogenic" ones.

In the modern sense, rifts are extended, fault-limited, elongated grabens, troughs. The term characterizes the process of rupture (stretching) of the previously continuous medium [8]. Under the rifts, the entire thickness of the lithosphere is reduced due to stretching that occurs during the formation of these structures) (Sengor, Burke, 1978; Sengor, 1995).

According to a number of scientists, the Central Kazakhstan paleorift is active, the rifting of which is caused by the mantle diaper rise. However, in such settings, rifts form as a result of crustal extension (stretching of the outer arc of the concentric fold, i.e., on the stretching side of the neutral surface) caused by the dome formation (Cloos, 1939).

Rifts form in almost all the tectonic settings (including those over mantle plumes) and at all the stages of the Wilson cycle of ocean opening and closing (Burke, 1978). Sedimentary basins in rift zones retain a record of the tectonic settings of their origin and (or) development much better than orogenic belt basins, although the range of tectonic settings that form in them is limited. The range of rock types in rift zones is poorer than in orogenic areas [9]. Metamorphism of rocks in rifts is much less pronounced compared to the metamorphism that accompanies orogenic processes (Burchfiel, et al., 1992; Davis, et al., 1996). The term "graben" is applicable only to those structures that do not extend to the entire surface of the lithosphere. These are depressions, or troughs in horizontal layers, which are much longer than their width. This concept is purely descriptive (Rosenfeld and Schickor, 1969). This term is applicable to those structures that do not pass through the lithosphere.

Morphological features of continental rifting are the result of deep processes. All the continental rifts tend to have similar geological characteristics. Dome structures and depressions separating them are clearly expressed in the relief [10]. The planned location of rift basins has certain regularities: an asymmetric transverse profile of zones, which is maintained at considerable distances, frequent asymmetry of the rift valley and the constancy of the width of rift basins, which is the most important common feature of continental rifts [11].

Thus, the Uspenskaya and Zhailma "riftogenic structures" are antipodes of rifts, and the ideas of the "riftogenic" genesis of the Zhailma depression developed more than 30–60 years ago and based on the ideas that existed at that time of the rifts as of deflections limited by parallel faults, do not correspond to modern ideas and require revision.

As a result of the comparative analysis of the Zhailma structure with modern rifts of the world, the authors admit not the "rift" genesis but its more complex origin and tectonic development.

The Zhailma graben-syncline is located in the junction zone of the volcanic structures of the Sarysu-Teniz segment of the DVPB with the complexly dislocated Caledonian structures of the Atasu anticlinorium [12]. Thus, from the east, the Famennian-Carboniferous sedimentary formations that fill the graben-syncline directly overlap the Caledonides of the Atasu anticlinorium; from the south, north and west they overlap the Devonian volcanics.

The Atasu anticlinorium is mainly composed of siliceous-terrigenous formations of the Karashoshak suite (€$_3$-O$_1$ *kr*) and terrigenous-siliceous formations of the Karatas (O$_{1-2}$ *kt*), which make up a single intensely deformed siliceous-volcanogenic-terrigenous formation occurring in the form of allochthonous plates of microquartzites, jasper, siliceous-carbonaceous shales. They are unconformably overlain by a complex of rocks of the flysch formation of the Kogalinskaya suite (O$_{2-3}$ *kg*). In the Sarysu-Teniz segment, Devonian volcanism developed on the active margin of the Caledonian paleocontinent [13].

The works by many researchers revealed the main features of the structure and development of the marginal belt, its transverse and longitudinal heterogeneity, and the features of variations in the material composition of igneous rocks along the lateral and in the section. A lot of works are dealing with this belt (Bogdanov, 1959, 1965; Bogdanov, et al., 1963; Shcherbakova, 1963; Markova, 1964; Nikitina, Aksamentova, 1965; Aksamentov, et al., 1966; Chetverikova, 1966, 1970; Shuzhanov, 1967, 1968, 1984; Mossakovsky, 1968; Nikitina and Shuzhanov, 1969, 1974; Aksamentova, 1970, 1972; Geology of the USSR, 1972; Azbel, et al., 1973; Tikhomirov, 1975; Bakhteev, 1987; Bekzhanov, 1994, and others).

Stages of magmatism development. The development of magmatism was characterized by the succession of differentiated basalt-andesite-dacitic formations (Early Devonian), predominantly rhyodacitite-rhyolite of the middle stage (Early-Middle Devonian), and, finally, contrasting basalt-rhyolite or single-rock formations of increased alkalinity of the late stage of development (Middle Devonian, Late Devonian, Zhaksykonskaya Series). In general, igneous formations of volcanic belts [14, 15] belong to two groups: sialic and mafic formations. In both groups, the formations of rocks of the normal calc-alkaline and elevated subalkaline series are developed, while the total alkalinity and potassium content increase from early to late formations and from the rear parts of the belts to the frontal ones.

Based on the existing ideas of the stratigraphic section of the region, four stages can be distinguished in the development of magmatism, whose manifestations strictly correspond to certain phases of tectogenesis, in the Atasu region, three of which are associated with magmatism.

The Early Devonian stage is characterized by local outpourings of basalts. Judging by their limited distribution, they originated from small slag and fissure-type volcanoes. Their outcrops are known in individual fragments of the Ustanynzhal block, in the core of the Karazhal brachianticline, and in the southern edge of the Zhailma syncline. The Lower Devonian granodiorites and quartz diorites of the Karamenda intrusive complex are spatially and genetically related to it.

The lithological composition of this period formations indicates the absence of major tectonic rearrangements in the region.

The Early-Middle Devonian stage of magmatism is associated with emissions of huge volumes of acidic pyroclastics (crystal-clastic tuffs, ignimbrites, clastolaves, fluidal lavas). At the final stage of volcanism, rhyolitic extrusive domes and dikes form (the Zheltymes and Uguztau formations). Volcanics of the second stage make up the core and wings of the Bektau anticline, their small outcrops are known to the north of the Zhairemskoye deposit and at the northern end of the Syurtysu syncline. In work [1], the authors suggested that the volcanic rocks developed in the Bektau anticline and north of the Syurtysu syncline are close to the "centers of the Middle Devonian magmatism". The occurrence in the form of a crescent bordering the tectonic block of the Early Paleozoic rocks from the north-west, the variegated petrochemical composition of the rocks of the suite – from anlesites, trachydacites and trachyrhyolites, wide development of crystalline tuffs, the presence of subvolcanic bodies, the radial-concentric location of faults make it possible to consider the north-western closure of the Alka-Adyr brachianticline as a part of a large volcano-tectonic edifice preserved from erosion. The inclination angles of the seams in the north are 20–45°, in the south-west direction they dip at the angles of 35–50°. In the southern frame of the Zhailma syncline (near the city of Karashoky) there is a sharp increase in the angle of incidence up to 40–50°. Another center of distribution of the Middle Devonian effusive magmatism is assumed in the mountains of the S. Kedeytau, where it is apparently fixed by the dome-shaped extrusive body of liparites squeezed onto the surface. The rocks in the blocks of the eastern part of the anticline are inclined to the south at the angles of 30–60°.

The stage of intense manifestation of felsic volcanism ended with the intrusion of intrusive rocks of the Middle Devonian (Terekta) complex of biotite-hornblende granites. The dissected relief at the end of this stage is evidenced by the presence of a large number of coarse clastic boulder-pebble formations.

As Erlich E. N. (1979, 1966, 2020), notes in his works, for the Quaternary volcanism of the western part of the Pacific Rim, massive eruptions of acidic volcanic material mark a very important (turning point) moment in the evolution of the tectonics of the region [16]. Within this period, the main systems of horst-anticlinal uplifts are formed, with the parallel development of the graben system. The total amplitude of uplifts is 600–800 m, and the range of movements, taking into account the subsidence of grabens, is 1200 m. Huge ring volcano-tectonic structures with the diameter of 8–12 to 40 km are formed within the volcanic belts, with the subsidence amplitude of up to 1000 meters. Thus, this stage is a powerful outbreak of orogeny.

The Middle-Late Devonian stage of magmatism is characterized by the development of contrasting series: trachyrhyolites and trachybasalts. Partially, the eruptions were of an inherited nature, or originated from smaller cinder and lava cones, fissure-type volcanoes. In local depressions, the products of washing out the volcanoclastic material accumulated. This stage of magmatism is represented by volcanogenic-sedimentary analogs of the Zhaksykon series of the Sarysu-Teniz watershed composed of volcanomictic conglomerates, sandstones, tuff sandstones, felsic tuffs, agglomerate tuffs, basalt horizons, 500–1500 m. The Devonian orogeny ended with the intrusion of Late Devonian granites (Kokkuduktyubinsk) subalkaline intrusive complex.

Thus, the most powerful Devonian tectonic restructuring of the region is associated with intense manifestations of rhyolitic volcanism. The first and final periods were marked by relatively weak manifestations of tectonic activity.

Volcanic Devonian formations are overlain by terrigenous carbonate-terrigenous sediments of the Late Frasnian-Famenian-Early Carboniferous transgressive series.

The Late Frasnian-Famennian-Early Carboniferous (taphrogenic) complex is represented by the Daira Formation, which is eroded on the underlying formations. The suite, 10–750 m thick, is composed of basal conglomerates, sandstones, siltstones, with lenses of trachyrhyolites, trachybasalts. A sharp drop in the thickness of the suite sediments testifies to the extremely dissected (volcanogenic) character of the bed of the suite's sediments. The red-colored terrigenous rocks of the suite are overlain by the Famennian-Early Carboniferous terrigenous-carbonate and carbonate formations, according to which they lie on the rocks of the Dairinskaya suite and often have facies mutual transitions with it.

According to Vasyukov Yu. A. [1], three structural-facies zones (SFZ) of Famennian sedimentation are distinguished in the Zhailma graben-syncline: Northern, Middle, and Southern. The determining factor of such a selection is the presence of an arcuate band of continuous distribution of relatively deep-water clayey-siliceous-carbonate deposits extending from the northeast to the west of the structure and for the most part coinciding with the strike of the Zhailma trough. In the Northern and Southern SFZ, the famen is represented by shallow-water organogenic and organogenic-detrital limestones. Such zoning persisted during the Famennian, Tournaisian and Visean times.

Thus, the Zhailma SFZ is an extended "arc-shaped" trough, maximally sag in the central part, which existed for a long time against the background of the general weak subsidence and accumulation of shallow-water sediments along the periphery. The gradual compensatory nature of the accumulation of carbonate and carbonate-terrigenous sediments is evidenced throughout the depression by the presence of stepped normal faults along its sides and the absence of blocky, coarse-grained facies.

Ancient volcanic apparatuses of Central Kazakhstan. For the first time, the presence of a large number of ancient volcanoes developed on the sides of the Zhailma depression was noted by G. N. Shcherba (1964). In work [2], the author cites the data of intense volcanism of the Lower Devonian, and then the Givetian-Franian time, which determined the location of the main volcanic centers at the intersection of faults along the main northeastern and northwestern large faults. These were dynamic effusive-explosive processes accompanied by ejections of first basic, and then medium and acidic lavas and their products, the rapid growth of volcanic cones (the Taszhargan, Kedeytau, Mur-zashoky, S. Zhayrem, Ushkul volcanoes). Later, the activity of volcanism clearly weakened.

Some of these volcanoes are clearly observed in the form of fragments of ring structures bordered along the periphery by dike belts. Volcanogenic structures are most clearly shown on the geological map compiled by V. I. Schibrik (1989). On this map, the authors highlighted dikes of basalts, diabases and rhyolites, trachyrhyolites, and fragments of radial and ring faults (Fig. 1).

This made it possible to establish with a high degree of reliability and clarity the presence of two large volcanoes on the northern side of the caldera structure: North Zhairem and Ustanynzhal. To the south, in the central part of the Zhailma depression, the buried volcano Zhairem stands out in a practically closed ring, with the caldera diameter of 20–22 km, which probably corresponds to the later (Givetian-Franian) stage of volcanism. At the same time, the entire Zhailma syncline is completely limited by an arcuate fault, which coincides well with the outer boundary of the arcuate trough (Yu. A. Vasyukov, et al., 1991), with the radius of about 40 km developed parallel to the boundaries of the Usta-nynzhal caldera. This makes it possible to consider the basin as a fragment of the outer part of the volcano-tectonic depression genetically related to the process of subsidence of the surface, the second (orogenic) stage in the development of magmatism.

Ring structures in the Zhailma syncline include vent (extrusive), dike, lava facies, eroded and redeposited remains of cinder cones, fragments of systems of radial and ring faults. Ring elements expressed as a complex of supply channels, are presented indistinctly and sporadically, giving way to linear supply channels. The outer framing of the massifs is dominated by volcano-tectonic "leaning" contacts, which can create a false illusion of active (intrusive) contacts. This feature of the volcanic rocks occurrence, which is easily established by the example of the Late Paleozoic orogenic complex, is of a general nature and is characteristic of all the paleovolcanic regions of Central Kazakhstan. Relatively young suites everywhere "lean" against the slopes built by the older ones. Therefore, the height marks of both turn out to be approximately the same, and often the ancient formations lie above the young ones. Similar relationships of suites are observed strictly along their uneven contacts, which have irregular changing contours, their own layout plan and cannot be explained by movements along ordinary faults

Subsidence in these isometric or more complex volcano-tectonic depressions covering areas exceeding the diameter of

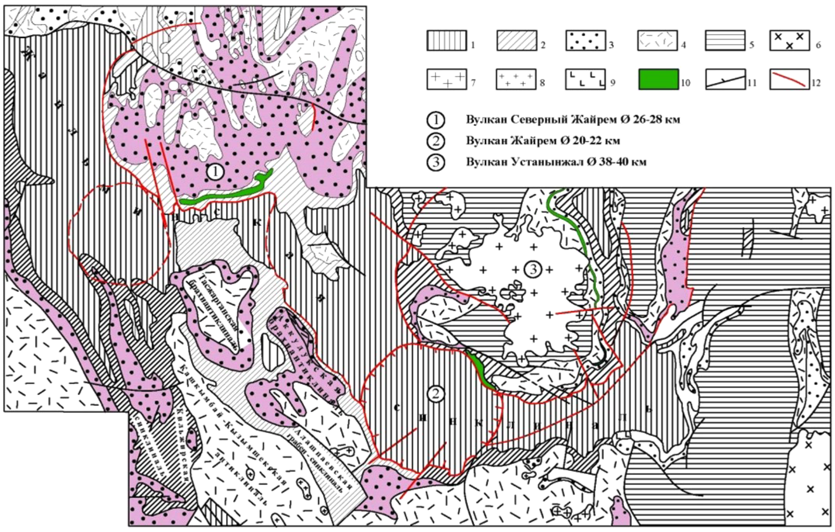

Fig. 1. The alleged volcanic apparatuses that existed on the Zhailma structure:

1 — C_1, Lower Carboniferous: limestones, mudstones, sandstones; 2 — D_3fm, Famennian Stage: limestones, clayey-siliceous-carbonate rocks with layers of iron-manganese ores, tuff tuffites; 3 — D_3dr, Upper Devonian Daira Formation: red-colored conglomerates, sandstones, siltstones, lenses of trachydacitic porphyrites; 4 — D_{1-2}, Lower-Middle Devonian: terrigenous-volcanogenic deposits; 5 — PZ_1, Lower Paleozoic: metamorphosed volcanogenic-terrigenous deposits; 6 — P_3–$T\gamma$, Upper Permian—Lower Triassic granites; 7 — Devonian granitoids; 8 — subvolcanic quartz porphyry bodies; 9 — dikes of diabase porphyrites; 10 — ring dikes of basalts, diabases, rhyolites, trachyrhyolites; 11 — discontinuous violations; 12 — fragments of radial and ring faults

a deep volcanic chamber, or not at all coinciding with the centers of individual chambers, was named "external" by E. E. Milanovsky. They can be contrasted with internal depressions: calderas.

The proposed sequence of the volcanism development in the Zhailma trough is in good agreement with the scheme (Fig. 2).

The burial of the ancient relief expressed by peculiar primary "ingressive" volcanic unconformities, testifies to the rapid filling of low spaces with volcanic mass, its great fluidity and spreading over a large area. Descriptions of such geological phenomena in paleovolcanic regions are available in a number of works.

Internal structure, shape and patterns of the volcanic structures location. These factors depend on faults of different scale and genesis that controlled the rise of magma. This leading position of volcanology finds confirmation and substantiation in many works dealing with geology of Central Kazakhstan.

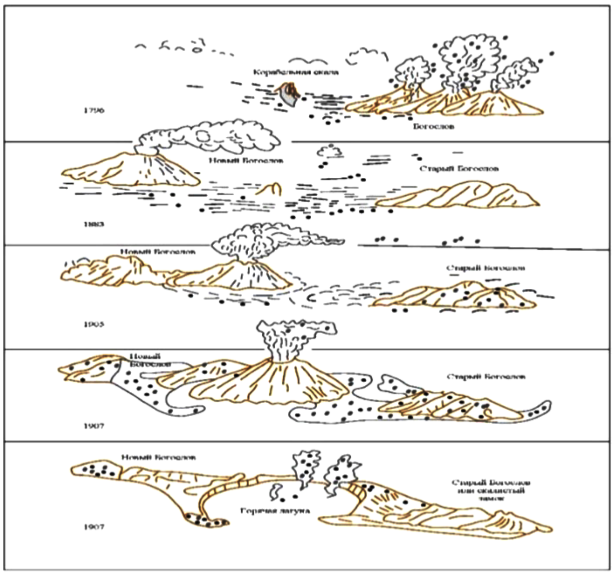

Fig. 2. Scheme of forming volcanoes on the example of the Theologian (Bogoslov) volcano (according to Lobeck, 1939)

The greatest attention is attracted by large volcano-tectonic structures, depressions and subsidence calderas developed above volcanoes due to the removal of huge masses of the volcanic material to the surface (Tikhomirov V. G., 1973).

According to the mid-frequency seismic data [5], the Zhailma graben-syncline cross section is a "backer-shaped" trough, with the depth of 5 to 8 km with the ledge-shaped structure of the wings formed on the Caledonian (Early Paleozoic) base. The base surface is represented by a reflecting horizon, sharply discordant with the overlying subhorizontal boundaries; below the section is uniform. At the depth of 8 km, shear movements in the northeast direction are recorded, indicating the thrusting of the folded complexes of the Aktau-Mointinsky uplift onto the board of the Zhailma trough.

In the geoelectric field [7], along the profile that crossed the Zhailma graben-syncline and the Atasu uplift in the northeast direction, two horizons are reflected: the first one with rock resistivity of 2—10 Ohmm and the thickness of up to 70 m corresponding to the Mesozoic Cenozoic deposits, and the second one with resistivity of up to 100—200 Ohmm, the thickness of 800—3000 m characterizing the upper sedimentary part of the structure section.

The northeastern side of the graben in the deep section starting from the depth of 4 km, is sharply limited by a steeply dipping southwest zone of convergent field gradients, although on the surface its boundary with the Atasu uplift is shifted far to the northeast. To the north-east of the gradient zone characterized by resistivity of 100—200 Ohmm, below 3.5—4.0 km, the sedimentary complexes of the graben-syncline are underlain by high-resistivity (300—1500 Ohmm) rocks, similar in electrical resistance values to those neighboring the Atasu uplift. This pattern is typical for thrust deformations.

Thus, the results of seismic and electrical exploration do not contradict the the authors' ideas of the volcanogenic origin of the Zhailma graben-syncline and contribute to the deciphering of the structure of the northeastern wing of the trough, which turned out to be elevated relative to its central part, due to thrusting ("underthrusting") under the Famennian-Early Carboniferous (plastic) carbonate formations, in the form of tectonic plates and wedges of hard (siliceous-terrigenous) rocks of the early Paleozoic. One of these plates is exposed on the daylight surface in the vent part of the Ustanynzhalsky paleovolcano, cut through by the Devonian granitoid intrusion.

According to Shcherba G. N., the Taszhargan brachianticline is also a volcanic apparatus, whose vent part is made by extrusion of trachyrhyolites.

The formation of the Zhailma depression is caused by the development of intense volcanic processes, a system of plicative and disjunctive dislocations developed along deep basement faults.

Within its limits, a series of brachifolds has been established, less often linear with dips on the wings from 30 to 80–90°, complicated by flexures, faults, strike-slips, thrusts, interformational failures, brecciation zones [17]. A complex combination of tectonic processes led to the development of the dissected topography at the base of the Famennian sediments (Fig. 3). This is very important for the processes of formation and accumulation of "metal-bearing" solutions.

Faults in the Zhailma structure are divided into tectonic blocks, whose boundaries are marked by zones of high gradients of the gravimetric field. The time of laying belongs to the Devonian period characterized by tectonomagmatic activation, manifestation of intense volcanism and blocky deformations of the Caledonian base, as well as the formation of consedimentary horst anticlines and graben synclines [18].

Volcano-tectonic structures of subsidence in the latitudinal branch of the Devonian volcanic belt, are described by Fedorov T. O. Various volcano-tectonic depressions are developed, according to M. K. Bakhteyeva, A. E. Mikhailova, and others, V. G. Trifonova, M. N. Shcherbakova, in the southern part of the Tokraus and North-Balkhash depressions.

In ancient volcanoes, as well as in modern ones, one can firstly distinguish a surface structure (superstructure) formed by lavas and ashes of successive eruptions along with intrusions penetrating them; secondly, deep substructure covering the area of the earth's crust between the roots of the volcano and the earth's surface, and thirdly, the volcanic hearth (focus), due to which volcanic eruptions are fed. All these parts are successively exposed by erosion (Tyrrel G., 1931) (Fig. 3).

The upper part of the volcanic edifice (Oberbau) has a caldera and a central cone, bedded, conical and radial veins, with a crater and a vent. The deep part (Unterbau) has conical and ring veins (partially continuing the ring caldera).

The translational movement of the melt is associated with modern concepts of segregation: the process that plays a particularly important role in the formation of banded textures of volcanic rocks, and determines the lava fluidity. The distribution of roots feeding volcanic activity is strictly subordinated to the structural setting and is controlled in a number of cases by a system of tension cracks in the domes.

The typical structural features of the deep root zones of ancient volcanoes do not differ in morphology from modern ones. Different sections can expose either supercrystal or deep roots of ancient volcanoes, heterogeneous in structural features at different depths. The root zones of the upper intercrystal stage are characterized by intrusions under volcanoes or subvolcanoes combined with volcanogenic formations, which represent structural elements of the ancient supercrystal apparatus preserved from erosion and destruction. Intrusive, outflowing and pyroclastic rocks are typical for the upper tier (Luchitsky I. V., 1971).

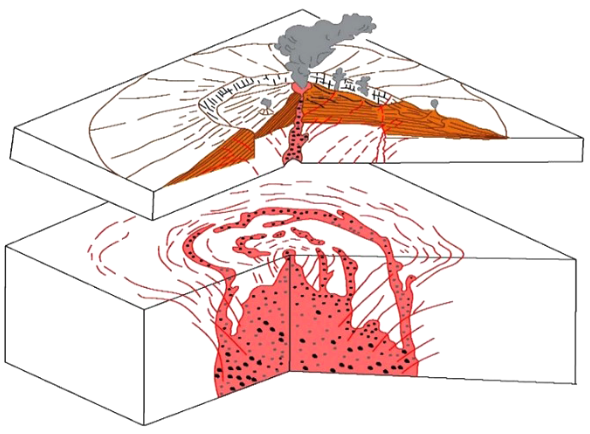

Fig. 3. Scheme of the volcano structure (according to Cloos, 1936)

Thus, the Ustanynzhalsky and Northern Zhairem paleovolcanoes correspond to the zone of the upper intercrystal layer of ancient volcanoes.

The presence of large Devonian volcanic structures is also characteristic of the Munglu-Uguztau horst anticline, the southern flank of the Zhailma trough.

The data given by the authors basically coincide and partially supplement the conclusions of Patalaha G. N. and Shuzhanov V. M. that the "Atasu metallogeny", in fact, completes the process of formation of the Devonian volcano-plutonic belt in the Carboniferous, i. e. is Caledonian at the Hercynian stage characterized, however, by a very specific structural localization; it is confined only to the outer peripheral structures of this belt, such as grabens with basaltic magmatism, which experienced a steady deflection throughout the entire history of the belt evolution. It is this main specific feature of the structures of the Zhailma type that provides a real key to understanding why the search for deposits of the Atasu type carried out over many decades in Kazakhstan, has been so unsuccessful.

Conclusions.

1. The initiation and development of the Zhailma graben-syncline is closely related to the processes of tectonomagmatic evolution of the Devonian volcano-plutonic belt.

2. The development of magmatism was characterized by the change in differentiated basalt-andesite-dacitic formations (Early Devonian), the predominant rhyodacite-rhyolite of the middle stage (Early-Middle Devonian) and finally contrasting basalt-rhyolite or single-rock formations of increased alkalinity of the late stage of development (Middle-Late Devonian, Zhaksykonian series).

3. The formation of the Zhailma volcanic depression, surrounding the Ustanynzhal caldera in the form of a ring, is associated with Early-Middle Devonian volcanism associated with powerful eruptions of large volumes of rhyodacite-rhyolite volcanic rocks from large stratovolcanoes (Northern Zhairem and Ustanynzhal), accompanied by subsidence surfaces above the foci of emptying magmatic chambers.

4. At the final stage of Devonian magmatism, a parasitic crater (Zhairem) arose in the Zhailma depression probably composed of loose volcaniclastic formations, which were later completely eroded and only trachyrhyolites and trachybasals of dike and extrusive facies were preserved, which created an extremely complex, rugged nature of the sediment bed of the transgressive series.

5. Thus, the most powerful Devonian tectonic restructuring of the region was associated with intense manifestations of rhyolitic volcanism. The first and the final periods were marked by relatively weak manifestations of tectonic activity.

6. The final (taphrogenic) stage was marked by the period of the Late Frasnian-Famennian-Early Carboniferous transgression with the accumulation of thick carbonate and carbonate-terrigenous sediments, including ore-bearing ones.

7. Thus, predictive metallogenic and accordingly prospecting work is recommended to be carried out within the graben-synclines of the Sarysu-Teniz segment of the Devonian volcanic belt, where such deposits of ferromanganese ores as Tur, Bogach and Karaadyr of the Atasu type are already being developed in the Aydagarla graben-syncline.

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Особливості формування Жаїльмінської вулкано-тектонічної западини

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Мета. Виявлення особливостей формування Жаїльмінської вулкано-тектонічної западини, а також принципів і факторів, що впливають на рудоутворення цієї структури.

Методика. Аналіз результатів ізотопного датування гірських порід, критичний аналіз літературних і фондових матеріалів, аналіз генези та специфіки зруденіння Жаїльмінської структури, особливостей формування вулкано-тектонічної депресії.

Результати. Формування Жаїльмінської грабен-синкліналі пов'язане із просіданням після викидів значних мас кислого магматичного матеріалу стратовулканів, сконцентрованих на Жаїльмінській структурі. Закладення й розвиток грабен-синкліналі тісно пов'язане із процесами тектономагматичної еволюції девонського вулканоплутонічного поясу.

Наукова новизна. Переглянута пошукова модель для стратиформних родовищ Атасуського типу з урахуванням оригінальної теорії вулкано-тектонічного походження структури, сформованої на завершальних етапах становлення й розвитку девонського вулкано-плутонічного поясу. Генезис родовищ Атасуського типу сприймається як осадово-гідротермальний, пов'язаний із процесами діагенезу й катагенезу, що відбуваються всередині осадових басейнів. Обґрунтована наявність на північному борту структури кальдери двох великих вулканів: Північний Жайрем і Устанинжал.

Практична значимість. Рекомендовано проведення прогнозно-металогенічних і, відповідно, пошукових робіт родовищ Атасуського типу в межах грабен-синкліналей Сарису-Тенізького сегменту девонського вулканічного поясу, де в Айдагарлінській грабен-синкліналі вже розробляються родовища залізомарганцевих руд Тур, Богач і Караадир.

Ключові слова: *вулканічна грабен-синкліналь, ізотопний аналіз, девонський вулкано-плутонічний пояс, Атасуський рудний район, континентальні рифти*

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