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Notes

Fluorite deposits in Mongolia : an outline

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Abstract : Fluorite is one of the leading economic minerals the same as copper, molybdenum, gold and coal in Mongolia. The reserve of fluorite of Mongolia ranks fifth in the world. There are more than 600 fluorite deposits in Mongolia. Especially eastern and central parts of Mongolia are important for economical fluorite deposits. Most of the fluorite deposits in Mongolia are hydrothermal type, and can be divided into two groups by their genetical relation to magmatic rocks. One group has relation to volcanic rock, and the other to plutonic rock. The former is classified in epithermal fluorite deposit and fluorite deposit in carbonatite host. The latter is classified in bertrandite-phenacite-fluorite, albitite, Mo/Sn-W and pegmatite deposit. The total annual production of fluorite reached 527,000 t in 1995. At present Bor-Öndör, Adag, Bujgar, Zuun-Tsagaan-Del, Tsagaan-Elgen, Örgön and Delgerkhaan deposits are in commercial production, and further exploration is being carried out. Bor-Öndör is the biggest mining and processing complex.

1. Introduction

In Mongolia, fluorite is one of the leading economic minerals the same as copper, molybdenum, gold and coal. Mongolia's production of fluorite is about 15 % in the world (MMAJ, 1993). In Mongolia, fluorite was used to prevent decay of milk before, and nowadays it is mainly used for production of aluminum, iron, hydrofluoric acid, special glass and special optical glass. The first fluorite deposit in Mongolia was found in 1933, and the first economical fluorite deposit, Dojiru, in 1939. After the World War II, several economic cooperations with Soviet Union and China promoted the exploration and discovery of many fluorite deposits in central and eastern Mongolia (Kishimoto, 1982).

General descriptions of fluorite deposits in Mongolia were reported by Marinov (1958, 1980), Kalenov and Khasin (1965), Konstantinov and Zimina (1966), Kovalenko *et al.* (1976), Khrapov *et al.* (1977), Ontoev *et al.* (1977), Kotov *et al.* (1979), Ontoev *et al.* (1979 a), Volchanskaya and Korytov (1980), Shuvalov *et al.* (1980), Batjargal *et al.* (1982, 1985), Kandinov and Dobrolyubov (1984), Koshelev (1985) and Jamsran *et al.* (1986).

Mineralogy, geochemistry and genesis of fluorite deposits in Mongolia have been studied by Lkhamsuren and Batjargal (1975), Naumov and Ivanova (1975), Lkhamsuren (1976, 1984, 1988), Lkhamsuren *et al.* (1979), Ontoev *et al.* (1979 b), Korytov *et al.* (1980), Frikh-Khar and Volchanskaya (1982), Tumenbayar *et al.* (1986), Voinkov and Lkhamsuren (1986), Tumenbayar (1987) and Batjargal and Lkhamsuren (1987).

In this paper, we review classification and characteristics of fluorite deposits in Mongolia mainly based on mineral assemblage and ore genesis.

2. Outline of geology and geological structure of Mongolia

Mongolia is situated in the folding zone between the Siberian and North China Platforms (Janshin, 1989). The folding zone was formed by several orogenic movements in Precambrian and Paleozoic. The zone consists of ophiolite, high-pressure metamorphic rocks, granitic intrusions, arctic volcanic rocks and several large-scale strike-slip faults. The age of metamorphism and granitoids become younger toward southern area. Therefore, the folding zone is accretional zone, which was formed by subduction of oceanic plate and island arc to Siberian Plate (MMAJ, 1991). In eastern part of Mongolia, many volcanic and granitic rocks of Jurassic to Cretaceous are also distributed.

Mongolia is rich in many kinds of mineral resources. Many fluorite deposits are distributed especially in central and eastern parts of Mongolia (Fig. 1). The fluorite mineralization of late Jurassic to early Cretaceous is important for economical fluorite deposits (MMAJ, 1993).

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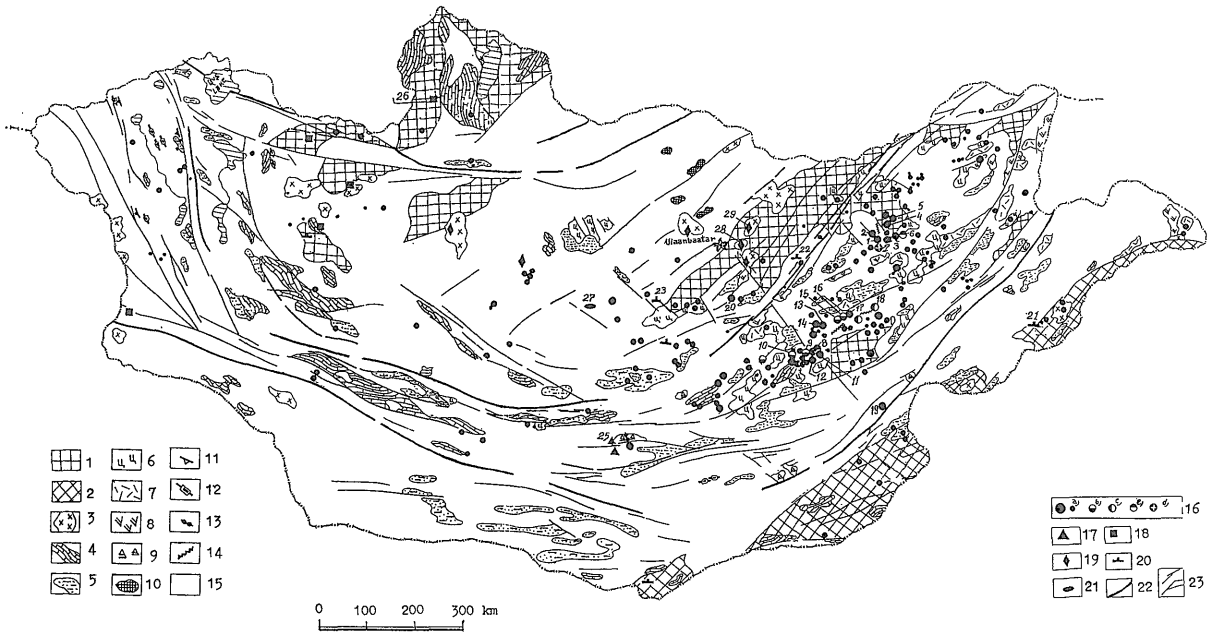
Keywords : Fluorite deposits, Mongolia, eastern and central parts, hydrothermal type, volcanic rocks, plutonic rocks



Deposit No.									
1	Berkh	7	Idermeg-bayan-Khaan	13	Bor-Öndör	19	Örgön	25	Mushugai-Khudag
2	Chimid	8	Khar-Airag	14	Adag	20	Chuluut-Tsagaan-Del	26	Altan-Boom
3	Delgerkhaan	9	Khongor	15	Khajuu-Ulaan	21	Eguzer	27	Dulaan-Ovoo
4	Yamaat	10	Bujgar	16	Zuun-Tsagaan-Del	22	Modoto	28	Gorykho
5	Shuvuutai	11	Khairt	17	Tsagaan-elgen	23	Ikh-Khairkhan	29	Zuun-Bayan
6	Dojir	12	Tsagaan-Del	18	Gal-shar	24	Baga-gazariin-chuluu		

Fig. 1 Schematic metallogenic map of fluorite mineralization in Mongolia (modified from Lkhamsuren, 1988). 1-4: Premesozoic rocks (1: Proterozoic basement in Caledonian folding area, 2: Early Paleozoic basement in Hercynian folding area, 3: Late Paleozoic to early Mesozoic granite, 4: Various ages of carbonate-chert and carbonate formations), 5: Mesozoic rocks (molasse and coal-bearing molasse formations, with some volcanic rocks), 6-9: Volcanic rocks (6: Basalt, andesitic basalt, trachy basalt and trachy andesite, 7: Dacite to rhyolite and trachy rhyolite, 8: Trachy andesite, trachy rhyolite and andesite to rhyolite, 9: Potassium alkaline basalt), 10-15: Intrusive rocks (10: Gabbro, 11: Diabase and dolerite, 12: Potassium alkaline ultrabasite, 13: Potassuim alkaline ultrabasite with carbonatites, 14: Alkaline basaltoid, 15: Rocks which are genetically not related with fluorite mineralization in composition and age), 16-21: Fluorite mineralization types (16: Epithermal fluorite deposit; main mineral assemblage is, a: quartz-fluorite (large and small deposit), b: calcite-quartz-fluorite, c: barite-quartz-fluorite, d: sulfide-quartz-fluorite and e: adularia-quartz-fluorite, 17: Fluorite deposit in carbonatite host, 18: Fluorite-bearing albitite, 19: Fluorite-bearing pegmatite, 20: Mo-W and W-Sn deposit, 21: Bertrandite-phenacite-fluorite deposit), 22: Main regional and deep fault, 23: Deep fault and fracture zone.

3. Fluorite deposits in Mongolia

3.1 Classification of fluorite deposits

There are more than 600 fluorite deposits in Mongolia (Jamsran *et al.*, 1986; Lkhamsuren, 1988). Fluorite deposits in eastern Mongolia have been classified by Kalenov and Khasin (1965), Konstantinv and Zimina (1966), Marinov (1980) and Fillipova *et al.* (1984). Jamsran *et al.* (1986) and Lkhamsuren (1988) have classified all types of fluorite deposits in Mongolia more minutely. Most of the fluorite deposits in Mongolia are of hydrothermal type, and can be divided into two groups by their genetical relation to magmatic rocks. One group has relation to volcanic rocks, and the other to plutonic rocks. The former is classified as epithermal fluorite deposits and carbonatite hosted deposits. The latter is classified as bertrandite-phenacite-fluorite deposits, albitite, tin-tungsten vein, tungsten-molybdenum vein, greizen and pegmatites depending on main mineral assemblage. The classification is summarized in Table 1.

3.2 Epithermal fluorite deposit

Epithermal fluorite deposit is the only economical deposit type in Mongolia at present. Quartz and fluorite are major minerals. Jamsran *et al.* (1986) and Lkhamsuren (1988) distinguished five mineral assemblage types of epithermal fluorite deposits based on major minerals in the ore body. The types are 1: quartz-fluorite, 2: calcite-quartz-fluorite, 3: barite-quartz-fluorite, 4: aduralia-quartz-fluorite and 5: sulfide-quartz-fluorite. Quartz-fluorite type is the most dominant in occurrence. Most of calcite-quartz-fluorite type was formed by hydrothermal metasomatism of

Table 1 Classification of fluorite deposits in Mongolia.

	Deposit type	Shape of deposit	Mineral assemblage		Representative deposit	Genetical related rock	radiometric age (Ma)
			Main minerals	Minor minerals			
1	Epithermal fluorite deposit	· vein · brecciated · disseminated · irregular · metasomatic body · lense	Qtz, Fl	Kao, Cal, Adu, Fe-Mn-oxide	· Berkh · Delgerkhaan · Khar-Airag · Adag · Bor-Öndör · Örgön	· Alkaline basalt · High potassium tracky basalt · taracky rhyolite · High alkaline differenciated from basalt-tracky rhyolite series	131-116
			Cal, Qtz, Fl	Py, Se, Adu, Chp, Sid	· Zuun-Tsagaan-Del · Chuluut-Tsagaan-Del · Bujgar · Khongor		
			Bar, Qtz, Fl	Py, Gln, Cal	Gal-shar		
			Adu, Qtz, Fl	Kao, Cal, Fe-Mn oxide	Dojir		
			Slf, Qtz, Fl	Py, Gln, Sph, Tet, Cin, Dik, Chp	Idermeg-Bayan-Khaan		
2	Fluorite deposit in carbonatite host	· vein · disseminated · in stock	Ap, Mgt, Fl	Fd, Cal, Bar, Cel, Qtz, Do	Mushugai-Khudag	· Alkaline ultramafic rock	153-136
			Qtz, Cal/Cel, Fl	Bar, Ank, Bst, Phg			
3	Bertrandite-Phenacite-fluorite deposit	· disseminated · irregular	Qtz, F, Brd, Ph, Fl	Brl, Py	Dulaan-Ovoo	· High alkaline granitic intrusion	154-180
4	Albitite	· disseminated · irregular	Ab, Qtz, Fl, Mc, Nb oxide, Bst	Ta-Nb-Ti oxide, Cry, Ilm, Cbt, Tt, Pyc, Zr, Arf, Rbe, Lpd	· Altan-Boom · Buural-Khangai	Alkaline granitoid	
5	Mo-W deposit	· greizen · vein · stockwork	Qtz, W, Mo, Fl	Brl, Mc, Tpz, Py, Gln, Sph, Bi	· Eguzer · Ikh-khair-khan	· Granite · Alaskite	126-210
	W-Sn deposit		Qtz, W, Cas, Fl	Tpz, Zin, Sch, Py, Gln, Sph, Bi	· Baga-gazariin-chuluu · Modoto		175-205
6	Pegmatite	· lenticular · columnar · vein	Mc, Qtz, Fl	Mica, Ab, Tm, Tpz, Brl	· Gorykho · Zuun-bayan	Granite	205-220

〔abbreviation〕 Ab: albite, Adu: aduralia, Ank: ankerite, Ap: apatite, Arf: arfvedsonite, Bar: barite, Bi: bismuthinite, Brd: bertrandite, Brl: beryl, Bst: bastnacite, Cas: cassiterite, Cal: calcite, Cbt: columbite, Cel: celestite, Cin: cinnabar, Chp: chalcopyrite, Cry: cryolite, Dik: dickite, Do: dolomite, Fd: feldspar, Fl: fluorite, Gln: galena, Ilm: ilmenite, Kao: kaolinite, Lpd: lepidolite, Mc:microcline, Mgt: magnetite, Mo:molybdenite, Pyc: pyrochlore, Ph: phenacite, Phg: phlogopite, Py: pyrite, Qtz: quartz, Rbe: riebeckite, Sch: scheelite, Se:sericite, Sid: siderite, Slf: sulfide, Sph: sphalerite, Tet:terahedrite, Tm: tourmaline, Tpz: topaz, Tt:tantalite, W: wolframite, Zin: zinnwaldite, Zr: zircon

limestone. Fluorite content in ore of these types is 36 to 64 %, and exceptionally very high grade, 90.0-98.5 %, at Berkh deposit.

The deposits occur as veins, irregular and lense-like shape, and in brecciated and disseminated zone. The vein deposits are dominant in occurrence. The veins are 1 to 30 m thick and 30 to 1300 m long, exceptionally 3000 m long at Bor-Öndör deposit. Otherwise 60-70 m thick veins were observed at Khongor and Bujgar deposits. Host rocks are precambrian schists, proterozoic limestones, paleozoic granites, mesozoic basalts, rhyolites, basaltic and rhyolitic tuffs. For example, the deposits are long fluorite veins in granite at Berkh (Fig. 2), several veins in basalt and andesite at Zuun-Tsagaan-Del (Fig. 3), large veins in volcanogenic rocks at Bor-Öndör (Fig. 4), ore bodies in volcano-tectonic structure at Khongor (Fig. 5) and metasomatic bodies and lense-like shape at Bujgar. Ratios of quartz to fluorite, two main minerals, vary in a wide range. Quartz commonly occurs as chalcedony-like, fine-grained or columnar crystals. Fluorite in ore is frequently coarse-grained, massive, columnar, rarely fine-grained and microcrystalline or cryptocrystalline. Fluorite occurs in various colors, for example, violet, dark violet, green and bluish-green. Fluorite in late stage has a pale color or is colorless. The formation temperature of all types of fluorite is 270 to 120℃based on the fluid inclusion study. Radiometric age of the epithermal fluorite deposits varies from 131 to 116 Ma (Kandinov and Dobrolyubov, 1984). The representative deposits are Berkh, Khar-Airag, Zuun-Tsagaan-Del, Bor-Öndör, Örgön, Chuluut-Tsagaan-Del, Khongor, Gal-shar, Dojir and Tsagaan-elgen.

3.3 Fluorite deposit in carbonatite host

The carbonatite hosted deposits were discovered in southern Mongolia (Baskina and Volchanskaya, 1976). The deposits occur as veins, in disseminated zone, stock and cone dyke. The vein deposits are dominant in occurrence. Based on the major mineral assemblage, they can be distinguished into two kinds of veins: 1) fluorite-apatite-magnetite-quartz, 2) fluorite-calcite or celestite-quartz which are accompanied with feldspar, barite, dolomite, ankerite, bastnasite, phlogopite as minor minerals. They are 5 to 70 m in length and 3 to 30 m in thickness. Fluorite content is 30-40 % in ore. The veins are related to alkaline intrusive rocks or syenites. Radiometric age of alkaline volcano-plutonic complex is 153 to 135 Ma (Kovalenko *et al.*, 1976; Baskina *et al.*, 1978). The representative deposit is Mushugai-Khudag.

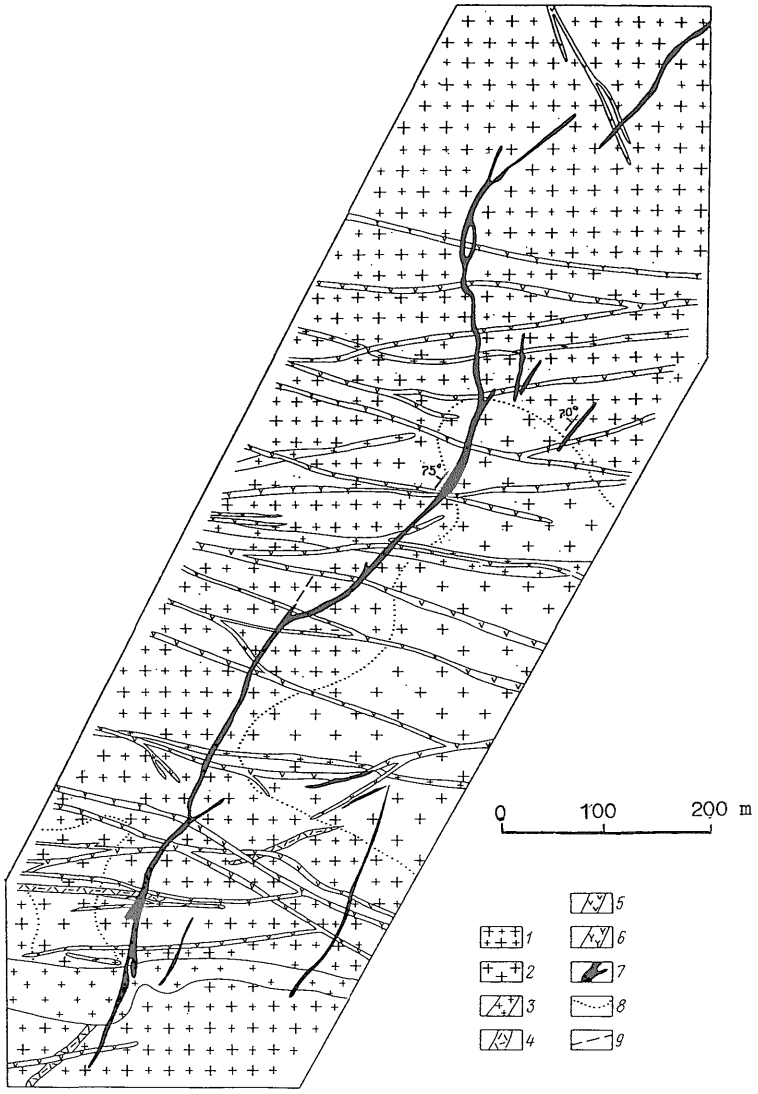


Fig. 2 Geological map of Berkh deposit (Khrapov *et al.*, 1977). 1-2: Permian granite (1: Biotite-hornblende porphyritic granite, 2: Coarse biotite granite), 3-6: Dike (3: Aplitic granite, 4: Quartz porphyry, 5: Diabase porphyry, 6: Gabbro to diorite), 7: Fluorite vein, 8: Boundary of granite phase, 9: Fault.

3.4 Bertrandite-phenacite-fluorite deposit

Bertrandite-phenacite-fluorite deposits are found in central Mongolia (Kostyrev *et al.*, 1977; Korytov *et al.*, 1978). They are veins with up to 1.5 m thickness, and located in a fractured zone with a few ten meters length and up to 10 m thickness in the exocontact of the early Mesozoic subalkaline granite massifs. Main minerals are quartz, feldspar, bertrandite, phenacite and fluorite, and minor minerals are beryl and pyrite. The maximum content of fluorite in ore is 30 %. The fluorite is richer in feldspar-fluorite veins with phenacite. Although bertrandite is a characteristic mineral for this deposit type, it is not found today. Radiometric age of the deposits varies from 154 to 180 Ma (Kotov *et al.*, 1979).

3.5 Albitite

Metasomatic albitite formation related to alkaline granite and syenite is confined to activated deep faults in late Paleozoic to early Mesozoic. The albitite is characterized by high content of Y, Zr, Nb, Ta, Be, Sn and REE, which may be included in pyrochlore, zircon, columbite and cryolite with bastnasite and fluorite (Yashina, 1975, 1982). Zonal albitite was formed as a result of multistage post-magmatic activities. Main minerals are albite, quartz, fluorite, microcline and bastnasite, and minor minerals are cryolite, lepidolite, ilmenite, columbite, tantalite, riebeckite, arfvedsonite and so on. Representative occurrences are Buural-Khangai and Aaltan-Boom.

3.6 Mo-W and W-Sn deposit

Rare metal-bearing fluorite deposits associated

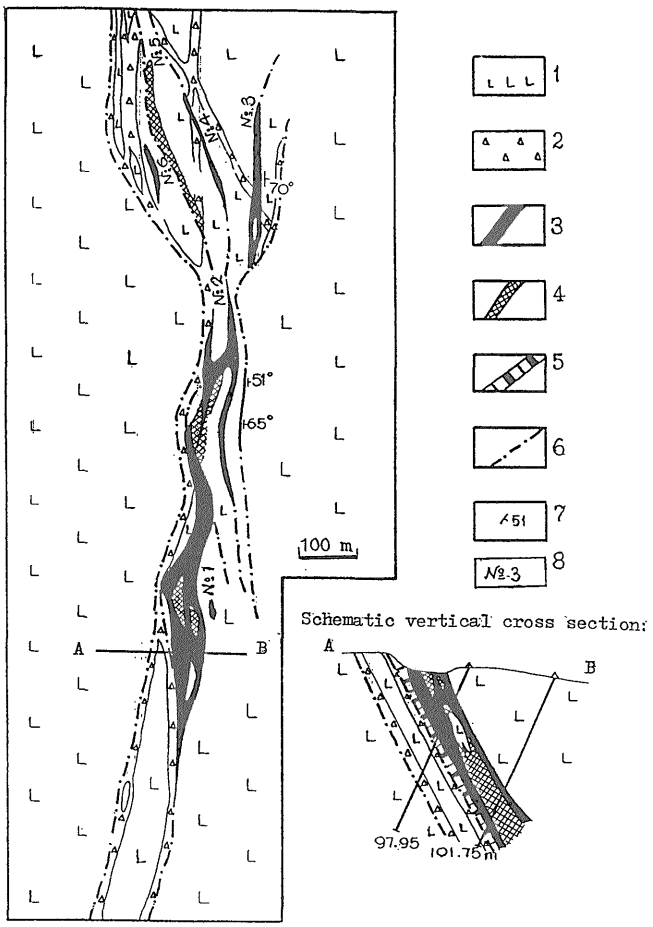


Fig. 3 Geological map of Zuun-Tsagaan-Del deposit (Koshelev, 1985). 1: Volcanic rocks in late Jurassic to early Cretaceous (basalt, andesite, andesitic basalt), 2: Breccias of rhyolite, trachy rhyolite and quartz porphyry, 3: Quratz-fluorite vein (sometimes with calcite), 4: Brecciated and intensive argillized zone with veinlets disseminated fluorite mineralization, 5: Ankerite-siderite-calcite vein, 6: Fracture zone, 7: Dip angle of vein and fault, 8: Number of ore body.

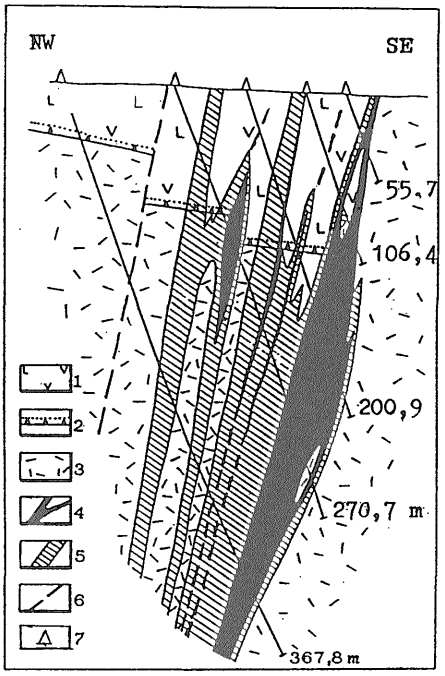


Fig. 4 Schematic vertical cross section of Bor-Öndör deposit (Koshelev, 1985). 1-2: Upper Jurassic to lower Cretaceous rock (1: Basalt and andesite, 2: Basal breccia), 3: Lower Permian quartz porphyry and tuff, 4: Quartz-fluorite vein, 5: Argillized zone, 6: Fault, 7: Bore hole.

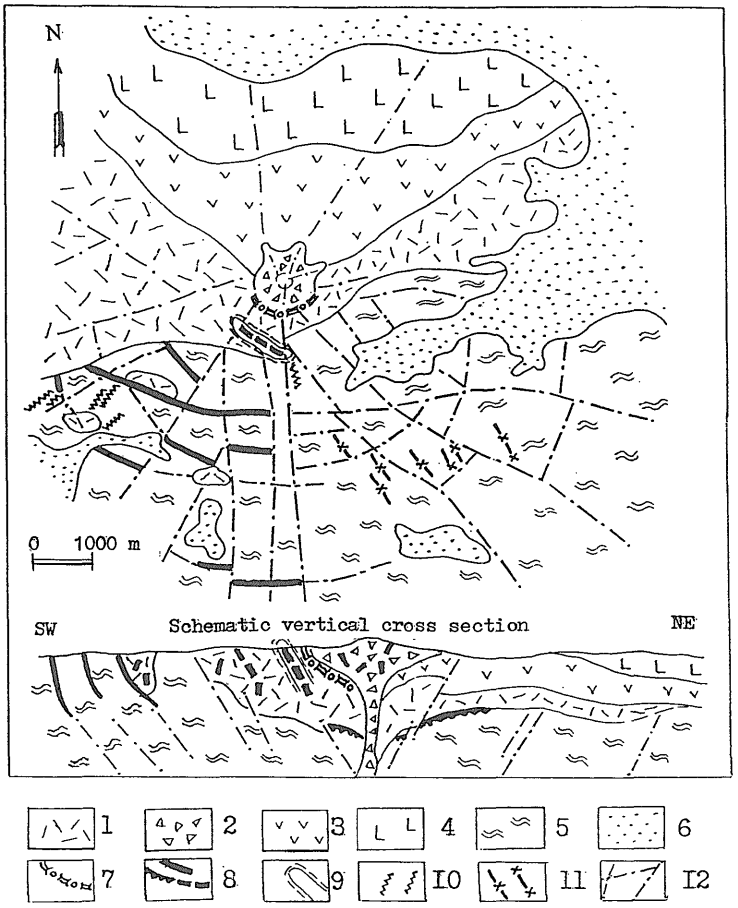


Fig. 5 Geological scheme of volcano-tectonic fluorite-bearing structure of Khongor deposit (Batjargal *et al.*, 1979). 1-4: Upper Jurassic to lower Cretaceous volcanogenic formation (1: Lava and dike of trachy rhyolite or quartz latite, 2: Dacite and dacitic porphyrite, 3: Trachy andesitic agglomerate and trachy andesite, 4: Lava and tuff breccia of basalt or andesite), 5: Precambrian mica-argillic schists with limestone interlayers, 6: Quaternary sediment, 7: Secondary quartzite, 8: Fluorite ore body, 9: Kaolinite distribution area, 10: Felsic dike and subvolcanic intrusion, 11: Mafic dike, 12: Fault and fracture.

with molybdenum-tungsten and tungsten-tin mineralization occur as greisen or veins. Ivanova (1972, 1976) studied geology, mineralogy and geochemistry of fluorite-bearing Mo-W and W-Sn deposits in eastern Mongolia. Typical deposits are Eguzer, Baga-gazariin-chuluu, Ikh-Khairkhan, Elstei, Buren-Tsogt, Tumen-Tsogt and Modoto. Especially in Eguzer Mo-W deposit, fluorite is concentrated in greizen, vein and shatter zone. In this deposit fluorite crystallized in two stages. In the early stage fluorite was formed at 460-220℃ in association with quartz, wolframite, beryl, molybdenite and topaz. In the late stage fluorite was formed at 200-100℃ with chlorite, pyrite, calcite and siderite. Ore-bearing greisens and greisened granite porphyries are 400-500 m in diameter and 30-40 m in thickness. Quartz-wolframite veins in hornfels are 70-80 m in length and 0.1-0.6 m in width.

3.7 Pegmatite

Mesozoic granitoids containing fluorite in pegmatite are located in near-margin part of eastern Mongolian volcanic belt. These pegmatites are mainly composed of quartz and feldspar, and accompanied with fluorite, topaz, beryl, tourmaline, albite, biotite and magnetite. They frequently have a symmetric zonal structure. The formation temperature of fluorite is 250-130℃ and rarely 480-250℃ for early stage. Representative deposits are Gorykho, Zuun-Bayan, Janchivlan and Bayan-Tsogt.

4. Production of fluorite

Eastern and central parts of Mongolia are more productive for economical fluorite deposits. Especially in the mesozoic volcanic belt of eastern Mongolia, large fluorite deposits such as Bor-Öndör, Adag, Berkh, Delgerkhaan, Zuun-Tsagaan-Del, Chuluut-Tsagaan-Del and Örgön are located (Table 2, Fig. 1).

The total reserve of fluorite in Mongolia amounts to 18.4 million tons. The reserve ranks fifth in the

Table 2 Main fluorite deposits in Mongolia

Large deposit (proved reserve of about 2-20 million tons)

1. Bor-Öndör	Epithermal vein type deposit
2. Adag	
3. Berkh	
4. Delgerkhaan	
5. Zuun-Tsagaan-Del	
6. Chuluut-Tsagaan-Del	Epithermal metasomatic deposit
7. Örgön	

Small deposit (proved reserve of about 0.2-2.0 million tons)

1. Khar-Airag	Epithermal vein type deposit
2. Tsagaan-elgen	
3. Khamar-Us	
4. Tsagaan-Takhilch	
5. Dojir	
6. Khajuu-Ulaan	
7. Saikhan-Uul	
8. Baruun-Tsagaan-Del	
9. Chimid	
10. Shuvuutai	
11. Bor-tolgoi	
12. Gal-shar	
13. Khuviin-Ovgor	
14. Khongor	Epithermal metasomatic deposit
15. Mainkhant	
16. Bujgar	

world. Fluorite is one of the leading economic minerals the same as copper, molybdenum, gold and coal in Mongolia. The first production of fluorite began at Berkh deposit in 1954. In the middle 1970's, the joint enterprise of Soviet Union and Mongolia, Mongolsovsvetmet, has been published, and Mongolo-Czechoslovak has followed in 1980. They account for a large ratio of fluorite production in Mongolia. The total annual production of fluorite reached 527,000 t in 1995 (Table 3). Fluorite is mined by opencut and gallery. The opencut produces 63 % of the total ores. At present Bor-Öndör, Adag, Bujgar, Zuun-Tsagaan-Del, Tsagaan-Elgen, Örgön and Delgerkhaan deposits are in commercial production. Further exploration in each mine is being carried out. Bor-Öndör is the biggest mining and processing complex (Damdinsuren, 1995).

Table 3 Production of fluorite of Mongolia (National Economy of Mongolia, 1984, 1990, 1995).

year	1000 t
1960	40.3
1965	49.6
1970	76.9
1975	290.6
1980	603.5
1985	786.8
1990	512.1
1995	527.0

5. Conclusions

Fluorite is one of the leading economic minerals the same as copper, molybdenum, gold and coal in Mongolia. There are more than 600 fluorite deposits in Mongolia. Especially eastern and central parts of Mongolia are important for economical fluorite deposits. Most of the fluorite deposits in Mongolia are hydrothermal type, and can be divided into two groups based on their genetical relation to magmatic rocks. One group has relation to volcanic rocks, and the other to plutonic rocks. The former is classified in epithermal fluorite deposit and carbonatite hosted fluorite deposit. The latter is classified in bertrandite-phenacite-fluorite, albitite, Mo/Sn-W and pegmatite deposit.

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モンゴルの螢石鉱床の概要

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要　旨

モンゴルでは，蛍石は銅・モリブデン・金・石炭と同様に主要な鉱物資源の一つであり，蛍石の埋蔵量は世界第5位である．モンゴルには600以上の蛍石鉱床が存在し，特に国内東部と中央部は経済的価値の高い蛍石鉱床に関して重要である．モンゴルの蛍石鉱床はほとんど熱水成であり，関係火成岩によって2種類に分けられる．一つは火山岩に，もう一つは深成岩に関連している．前者は浅熱水成鉱床とカーボナタイト中の鉱床，後者はベルトランダイト-フェナサイト-蛍石，アルビタイト，Mo/Sn-Wそしてペグマタイトの各鉱床である．1995年の蛍石生産量は527000トンであった．現在では，Bor-Öndör, Adag, Bujgar, Zuun-Tsagaan-Del, Tsagaan-Elgen, Örgön, Delgerkhaanの各鉱床が開発され，さらに探査活動も行われている．このうちBor-Öndör鉱床からの生産量が最も多い．