LEAD - ZINC ORE DEPOSITS IN MONGOLIA

Sh. Batjargal (Mongolian Technical University, Ulaanbaatar, Mongolia)
J. Lkhamsuren (Museum of Geology and Mineral Resources, Ulaanbaatar, Mongolia)
D. Dorjgotov (Institute of Geology and Mineral Resources, Mongolia)

Recently, in the territory of Mongolia were discovered some 250 mineral occurences, containing Pb - Zn mineralization. Hydrothermal veins form the most common type (180), followed by skarns (60), and some stratiform bodies (10). Four small to medium size vein and skarn base metal deposits were delineated.

Ore mineralization is related to the following genetic types (Table.1.) : Pyritic deposits are related to submarine volcano-sedimentary units, submarine volcanism within continental geosynclinal depressions; skarn and hydrothermal veins related to volcano-plutonic associations; and also concordant polymetallic ore bodies occuring in Rephean and Devonian limestones, of platform type.

Well studied are zinc-calcereos skarns, containing Cu - Zn - Pb and Ag - Pb ores, related to potassions enriched, subalkaline plutogenic, volcanoplutonic and volcanogenic associations.

They are predominantly localized within mega depressions and form ring structures.

The territory of Mongolia is divided into four metallogenic belts, containing polymetallic mineralization. (Fig.1.) They are :

1. Deluun Belt
2. North-Western Khangai Belt
3. Dornod (East Mongolia) Belt
4. Gobi-Nukhetdavaa Belt

In general, the Deluun belt is characterized by pyritic ore mineralization; the North Western Khangai belt by stratiform polymetallic bodies, and the Dornod and Gobi-Nukhetdavaa belts by skarn and hydrothermal polymetallic ore mineralization.

In the 1970s and 1980s large and medium-scale lead-zinc deposits and a number of promising ore occurrences, such as Ulan, Mukhar, Tsav, Tumurtiyn-Ovoo, Bayan-Uula, Altan-Tolgoi, Mungun-Undur and others were revealed and explored in the eastern part of the country. These targets paved a way for establishing a mineral -raw material base of polimetals in the country.(Fig.1).

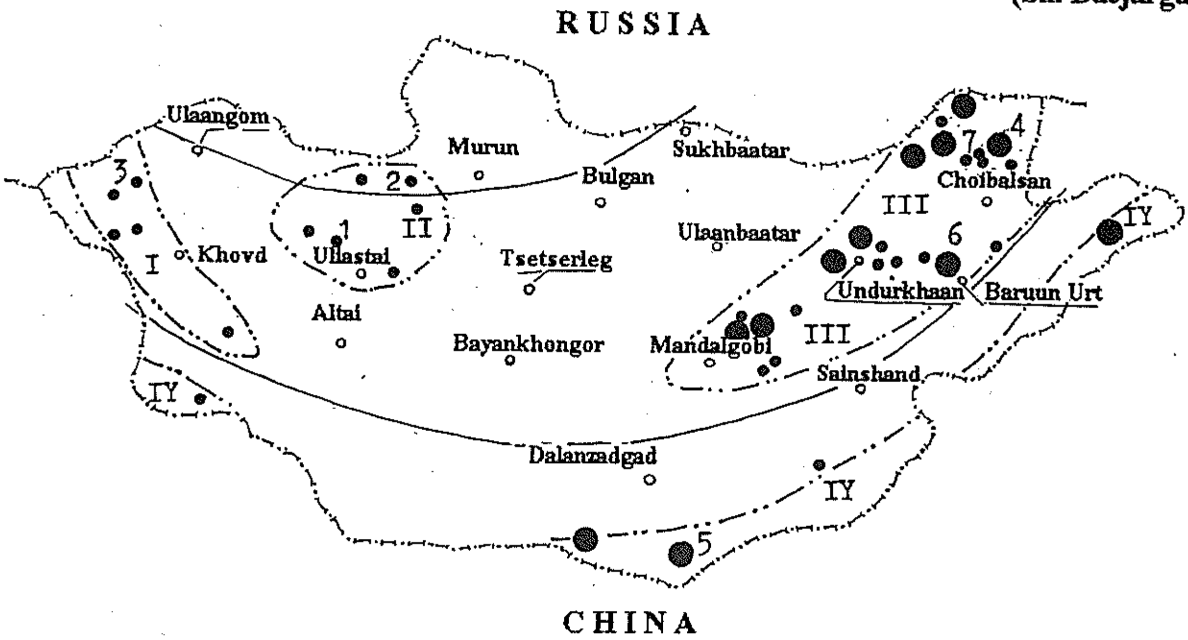
The known base metal deposits were mainly formed in the Mesozoic. They are concentrated within Eastern Mongolian volcanic belt and usually occur in near-margin parts of Late Mesozoic depressions, filled with Upper Jurassic - Lower Cretaceous volcanites of rhyolite-trachirhyolite formation of the basalt-rhyolite association and the basement inliers composed of Devonian volcano-terrigeneous-carbonate and older units and, less frequently, of Early mesozoic granitoids.

The known base metal deposits belong to four economic types : mineralized fluido-explosive pipes; veins in various rocks; mineralized shier zones in rocks of various composition; and aposkarn metasomatic bodies in limestones.

Fluido-explosive deposits of the explosion pipes.

Fig.1- DISTRIBUTION OF LEAD - ZINC ORE MINERALIZATION IN MONGOLIA
Scale 1 : 15 000 000

(Sh. Batjargal)



Metallogenic belts of polymetallic ore mineralization

I - Deluun
II - North - Western Khangai
III - Eastern Mongolia
IY - Gobi - Nukhet davaa

Major deposits

1. Zavkhan Mandal
2. Tsagaan Uul
3. Dulaan Khar Uul
4. Tsav
5. Khar tolgoi
6. Tumurtiin Ovoo
7. Ulaan

Table 1 - GENETIC CLASSIFICATION OF POLYMETALLIC ORE MINERALIZATION OF MONGOLIA

(Sh. Batjargal)

N	Genetic group	Genetic type	Typical examples
1.	Skarn	Calciferous	Tumurtiin Ovoo, Bayandun,
2.	Hydrothermal	a. Plutogenic-hydrothermal	Modon, Mungun-Undur, Tugalgatai Nuruu
		b. Subvolcanic-hydrothermal	Tsav, Delger Munkh, Khar tolgoi, Altan tolgoi
		c. Volcanic hydrothermal	Ulaan, Mukhar, Idermeg Bayan khaan
		d. Telethermal (stratiform in carbonaceous layers)	Boorjie, Nomin Am, Zavkhan Mandal, Nukhet
3.	Pyrite	a. Pyrite in terrigenic rocks	Tsagaan Uul, Khunkh Tsakhir
		b. Pyrite in volcanic rocks	Khukh maikhan, Dulaan khar Ovoo

This economic type includes the deposits of the Ulan ore field, occurences of Zaan-Shiree and others.

The Ulan ore field is situated in the forest-steppe hilly zone 120 km north of the town of Choibalsan. The ore field covers the junction of north Choibalsan basement inliers and the late mesozoic Dornot depression. The strongest base metal mineralization is confined to the nothern part of the just mentioned depression representing a Late-jurassic-Early Cretaceous volcano-tectonic structure(Fig. 2). It's basement is made up of Early Paleozoic granodiorites and granites including the remnants of Proterozoic metamorphics consisting of biotite-amphibole schists, granite-gneisses, amphibolites, limestones and pyroxene-magnetite and pyroxene-garnet scarns developed after limestones.

The structure of the ore field is predetermined by the NNW trending Mukhar fault zone and the EN-trending tectonic fracturescrossing the zone. Specific bodies of fluido-explosive breccias, "explosion pipes" or fluido-explosive structures were formed at their intersections. They formed at the closing stage of volcanic activity and became the centres of base metal mineralization.

The bodies of fluido-explosive breccias are pipe-like in shape with various outline in the horizontal cross-section, have a steep, near vertical dip had are traced for a depth exceeding 800 m. Individual pipes measure 70-120x120-650m in horizontal cross section. Some of them crop out, others are found to occur at a depth of 100 - 300 m. A set of such bodies form the intricately built Ulan fluido-explosive structure and the Mukhar structure, which is simple in morphology. Each structure accomodate a deposit of the same name. Structural position, geological structure, material composition of these deposits are similar.

The structures in question are composed of (in descending order) : breccias with quartz-fluorite-sulfide or, less common, quartz-sulfide cement, breccias with epidote-actinolite cement bearing stringer-impregnated and nest-like sulfide mineralization, epidote-actinolite-metasomatites after brecciated rocks with impregnated-nest-like mineralization, and, finally, magnetite-pyroxene, wollastonite-pyroxene skarns developed on the level of basement and also bearing superimosed polymetallic metallization.

Practically all parts of the breccia bodies are to this or that extend mineralized. Mineral composition of ores is characterized by a great variety. Primary ores and ores touched by oxidation contain sphalerite, galena, pyrite, marcasite and subordinate chalcopyrite, magnetite, hematite, arsenopyrite. Pyrrhonite, cubanite, argentite, fahlore, native silver, covellite are less common. Smithsonite, cerussite, anglesite, malachite, limonite and others are encountered in the oxidation zone. Among gangue constituents quartz, feldspar, actinolite, grosullar, pyroxene, epidote, chlorite, carbonate, fluorite, phlogopite, axinite, kaolin, illite and others are developed.

The contents of major by-products in ores fluctuate within the following limits, % : Pb - 0,1 - 3,4; Zn - 0,1 - 19,9; Ag(g/t) - 0,16 - 0,33; Cd - 0,008 - 0,01; S total - 2,61 - 3,10.

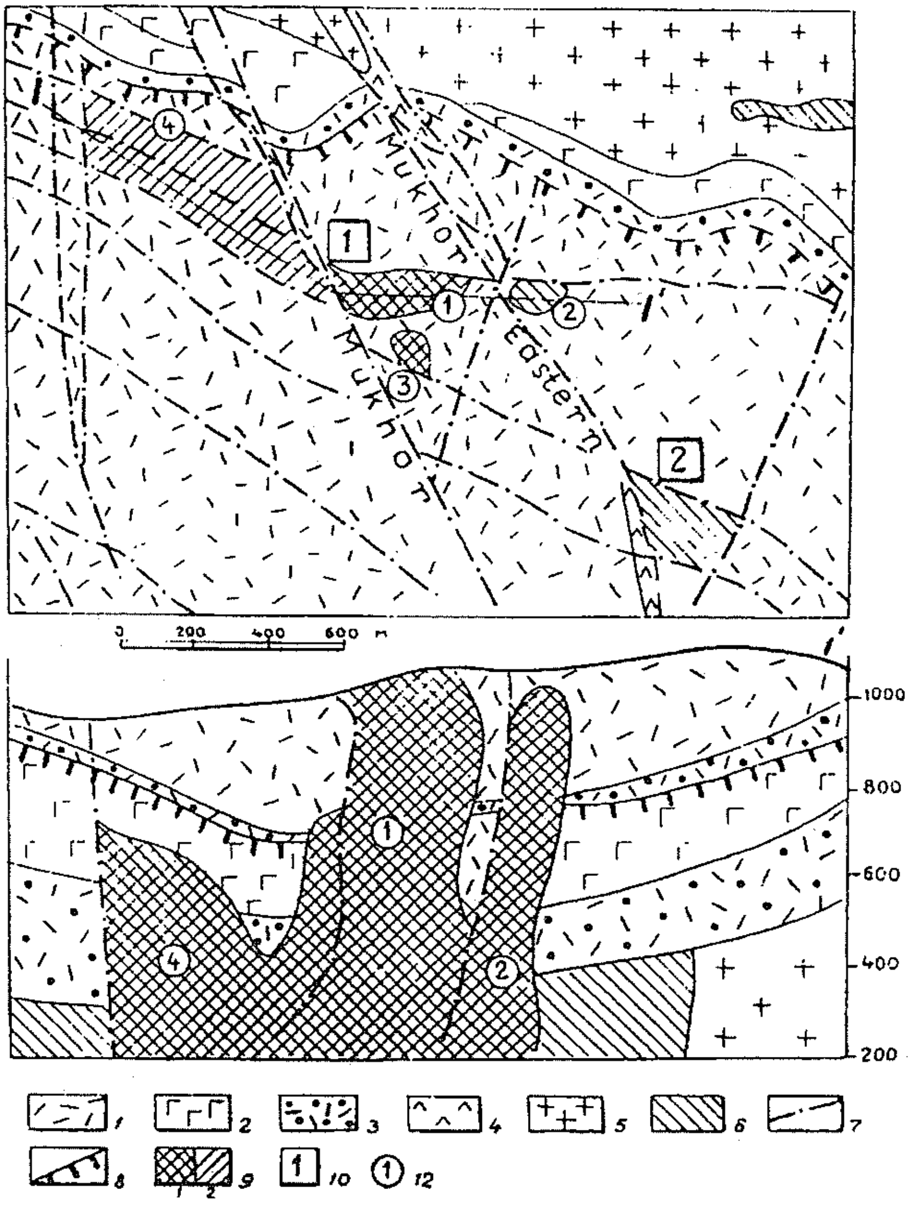


Fig. 2. Schematic structure of the Ulaan ore field. From Yu.B.Mironov and N.S.Soloviov (1989).

1 - 4 - Upper Jurassic - Lower Cretaceous : 1 - rhyolites, their tuffs, perlites; 2 - andesibasalts; 3 - acidic tuffs; 4 - quartz porphyry dykes;
5 - Early Paleozoic granitoids; 6 - Proterozoic schists, amphibolites, gneisses; 7 - faults; 8 - gentle bedding - plane slips; 9 - pipes (in plan), filled with fluidal - explosion breccias and epidote - actinolite metasomatites with base - metal mineralization :
1 - cropping aut, 2 - concealed. 12 - Circled numbers denote pipe-like bodies : 1 - Main, 2 - Eastern, 3 - Southern, 4 - Western; 10 - Sqaured numbers denote deposits : 1 - Ulaan, 2 - Mukhar.

The Ulan deposit represents an intricately built fluido-explosive structure consisting of four breccia pipes, namely the Basic and Southern structures cropping out on the surface, and the Western and Eastern structures which are concealed. All of them caolesce at depth of 200 - 500 m in a single body. (Fig.3).

The Basic pipe contains the bulk of base metal ore the deposit. It is filled with fluido-explosive large-fragmental and small-fragmental breccias consisting of clasts of wallrock and cement of two types : explosive, compositionally corresponding to volcanite fragments, and ore fluidal (hydrothermal). Quantitative proportion of the two types of cement is approximally equal.

The contents of major and associated components from individual bodies and blocks of the deposit are characterized by the following figures (%) :

Primary ores :

Pb - 1,00 - 1,18; Zn - 1,72 - 2,12; Ag(g/t) - 48 - 55; Au(g/t) - 0,16 - 0,23; Cd - 0,008 - 0.011; S total - 2,61 - 3,10.

Oxidized and mixed ores :

Pb - 1,34 - 1,45; Zn - 0,44 - 1,72; Ag(g/t) - 27 - 42; Au(g/t) - 0,22 - 0,33; Cd - 0,001 - 0,009; S total - 0,37 - 2,60.

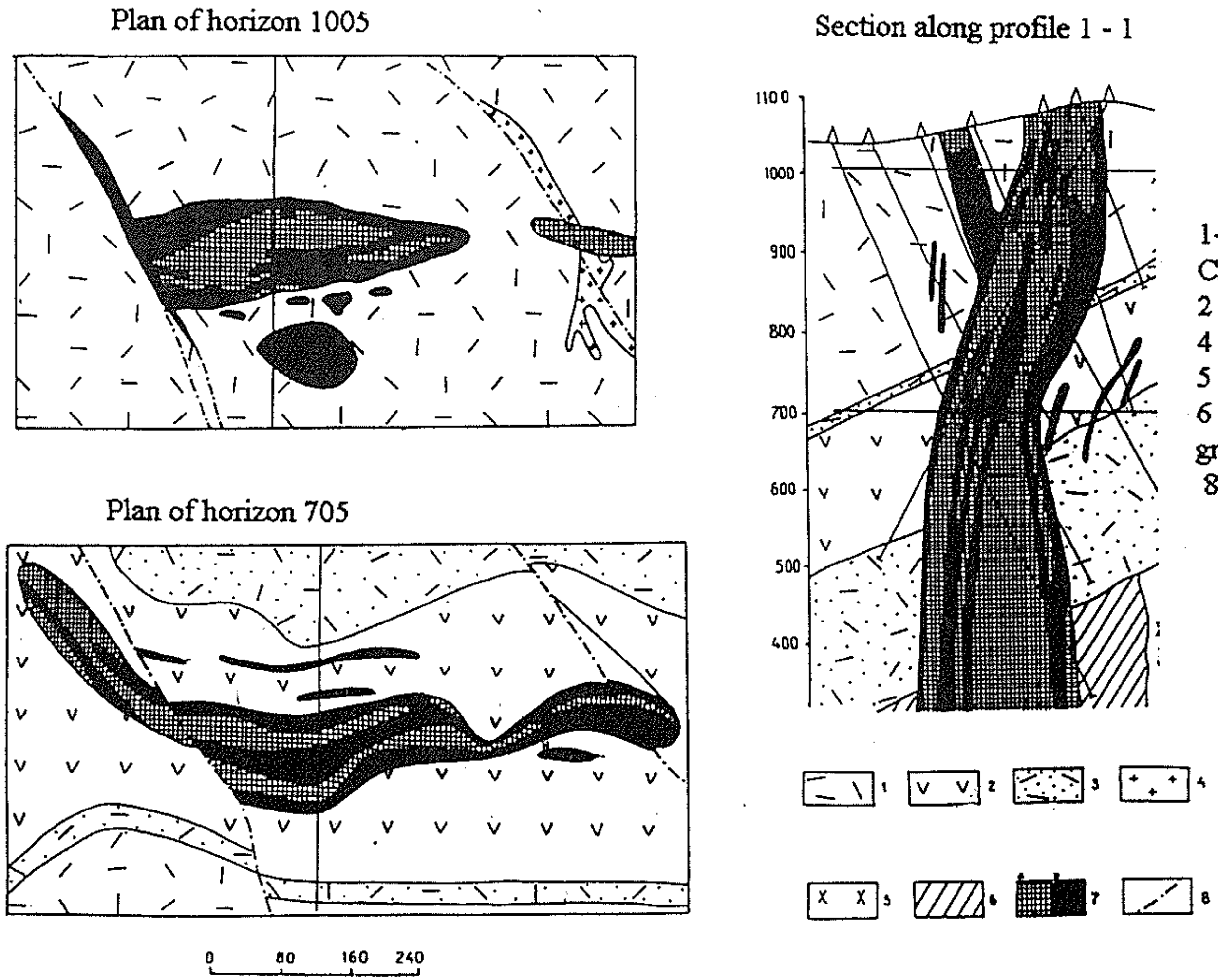
The ores of the Ulan deposit are easy-to-process. Lead, zinc and pyrite standard concentrates are obtained by collective-selective flotation. Lead concentrate with high metal recovery (85 - 92%) contains sizeable amounts of silver, gold, copper, cobalt; zinc concentrate contains cadmium.

Total reserves of the main metals from the Ulan deposit amount to 830 000 ton lead, 1 815 000 ton zinc at average contents of 1,0 - 1,45% and 0,4 - 4,44%, respectively. Prognostic recources of deep horizons are estimated to be 300 000 ton lead and 600 000 ton zinc. The geotechnical mining conditions of the deposit are not demanding.

The Mukhar deposit was revealed in 1982. It is situated 1 km southeast of the Ulan deposit in the similar structural-tectonic setting. Boreholes, although drilled to a depth of 800 m failed to strike the basement. According to geophysical data it occurs at a depth of 100 - 1200 m. The position of the deposit is controlled by NW -, EW -, NE -, NE - and NS - trending faults.

The inner structure of the pipe is complex. Rhyolite dykes, blocks of host rocks measuring 20 x 80 and 50 x 260 m with major axes oriented subvertically as the pipe itself are noted to occur among breccias. The upper boundary of the breccia pipe is uneven and occurs at a depth of 130 - 150 m. The pipe is largely composed of breccias of the host rocks with quartz-fluorite-sulfide and and, less common, quartz-sulfide cement.

Within the pipe orebodies are controlled by EW - trending faults. They are represented by streeply-dipping 0,7 - 57,0 m thick lenses extending for 40-350 m along the strike and 140 - 160 m downdip. Some veinlike bodies extend upward for 50 - 180 b beyond the limits of the pipe. Mineralization was traced to a depth of 700 m without signs of attenuation. At a cut-off grade of 2% of arbitrary zinc, 20 ore-bodies were delinited. They are spaced at intervals not exeeding 2 - 20 m. The average contents in the ores include 0,64% lead, 3,44% zinc, 90-110 g/t silver. With lead and silver taken into account, the arbitrary content of zinc is



1-4 - Upper Jurassic - Lower Cretaceous rocks : 1 - felsites, 2 - andesibasalts, 3 - acidic tuffs; 4 - quartz porphyry dykes; 5 - Early Paleozoic granitoides; 6 - Proterozoic schists, amphibolites gneisses; 7 - ores : a) standard, b) rich; 8 - faults.

Fig.3 . Geological structure of the Main pipe of the Ulaan deposit.
From G.N.Gubkin, J.N.Babkin, V.Ya.Kiselev (1984)

8-9%. The contents of lead and silver decrease with depth, the zinc content remains unchanged. Maximum silver content is noted at the 350-550 m depth interval, in a zone influenced by low-angled fault.

A preliminary estimate of reserves is some tens thousand ton and some hundred ton zinc.

Vein Deposits

This type includes the Tsav deposit, the Salkhit, Khaltar-Uula and other occurrences of the Baltsin-Ovoo.

The Tsav deposit is best studied. It is situated 90 km east of the Ulan base metal deposit. The Tsav deposit occurs within the Tsav-Bayangol ore centre incorporating also the Bayan-Uul, Altan-Tolgoi, Salkhit base metal occurrences. The ore centre is confined to the Khavirguin horst projection of the basement, modifining the Meso-Cenozoic Engershand volcanotectonic depression.

The deposit is localized in the zone of the Tsav fault which has a northwest strike transverse to the general grain of the Central-Mongolian volcanic belt. The basement projection and the base of the volcanotectonic structure consist of Late Proterozoic - Early Paleozoic granite gneises, gneises, quartzite-like sandstones, micaceous and mica-feldspathic schists with lenses of marbles, cut by Middle-to-Late Paleozoic granitoids, Early Mesozoic diorite-syenites, Late Jurassic intrusive and subvolcanic monzodiorites and granite-porphyries. The latter form an isometric circular stock comprising a peripheral fringe of monzodiorites and a central core of granite-porphyries. (Fig. 4).

In the western and southwestern parts of the deposit these rocks are overlain by Upper Jurassic - Lower Cretaceous volcanites consisting of basalts, andesibasalts, andesites, andesidacites, dacites, rhyolites with interbeds of tuff gravelstones, sandstones.

Dykes of diorites, monzonites, diorite and andesite porphyrites, granite-porphyrites, felsit-porphyries, sometimes controlling zones of base-metal mineralization are widespread.

On the 12 sq.km area of the deposit, a number of base metal mineralization zones were revealed. Nine of these zones are found to contain economic quantities of ore components forming veinlike orebodies.

The position of ore bodies is controlled by the feathering NW - and NS - trending faults. Veinlike bodies dip steeply to the east anc north-east. They extend for 350-2000 m along the strike. 200-600 m downdip, their thickness varies from 0,5 to 8,4 m and averages 0,8 m. A distance between individual ore bodies varies from 100 to 650 m. In the most cases they are localized in igneous rocks, seldomly effusive rocks. Wall rock alteration is presented by summary clarification of rocks in the result of their argillization cericitization and silicification. The widht of alterated hydrothermal zone varies from 1-2 to 30 m.

Ore bodies genetically and spatially associated with subvolcanic dyke formation complex of closing stage of Upper Mesozoic magmatism.

The character of ore mineralization is various : in addition to streaky, streaky-impregnated and pockety ore mineralization are occured veins 0,1-0,2 m wide,

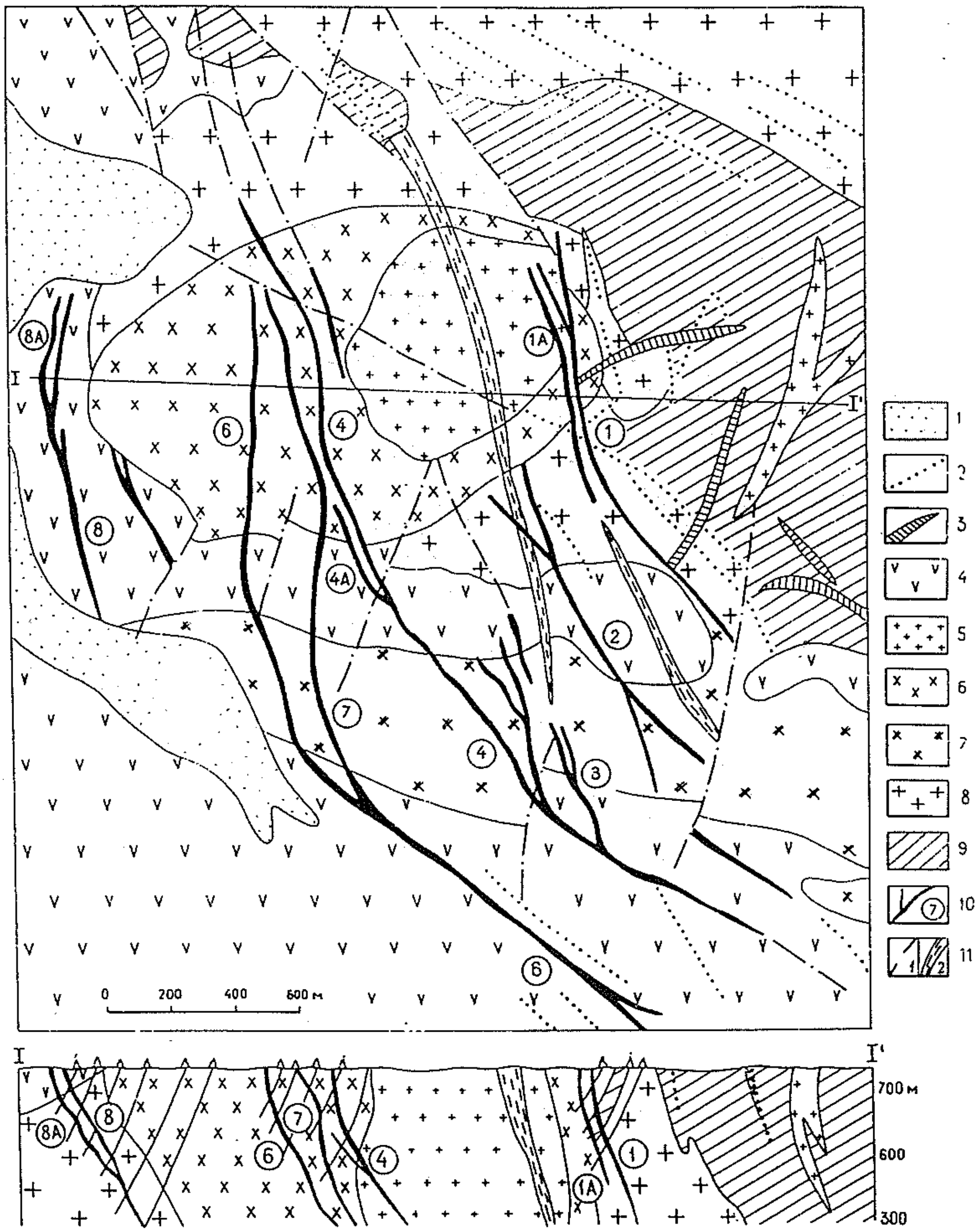


Fig. 4. Geological sketch map of the Tsav deposit.

From materials of Dornot Expedition (1989)

1 - Quaternary deposits; 2-4 - Late Jurassic - Early Cretaceous : 2 - dykes of diorites, diorite and andesite porphyrites, 3 - granite-porphyrites, felsite-porphyries, 4 - basalts, andesibasalts, dacites, their tuffolavas and lavabreccias; 5-6 - Late Jurassic : 5 - intrusive and subvolcanic granite-porphyries, 6- monzodiorites; 7 - Early Mesozoic diorite-syenites; 8 - Middle-Late Paleozoic granites; 9 - Proterozoic - Early Paleozoic schists, gneisses, granite-gneisses; 10 - orebodies and their numbers; 11 - faults (1) zones of shearing (1) and mylonitisation (2).

which made up massive aggregate of galenite and sphalerite or metasomatite breccias cemented by sulphide. The distinguishing of useful components in ore bodies is uncommon and varies in wide diaposon : Pb(%) - 0,12-49,5; Zn - 0,05-28,0; Cu - 0,02-1,19; Ag (g/t) - 80,5-39,9; Au(g/t) - 0,01-20,0.

In primary sulfide ores the amount of lead oxide minerals is not in excess of 10% , those of zinc - about 4%. The portion of secondary ores in reserves is modest - no more than 4%.

The paramount economic value is presented by primary ores which, in terms of material composition fall into silver-bearing quartz-base metal and carbonate-silver-base metal varieties.

The following ore minerals were found in these silver-bearing polymetal ores : silver-bearing galena, sphalerite, chalcopyrite, pyrite, arsenic-copper fahlore, rare native gold. Gangue minerals consist of metasomatic coarse-crystalline and drusy coarse-crystalline quartz, calcite, there are also fragments of strongly altered sericitized, silverfied and pyritized host rocks.

The following are the most characteristic structures of ores: massive, stringer-impregnated, less common brecciated, crustified and cockade. The ore are basically fine-grained, medium-grained with grain size from 1-1,5 to 2-3 mm. Silver of the ores of this type has practically no independent separate minerals and is incorporated in galena as microinclusions. The content of lead-zinc sum in the ore is high, 10-11%, the silver content ranges from 80 to 240 g/t. These is stable correlation between lead (%) and silver (g/t), which amounts to 1:2.

The carbonate-silver-base metal ores mostly characteristic of orebodies 8 and 8a, occuring in base effusives. Ore minerals established include : galena, sphalerite, pyrite, chalcopyrite, sulfoantimonite. Minerals of silver : pearciete-polybasite, proustite, pyrargyrite, freibergite (?), argentite, native silver. Gangue minerals are represented by calcite, manganosiderite, cryptocrystalline quartz, fragments of bleached host rocks. These rocks are characterized by colloform, banded, crustified and cockade textures, by comparatively low content of lead and zinc (sum 4,7%) and high silver content (310-390 g/t), reaching in individual cases more than 1000 gram per ton. No correlation between lead and silver exists.

Oxidized and semioxidized ores are characterized by development of secondary minerals : smithsonite, cerussite, calamine, anglesite, malachite, azurite, iron and manganese oxides. The base metal ores of the deposite are characterized by the following admixture-elements : cadmium, indium, germanium, antimony, arsenic, gallium.

The probable reserves in the main orebodies are estimated to be some hundreds for lead and zinc.

The content of silver changes in the orebodies from 80 to 390 g/t.

Deposits of Mineralized Shattered Zones

This type includes the Mungun-Undur deposit, the Tugultuin-Nuur, Bayan-Uul, Altan-Tolgoi, Khara-Tolgoi, Biluta-Ovoo ore occurrences as well as occurrences from the Khukhulin ore centre.

The Mungun-Undur silver-base metal **deposit** is best studied target of this type.

The area of the occurrence Bayan-Uul consists of Early Mesozoic (?) granitoids, including individual large (more than 2 sq.km) and numerous remnants of compositionally various gneisses and schists with horizons of quartzites, limestones and amphibolites of the Upper Proterozoic. Granitoids and metamorphics are cut stock-like bodies and dyxes of Late Mesozoic granites, diorites, granite-porphyries, rhyolites and other rocks. Dyxes form a near EW - trending zone and, in conjuction with tectonic fractures, emhasized the general orientation of the extensive Bayanguul fault zone. Ore-bearing zone is confined to the contact between granitoids and schists and is controlled by the cenyral branch of this fault and by the WNW-trending auxiliary fault. Ore mineralization is mainly concentrated within a linear quartz stockwork developed in Mesozoic granites and traced for 5700 m along the strike, 240-300 m downdip, its width varying from 20 to 400 m. Within this stockwork, quartz veins up to 5 m thick and extending for 1,5 km are noted to occur. The overall dip of the ore-bearing structure is to the north-north-east at angles of 60-75 . Granites hosting the stockwork are highly silicified, sericitized, chloritized and contain disseminated sulfide impregnation. The primary ore minerals of the stockwork are arsenopyrite, pyrite, galena, chalcopyrite, sphalerite, bismuthite and tetraedrite.

Average contents in these zones are 4,5% for lead, 1,26% for zinc, 168 g/t for silver, 1,1 g/t gold. Bismuth averaging 0,02% is persistently present; in a number of samples cadmium is detected; a high content of indium (up to 0,01%) was established.

Skarn deposits

To date, the Tumurtiyn -Ovoo, Salkhit, Tumurte-Western, Bayan-Dun, Erdenet-Tolgoi and other deposits and occurrences have been revealed and, to a various extent, studied.

The Tumurtiyn- Ovoo deposit is located 16 km north of the aimak (district) centre of Baruun-Urt. It has been exphored in detail.

The deposit is confined to the central part of the Devonian Tevshinishirin trough formed on the Early Caledonian basement and occurs in one of the roof-pendants of the Permian Baruun-Urt granitoid massif.

Late Paleozoic (293-312 m.y) leucocratic granites accompanied by microgranite dykes and volcano-extrusive complex including rhyolite tuffbreccias, dykes of diorite porphyrites, gabbro-diabases. A number of faults are traced at the deposit.

Devonian sedimentary-volcanogenic rock units suffered contact metamorphic alterations : the diabase sequence (mainly its upper part) is transformed into hornfels and hornfels blastides; lime-stone sequence - into marbles and various skarns, and shaly sequence - into plagioclase - pyroxene hornfels.

Skarns form a distinct horizon in the limestone sequence. The structure of this horizon reflects a certain succession in localization of skarns of various composition. In its lower part (at the contact with hornfels after diabase tuffs and diabase) there is a succession of intensely silicified garnetiferous, quartz-garnetiferous skarns and quartz-magnetite hornfels grading into each other. The upper part of skarn horizon is composed of garnitiferous and garnitifrous-magnetite skarns with superimposed sphalerite mineralization. The bulk of sphalerite mineralization is spatially coincided with a member of garnet-magnetite skärns of the upper part of this horizon. The major minerals of the ore-incorporating skarns consist of andradite, magnetite, rhodonite.

A principal lenticular zinc-bearing orebody and a number of accompanying ore lenses are outlined at the deposit (Fig. 5). The principal orebody elongated in NW direction crops out in the northern part of the deposit and dips concordantly with host rocks to the south-west, the angles being gentle (10-20) in the near-surface zone and steeper (50 -70) at the depth of 70 -100 m. It extends for about 800 m along the strike, for 480 m downdip in the Central part and 200-250 m downdip on the eastern and western flanks. It is as thick as 45 m in the central part, dwindles to 5-1 m on the periphery, and averages 14 m in thickness out or is limited by granites at a depth of 200-280 m.

The orebody is dismembered in anumber of blocks with small amount of displacement by tectonic fractures.

The orebody is composed, to an average depth of 60 m, of oxidized zinc ores followed by primary sulfide ores which are of principal economic importance.

Primary ores are dominanted by the following ore minerals : Shpalerite, magnetite, hematite. Galena, chalcopyrite and pyrite are less common. Sphalerite is the only sulfide mineral of economic interest. It usually occurs in close intergroth with garnet, magnetite, rhodonite-bustamite. The commonest gangue minerals consist of garnets of andradite series, minerals of wollastonite group, quartz and carbonates. The structures of ores are impregnated, banded, nest-impregnated, massive. Three varieties of zinc ores, namely magnetite-garnet-sphalerite, garnet-sphalerite, and hematite-pyrite-sphalerite, are recognized depending on prevalence of one ore other nonmetalliferous mineral. On technological relation they composed whole industry skarn-sphalerite type. Contents of major and accompanying components in primary ores presented in Table 2.

Table 2

Contents of major and accompanying components in skarn zinc ores of Tumurtiyn Ovoo deposit. (%)

Components	Average content	Components	Average content
Zn	10,9	Bi	0,12
Cd	0,02	Mo	0,02
In	0,0017	Sn	-
Pb	0,05	Ge	0,009
Cu	0,02	Co	0,02
Ag	3 - 5 g/t	Fe	17,20
As	0,07	Mn_2O_3	8,81

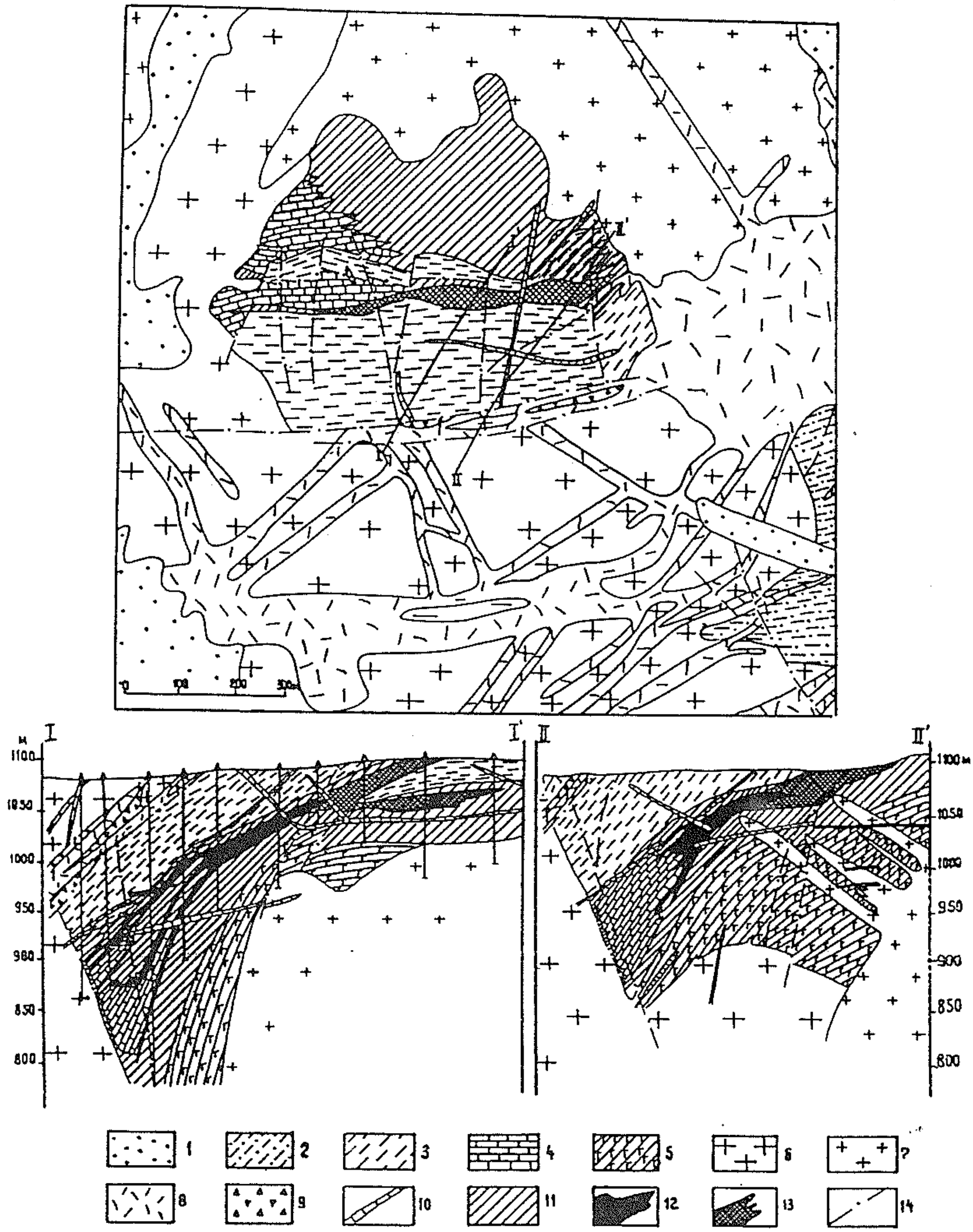


Fig. 5. Geological sketch map of the Tumurtiyn -Ovoo deposit.
From G.Dorj, O.Vaigert, A.Kampe (1976)

1 - Quaternary deposits; 2 - Middle Devonian sandstones, siltstones, shales; 3-5 - Lower Devonian volcanogenic-sedimentary complex : 3-shales, 4-limestones, 5-diabases ; 6-7 - Permian (?) leucocratic granites : 6-medium-to-coarse-grained, 7-fine-to-medium-grained; 8 - 10 - Lava flow-extrusive complex : 8 - liparites, liparite-dacites, 9-tuff breccias of liparite porphyries, 10-dykes of various composition; 11 - calcareous skarns; 12 - primary zinc sulfide ores; 13 - oxidized zinc ores; 14 - faults.

Sulphura, phosphorus, fluoride are contained in small quantity. Among accompanying components are important only cadmium contained such as isomorphic admixture. Content of zinc is 4,43% in oxidized ores.

The total zinc reserves in sulfide ores amount to 1 million ton. The average zinc content in ores is 10,4%. The reserves of cadmium are estimated to be 1770 t, the average content being 0,02%. Geotechnical and hydrogeological mining conditions are not complex.

The prospects for discovery of new lead-zinc deposits of the above described types in the eastern part of country as well as for larger-scale stratiform deposits in ancient metamorphosed volcanosedimentary sequences in the northern and western regions of the country are estimated to be favourable.

Further geological and mineralogical investigation of pyritic and stratiform mineralization is required.

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