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Geology and minerageny of the Bestobe deposit (Central Kazakhstan)

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ABSTRACT
Polygenic stratiform deposits are the largest in the world in terms of barite and manganese reserves, as well as lead and zinc reserves. In the mineral resource complex of the Republic of Kazakhstan, they are of great importance and are distinguished as an independent genetic Atasu type. In the article, the deposits of the Zhailma graben-syncline in a large riftogenic structure are considered as a reference for the Atasu type. The geological structure of the Bestobe stratiform polymetallic deposit located in the eastern part of the Zhailma synclinorium is presented. The stratigraphy of ore formations, mineralization features, morphology of the ore body and the pattern of zoning the distribution of elements in the ore-bearing rocks of the Bestobe deposit are shown. A feature of the deposit is the combination of layered iron-manganese and lead-zinc ores and superimposed zinc-lead-barite mineralization; the sharply subordinate role of hydrothermal-sedimentary ores in the total reserves of lead and zinc; comparative abundance of lead, copper and silver sulfosalts. The analysis of the materials indicates that mineralization at the Bestobe deposit is complex. Its main value is polymetallic ores. The role of iron ore mineralization of the deposit is insignificant. Manganese mineralization is practically absent. Polymetallic ores are conventionally subdivided into lead-zinc-barite, lead-barite, barite and lead-zinc. Strontium is a constant impurity in barites. Lead is mainly concentrated in galena; its insignificant amount is found in geocronite, boulangerite, jamsonite, bournonite, cerussite, anglesite, pyromorphite, plumboyarosite. The bulk of zinc is concentrated in the form of sphalerite.
Keywords: Atasu type, polymetallic, Zhayilma graben-syncline, lead-zinc-barite deposits.

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Introduction

Polygenic stratiform ferromanganese and barite-lead-zinc deposits isolated as an independent genetic Atasu type, are of great importance in the mineral resource complex of the Republic of Kazakhstan [1]. Polygenic stratiform deposits are the largest in the world in terms of barite and manganese reserves, as well as lead and zinc reserves [1]. In terms of paragenetic associations, the deposits of the Atasu type are either complex ferromanganese and barite-polymetallic ones (Ushkatyn I, II, III, East Zhairem, West Kamys, Arap, Keregetas, South Karazhal), or (according to the prevalence of Fe, Mn) ferromanganese ones (West and East Karazhal , Big, Middle and Small Ktai, Zhomart, Vostochny Kamys, Yuzhny Klych, Akshagat, Kentobe, Bogach, Tur, Shoyntas), or by the predominance of Pb, Zn, Ba, barite-polymetallic and polymetallic ones (Bestobe, Western and Far-West Zhairem, Karagayly , Akzhal, Uzunzhal, Mirgalimsay, Shalkiya, Achisay), or monobarite ones (Kentobe, Zhumanay, Zhalair), etc. (Figure 1) [1].

Experimental part

The deposits of the Zhailma graben-syncline (northwestern part of the Zhailma-Talkuduk rift zone) are considered as a reference for the Atasu type (Figure 2). The Zhailma graben-syncline (trough) is a large riftogenic structure, which is elongated from northwest to southeast. The rift-generating structure was formed in the Late Devonian during the destruction of the Epicaledonian Central Kazakhstan continental block [[2], [3], [4], [5], [6]].

The outer frame and the base of the graben-syncline (Figure 2) are composed of terrigenous-volcanogenic deposits of the Lower-Middle Devonian and volcanogenic-terrigenous deposits of the Daira Formation of the Upper Devonian. The total thickness of the Famennian and Tournaisian siliceous-terrigenous-carbonate deposits that make up the graben-syncline is more than 2500 m.

Rectilinear segments of its contours in the northwestern, latitudinal and less often northeastern and submeridional strike reflect the tectonic boundaries of the blocks of the rigid basement (Figure 2) [1].

The main value of the Atasu ore region is represented by stratiform complex deposits of iron-manganese, lead-zinc and barite ores of multi-stage and complex formation identified as an independent Atasu genetic type, one of which is the Bestobe deposit (Figure 3).

The Bestobe deposit is located in the eastern part of the Zhailma synclinorium (Zhairem, Ushkatyn, Zhumart are in the western part) and reveals a closer spatial relationship with the northeastern faults represented by barite, barite-polymetallic, polymetallic and iron-manganese deposits [[4], [9], [10], [11]]. Below iron-manganese ores, there are layered and secant bodies of lead-zinc-barite ores of the same two main stages of mineralization. Baritization was manifested in two stages: the first proceeded before folding, and the second one after it. Early fine-grained barites contain relict layered textures, sometimes they contain conformable interlayers with manganese mineralization. Late bodies of large-crystalline barite with sulfide mineralization replace even silicites, they are affected by shearing and faults associated with regional movements along the Uspenskaya mobile zone [8].

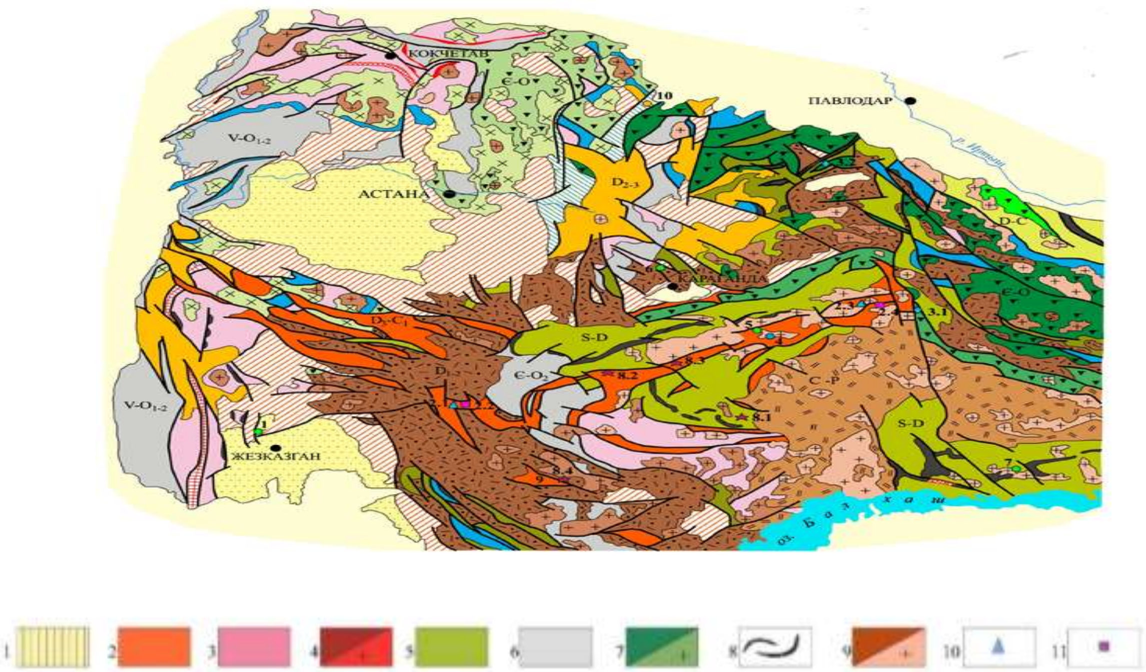

Figure 1 - Geodynamic position of the fields [[4], [5], [6]]:
1 - riftogenic structures (D_3-C_1); 2 - geological complexes of the inland sea basin (D_3-C_1); 3–7 - pre-Middle Devonian continental crust: Precambrian sialic massifs (3), Devonian runway (4), marginal sea basin (S_1-D_2) (5), passive continental margin (∈-O_3) (6), island arcs (∈-O_2) (7), tectonized ophiolite zones (8); Late Paleozoic runway (9); deposits: barite-polymetallic (10): Zhairem (2.1), Karagayly (2.3); ferromanganese (11): Ushkatyn (2.2), Kentobe (2.4) [[5], [6], [7]]

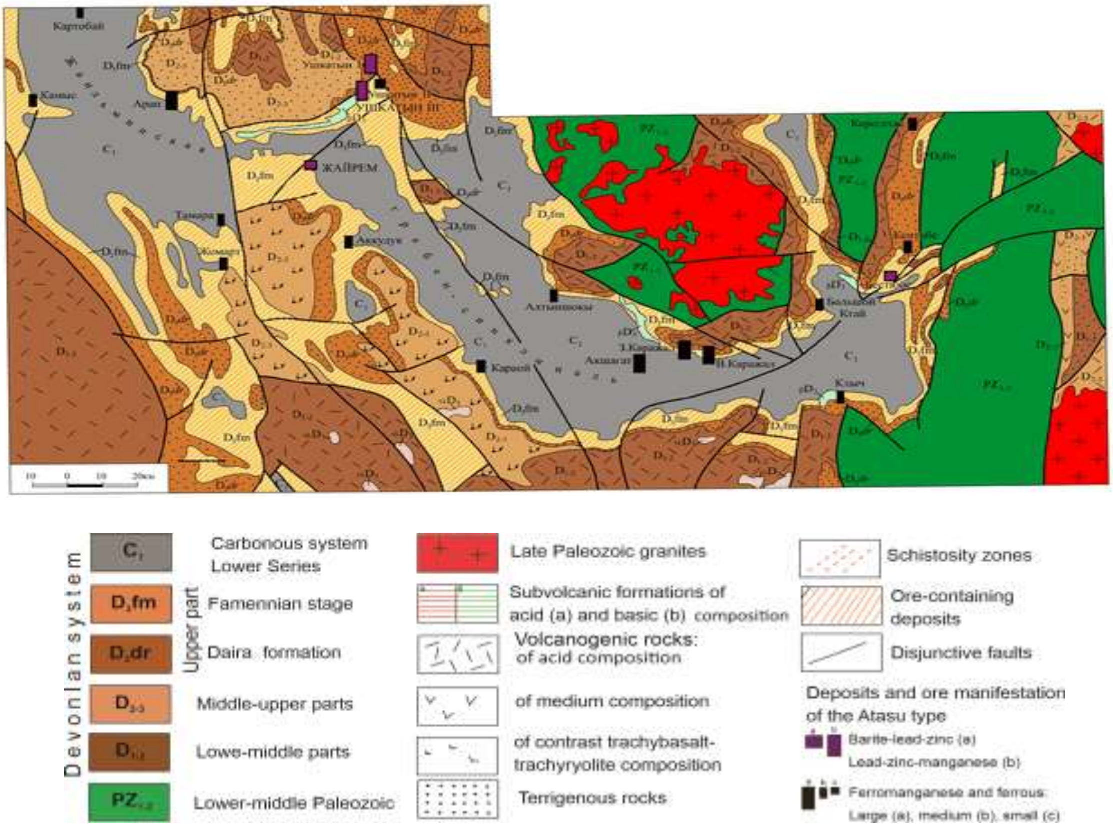

Figure 2 - Schematic geological map of the Zhailminsky and Karazhal ore clusters (according to A.A. Rozhnov et al.) [[3], [4], [5], [9]]

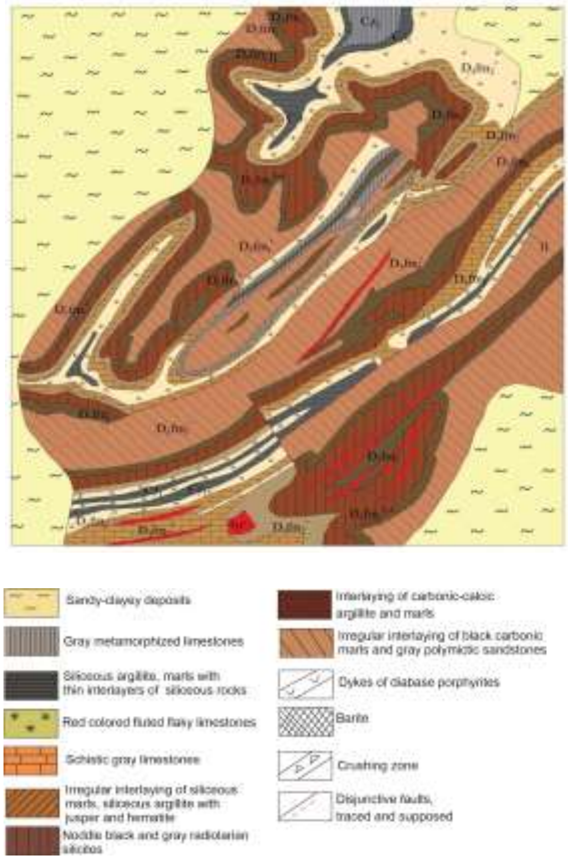

Figure 3 – Pattern of geological structure of the Bestobe deposit (acc. to N.S. Bozhukha) [[9], [11]]

As an occurrence of iron, it has been known since the late thirties. Zinc-lead-barite mineralization was discovered on it in 1952 by I.S. Syromyatnikov [[9], [11], [12], [13], [14]].

The deposit is composed of Upper Devonian and Lower Carboniferous sedimentary rocks containing an admixture of volcanic material [15].

There are distinguished the Daira Formation (D_3fm_1dr and Famennian deposits subdivided into five units: unevenly layered (D_3fm_1a), rhythmically layered (D_3fm_1b), flyschoid (D_3fm_1c), gray-colored (D_3fm_2a) and red-colored (D_3fm_2b), as well as Tournaisian rocks: dark gray pack (C_1t_1a) (Figure 4).

The features of the deposit are as follows: the combination of layered iron-manganese and lead-zinc ores and zinc-lead-barite mineralization superimposed on them; the sharply subordinate role of hydrothermal-sedimentary ores in the total reserves of lead and zinc; comparative abundance of sulfosalts of lead, copper and silver.

The deposits of the Famennian stage, according to lithological and petrographic features, are divided into horizons of terrigenous-carbonate rocks, black clayey marls, gray and black clayey silicites, ore, gray-colored and red-colored limestones (Figure 4).

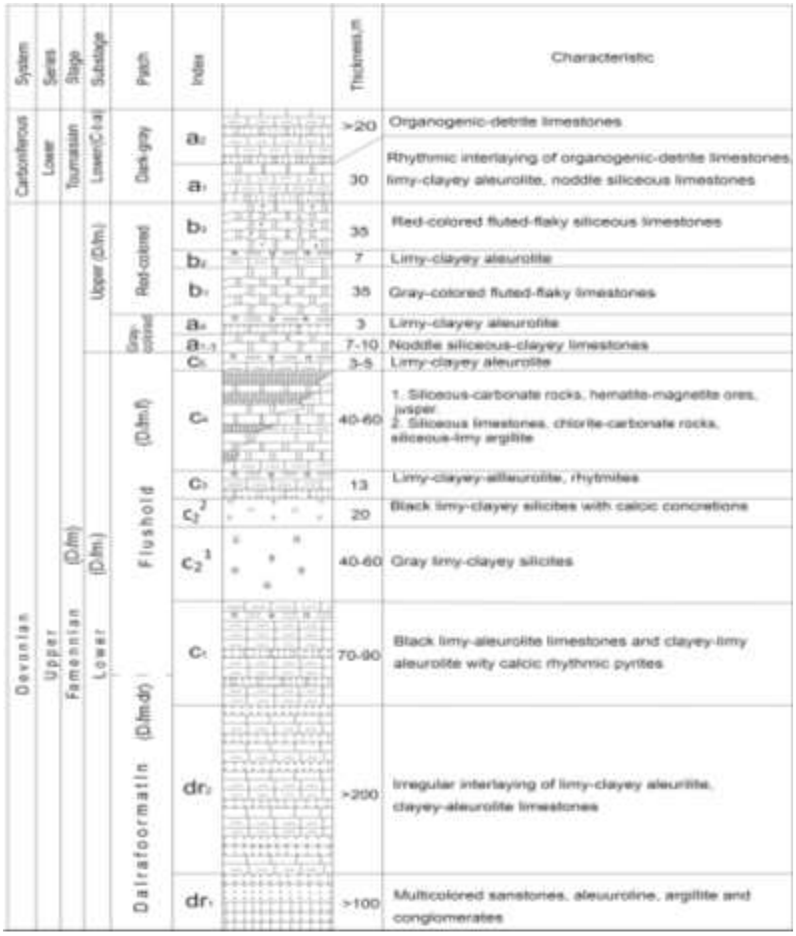

Figure 4 - Stratigraphic column of the Bestobe deposit [9]

Results

The Bestobe section is dominated by calcareous rocks, there are organogenic limestones; everywhere there are also horizons of lithocrystalline tuffs (up to 5 m thick) of liparite-dacitic composition, subvolcanic bodies of diabase porphyrites. The age of enclosing rocks, according to A.M. Sadykov is Upper Famennian [8]. In the ores of the deposit [9] there are about 60 minerals, of which the main ones are galena, sphalerite, pyrite, and barite.

The main reserves of barite-polymetallic ores of the deposit are confined to two synclinal structures located in the central part of the ore field (Figure 3).

The synclinal structures of the First section have been traced for more than 4 km, have the width of 150-250 m and the minimum depth of 170 m; the Second section of the deposit is up to 400 m wide and 350-400 m deep (Figure 5).

Morphologically, the ore bodies of the deposit are characterized by sheet-like and lenticular forms. They have the same occurrence elements as their enclosing rocks. In the First and Second sections, the ore bodies are elongated in the northeastern direction along the azimuth of about 45° and dip to the northwest at the angle of 30 to 90°. Their length is hundreds meters, the thickness is from a few to tens meters; in strike and dip they are unsteady. From the flanks to the central parts of the ore bodies, the thickness increases.

The internal structure of ore deposits is quite complex. Thus, alongside with an extremely uneven distribution of ore types, they also contain barren interlayers up to 5 m thick. The morphology of individual ore bodies is complicated by numerous late faults of various scales.

Lead-zinc-barite, lead-barite, barite and lead-zinc ores have been identified at the deposit. Lead-zinc-barite ores are developed in the lower parts of the ore bodies, lead-barite ores stand out as independent deposits in the central part and on the southwestern flank of the deposit, barite ores are widely developed in the near-surface part of the ore areas and lead-zinc ores form small lenticular bodies in the lower part of the ore horizon and in the upper layer of black clayey silicites. Thus, the deposit exhibits vertical zonality in the distribution of mineralization.

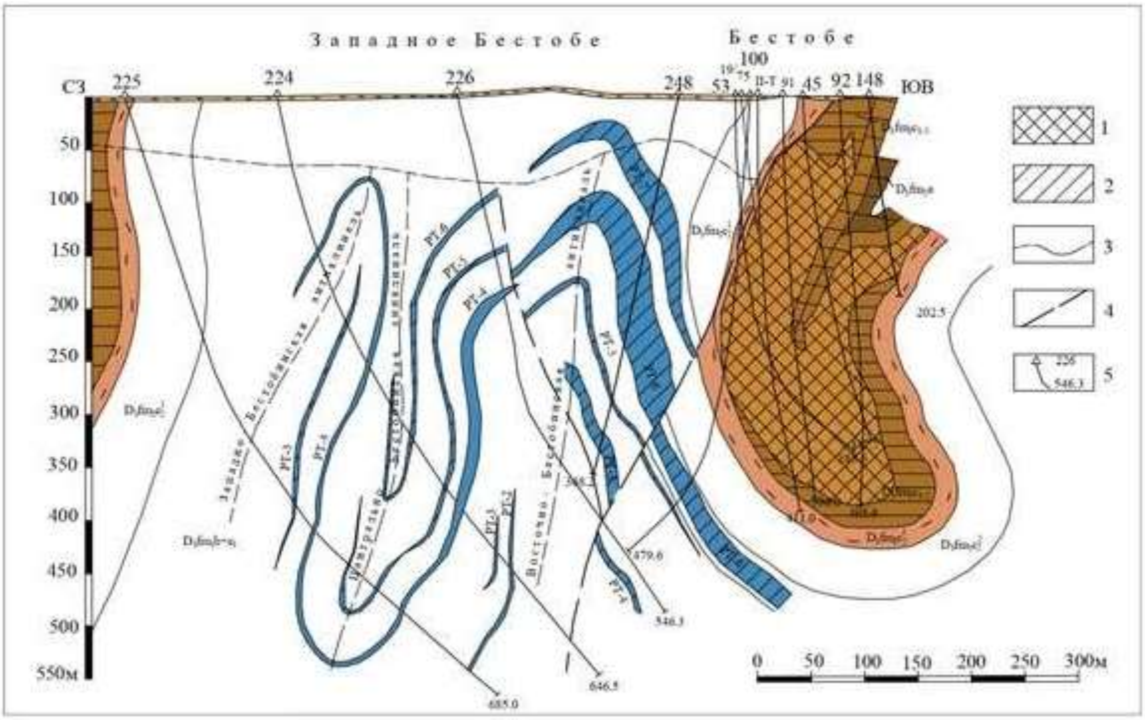

Figure 5 - Schematic geological section [7]
1 - barite-polymetallic ores; 2 – polymetallic ores; 3 – lower boundary of the weathering crust; 4 - tectonic faults; 5 – wells

In the distribution of elements in ore-bearing rocks, zoning is also observed (Table 1). It is characterized by different concentrations of elements above and below the ore bodies. Thus, the content of all the elements, except for copper, in the over-ore stratum is usually several times higher than in the under-ore one. Easily mobile elements in the under-ore zone are found in small quantities. In the over-ore stratum, the elements are dispersed over long distances from the ore bodies and form high concentrations, for example, arsenic.

Table 1 – Elements distribution zonality in ore-containing rocks of the Bestobe deposit

Zones	Number of samples	Distance from the ore body, m	The elemental composition of the zone		
			Basic	Rare	Very rare
IV above the ore	910	from 150 to 350	Hg	Ba, As	Ba, As
III above the ore	710	from 50 to 150	Ba, As, Hg	Pb, Zn, Cu, Sb	Tl, St
II above the ore	605	from 10 to 50	Pb, Ba, As, Hg, Ag, Cu, Zn, St	Sb, Cd, Tl	Mo, V, Ge et al.
Above the ore	373	up to 10	Pb, Ba, As, Hg, Ag, Cu, Zn, St, Cd, Ge, Sb, Tl	Ga, Mo, Bi, In	Cr, Co, Zr, Li et al.
Ore		Ore body	Pb, As, Hg, Ag, Cu, Zn, St, Cd, Ge, Sb, Tl	Ga, Mo, Bi, In	Cr, Co, Zr, Li et al.
I under the ore	393	up to 5-6	Ba, Pb, As, Hg, Ag, Cu, Zn, Sb, Cd		
II under the ore	252	from 5-6 to 20-30	Ba, Pb, Zn, Cu		
III under the ore	379	from 20-30 to 70-100	Ba, Cu		

The zonality in the distribution of elements around the ore bodies of the First and Second sections is generally the same. There are clearly distinguished the internal, intermediate and external zones. In the internal zones, elevated contents of those elements that are concentrated in the ore body are noted. In the intermediate zone, there are mostly common contents of lead, zinc, barium and arsenic, mercury. In the outer zone, significant concentrations of only volatile elements (mercury, sometimes arsenic) are noted. The most extensive halos are confined to the First section, where the enclosing rocks are intensely dislocated and where the thickest ore bodies have been identified. Such dimensions of the ore tail can be related to the superimposed dynamometamorphic flow.

When moving from one zone to another (in the direction from the ore bodies), the list of elements is reduced. So, if the number of elements in the halo in the first over-ore zone is 11, then in the second one it is 8, in the third one it is 3, and in the fourth one it is only one (mercury). The elemental composition of ores in the first over-ore zone is similar, i.e., this zone is a natural continuation of the ore body. There is noticed asymmetric distribution of moving elements relative to the ore bodies. If in the under-ore strata they (mercury, arsenic) form only internal zones, then in the over-ore stratum they form external ones.

The main components of the ores of the deposit (Table 1) are lead, zinc and barium, the content of which ranges from tenths to 98-99 %. Strontium is a constant impurity in barytes. Lead is mainly concentrated in galena, its insignificant amount is found in geocronite, boulangerite, jamsonite, bournonite, cerussite, anglesite, pyromorphite, and plumboiarosite. The highest lead content is found in the upper parts of the ore deposits, and the lowest content is in the lower ones.

The bulk of zinc is concentrated in the lower parts of the ore horizon in the form of sphalerite. Copper is a constant component of ores present as chalcopyrite, less commonly as fahlore, bournonite, enargite, chalcocite, and luconite. Silver is the most widespread impurity in ores. Its contents range from 3-109 g/t, the highest concentrations are found in galena (up to 500 g/t), fahlore and geocronite.

Cadmium is common in ores. Its high content was established in the significantly zinc varieties. In sphalerite, the content of cadmium is the highest; it is lower by 1-2 orders of magnitude in other sulfides. Mercury is constantly present in fahlore, sphalerite, as well as in the form of independent minerals: cinnabar and schwazite. Thallium was not detected in ores at the spectral analysis sensitivity of 0.0001 % [16]. But it is found in almost all the samples of globular pyrite, in galena and minerals of the jordanite-geocronite-schulcite series. Germanium occurs sporadically in zinc-lead-barite ores. Its own mineral, vanadium-arsenic germanite, was found at the deposit. In the ores there is almost absent bismuth, selenium and tellurium, which sharply distinguishes Bestobe, like other deposits of the Atasu type, from deposits of other genetic groups.

Conclusions

The analysis of the materials indicates that mineralization at the Bestobe deposit is a complex one, of the Atasu type. Its main value is polymetallic ores, the role of iron ore mineralization of the deposit is insignificant, manganese mineralization is practically absent.

Polymetallic ores are conditionally subdivided into lead-zinc-barite, lead-barite, barite and lead-zinc ones. According to the composition and content of lead minerals, the ores of the deposits are divided into three grades: sulfide (20 %), oxidized (60 %), and mixed (20–60 %). The main ore-forming minerals are galena, barite, sphalerite, the main mineral of the oxidation zone is cerussite.

Conflict of interests. On behalf of all authors, the correspondent author declares that there is no conflict of interests.

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ТҮЙІНДЕМЕ

Полигендік стратиформды кен орындары барит және марганец қорлары, сондай-ақ қорғасын және мырыш қорлары бойынша әлемдегі ең ірі кенорындарына жатады. Қазақстан Республикасының минералдық-шикізат кешенінде олардың маңызы зор және дербес генетикалық Атасу типіне жатқызылған. Мақалада ірі рифтогендік құрылымдағы Жайылма грабен-синклиналь кен орындары Атасу типінің эталондық түрі ретінде қарастырылады. Жайылма синклинорийінің шығыс бөлігінде орналасқан Бестөбе стратиформды полиметалл кен орнының геологиялық құрылымы ұсынылған. Кен түзілімдерінің стратиграфиясы, кендену ерекшеліктері, кен денесінің морфологиясы және Бестөбе кен орнының кен сыйыстырушы жыныстарындағы элементтердің аймақтық таралу схемасы көрсетілген. Кен орнының ерекшелігі: қабатталған темір-марганец және қорғасын-мырыш кендері мен оларға үстемеленген мырыш-қорғасын-барит кендерінің бірігуі; қорғасын мен мырыштың жалпы қорындағы гидротермалды-шөгінді кендердің күрт бағыныңқы рөлі; қорғасын, мыс және күміс сульфо тұздарының салыстырмалы көптігі. Материалдарды талдау қорытындысы Бестөбе кен орнында кендену кешенді болып табылатынын көрсетеді. Оның басты құндылығы-полиметалл кендері. Кен орнының темір кенді кенденуінің рөлі шамалы. Марганецті кендену іс жүзінде жоқ. Полиметалл кендері шартты түрде қорғасын-мырыш-барит, қорғасын-барит, барит және қорғасын-мырыш болып бөлінеді. Бариттерде қоспада тұрақты стронций болады. Қорғасын негізінен галенитте шоғырланған, оның аз мөлшері геокронитте, буланжеритте, джемсоните, бурноните, церусситте, англезитте, пироморфитте, плумбоярозитте болады. Мырыштың негізгі бөлігі сфалерит түрінде шоғырланған.

Түйін сөздер: Атасу типі, полиметалдар, Жайылма грабен-синклиналь, қорғасын-мырыш-барит кен орны.

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АННОТАЦИЯ

Полигенные стратиформные месторождения являются крупнейшими в мире по запасам барита и марганца, также по запасам свинца и цинка. В минерально-сырьевом комплексе Республики Казахстан они имеют важнейшее значение и выделены в самостоятельный генетический Атасуйский тип. В статье в качестве эталонных для Атасуйского типа рассматриваются месторождения Жаильминской грабен-синклинали, в крупной рифтогенной структуры. Представлено геологическое строение стратиформного полиметаллического месторождения Бестобе, расположенное в восточной части Жаильминского синклинория. Показана стратиграфия рудных образований, особенности оруденения, морфология рудного тела и схема зональности распределения элементов в рудовмещающих породах месторождения Бестобе. Особенностью месторождения является: совмещение слоистых железомарганцевых и свинцово-цинковых руд и наложенного на них цинково-свинцово-баритового оруденения; резко подчиненная роль гидротермально-осадочных руд в общих запасах свинца и цинка; сравнительное обилие сульфосолей свинца, меди и серебра. Анализ материалов свидетельствует о том, что оруденение на месторождении Бестобе является комплексным. Главную его ценность составляют полиметаллические руды. Роль железорудного оруденения месторождения незначительна. Марганцевое оруденение, практически, отсутствует. Полиметаллические руды условно подразделяются на свинцово-цинково-баритовые, свинцово-баритовые, баритовые и свинцово-цинковые. В баритах постоянной примесью является стронций. Свинец сосредоточен, в основном, в галените, незначительное его количество находится в геокроните, буланжерите, джемсоните, бурноните, церуссите, англезите, пироморфите, плюмбоярозите. Основная масса цинка сконцентрирована в виде сфалерита.

Ключевые слова: Атасуйский тип, полиметаллы, Жаильминский грабен-синклиналь, свинцово-цинково-баритовые месторождения.

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