

Original Research Article

Mineralization and metallogenic model of Daletingchagan Pb-Zn-Ag polymetallic ore in Dong Ujimqin, Inner Mongolia

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Abstract: Daletingchagan Pb-Zn-Ag polymetallic ore, located 70 km away to the Baogeda Mountain in Dong Ujimqin, Inner Mongolia, is a Pb-Zn-Ag polymetallic ore field, found based on the Geological Prospecting Institute of Liaoning province carrying out synthesis method for the prospecting project of the Baogeda forest field. This mineral deposit could be divided into two ore blocks: genetic types of west ore block is contact metasomatic type, while the east ore block is shallow epithermal deposit related to volcanic agencies and the subvolcanic. This paper focuses mainly on a comprehensive study of the east ore block mineralization, aiming at providing a beneficial reference of further exploration for concession.

Keywords: shallow epithermal deposit; cryptoexplosive breccia; mineralization enrichment regularity; Daletingchagan Pb-Zn-Ag polymetallic ore

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Introduction

Daletingchagan Pb-Zn-Ag polymetallic ore is a Pb-Zn-Ag polymetallic ore field, found through the synthesis method by the Geological Prospecting Institute of Liaoning province. According to the current level of work, it is estimated that there are 333 ± 334 classes of mine ore with a resource of 222.24 tons in concession, in which pyrite is 2.24 tons. The Ag metal content is 75509 kg, Pb metal content is 4847 tons, Zn metal content is 17, 420 tons, and Cu metal content is 177 tons.

This mineral deposit could be divided into two ore blocks: the genetic type of the west ore block is contact metasomatic, while the genetic type of the east ore block is shallow epithermal deposit. This paper mainly focuses on a comprehensive study of the east ore block mineralization, aiming at providing a beneficial reference of further exploration for concession.

Regional geology

Concession tectonic position belongs to the Siberia plate (III)–southeast Siberian marginal hyperplasia belt (III₁)–Dong Ujimqin-Zalantun volcanic type passive margin (III₁³) (*Figure 1*). Inner Mongolia, an ancient Asian metallogenic domain—west of the Greater Xing'an Mountains metallogenic province, Yanshan iron, Zn, tungsten, gold, and

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chromium metallogenic belt Huali Da Hinggan Mountains in the middle^[2]. Since the Mesozoic, Cenozoic volcanic rocks in this area belonged to the greater Xing'an Mountains, the Mesozoic volcanic rocks throughout the region and the volcano-tectonic structure in this area constitute the main body of intrusive rocks. Cenozoic volcanic activity is still present in this area, at the Pliocene basalt Wuchagou valley along ulgai distribution. Volcano-tectonic structure constitutes the main body of the area. NEE tectonic pattern is changed into NNE, and there is superimposed phenomenon of the two.

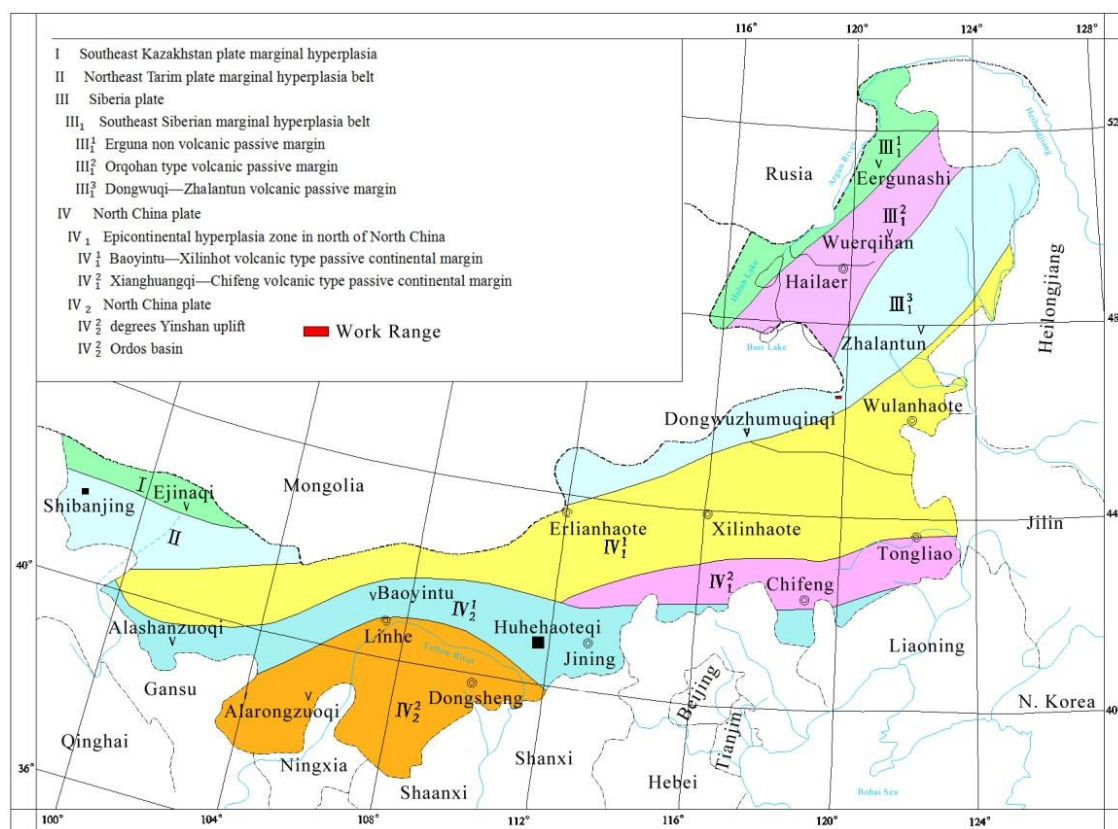


Figure 1. Tectonic unit partition sketch of the Daletingchagan ore

Geologic feature of the concession

Stratum

Exposed stratum in the concession is of the Devonian system ingres ulla group (D3a); the main lithology is dark green, yellow green silty mudstone, argillaceous slate, iron siliceous slate, and metamorphic fine-grained lithic feldspar sandstone. For the Upper Jurassic Manketouebo Formation (J3mk), its main lithology is flow grain quality sinter el brecciated tuff, rhyolitic ignimbrite, rhyolitic breccia tuff, rhyolitic chip quality, crystal glass crumbs tuff, and tuffaceous sandy conglomerate. Rhyolitic volcano breccia (chip) tuff, rhyolitic mass containing volcanic breccia bo crumbs tuff and altered volcanic breccia tuffaceous could be seen in the hole (Figure 2).

Structure

Volcanic institution

There is a volcanic edifice in the area, 1277.2m high cone volcanoes, located in durham, katyn ZhaGanNa west. The landscape is the plum blossom mountain, constituted by the central dome mountain and outward scattering disc shape ridge.

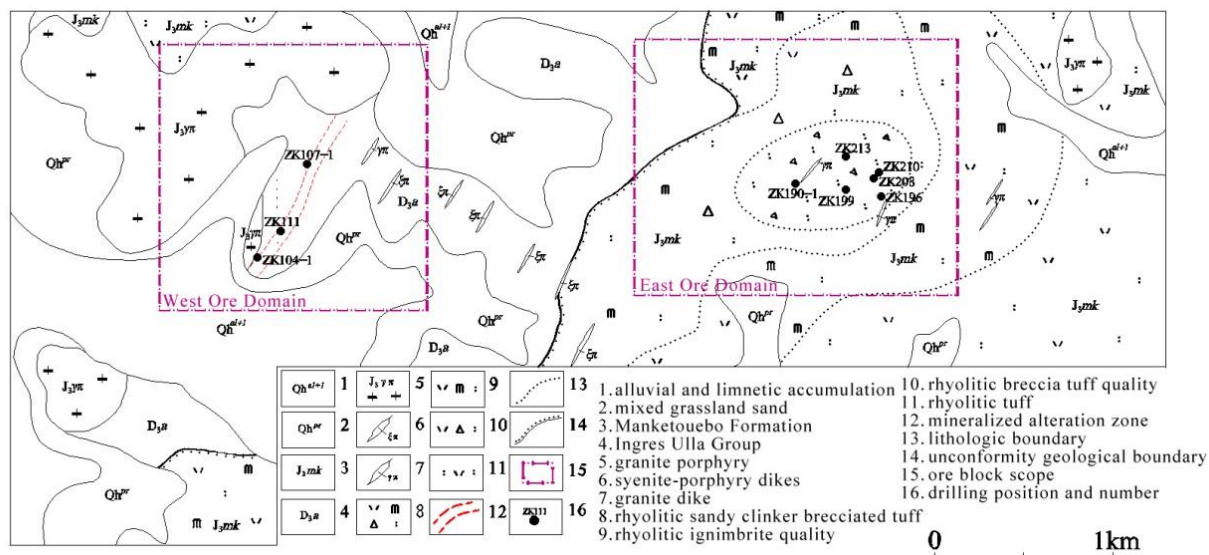


Figure 2. Generalized geologic map of Daletingchagan ore

The central mountain area of brecciated tuff fills the crater. The outward is flow grain quality sinter brecciated tuff, rhyolitic ignimbrite, rhyolitic tuff, and rhyolitic quality sinter brecciated tuff. They are thick and white layers distributed in each petal shaped ridge. The surrounding bed close to the strata center inclined inward, with a dip angle of 20° – 40° , and the lateral strata leans out. The western edge of institution has an angle of floor rock stratum with the ulla group exposed; the east has a granite porphyry intrusion.

Near the center of the institution, rocks are kaolinited and the sericite is kaolinited and chloritized very strongly. Alteration of the mineral content is generally between 15%–30%, and a handful of up to 60%–65%. At the center of the geochemical anomalies, the exploratory trench and drilling is in the Pb and Zn Ag.

According to the analysis of lithology, facies, and relationships, during the early stage, intermittent outbreak is given priority; mainly eruptions are around the center accumulation, constituting the main body of the volcanic edifice; Mid-term caldera subside, resulting stratum near the center inclined inward. Late volcanic activates again, magma along the volcano channels and tectonic weak parts of the early leaching, appeared in the crater area and the surrounding granite porphyry. Magmatic activity adjoined with gas liquid activity, producing altered mineralization. The volcanic edifice is the foundation factor of bed forming system of east ore block, and main factor of accusing and ore-controlling of rock.

Fracture structure

Direction of fracture structure development in the concession is mostly north-west, north-east, and near east-west is complementary. Hide in cossion is strong, the larger north-west fracture is valley straight to extension on the north-west on the landscape, filled by a quaternary system of loose sediment, the strike of ridges on both sides of fracture shows significant nosedive along its extension direction to the ridge. The main fracture in the area is the F1 fracture, north-west fracture in the 1193 upland; on the north-east side of the 1193 highland, the strike is 317° , the inclination dip angle is unclear, and about 1.1 km wide. Generated in the Manketouebo Formation, the north-east plate rhyolitic tuff displaces to the north-west about 150 m compared to the same formation of the south-west plate. The andrhyolitic tuff on the west-south side contains brecciated tuff broken along the strike. Its surface is cataclastic rock belt, the lithology is cataclastic flow grain quality glass crumbs tuff, filled by siliceous along the fissure. It is a transtensional fault.

Intrusive contact structure

After volcanism in concession, the granite porphyry intrus. The tensile fracture is often formed on the top of the magma in the process of magma invasion upside; fracture or fracture zone are formed in the contact zone between magma and surrounding rock, has the symmetry developmental characteristics of opposite tendencies, and with a smaller scale; the fracture is often concealed fault, an important ore structure, with multiple small vein ore bodies, and delineated drilling verification. It is speculated that this small fracture exists in ore bodies.

Magmatic rock

Magmatic rocks are widely distributed in the area, mainly volcanic rocks and a small amount of ground. Volcanic rocks are mainly concentrated in the central, western, and northern lithology in the late Jurassic Shi Yingzheng long porphyry, granite porphyry in the middle Jurassic, vein rocks (positive long porphyry, granite porphyry, diorite porphyrite) concentrated in the Middle East, toward north-east direction.

Granite porphyry is related to the mineralization, rock weathering profile presents grayish yellow, and the fresh profile is in light grey. Rock, porphyritic structure matrix microcrystalline structure, blocks structure. The rock is composed of phenocryst, with a matrix of 15% and 85%. Spot for feldspar, quartz, crystal size 0.2–1.5 mm, feldspar, sericitization, soil matrix of aphanitic—microcrystalline feldspar and quartz. Rocky fracture, fracture alteration is particularly serious, chloritization, kaolin, sericitization, local fracture for silica, iron, manganese mineral filling.

Granite porphyry is found in 272–398 m of the ZK208 hole. An important feature of deep granite porphyry is serious partial rupture, with siliceous cements, pyrite, and sphalerite. The cause of rock fragmentation is concealed explosive effect happened in deep, causing the rock fracture, and forming Zn-Ag ore body with a large thickness on and high grade on top of the granite porphyry.

Geophysical-geochemical anomaly characteristic

1:50000 geochemical anomalies (*Figure 3*) are mainly Pb, Zn, Ag, Mo, Sn, W, Bi, As, Sb, Au, Cu, and Fe_2O_3 . The main ore-forming elements are Ag, Pb, Zn, and Pbing edge element As, Sb, with good register in space position, and abnormally is in larger scale, the intensity is high. Concentration zonings of Ag, Pb, As, Sb, and Bi are up to level 4, Mo and Sn element anomalies are developed in abnormally concentrated hearts of the above elements.

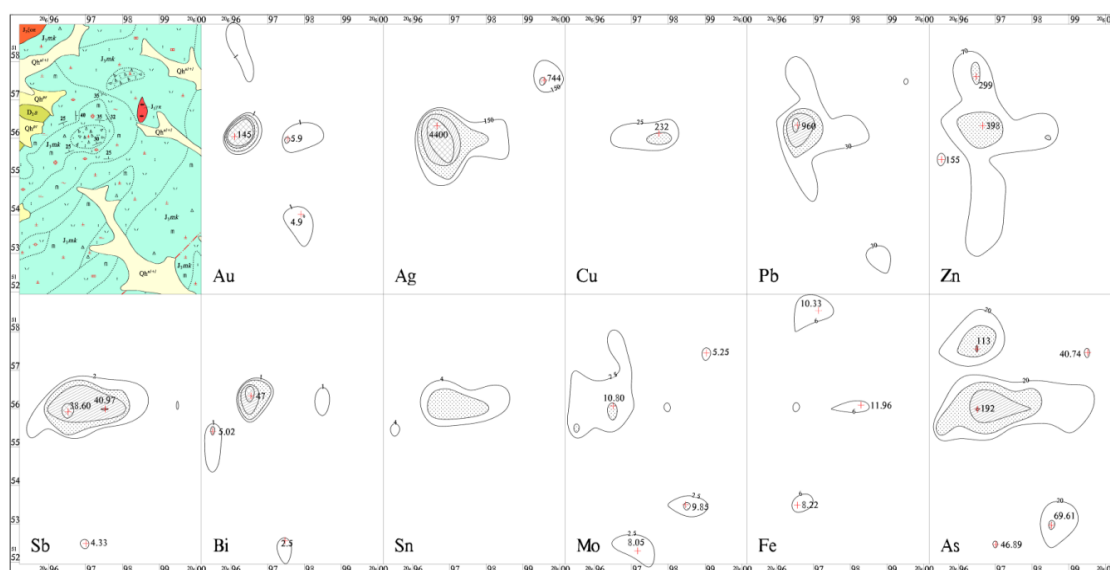


Figure 3. Profile chart of 1:50000 geochemical anomaly of the east ore block in Daletingchagan

The formation of abnormalities is related to mineralization superimposed by multiple time periods, becoming more unstable. Multiple Pb-Zn-Ag ore bodies were discovered by engineering verification.

1:10000 soil measurement results are shown in *Figure 4*. Abnormal return and abnormal AP11-2 and 1277.2 high volcano organization center parts, elements combination for Au, Ag, Cu, Pb, Zn, W, Sn, Mo, Sb and Bi. Main ore-forming elements Ag, Pb, Zn and associated elements nested sex is wonderful, unusually strong heart clear, high strength, large scale. Ag, Cu, Pb, Sn, Sb, Bi concentration level to level 4.

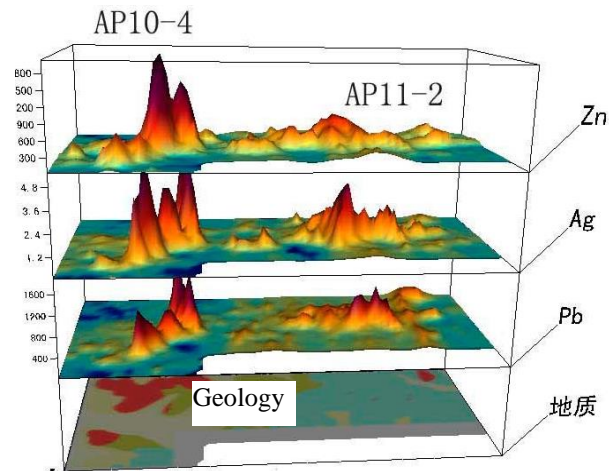


Figure 4. Space diagram of 1:10000 Pb-Zn-Ag geochemical anomaly of the east ore block in Daletingchagan

Deep geophysical profile survey shows that there is a body with low resistivity, high polarization and high density, controlled source measurement show that there are obvious interface of low resistance and high resistance in the 500–600 m depth, it is speculated that concealed rock mass exists in deep.

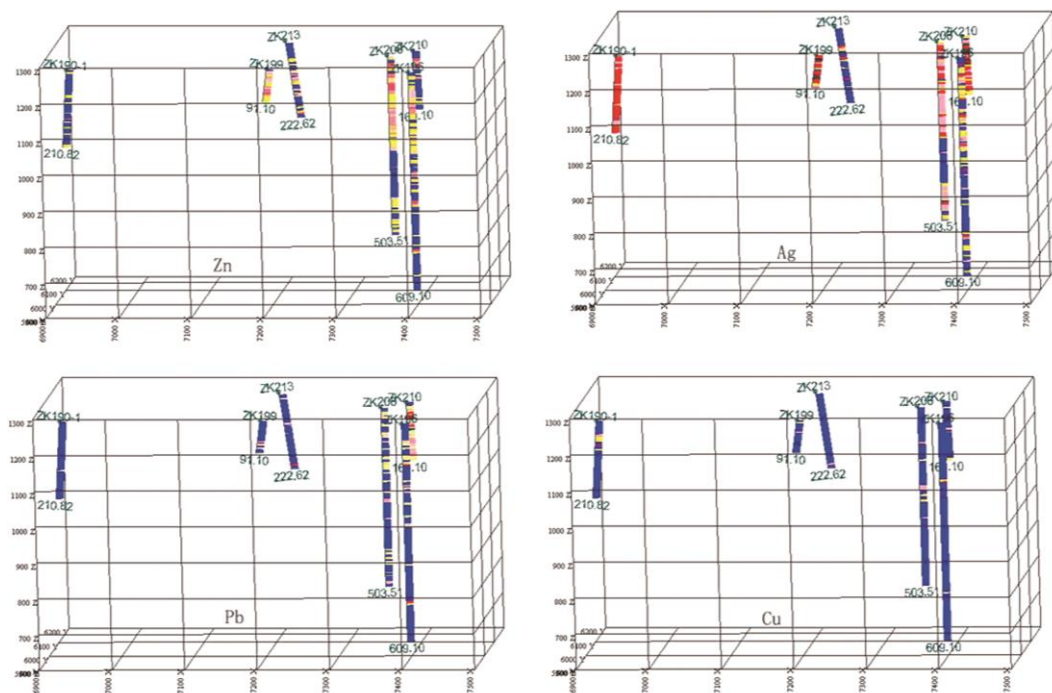


Figure 5. Borehole primary halo zoning map of east ore block in Daletingchagan

Bedrock spectrum sample is taken as long as 5 m in the whole hole, which is primarily a halo zoning map (*Figure 5*) is drawn according to the analysis result of bedrock spectral analysis. The analysis results show that the concession is

mainly mineralized with Zn and Ag, with a close relationship. The thicknesses of Zn and Ag mineralization belt of the three holes, ZK196, ZK199 and ZK208 are larger, and the two closely associated boreholes, ZK190 and ZK210 are developed by Ag mineralization; Ag and Pb are closely associated in borehole ZK210. Pb mineralization of ZK210 hole is thicker, Pb mineralization of other holes are not obvious, and Cu mineralization undeveloped, not only in individual drilling parts.

Geological characteristic of deposit

Mineralization type and ore body characteristic

Ore body concessions found in the Daleting east ore block includes Pb-Zn-Ag, Ag, Pb, Zn, Ag, and Cu. According to the core logging, mineralization types can be divided into two kinds: one is controlled by the fracture of the vein mineralization (nervation ore body), the other is a kind of cryptoexplosive breccia type mineralization (tubular ore body) (Figure 6).

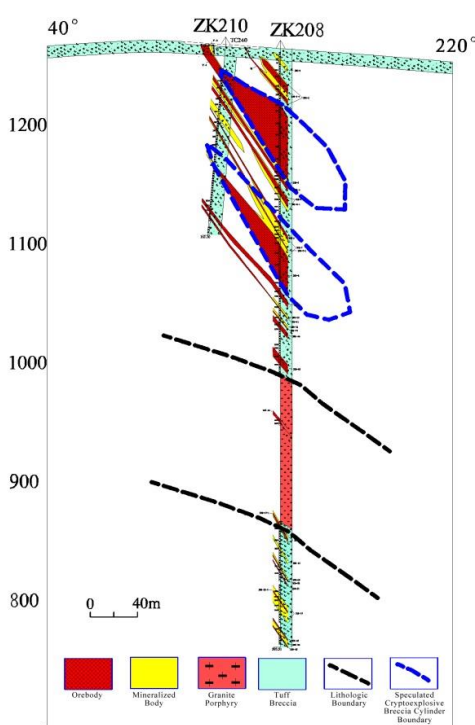


Figure 6. Prospecting line profile

Veined ore body controlled by fracture

The vein ore body controlled by the fracture in concession is hydrothermal filling type ore bodies controlled by the fracture. Ore bodies tend to be 15° – 220° , with an angle of 45° – 85° ; it has obvious difference from sive breccia type ore bodies. On the morphology, the main forms are vein, layered, mainly of article development vein, and banded structure, the characteristic hydrothermal along the fissure filling is obvious, the main sulfide ores are sphalerite, galena, pyrite, and chalcopyrite.

Vein ore body is more developed in concession, framed vein ore body is 50, including 7 Pb-Zn-Ag polymetallic ore bodies, 0.5–3.52 m thick, Ag grade 40.1–114.75 g/t, Pb grade 0.37–1.82%, Zn grade 0.41–2%; 2 Pb-Ag polymetallic ore bodies, 0.64 m thick, Ag grade 55.9–85.91 g/t, Pb grade 1.61–1.82%; 1 Zn-Ag polymetallic ore body, 0.34 m thick, Ag grade of 101.75 g/t, Zn grade 0.62%; 3 Pb-Zn polymetallic ore body, 0.51–1.28 m thick, Pb grade 0.255%–0.5%, Zn grade 0.48–0.62; 21 Zn ore bodies, 0.51–26.62 m thick, grade 0.53%–5.57%; 1 Pb ore body, 0.58 m

thick, grade is 0.42%; 10 Ag ore bodies, 0.17–7.37 m thick, grade 45.33–211.14 g/t; 5 Cu ore bodies, 0.71–2.26 m thick, grade 0.21%–0.27%; 1 Non-metallic pyrite body, 1.66 m thick, S grade of 38.62%. Ore rock containing breccia tuff and volcanic breccia, granite porphyry.

Cryptoexplosive breccia type orebody

Cryptoexplosive breccia type ore body has characteristics of large thickness and high grade. They are produced at the top of the intrusion, brought by the magma invasion on the ore-bearing hydrothermal concentrated at the top. As the pressure increases, the top tensile fracture stress release, cryptoexplosive breccia formed tube and filling mineralization. Rock lithology is mainly within the cylinder, volcanic breccia, breccia tuff. ZK208 hole in 46.75–100.18 m cryptoexplosive breccia ore body is delineated a, 53.43 m thick ore body wear, Zn grade 0.11–5.13%, the average grade of 1.28%. 1 article 164.07–197.32 m cryptoexplosive breccia for delineating ore body, ore body wear thick 33.25 m, Zn grade 0.18%–5.57%, the average grade of 1.13%. Cement for pyrite, sphalerite, and siliceous. The ore body is located at the top of the granite porphyry cryptoexplosive breccia in the cylinder.

Ore characteristic

Architecture and structure of ore

Ore structure mainly is seriate structure, granular structure, since the shape-form of a granular structure, the structure of the crushed. Ore structure is mainly block structure, vein structure, disseminated structure and breccia structure.

Mineral composition of ore

Metal mineral in the ore mainly has toxic sand, argentite, sphalerite, galena, chalcopyrite, pyrite, white iron ore, limonite, and so on.

The gangue minerals in the ore mainly have quartz, sericite, chlorite, kaolinite, potassium feldspar, plagioclase, epidote, and calcite take second place.

Output characteristic of main metallic mineral

Pyrite: Yellow-white, idiomorphic, and half idiomorphic to anhedral, granular, and seriate structure, 55% reflectivity, homogeneity, not easy to polish, intergrows with white iron, which can be divided into two generations, tiny particles, the second generation is in aggregate, crushing structure, and replacement of sphalerite, a vein along the rock fracture or fissure distribution of sphalerite, content 1%–60%.

White iron ore: White, reflectivity of 50%–55%, heterogeneity, part of the wood grain shape, content is about 3%.

Arsenikstein: From form to half euhedral crystal, 51% reflectivity, strong heterogeneity, content is 1%.

Sphalerite: gray, more show anhedral, granular scattered distribution, 18% reflectivity, homogeneity, crushing architecture, and pyrite along the crack distribution, part of the sphalerite by pyrite metasomatism, or parcel by pyrite, in which part of chalcopyrite is emulsion droplet distribution, a small amount.

Chalcopyrite: Yellow, 40% reflectivity, weak heterogeneity, weak double reflection, emulsion droplet shaped in sphalerite, part is disseminated, part a vein along the rock fracture distribution, part and sphalerite in solid solution, trace amount.

Metal mineral produce order arsenopyrite, sphalerite, white pyrite, pyrite, chalcopyrite, and pyrite.

Wall rock alteration

East ore block mineralized alteration near a 1277.2 upland volcanic edifice and its main development, face type alteration for common development. Mineralized alteration of the main types are: kaolinization, sericitization, ferritization, pyritization, silicification, biotite—chloritization. Kaolinization, sericitization, ferritization, and pyritization mainly occurs in close to the top of the mountain of grey alteration tuffaceous breccia, sericitization, kaolinization, and ferritization mainly occurs in tuff, showing in the composition of glass crumbs tuff shape disappeared, has devitrified crypto-crystal-felsitic with sericitization, kaolinization, and ferritization, sericite and clay content of alteration strong location is 65%.

Silicide, biotite-chloritization mainly distribute in the mineralized fracture alteration belt, show the siliceous, biotite, chlorite into stripes, crumb, and pyrite, galena (occasional) is concomitant, fissure distribute in the altered rock. Silicide, biotite, chlorite and Pb, Zn, Ag, Mo polymetallic mineralization.

Pyritization has two forms, the first shows pyrites arranged into dotted stars, with fine veins scattered in the rock. Sericitization and kaolinization is concomitant, and have a wide development of surface features. Another is concentration distribution in the mineralized fracture alteration belt of the altered rock, with concomitant silicide, biotite-chloritization, clouds block, aggregate of arteries and veins along the altered rock fracture distribution.

Mineral deposit zoning characteristics

According to the vertical zoning characteristics of Daleting concession, the concession vertical zoning model is established, four belt is selected from top to bottom, surface marking tape-veined mineralization belt-veined and tubular mineralization belt-porphyry type mineralization belt (presumably) (Figure 7).

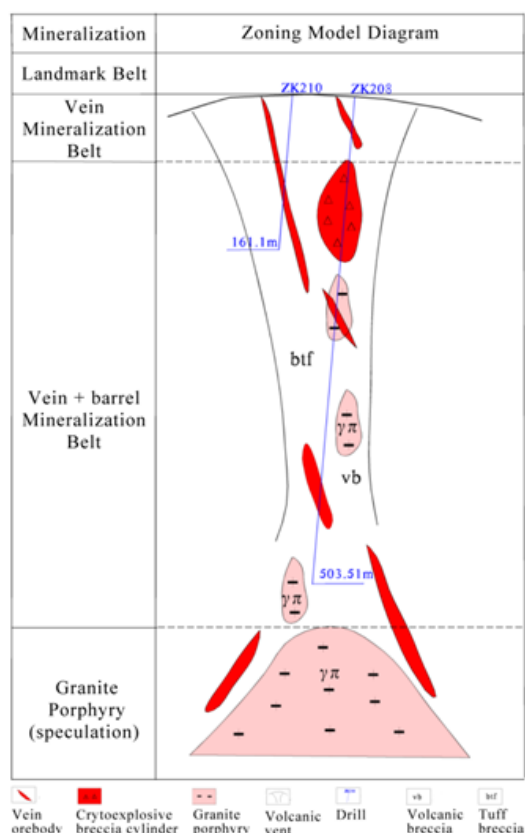


Figure 7. Zoning model diagram of the east ore block in Daletingchagan

Surface side marker: Fracture breccia belt of silicification and ferritization

The east ore metallogenic system of Daletingchagan concession is in 1277.2m internal volcanic edifice. The surfaces of the mineralized alteration are mainly developed in the center of volcanism, characterized by oval silicide, limonite, kaolin, and sericitization fragmented breccia. Fracture breccia is silica, iron, manganese with fine vein filling, the logo can be used as direct ore-prospecting criteria.

Veined and mineralized alteration zone

Concession construction of six vein ore bodies in drill at a controlled depth of 609 m, fractured ore bodies and ore-forming elements with Ag, Pb are given priority as the ore-bearing hydrothermal fault structure filling. The ore-bearing lithology is mainly tuff breccia and volcanic breccia. Alterations are mainly silicification, sericitization, kaolinization, and mineralization mainly in galenas, sphalerites, and pyrites.

Vein and tubular mineralization belt

According to the current level of work, only between 40–200 m ZK208 drilling found cryptoexplosive breccia tubular ore bodies, accompanied by vein ore bodies. Tubular ore bodies are high grade, ore-forming elements and are mainly Zn. Cryptoexplosive breccia cylinder is cataclasis, brecciated 2–40 mm; the composition is mainly tuff and rhyolite. Cryptoexplosive breccia region of the development of cylinder granite porphyry small rock drop also developed. Cryptoexplosive breccia alteration within the cylinder is mainly silicification, kaolin, chloritization, and sericitization. Mineralization occurs mainly in sphalerite and pyrite—thin vein, crumb, and brecciated shape distribution.

Porphyry type mineralization belt

ZK208 drilling found cryptoexplosive breccia, located at the top of the granite porphyry, the granite porphyry is penetrating, wear thick 126 m, the granite porphyry rock into small droplets. It is not possible to form at the top of the scale of the cryptoexplosive breccia, it is speculated that deep there is a big porphyry granite, and controlled source magnetotelluric sounding speculated that deep and the 600 m high and low impedance interface, it is concealed rock mass exist.

Metallogenic model and prospecting criteria

Metallogenic model

Zonation of mineralized alteration

Block metallogenic system of east polymetallic ore in Daletingchagan Pb and Zn Ag polymetallic ore is controlled by 1277.2 volcanism, produced in the Mesozoic volcanic channels, two types of mineralization have been identified, vein mineralization, mineralized cryptoexplosive breccia drum, speculated that deep porphyry mineralization, depth of control mineralization is 609 m. Vein mineralization is throughout the total depth, cryptoexplosive breccia type mineralization is only found between 50–200 m at present.

System change rule from top to bottom and typical low temperature alteration characteristics of Daleting mineral deposit show that the deposit is formed in volcanic edifice of shallow, belongs to hypabyssal hydrothermal deposit of low temperature and temperature, the pressure gradient control the vertical zoning characteristics of the ore deposit, metallogenic systems have the same hot fluid source area in the deep.

Ore-forming material source

Orebody in concession mainly occurs in Manketouebo Formation rubblerock, the horizon is not area of ore-bearing bed,

it is speculated that the ore-forming material and granite porphyry have homologous characteristics, from the deep magma.

Mineralization model

Above all Daletingchagan deposit formation can be divided into two metallogenic stages.

1. High evolution stage of formation of granite porphyry, ore-forming space

Mesozoic volcanic activity formed 1277.2 m high volcanic institutions, volcanic institutions become the basis control factor of ore controlling and rock controlling. Late magmatic evolution process, forming a rich in volatile and the high evolution of ore-forming elements in granite porphyry magma, laid a foundation for the formation of the ore-forming hydrothermal. High evolution granite porphyry in the volcanic channel emplacement, fracture cracks, formed in the tectonic weak positions for precipitation of ore fluid migration and provides a good space.

2. Ore fluid migration—ore body in stage

From the vein orebody cut through granite porphyry, it can be seen mineralization is slightly later than granite porphyry emplacement. As the volcano channel is blocked by pre-intrusive volcanic granite porphyry, much ore-bearing hydrotherm differentiated by deep magmatism in later period rapidly escape, causing the fluid pressure increase, forming in the tectonic weak parts of the plant at the top of the rock cryptoexplosive breccia, breccia tube type ore body is formed by mineral fluid filling in along the breccia, ore fluid go up along the fracture at the same time, forming vein orebody. Due to the deposit formed in shallow crust broken volcanic institutions, temperature-pressure gradient change obviously, forming the good ore tumble belt.

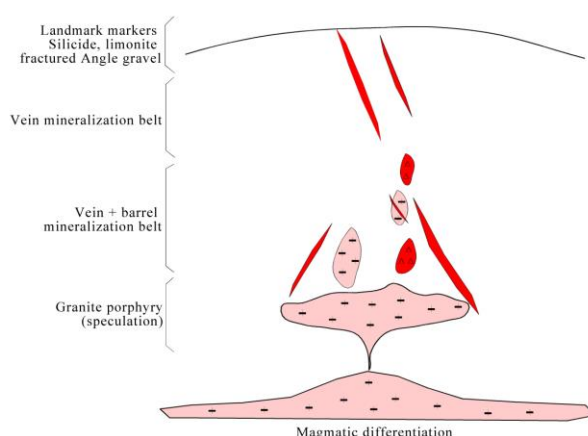


Figure 8. Metallogenic model diagram of east ore block in Daletingchagan

Prospecting criteria

1. Geochemical prospecting criteria: geochemistry comprehensive anomalies of multielement, Au, Ag, Cu, Pb, Zn, W, Sn, Mo, Sb and Bi.
2. Geophysical prospecting criteria: body with low resistance, high polarization and high density.
3. Geological prospecting criteria:

- Silicide, limonite, kaolin, sericitization fragmented breccia body

Daletingchagan deposit metallogenic system is controlled by volcanic edifice, the surface show oval cataclastic rock mass of silicide, limonite, kaolin, sericitization, with cementation by silica, iron, manganese, which can be served as direct ore-prospecting criteria of deposit.

- Granite porphyry in volcano channel

Cryptoexplosive breccia type ore body concession, the main development in cryptoexplosive breccia cylinder, and cryptoexplosive breccia drum major development at the top of the granite spot intermediated-acidic strains. Through the granite porphyry recourse orebody mining prospecting exploration is an important way.

Conclusion

Daletingchagan Pb-Zn-Ag polymetallic ore is epithermal deposit produced in volcanic institutions. The deposit has obvious vertical zoning features, with two types of mineralization, vein type and cryptoexplosion breccia type mineralization, it is speculated that there is granite porphyry in deep, and there maybe porphyry mineralization. Geochemical exploration, geophysical prospecting and geological prospecting mark of mineral deposit are established. The mineralization model of deposit is established, zoning of deposit and source of ore-forming materials are discussed.

Conflict of interest

The authors declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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