CHAPER 3 EXISTING GEOLOGICAL INFORMATION

3-1 General Geology of the Surrounding Area

(1) General geology and ore deposits in Mongolia

Geographically, Mongolia is a country located between Russia to the north and China to the south. Geologically, Mongolia is located in the eastern edge of orogenic belt (Central Asia Folded belt) between Angara craton (Siberian Block) to the northern side and the Northern China craton to the southern side. The mobile belt of about 2,000km existing from Mongolia to Far East Russia is called the Mongol - Okhotsk Fold Belt or the Ural - Mongol Fold belt. According to several studies, the geological framework of Mongolia is formed by Cordilleran type orogeny or Collision type orogeny (Maruyama et al., 1997). The Cordilleran type orogeny forms accretionary prism – magmatic arc accompanied with subduction surrounding Siberian craton and North-China craton in the Paleo Asia Ocean or Mongolian Seaway. The Collision type orogeny was formed by the approach of two cratons. Recently it is vastly recognized that island arcs and micro-continentals existed in Altaids and that the Mongolian geological formation consists of the assembly of accretionary prism and magmatic arc; however, the stratigraphic correlations between geologic divisions have not been analyzed yet.

Various mineralization types exist in Mongolia. They are due not only to magmatic activity accompanied by a subduction process in the Tuva-Mongol island arc with continental crust existing from early Proterozoic, but also to magmatic activity accompanied by the collision process of Angara craton and North-China craton. The porphyry type copper-molybdenum deposits and the gold deposits related to the plutonic rocks are considered to have considerable economic significance.

(2) General geology in the project area.

(a) General geology

The project area is located in the western Tuva-Mongol Unit on the south of the Vitim Structure, which is a large structural line trending east to west. The geology in the area corresponds to magmatic island arc formed by accretion on subduction system from Vendian of Proterozoic to late Permian.

Based on the existing geological data, general geological maps in the project area are shown in the Fig I-3-1 (1) and (2). A geological map compiled from the interpretation results of JERS-1 imagery (MMAJ, 2001) is presented at Fig.I-3-2. The generalized stratigraphic columnar section in the project area is shown Fig. I-3-3.

In the eastern project area, trachybasalt, trachyandesite, tuff and sandstone from Permian to Triassic are widely exposed. The Selenge complex from Permian to Triassic consisting of granite, granodiorite, gabbros, etc., and the Triassic granitic rocks of monzonite, granite, granodiorite and

syenite, intrude in the above Permian to Triassic sedimentary rocks. The Triassic to Jurassic volcanic rocks cover them. Finally, the Quaternary alluvial deposits are distributed along streams.

(b) Geological structure

The project area is geologically located in the western Tuva-Mongol Unit on the south of the Vitim Structure, which is a large structural line trending east to west. The geology in the area corresponds to magmatic island arc formed by accretion on subduction system from Vendian of Proterozoic to late Permian.

In the project area, it can be confirmed the structure of plutonic rocks arrangements, the basin structure, dyke arrangement structure and fault structures.

Plutonic rocks arrangements: Permian to Triassic plutonic rocks are arranged along a NW-SE direction around the Erdenet mine area and the Mogoin gol area. On the other hand, the distributions and the arrangements elongate to NS direction in the northeastern part of the area.

Basin structure: Late Triassic to early Jurassic Volcanic rock is distributed in the circular area from the Erdenet mine area to the Mogoin gol/Khujiriin gol area. This distribution shows the basin structure with diameters around 40 km in the EW direction and 30 km in NS direction.

Small body structure: Liparite dyke and stocks are developed surrounding the basin structure including the distribution of the Triassic to Jurassic volcanic rocks. The direction of dykes in the southwestern part of the project area is probably controlled by the existence of deep faults in the area.

Faults structure: Typical faults can be recognized in the existing geological map of the project area. NW-SE faults system is developed in the western part of the area. In the northeastern part of the area, NE-SW faults are developed. The Erdenet mine exists in the junction of the NW-SE faults and NE-SW faults.

Ring structure: Ring structure of about 20 km in diameter can be recognized in the existing geological system. Erdenet porphyry copper ore deposits are located at the crossing place between linear structure of the plutonic rocks arrangements and the faults structures and also at northern outside of the great scale ring structure.

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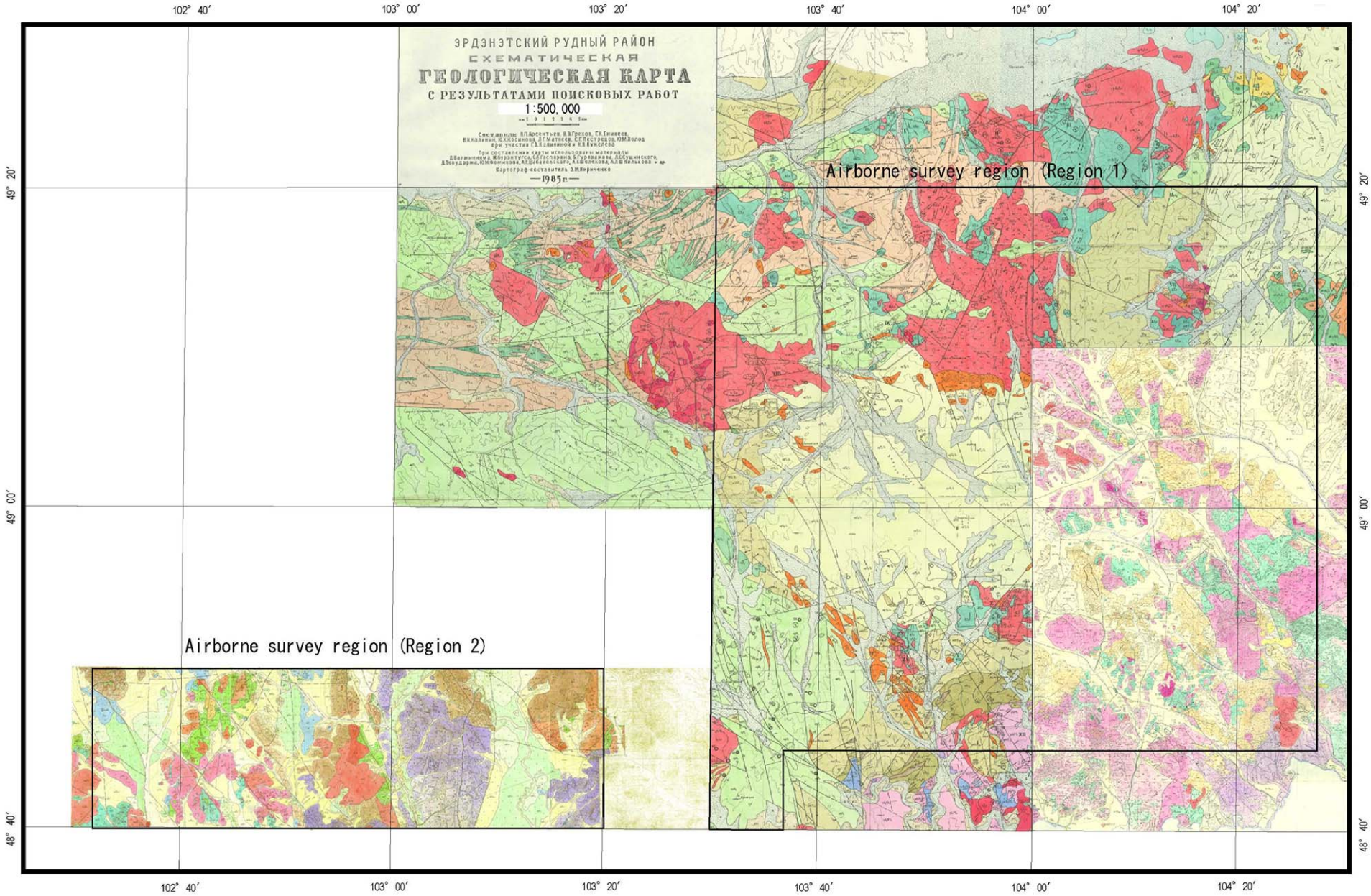


Fig.I-3-1(1)　Existing geological map in the project area in Mongolia

L E G E N D

(Central Area)

CENOZOIC SEDIMENTARY AND VOLCANIC ROCKS

βKZ	Cenozoic basalt
Q	Quaternary deposits; loam, silt, sand and gravel

JURASSIC TO CRETACEOUS SEDIMENTARY ROCKS

J2–K1	conglomerate, gravel stone, sandstone

TRIASSIC TO JURASSIC SEDIMENTARY AND VOLCANIC ROCKS

αβT2–J1	andesite, andesitic basalt, trachy-andesite, trachy-basalt, dacite and tuff-breccia, tuff stone, tuffaceous sandstone
tT2–J1	sedimentary rock: conglomerate, gravel stone

PERMIAN SEDIMENTARY AND VOLCANIC ROCKS

αβP2	andesite-basalt and tuff, trachy-basalt and tuff, tuffaceous conglomerate
tP1-2	tuff, sandy tuff, gravel stone, conglomerate
αγtP1-2	andesite to liparite, liparite, andesitic tuff, tuffaceous stone, tuff
αP1-2	andesite, andesite to basalt, tuffaceous stone

DEVONIAN

RIPHEAN TO CAMBRIAN

V-Є	Riphean to Cambrian; limestone

INTRUSIVE ROCKS

Jurassic

λJ	Jurassic subvolcanic rock; liparite, andesite-dacite
γ3J1s	Third phase: fine to moderate grained, leucocratic granite
γξ2J1s	Second phase: moderate to coarse grained, porphyry, biotite granosyenite
(δ-γδ)J1s	First phase; fine to moderate grained, diorite, biotite granodiorite

Triassic to Jurassic

νβT2–J1	Middle Triassic to Jurassic subvolcanic rocks; gabbro, diabase, diabasic porphyry

Triassic

γ3T1s	Third phase: fine to moderate grained, porphyry, leucocratic granite porphyry, granite porphyry, granodiorite porphyry
(γ - δ)T1s	Second phase; medium grained, biotite granodiorite, diorite, granite, granosyenite
(υ - δ)T1s	First phase; medium to coarse grained, gabbro, gabbro to diorite, diorite
υβP2	Late Permian; Gabbro-diabase, diabase, diabase porphyry, gabbro
λP1-2	Lower to upper Permian subvolcanic rocks

Devonian

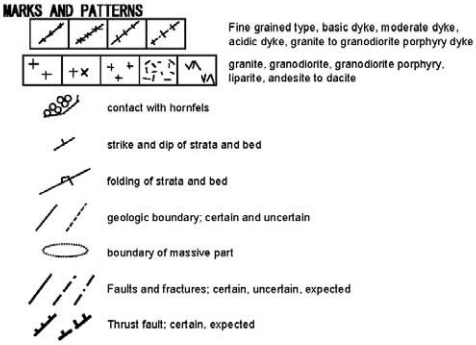
Paleozoic

γδPZ1	Second phase; medium to coarse grained, biotite granodiorite, granite
(υ - δ)PZ1	First phase; medium to coarse grained, pyroxene gabbro, gabbro to diorite, diorite

(Southwestern and Southeasteren Area)

cQIV, caQIV, apQIII-IV	Quaternary deposits; loam, silt, sand and gravel
βzQII-III	Cenozoic basalt
J2sh	Jurassic to Cretaceous deposits; conglomerate, gravel stone, sandstone
T3–J1mg	andesite, andesitic basalt, trachy-andesite, trachy-basalt, dacite and tuff-breccia, tuff stone, tuffaceous sandstone
P1uz2	andesite to liparite, liparite, andesitic tuff, tuffaceous stone, tuff
P1uz1	andesite, andesite to basalt, tuffaceous stone
D2ot2	andesite, dacite, it's tuff
ξJ1	syenite
γ3P2-T1sl	Third phase: leucocratic granite porphyry, granite porphyry
ε γP2-T1sl	Third phase: fine to moderate grained, porphyry, leucocratic granite porphyry, granite porphyry, granodiorite porphyry
γξ2P2-T1sl	Second phase; medium grained, biotite granite, granosyenite
ξδ1P2-T1sl	First phase; medium to coarse grained, granodiorite, syenitic diorite
δη1P2-T1sl	First phase; medium to coarse grained, gabbro to diorite, diorite
δ1P2-T1sl	First phase; medium to coarse grained, diorite
γ3D2	Third phase; granite, granosyenite and granosyenite.
ι γ3D2	Third phase; leucocratic granite
ε ι γ3D2	Third phase; fine grained leucocratic alaskite granite and aplite
γ2PZ1	Second phase; granite
γδ2PZ1	Second phase; granodiorite
δ1PZ1	First phase; diorite

GEOLOGICAL MARKS AND PATTERNS



Fine grained type, basic dyke, moderate dyke, acidic dyke, granite to granodiorite porphyry dyke

granite, granodiorite, granodiorite porphyry, liparite, andesite to dacite

contact with hornfels

strike and dip of strata and bed

folding of strata and bed

geologic boundary; certain and uncertain

boundary of massive part

Faults and fractures; certain, uncertain, expected

Thrust fault; certain, expected

ALTERATION

Alterated and metasomatic zone

Limits	Mark	Alteration
	mk	potassic alteration
	q	silicification
	tu	tourmaline
	src	sericitization
	py	pyritization

MINERALIZATION

Copper mineralization area

Area	Copper showing	Geochemical anomaly	Mineral distribution
I	●: Cu > 0.2 % ○: Cu < 0.2 %	Cu > 0.01% Mo > 0.0005%	ch :chalcopyrite
I - Nurain	VII - Zuukhiin	Pb > 0.01 % Zn > 0.03 % Ag > 0.0001%	mo :molybdenite
II - Tarimaliin	VIII - Mujirt		ma :malachite
III - Iitiin	IX - Mogoin		gn :galena
IV - Havchugin	X - Zalugiin	Cu, Mo, Pb, Zn, Ag	ce :cerussite
V - Buhain	XI - Danbatseren		cs :cassiterite
VI - Ingetiin	XII - Haliun		sh :scheelite
			au :gold

Fig.I-3-1(2) Legend of existing geological map in the project area in Mongolia

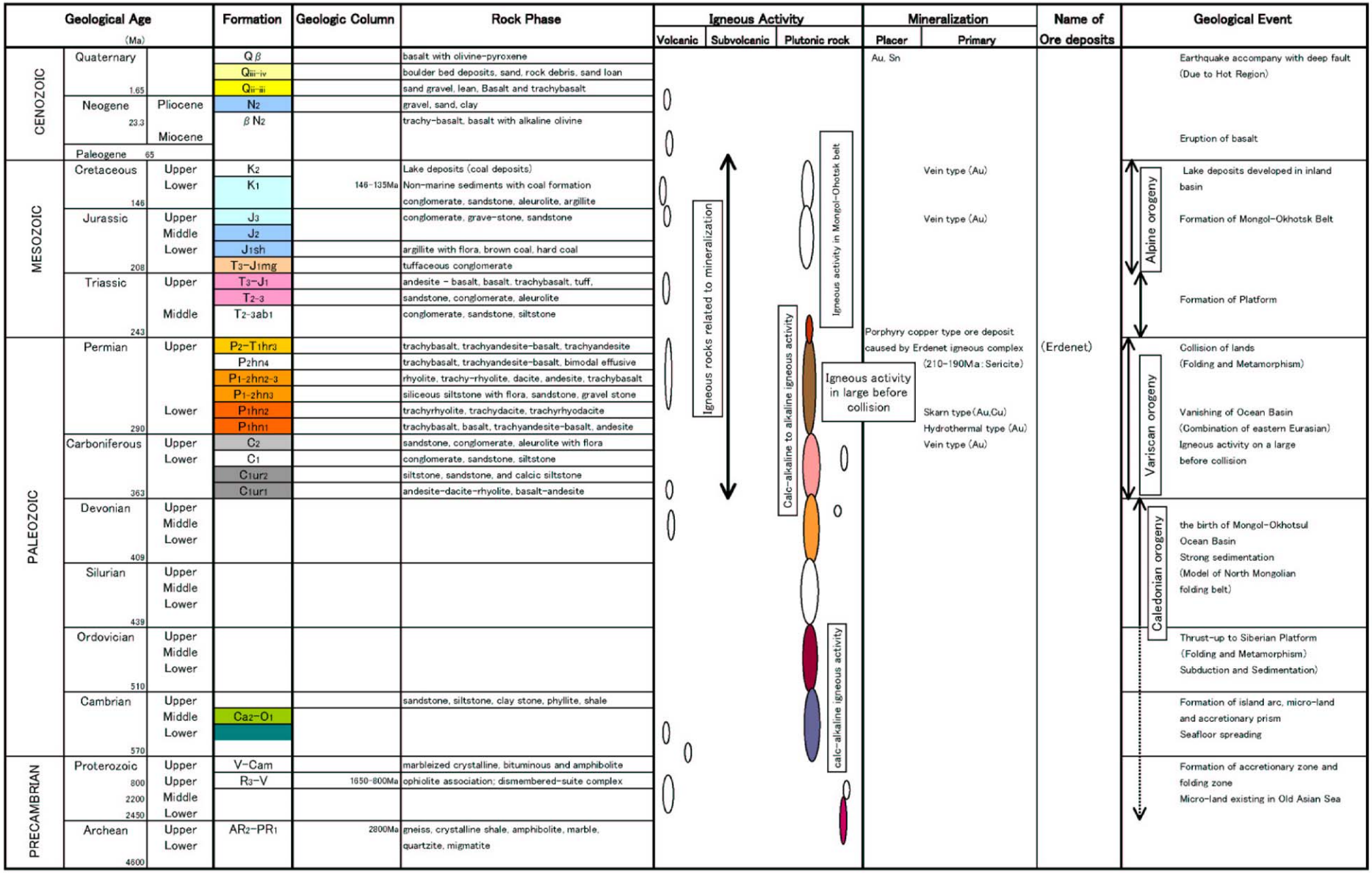


Fig.I-3-2 Generalized stratigraphic columnar section in the project area, Mongolia

3-2 Mineralization in the Project Area

(1) Mineralization types

Mineral deposits and occurrences in the project area are indicated in the mineral location map (G. Dejidmaa etc, 2001) shown in Fig. I-3-4. Three types of mineralization exist in the project area as follows:

①Porphyry Cu-Mo deposits and mineralization zones hosted in the porphyry and granitic rocks,

②Copper mineralization related to basalt dykes, and

③gold vein type and stockwork type related to granitic rocks.

① Porphyry Cu-Mo deposits hosted in the porphyry and granitic rocks

Typical ore deposit distributed in the area is the Erdenet ore deposit which is composed of the Erdenet NW deposit, the Erdenet Central deposit, the Erdenet Intermediate deposit and the Erdenet SE deposit. In the southeastern part of these deposits, there can be seen the Shand mineral showing, the Tourmaline mineral showing, the SAR188 mineral showing and the SAR200 mineral showing.

Other mineralization showings such as the ones at Zuukhiin gol, Mogoin gol, Khujiriin gol, Tsagaan Chuluut, Danbatseren and Undrakh are known to be of the same type of mineralization. In the western part of Bulgan city, there are several showings as well.

(2) Mineralization characteristics of the Erdenet deposit

Regional background: The Erdenet ore deposits are reported to form in relation with the Permian to Triassic collision process (240 Ma) of the Siberian Block and the Mongol-Northern China block in the Eurasia (Watanabe 1998, 1999). The Selenge complex (290 to 240 Ma) represents deeper lithofacies of the igneous activities in the volcanic arcs that were formed in the northern, central and southern part of Mongol before the collision. At the latest stage of the igneous activity, the Erdenet complex (granodioritic porphyry; 250 to 245 Ma, 250 to 220 Ma and 205 to 195 Ma) (Berzina et al., 1999) and the alkali rock (180 Ma) intruded and the Erdenet ore deposits were formed (190 to 210 Ma).

Geology: The Erdenet ore deposits exist in the junction of the granitic rocks arrangements, the dyke and the fault systems in NW-SE direction and the fault systems in NE-SW direction. They also exist in the southern edge of the Basin structure, late Triassic to early Jurassic deposit. Permian volcanic rocks, the Selenge complex intrusion in the Permian intrusion and the Erdenet complex intrusion in the Selenge complex distributed around the Erdenet mine. In and around the Erdenet mine, the host rock of the porphyry Cu-Mo mineralization is the Selenge Complex, and the igneous rock related to the Erdenet ore deposit, the porphyry cupper-molybdenum deposit, is the Erdenet Complex composed of granite porphyry and granodiorite porphyry. The Erdenet Complex is composed of granite-porphyry, diorite porphyry and granodiorite porphyry.

Geological structure: In the project area, the geological structure consists of granitic rocks arrangements, dyke and the fault systems in NW-SE direction and fault systems in NE-SW direction, as shown in Fig. I-3-1. The Erdenet mine exists in the southern edge of the basin structure and also in the junction of these main faults.

Alterations: The alteration assemblages present strong silicification- greisen zone, quartz-sericite zone, sericite-chlorite zone and calcite-epidote-chlorite zone from the center to outward, accompanied with other spotty alterations (Naito and Sudo, 1999). Acid alteration, called as the advanced argillic alteration (the Tsagaan Chuluut area) and sericite alteration (the Mogoin gol area) are recognized related to the formation of porphyry Cu-Mo deposits in the project area.

Mineralizations: Oxide and leached zone is situated on the surface and the secondary enrichment zone composed of chalcocite, bornite, covelite and oxide copper beneath the oxide and leached zone. Primary ores are composed of chalcopyrite, bornite, pyrite and molybdenite beneath the secondary enrichment zone.

Results of the airborne geophysical survey: The Erdenet mine is located in the northern part of the lowest small magnetic zone in a lower magnetic anomaly trending NW-SE direction. Porphyry forming the Erdenet complex is located in the lowest small magnetic anomaly and thus it is recognized that the porphyry is related to the generation of porphyry copper-molybdenum deposits. High potassium content results are caused by the Erdenet deposits and coincide with the rocks in the open pit and its surrounding waste dumps that reflect the alteration rocks bearing potassium.

3-3 Outline of the Mining History

The biggest porphyry copper-molybdenum deposit in eastern Asia exists is the Erdenet copper deposit. This deposit is composed of the Erdenet NW ore deposit, which is being mined as an open pit, the Erdenet Central deposit, the Erdenet Intermediate deposit and the Erdenet SE (Oyut) deposit, from north to south direction. The Erdenet Central deposit, the Erdenet Intermediate deposit and the Erdenet SE (Oyut) deposit already finished exploration including feasibility studies.

In 1941, the Erdenet deposits were firstly reported.

During 1964 and 1969, ore reserves were 512,000,000 tons (metal copper: 4,300,000 tons).

In 1972, it was taken the decision of development in cooperation with the Soviet Republic.

In 1978, the Erdenet mine operations started production (4,000,000 tons per year).

In 1983, the production increased to 16,000,000 tons per year.

In 1989, the production was 20,000,000 tons per year.

To 1990, the copper concentrate (30 % to 32 %Cu) produced 350,000 tons.

In 1995, the ores extracted 20,900,000 tons (0.73 %Cu and 0.02%Mo) with Cu concentrate production of 346,300 tons Cu (about 40%) and 3,900 tons Mo.

In 2000 the production summary of the Erdenet mine was:

- Annual production: 40,000,000 tons/year
- Production of concentrate: 400,000 tons per year at 30%Cu, 1%Mo
- Ore reserve in 1999: 1,400,000,000 tons at 0.25%Cu COG
  (7,000,000 tons Cu, 200,000 tons Mo)

On the basis of exploration studies surrounding the mine and feasibility studies, the ore reserves in the Erdenet Central deposit and the Erdenet Southeast (Oyut) deposit were calculated 1,250,000 tons (0.43%Cu, 0.018 %Mo) and 41,890,000 tons (0.40%Cu, 0.007%Mo) respectively.

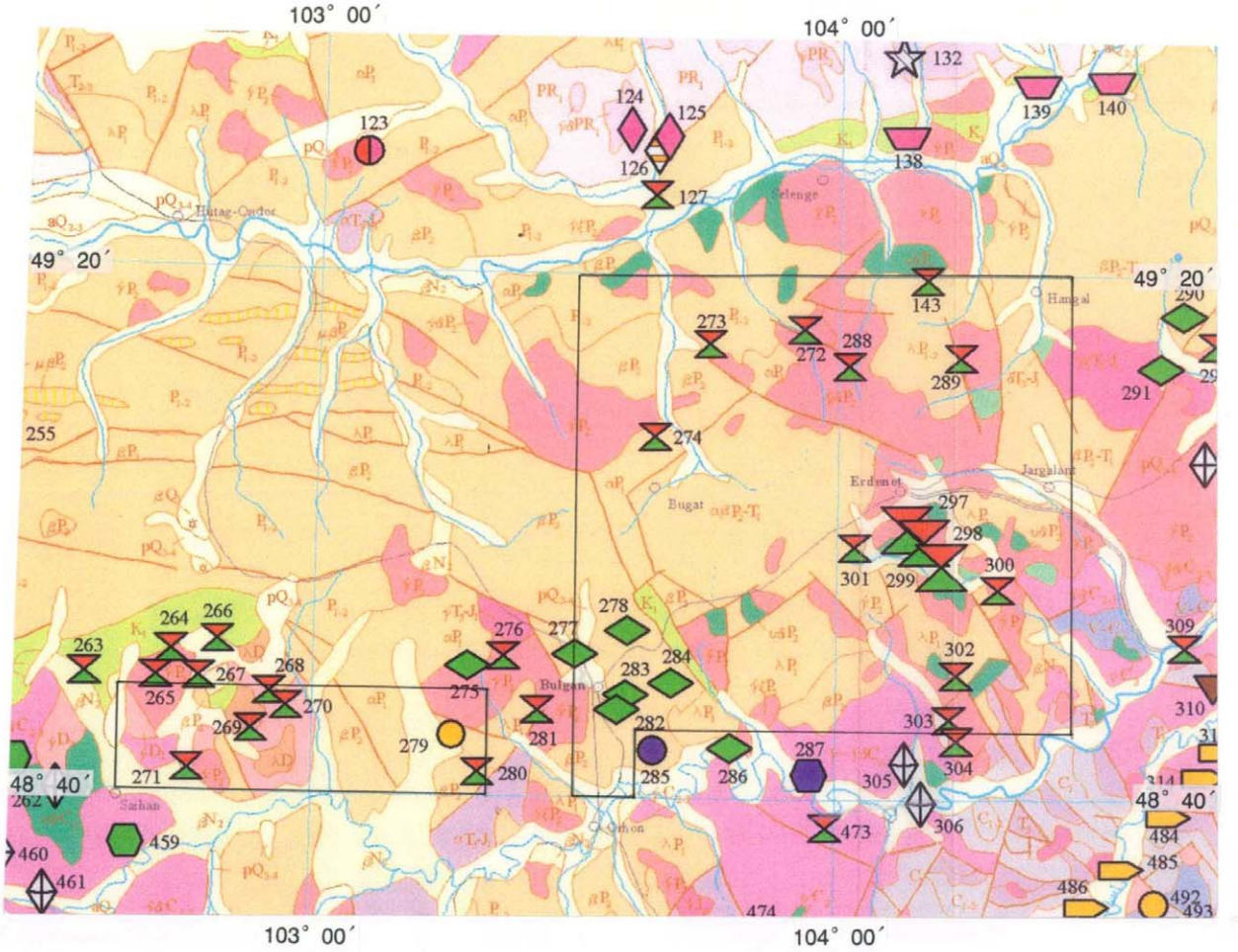


Fig.I-3-3 Generalized mineral location map in Western Erdenet area

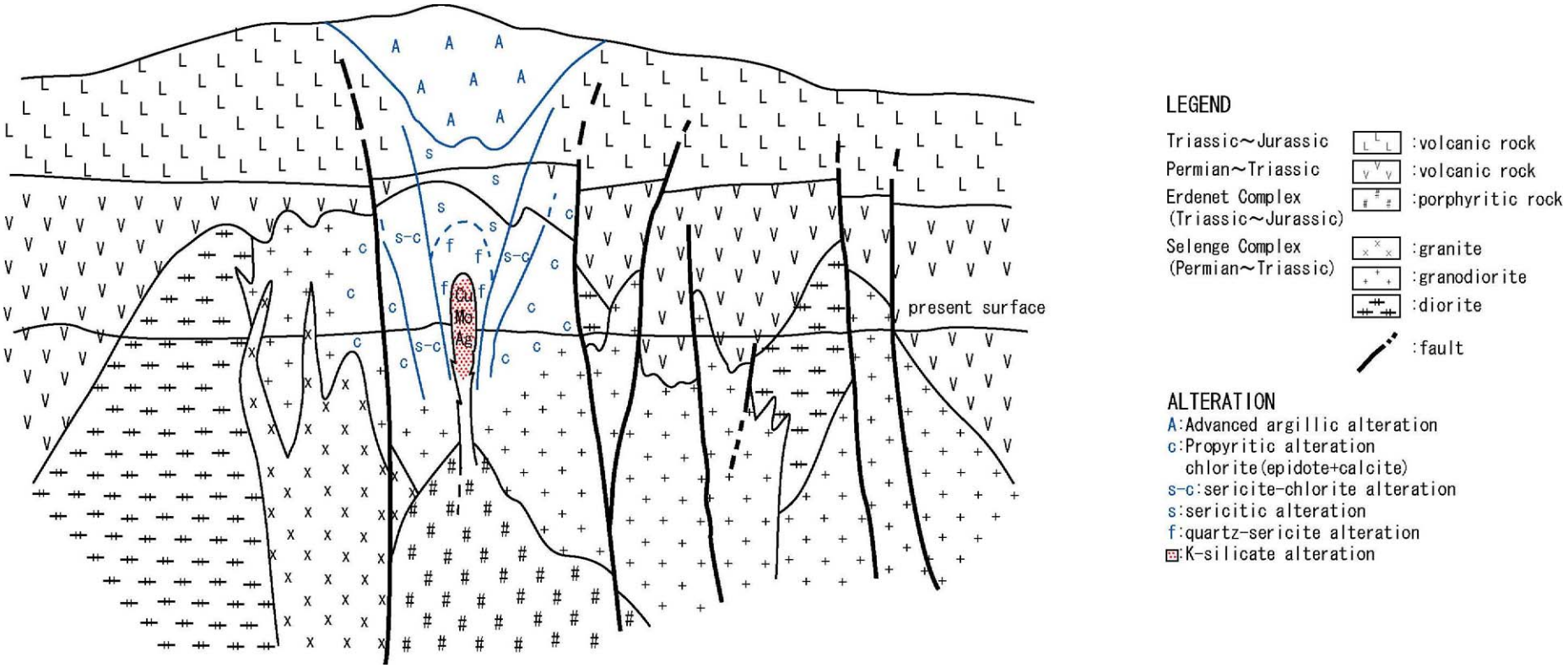


Fig.I-3-4　Genesis model of Erdenet ore deposit in early Jurassic