Chapter 3 Geology, Mineral Deposits, and Mining of the Survey Area

3.1 Outline of geology and mineral deposits of Mongolia

Geographically, Mongolia is an inland locating between Russia in the north and China in the south. Geologically, it is located in the eastern edge of the orogenic belt (Central Asian Folded Belt: Mossakovsky et al., 1994 or Altaids: Sengor et al., 1996) between Angara craton (Siberian Block) in the northern side and the North China craton (Sino - Korean Massif) in the southern side. The mobile belt of about 2,000 km extending from Mongolia to the Russian Far East is called Mongol - Okhotsk Fold Belt or Ural-Mongolia Fold Belt (Zonenshain et al., 1990, Milanovskiy, 1989). There is an opinion (Maruyama et al., 1997) that the skeleton of geological structure of Mongolia was formed by the Cordilleran type orogenesis which formed the accretionary prism-magma arc accompanied with subduction in Siberian craton and North China craton peripheral regions intercalating Paleo Asian Ocean or Mongolian Seaway and the collision type orogenesis by the approach of both cratons. But in recent years, it became to be generally recognized that there were island arcs which had continental crust or micro-continents in Altaids (for example, Sengor et al., 1996; Tumurtogoo, 1996; Sengor et al., 1993; Tseden et al. 1992). Up to now, several research works for tectonic classification have been tried. In this report, the classification of tectonic units and the tectonic evolution are described mainly on the basis of Sengor et al. (1996). The geotectonic maps by Sengor et al. (1996) and the Mineral Resources Authority of Mongolia (unpublished) are shown in Figures I-3-1a and b respectively. Since names of similar geological bodies are sometimes used for different ones, in order to avoid the confusion, the correlation of representative structural classification is shown in Table I-3-1. Also, the geological structure of Mongolia is, as above mentioned, a collective body of accretionary prism and magma arcs related to the subduction. Therefore correlation of stratigraphy among each geological body would be preferable, but they have not been analyzed yet. Approximate characteristics and distribution of lithofaces are shown in Table I-3-2.

3.1.1 Tectonic evolution

The orogenic belt of Proterozoic to early Mesozoic which extends from Central Asia including Mongolia to Okhotsk has been called "Altaids" since the beginning of the 20th century, but since it has very little amount of wide and old terrane consisting of gneiss and molasse which has developed among continents, it is considered that it has its own characteristics which are different from the collision type orogenic belts like Alps and Himalayas. With a simple model in which accretionary prisms and magma arcs occurred

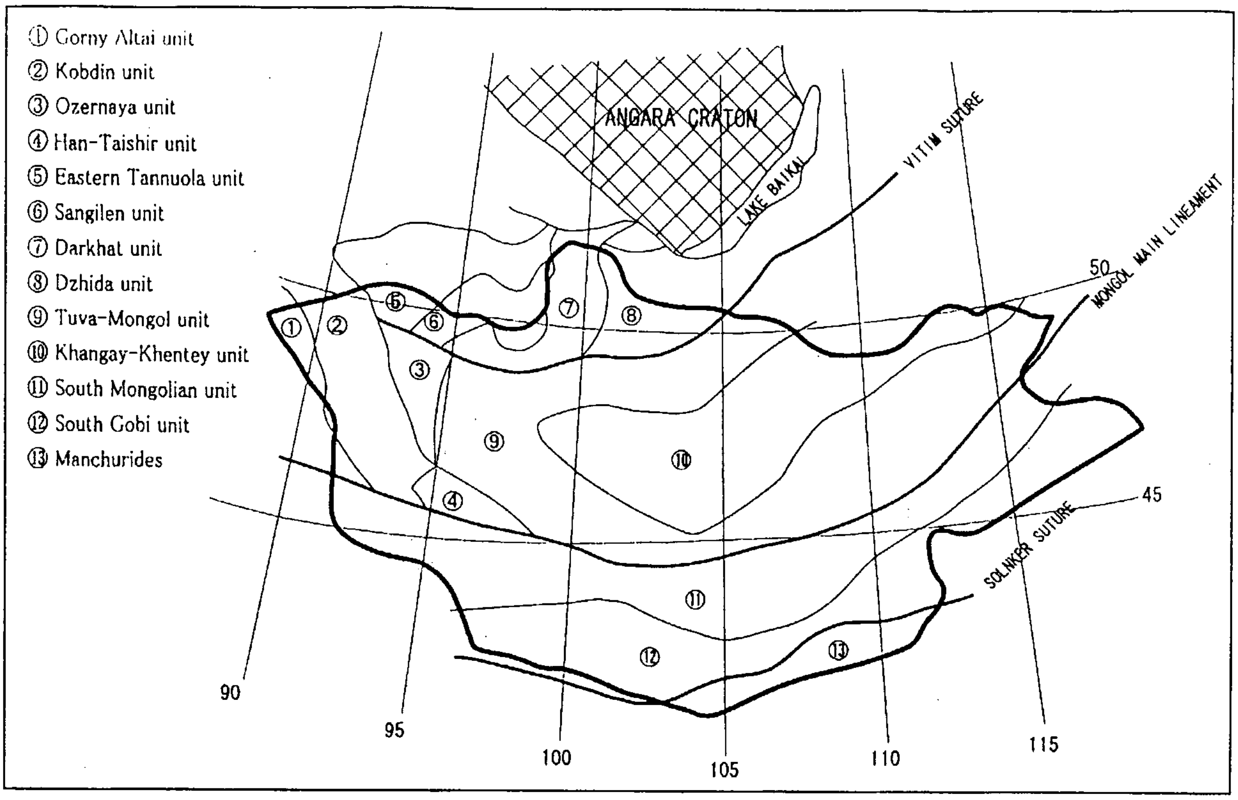

Fig. I-3-1a Tectonic units of Mongolia (Sengor et al., 1996)

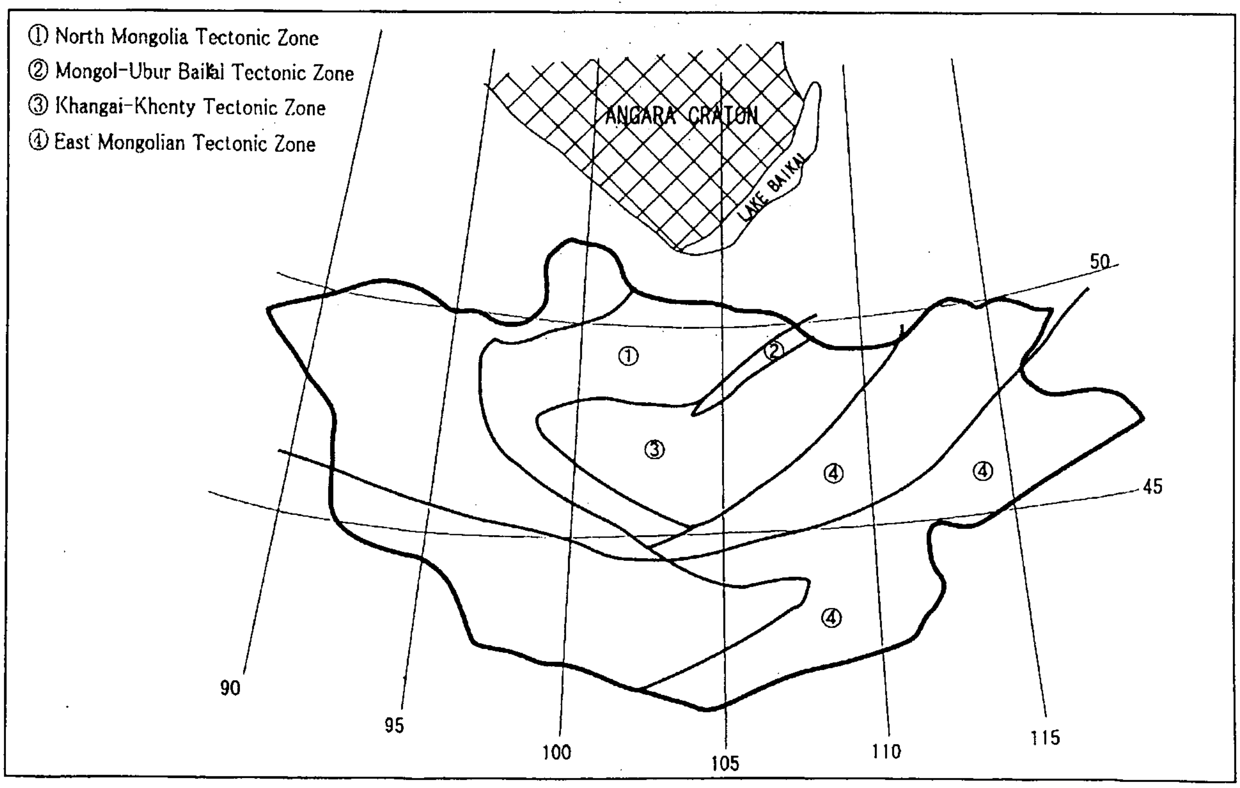

Fig. I-3-1b Tectonic units of Mongolia (MRAM, unpublished)

Table I-3-1 Comparison of the tectonic units of Mongolia

Sengor et al. (1996)
Eastern Tanuuola Unit < magmatic arc and accretionary complex> *(Early Paleozoic)*
Sangilen Unit <Baikalide micro continent>
Darkhat Unit <magmatic arc and accretionary complex> *(Riphean)*
Dzhida Unit <magmatic arc and accretionary complex> *(Early Paleozoic)*
VITIM SUTURE
Tuva-Mangol Unit <Pre-Altaid continental crust, magmatic arc and accretionary complex> *(Vendian ~ Triassic)*
Khangai-Khentey Unit <accretionary wedge and magmatic arc> *(Vendian ~ Carboniferous)*
Han-Taishir Unit <Pre-Altaid continental crust, accretionary complex and magmatic arc> *(Vendian ~ Early Cambrian)*
Gony Altay Unit <accretionary complex and magmatic arc> *Early ~ Middle Paleozoic*
Ozernaya Unit <accretionary complex and magmatic arc > *(Vendian ~ Early Cambrian)*
Kobclin Unit <Early ~ Middle Paleozoic accretionary complex and magmatic arc> *(Early and Middle Paleozoic)*
South Mangolian Unit <accretionary wedge which grew to the south of the Tuva-Mungolian unit> *(Ordovician ~ Early Carboniferous)*
South Gobi Unit <magmatic arc on pre-Altaid continental basement> *(Riphean ~ Lower Devonian)*
SOLONKER SUTURE
Manchurides <Precambrian continental crust?, subduction-accreation complexes and magmatic *(Paleozoic)*

Tumurtogoo (1996)		
Northern Mongolblock		**Uvs nuur, Eg-Eur Terrane** <ophiolite, high-P/T rocks> *(Riphean)*
Northern Mongolblock		**Eastern Khuvsgul Terrane** <polymentamorphosed complex> *(Cambrian ~ Lower Silurian)*
Northern Mongolblock	Tuva-Mongolian Superterrane	**Tes-Darhad Terrane** <active continental margin> *(Vendian ~ Lower Cambrian)*
Northern Mongolblock	Tuva-Mongolian Superterrane	**Shishigt Terrane** <accretionary prism>
Northern Mongolblock	Tuva-Mongolian Superterrane	**Ulaan Taiga Terrane** <passive continental margin>
KHANGAI DISPLACEMENT		
Middle Megablock	Khangai Superterrane	**Crystalline Core** <fragments of craton, passive margin> (Archean ~ Riphean)
Middle Megablock	Khangai Superterrane	**Darkhan Terrane** <active continental margin> *(Riphean)*
Middle Megablock	Khangai Superterrane	**Ulziiat Terrane** <active continental margin> (Riphean)
Middle Megablock	Ulaanbaatar Superterrane	**Northern Khentii Terrane** <continental margin> *(Upper Silurian ~ Devonian)*
Middle Megablock	Ulaanbaatar Superterrane	**Testsevleg - Zuunmodyn Terrane** <continental margin> *(Upper Silurian ~ Lower Carboniferous)*
Middle Megablock	Mongolian-Altay Superterrane	**Altay Terrane** <metamorphosed accretionary prism> *(Vendian ~ Lower Ordovician)*
Middle Megablock	Mongolian-Altay Superterrane	**Khoud Terrane** <metamorphosed accretionary prism> *(Vendian ~ Lower Ordovician)*
Middle Megablock		**Lake Terrane / Dariv Terrane / Bayankhongor Terrane** <ophiolite>
TRANS MONGOLIAN TECTONIC LINEAMENT		
Southern Megablock	Pre-Khentiin Superterrane	**Adagsag Terrane**
Southern Megablock	Pre-Khentiin Superterrane	**Ongi-Baly Terrane <micro continent>**
Southern Megablock	Southern Gobi-Erren Davaa Superterrane	**Ihibogd Suture**
Southern Megablock	Southern Gobi-Erren Davaa Superterrane	**Kherlen Terrane**
Southern Megablock	Southern Gobi-Erren Davaa Superterrane	**Gobi Altay-south Kherlen Terrane**
Southern Megablock		**Trans Altay Suture** *(Variscan)*
Southern Megablock		**Ajbogdyn Island Arc** *(Variscan)*
Southern Megablock		**Gabiin Suture** <ophiolite melange> *(Variscan)*
Southern Megablock		**Gobi-Tyanshany-Nukatdavaany Terrane**
Southern Megablock		**Zamyn-Undyn Suture** *(Variscan)*
Southern Megablock		**Totoshang Terrane** <micro continent>
Southern Megablock		**Solonkeryn Suture** *(Late Variscan)*

Tseden et al. (1992)	
North Large Block (north Mongolian Folded System)	**Shishikhid-Zeddin Megazone**
North Large Block (north Mongolian Folded System)	**Khangai-Khentiin Megazone**
North Large Block (north Mongolian Folded System)	**Nuriin Folded Belt**
North Large Block (north Mongolian Folded System)	**Central Mongolian Median Mass**
North Large Block (north Mongolian Folded System)	**Altay Folded Belt**
North Large Block (north Mongolian Folded System)	**Ulaanbaatar Folded System**
MONGOL MAIN LINEAMENT	
South Large Block	**South Mongolia Folded System** *(Variscan)*
South Large Block	**Inner Mongolia Folded System** *(late Variscan)*

Mineral Resources Authority of Mongolia (unpublished)	
North Mongolia Tectonic Region	
North Mongolia Tectonic Region	**North Mongolian Tectonic Zone**
North Mongolia Tectonic Region	**Mongol-Ubur Baikal Tectonic Zone**
North Mongolia Tectonic Region	**Khangai-Khenty Tectonic Zone**
North Mongolia Tectonic Region	**Eastern Mongol Tectonic Zone**
South Mongolia Tectonic Region	**Eastern Mongol Tectonic Zone**

Table I-3-2 Simplified stratigraphy of Mongolia

	PERIOD	EPOCH	LITHOLOGICAL CHARACTERISTICS	DISTRIBUTION
Cenozoic	Quaternary		glacial, aeolian, lacustarine, lacustarine-alluvial, talus-proluvial, volcanogenic	
	Tertiary	Upper Pliocene	brown and reddish silt, siltstone, gravel and debris	Selenge, Orhon river basin
		Lower Pliocene	Altanteel suite: fan debris gravel, gravel debris, argillite sandstone	foothills, slope of the Mongol Altai mountain range
			Hyargasnuur suite: light sand, silt, siltstone, marl	depression of large lake, valley of lakes
		Miocene	Luugiin suite: greenish and green carbonate-silt, siltstone, gravel, gravelstone and basalt	depression of large lakes, valley of lakes, eastern part of Gobi, Dariganga and Tamsag depression
			Oosh suite: yellow grey gravel, gravelite, sand, green-grey calcareous silt and marl	depression of large lakes
		Paleogene	Naranbulag, Bumban, Elgen, Ergeliin Zoo, Haichin, Holbooiinnuur, Shandgol suite :red or reddish-brown argillite, light sand, claystone, sandy silt, gravel and siltstone. Layered beds of basalt are observed in the Shandgol suite	valley of lake, eastern slope of the Gurvansaihan mountain range
Mesozoic	Cretaceous	Upper Cretaceous	Sainshand horizon: claystone, argillite, sandstone, siltstone	widely distributed; Lake, Ulaanuur, East Gobi, Borzon, Galbyn Gobi depression
			Bayanshireet horizone: sandstone, conglomerate, argillite, siltstone, volcanic flow	
		Lower Cretaceous	Guruvaneen horizon: calcaleous shale, argillite, snadstone, siltstone	Guruvaneen, Arhangai, Dornot
			Huhteeg horizon: coaly shale, coal, sandstone, conglomerate, siltstone, argillite	Nyalga, Dornot, Tamsag, east Gobi
	Jurassic	Upper Jurassic	Dariv, Ihesnuur, Tromhon, Jarantai, Ulaanereg, Seruunbulag, Urtgol, Yahyngobi series: breccia, conglomerate, sandstone (continental deposits)	depression of large lake, valley of lake and many of Gobi
		Lower-Middle Jurassic	Jargalant, Bahar, Tseel, Hoboohongor, Zuramatain suit: conglomerate, sandstone, siltstone, argillite	
		Lower Jurassic	siltstone, argillite, oil shale	
		Lower Jurassic-Upper Triassic	Mogod suite: sedimentary-volcanogenic series(trachyandesite)	Orhon, Tuul river, Tsoh river, east Mongolia
	Triassic	Middle-Upper Triassic	continental molasse	Selenge river basin, northern Gobi, Ukz-Herlen river, Noyosum depression
		Lower Triassic	marine deposits: basal conglomerate, sandy loam, siltstone, claystone, clay-coaly shale	Jargalart, Doch river basin
			continental deposits: coal bearing sedimentary rocks	Tenger uul-Nuhetdavaa
Paleozoic	Permian	Permian	Hanuyan series: subaerial basalt, andesite, trachybasalt, trachyandesite, rhyolite, comendite and their tuff	[North Mongolian volcanic belt] eastern and southern Khuvsgol, Orhon-Selenge basin
			Haraa-Tsohgolyn series: similar to the Hanunyn series, but no tuff and alkaline rocks	
			Serkhiinnuruu series: andesite-basalt, trachyrhyolite, trachybasalt	[Central Mongolian volcanic belt] south-western Khangai
			Buutasagaan series: trachydacite, andesite-basalt, trachyandesite, trachyrhyolite, terrigenous deposit	
			Luugyn Gol series: flysch-terrigenous deposit	southern Gobi
			Sulinheer allochtone: volcanogenic-terrigenous deposit	southern edge of the Luugyn Gol depression
	Carboniferous	Middle-Upper Carboniferous	alkaline-subalkaline continental volcanic rocks	[South Mongolian Volcanic Belt] Gobi, Tenger Uul-Nuhentdavaa
		Lowe-Middle Carboniferous	Arteel suite: sandstone series	Orhon river basin
			Baidrag and Orgochinuul suite: flysch series	Khangai, Khentij mountain
			flysch terrigenous series	Bayantsagaan
			carbonate-terrigenous-volcanogenic, volcanogenic series	Gobi Altai
			subaerial volcanic rocks, tuff, sandstone, siltstone	Gobi
			andesite, dacite, rhyolite lava, their tuff, tuffaceous sedimentary rocks	Hatansuudal, Tost mountain ranges
		Lower Carboniferous	Jargalant and Altan ovoo suites: flysch	Khangai, Khentii mountain
			Bayanhoshuu, Bagabayang and Tal suite: limestone, sandstone, siltstone, argillite, intermediate and acidic volcanics	Gichgene mountain range, Shine Jinst, Mandal ovoo
			Olonbulag, Nuhnjinuruu, Borhaihan and Tsahirynnuruu suite: sandstone, siltstone, argillite, limestone, acidic volcanics	Baruunhuurai depression
			basalt, andesite, latite, tuff. read chert, sandstone, limestone	Argalangt mountain range
			Ih Shanghai suite: tuff, siltstone, argillite	Nariin Huh, Gurvansaihan, Ih Shanghai
			Sainshandhudag and Tsagaansuvarga suite: sandstone, siltstone, argillite, conglomerate, gravelite	Ehiin gol, Dengiin mountain range, Baga Nomgon, Dersen us, Tsohiot, Tsagaansuvarga and Ulaanbadrah
			Jirem suite: sandstone, argillite, limestone	Solinheer
		Lower Carboniferous ophiolite	ophiolite suite of complex	Solinheer
		Upper Devonian-Lower Carboniferous	flysch series	
	Devonian		Alagabayan suite: sandstone, siltstone, argillite, intermediate and acidic volcanics	Ih Dariv , Gurvan Haraat
		Upper Devonian	Sammuuruul suite: conglomerate, sandstone, siltstone, siliceous tuffite	Baruunhuurai depression in Gobi
		Middle-Upper Devonian	Hutuugol and Tsagaansalaa suites: flysch, terrigenous deposits	Deluun-Sagsai depression
			Tsetserleg and Gorih suites: flysch, limestone, olistolith of red chert	Khangai, Khentii mountain range
			carbonate-terrigenous sediment	Ulz river basin
			Modonovoo, Erdenbayanhural and Deliinhar suites: sandstone, siltstone, tuffite, pillow lava, basalt, andesite, dacite, rhyolite, tuff, jasper	Gobi, Altai-Delin Har mountain
			Baruunhuurai suite: flysch, intermediate volcanics, limestone	Baruunhuurai depression, Erden Zoolon Gurvansaihan
		Middle Devonian	Togoot suite: limestone, sandstone, siltstone, intermediate volcanics	Gobi Altai
			sabalkaline basalt, andesite, shoshonite, quartz latite, tuff, jasper, sandstone, conglomerate, limestone	Baruunhuurain depression
			dark gray sandstone, siltstone	southern part of Atlas and Tsagaan
		Lower Devonian	Herlen and Harzaan series: black shale, carbonate and siliceous terrigenous sediments	Ereendavaa mountain range, Ulz river basin
			Ehiin gol suite: sandstone, siliceous siltstone, red chert, effusives, limestone, tuffite, andesite, dacite	Gobi Tenger, Elgen mountain, Hashaatyn Tsagaan
		Upper Silurian- Lower Devonian	Narijn suite: calc-alkaline subaerial volcanics	northern Terh, Chuluut basin
			Ulaanhan suite: carbonate-terrigenous deposits	Gobi Altai, Tenger mountain
Paleozoic	Silurian	Upper Silurian- Lower Devonian ophiolite	dismembered ophiolite, serpentinite melange	Ongon Ulann crest, Nemget, Zoolon, Gurvansaihan, Gobi
		Undivided Silurian	volcanogenic-terrigenous, tuffaceous-terrigenous, carbonate terrigenous, siliceous terrigenous	Mongol Altai, southern Kahangai, Herlen, Eg and Uur
		Upper Silurian	reef limestone, carbonate-volcanogenic-terrigenous deposits	Har Azrangyn, Erden, Halh river basin
		Lower Silurian	carbonate-terrigenous sediment of shelf facies	Mongol Altai, Nuur, Heren, Gobi Tenger
		Ordovician and Silurian ophiolite	dismembered ophiolite in the fault zone	Gobi, southern periphery of the Khangai-Khentii
	Ordovician	Upper Ordovician-Silurian	carbonate-volcanogenic-terrigeneous sediments, basic-intermediate volcanics, reef limestone, siliceous siltstone	Mongol Altai, Gobi Altai, Herlen
		Middle Ordovician-Lower Silurian	siliceous terrigenous sediment, limestone, volcanics	Herlen
		Upper Ordovician	carbonate-terrigenous, volcanogenic-carbonate-terrigenous sediments	Mongol Altai, Baidrag-Orhon
		Middle-Upper Ordovician	carbonate-terrigenous sediments	Mongol Altai, Herlen, Tenger Uul-Nhetdavaa
		Middle Ordovician	conglomerate, sandstone	Mongol Altai
		Lower-Middle Ordovician	andesite, andesite-basalt lava, tuff, tuffaceous sedimentary rocks	Mongol Altai
			terrigenous sediments, subaerial volcanics	large lakes
			Bayantsagaan suite: carbonate-terrigenous sediments	Gobi Altai
			volcanogenic-carbonate terrigenous member	Gobi Tenger Uul
		Lower Ordovician	sandstone, siltstone	Mongol Altai
		Middle Cambrian-Lower Ordovician	Mongol Altai series: flysch(4000-6000m)	Mongol Altai
			Zag and Haraa series: marine deposits(metamorphic age:454-440 Ma)	Kahangai-Khentii
			oligomictic flysch(2000m)	Eg and Uur river basin
	Cambrian	Lower-Middle Cambrian	carbonate-tuffaceous-terrigenous sediments	Seer mountain range, Ak-Bashi island
			olistostrome containing limestone, carbonate flysch	Ih Dariv mountain range
			carbonate-volcanogenic sediments	Baatarharihan, Har Azuarga
		Lower Cambrian	Khuvsgol and Tsagaannolom series: limestone, dolomite, siliceous rocks, sandstone, argillite, siltstone	Khuvsgol, Baidrag-Orhon
			carbonate-terrigenous olistostrome	Hanhuhii mountain range
			basal conglomerate, sandstone, limestone	southern Herlen
			Bargynuvoo suite: carbonate-terrineous sediments	southern Tenger uul-Nuhetdavaa
		Vendian-Lower Cambrian	basalt, andesite, rhyolite lava, pyroclastics, limestone, greywacke	Eg and Uur river basin, depression of large lake, Herlen
			limestone, greenschist, slate	southern Khangai
			dolomite, limestone, sandstone, conglomerate, slate	Orhon, western Gobi, Ulaan mountain
		Vendian-Middle Cambrian unclassified	Khuvsgol series: conglomerate, dolomite, limestone, phosphorite, slate	Khuvsgol, Baidrag-Orhon, Nuur
			Tsagaanolom series: conglomerate, dolomite, limestone, phosphorite, sandstone, argillite, flysch	
			Harhad series: conglomerate, dolomite, limestone	
			Heseen series: dolomite, limestone, phosphorite	
			Horidol series: limestone	
			Uhaatolgoi suite: tuff, terrigenous sediments	
			Uiig gol suite: limestone, calcareous clay, siliceous slate	
		Vendian-Early Cambrian ophiolite association	dismembered-suite complex(569±21 Ma)	Bayanhongor, Mongol Altai, Herlen
		Late Riphean-Early Cambrian undivided	marblized crystalline, bituminous and amphibolite, carbonate-chlorite, siliceous, clayey, and sericite schists	Khuvsgol
Precambrian	Proterozoic / Vendian			
	Proterozoic / Riphean	Late Riphean ophiolite association	dismembered-suite complex(695±25 Ma)	Khuvsgol, Hantaishir, Ih Dariv, Hanhuhii, Har Azraga, Erden
		Middle-Upper Riphean	quartz-sericite, sericite-chlorite, micaceous schist	Khuvsgol, Baidrag-Orhon, Herlen, Tenger uul-Nshetedavaa
		Middle Riphean	volcanogenic schist (624±52, 829±23 Ma) quartz-carbonate schist (840 Ma)	Ih Dariv, Hasagthairhan, Khuvsgol, Baidrag-Orhon, Tes, Zavhan, Khangaii
		Lower-Middle Riphean	marine sediment deposits	Gobi, Terger uul-Nuhetdavaa, Sulinheer
	Proterozoic / Early Proterozoic		Polymetamorphic formation(amphibolite gneiss, sillimanite schist etc.)	Baidrag-Orhon, Gobi, Khuvsgol, Herlen, Tenger Uul-Nuhetdavaa
			Bombagor, Esunbulag, Buteeliin, Nuruu complex	
			Tseel megacomplex	
			Haichiingol suite	
	Archean		Grey gneiss complex(fragment of Island arc volcanic-plutonic association) (2646±45 Ma)	Baidrag
			accumulate complex(proto-ophiolite)	Ih Dariv

Edited from Mineral Resources Authority of Mongolia and Mongolian Academy of Sciences (1998) outside the craton of the north and the south as a core and continental crust developed toward the outside due to the intrusion of a great amount of acid plutonic rocks, and then a collision type orogenic belt was formed by a clash between the two cratons, it is considered that the complicated tectonic evolution cannot be explained (Sengor et al., 1996). In the huge orogenic belt called Altaids, there are five orogenic belts, Mongolia - Okhotsk, Altay / Sayan, Kazakhstan, Tien Shan and Urals. These orogenes consist of lithologic assemblage which is similar to the present subduction - accretionary wedge which is accompanied with volcanic and / or plutonic rocks of magma arcs. These are considered to be the subduction - accretionary complex which was formed by one subduction facing the west and extending from the south to the north in the eastern side of the Angara and Russian craton which occurred in almost the same style at the same time in the Paleozoic (Figure I-3-2).

In the Vendian to Cambrian periods, Rodinia supercontinent was split by super plume and one of them became the Russian and Angara craton. On the eastern side of the continent, the eastern side of the Russian and Angara craton was the active convergent margin in the Ripheian to Vendian periods. The existence of micro-continents such as Baykalide Collision of Tuva - Mongol became the trigger of subduction on its outside (the eastern side). The subduction in the east and the northeast of Tuva - Mongol continued up to the Paleozoic.

After that, Kiptchak island arc which became a southern half of the split from the continent due to the split of the Angara and Russia craton in the Cambrian period.

By the Cambrian to early Devonian period, Kiptchak island arc of the southern part was split from the continent due to lifting of the Angara and Ruassian craton. On the northern side the subduction continued on both sides of the Tuva - Mongol arc like the present Philippines, and large scale accretionary prism and magma arcs have developed. In the Devonian, since both cratons approached nearer again, the orocline of Tuva - Mongol which extends to the north began, and due to the contraction along a trans-subduction fault and bending of the island arc, the island arc began to stack and accumulate on the inflection (Figure I-3-2 b). In the Carboniferous, the inflection and accumulation advanced further, and at the same time the center of magma activity moved to the fore arc side, that is to the northeastern side, to grow continental crust. On the other hand, in the margin of North China craton the accretionary prism-magma arc (Manchulides) was formed along the subduction zone and developed to the north. In the early Triassic, Solonker Ocean which existed between Tuva - Mongol island arc and North China craton was closed (Figure I-3-2 c). In the late Paleozoic to middle Jurassic, island arcs and cratons were amalgamated and the ocean disappeared to create a stable continent. In the amalgamated plate, igneous activities continued from the late Jurassic to Holocene. A geological map representing outline of geology in Mongolia is shown in Figure 1-3-3.

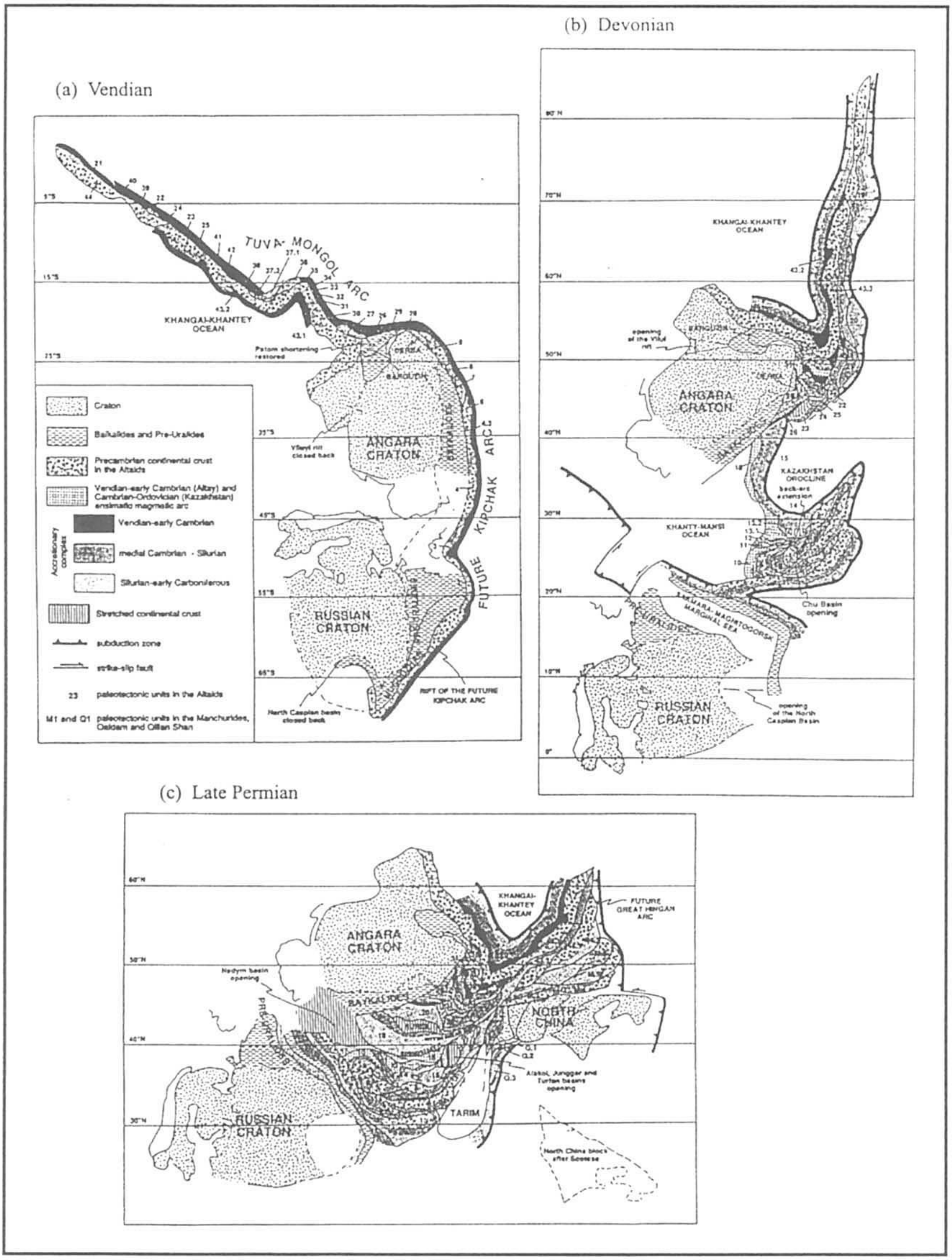

Fig. I-3-2 Schematic tectonic evolution of the Mongol - Okhotsuk folded belt (Sengor et al., 1996)

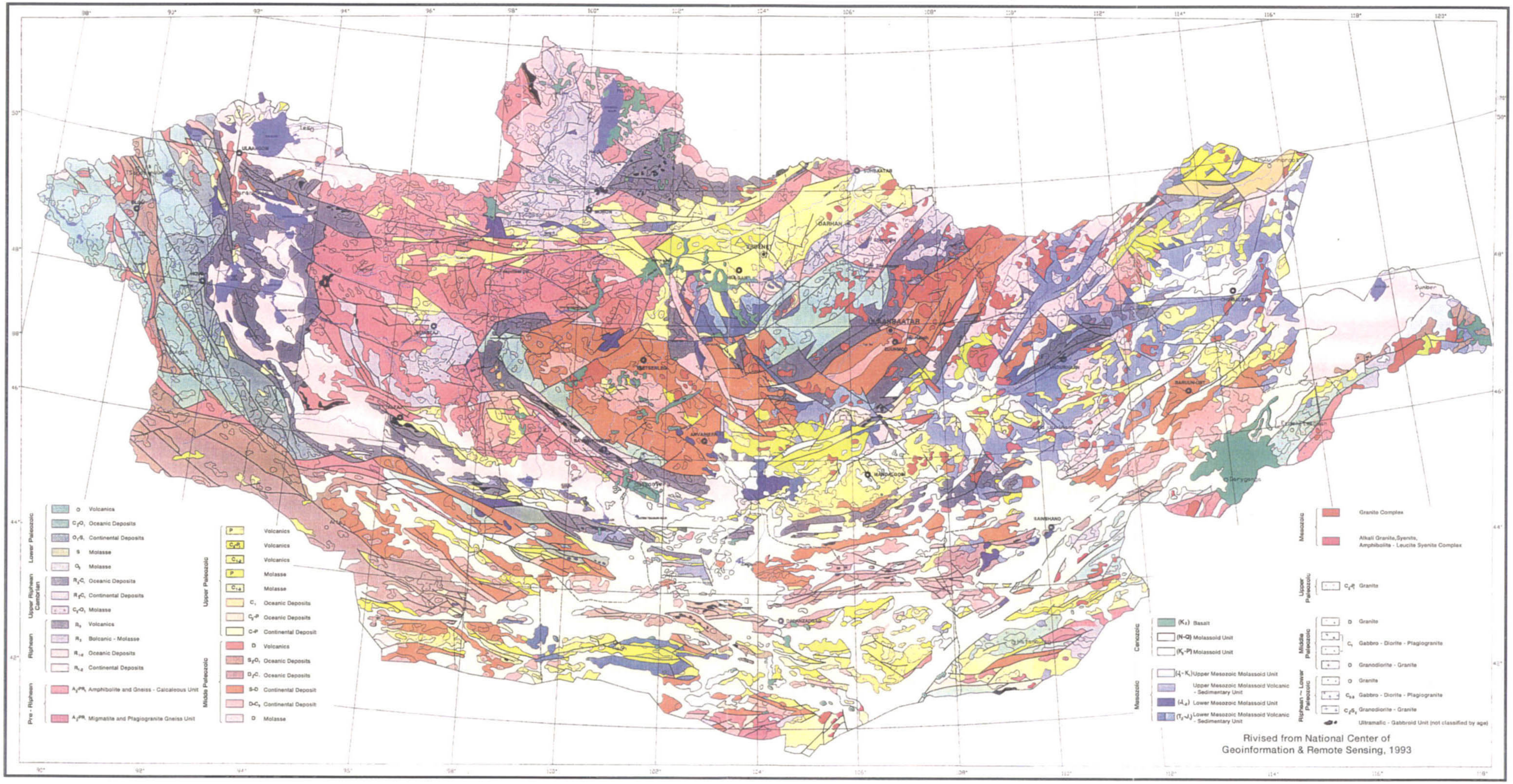

Fig. I-3-3 Geological and tectonic map of Mongolia (MRAM, 1993)

3.1.2 Geological units

In Mongolia, many significant tectonic lines of the eastern and western systems which are protruding in a convex on the southern side have developed. This reflects the geological structure which extends from west to east and which is intercalated in the cratons on the southern and northern sides. One of the significant tectonic lines is Mongol Main Lineament (MML) or Trans Mongolian Tectonic Lineament. With this lineament as a boundary Tseden et al. (1992) separated the area into the Northern Large Block and the Southern Large Block. Tumurtogoo (1996) separated the Northern Block into another two blocks by Khangai Displacement. Basically, Sengor et al., (1996) classified the area into the Khangai - Kheiti Unit which was the lens-like subduction - accretionary complex in the Vendian to Carboniferous extending from east to west in the central Mongolia, the Tuva - Mongolia Unit which was the subduction-accretionary complex based on Pre-Altaid continental crust surrounding the outside of the Khangai-Kheiti Unit, the South Gobi Unit and the South Mongolia Unit which were the subduction - accretionary complex in the Cambrian to Carboniferous developing in the south with MML, and the Manchurides Unit which was an accretionary complex to the North China craton which existed on the southern side. As described later, except for the Manchurides Unit, these units are folded accretionary complex and magma arcs which were formed by a continuous island arc (Tuva - Mongol island arc). It is inferred that prominent tectonic lines and lineaments in the east-west show trans-subduction fault structure of the time of being folded. The characteristics of each geologic body are described below.

(1) Gorny Altai Unit

This Unit consists of magma arcs and accretionary complex of the early Paleozoic. It consists of basalt, andesite, acidic volcanic rocks, conglomerate and reef limestone of the Vendian to middle Cambrian. The western part is changed to the environment of fore-arc and the shallow marine sediment is dominant. The accretionary prism consists of ophiolite, high pressure metamorphic rocks which shows 410-580Ma in geologic age and flysh sediment of the early Cambrian to early Silurian. Granite of the early Silurian associated with the activities of island arc magma occurs.

(2) Kobdin Unit (Nuriin Altai Folded Belt*)

This unit consists of magma arcs and accretionary complex of the early to middle Paleozoic. Turbidite of the middle Cambrian to early Ordovician unconformably underlies andesite, sandstone, mudstone and limestone of the Ordovician to Silurian. Granites of the

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* Classification by Tsuden et al., (1996)

Silurian to Devonian occur.

(3) Ozernaya Unit (Nuriin Altai Folded Belt*)

This unit consists of magma arcs and accretionary complex of the Vendian to Cambrian. The accretionary complex consists of serpentinite melange, chart and turbidite of the Vendian to early Cambrian. Neritic sediment of fore arc basin of the middle Cambrian which covers this accretionary complex occurs. A large amount of tonalite, granodiorite, granite and gabbro intruded. The radiometric geological age is 540-410 Ma.

(4) Han-Taishir Unit (Nuriin Altai Folded Belt*)

This unit consists of continental crust before Altaids formed, magma arcs and accretionary complex of the Vendian to early Cambrian. In the basement, the formation which posses complete ophiolite sequence occurs at the boundary with accretionary complex like the Tuva - Mongolia Unit. The accretionary complex consists of dismembered ophiolite, chert, turbidite, limestone and others. Island arc basalt and andesite occur in sedimentary rocks. Granite of the middle Cambrian occurs.

(5) Eastern Tannuola Unit

This unit consists of magma arcs and accretionary complex of the early Paleozoic. It consists of basalt, tuff, andesite, dacite, rhyolite and limestone which are products of magma arcs. The activities of the magma arcs ended by the intrusion of granite of the middle to late Cambrian. The accretionary prism consists of basalt, chert, limestone, sandstone and shale of the Vendian to early Cambrian and oliststrome and turbidite of the middle to late Cambrian. Neritic sediment of the Ordovician to Silurian occurs.

(6) Sangilen Unit (Darkhad-Zavkhan-Orkhon terrane*)

This unit consists of Baikalide micro-continents and others which collided with the Darkhat Unit and the Tuva - Mongolia Unit in the Riphean. This consists of gneiss of the Riphean (1,100 Ma), metamorphic rocks of granulite facies and the accretionary complex sliver with ophiolite - melange of the Vendian to early Cambrian.

(7) Darkhat Unit (Central Mongolian Median Mass*)

This unit consists of pre-Baikalid continental crust and magma arcs - accretionary complex of the Riphean. This consists of gneiss and crystalline schist of the early Precambrian, which are the basement, as well as basalt, rhyolite, tuff and terrigenous sediment which are products of magma arcs of the Riphean. The former is considered to be fragments of Baikalaid taken into Altaids. Rb-Sr radiometric age of the volcanic rocks is 718 Ma. Covering them unconformably, neritic limestones, dolomite, phosphorite and bauxite of the Vendian to early Cambrian as well as calcareous flysch of the middle to late Cambrian occur. On the eastern side of this unit, metamorphic rocks of green schist and ophiolite distribute, which is considered to be the accretionary complex accompanied with subduction.

(8) Dzhida Unit (A part of Shishihid - Zeddin Megazone*)

This unit consists of magma arcs and accretionary prism of the early Paleozoic. Island arc basalt and boninite overly ophiolite which is considered to be the magma arc of Vendian to early Cambrian. These are further covered with basalt, andesite, rhyolite, tuff, sandstone and limestone. Accretionary prism includes tectonic blocks which consist of ophiolite, turbidite, chert, and reef limestone.

(9) Tuva-Mongol Unit (Central Mongolian Median Mass*)

This unit consists of continental crust before the formation of Altaids and magma arcs of the Vendian to Permian. The continental crust which is the basement of the island arc consists of migmatite, granite, anorthosite and granulite, that is similar to the Angara craton. The island arc basement is intruded by granite of 2,364±6 Ma to 1,630 Ma (Mineral Resources Authority of Mongolia, 1998). This consists of high grade metamorphic rocks of the Archean which was separated by ophiolite of the Vendian to early Cambrian and island arc volcanics of the Riphean. The basement is covered by shelf limestone of the Vendian to Cambrian.

Clastic rocks of the early to middle Paleozoic and granites of the Paleozoic distribute over a wide area. Syenite of the Devonian to Permian, calc-alkaline rocks of the Devonian, and calc-alkaline and alkaline rocks of the Permian occur. About the origin of this unit, it is said that micro-continents gathered to form the Tuva - Mongol micro-continent and subduction zone developed at its margin and accretionary prism and magma arcs occurred (Tumurtogoo, 1996).

(10) Khangay - Khentiy Unit (Ulaanbaatar Folded system*)

This unit consists of accretionary prism and magma arcs. This consists of ophiolite, serpentinite melange, chert, limestone and shale of the late Riphean to early Cambrian as well as turbidite, basic to intermediate volcanic rocks, tuff and chert of the early Paleozoic to Carboniferous, and turbidite, gabbro and basalt of the Carboniferous to Triassic. This shows a shape of horseshoe opening toward the northeast and consists of a few island arc units which are folded and stacked. The respective units show the age polarities of getting younger toward the northeastern side. These are intruded by granites of the Permian, Triassic and Jurassic.

(11) South Mongolia Unit (South Mongolian Folded System*)

This unit consists of accretionary prism and magma arcs. The oldest zone of the accretionary prism spreads at the boundary of Tuva - Mongol Unit and becomes younger toward the south. These are intruded by granite of the Silurian and consists of reef type limestone of the early Devonian or turbidite of the middle to late Devonian, andesite, dacite, rhyolite, tuff, clastic rocks of the early - the late Devonian periods. In the island arc volcanic rocks of the early to late Devonian, rocks of the accretionary prism which are structurally of the same geological age occur periodically in space due to the strike-slip fault.

(12) South Gobi Unit (Inner Mongolian Folded System*)

This unit consists of continental crust of the pre - Altaids, island arcs of the Paleozoic and accretionary prism of the early to late Paleozoic.

The basement consisting of crystalline schist, gneiss, granitic gneiss, migmatite and amphibolite is unconformably covered by quartzite, dolomite, limestone and marble of the Rhiphean, Vendian to early Cambrian. The accretionary prism grows from the north to the south and consists of nitric sediment, terrigenous clastic rocks, shale, intermediate to acidic volcanic rocks and limestone of the Ordovician, Silurian, Devonian, Carboniferous and Permian. In the southern part, there is no accretionary prism of early Paleozoic.

(13) Manchurides

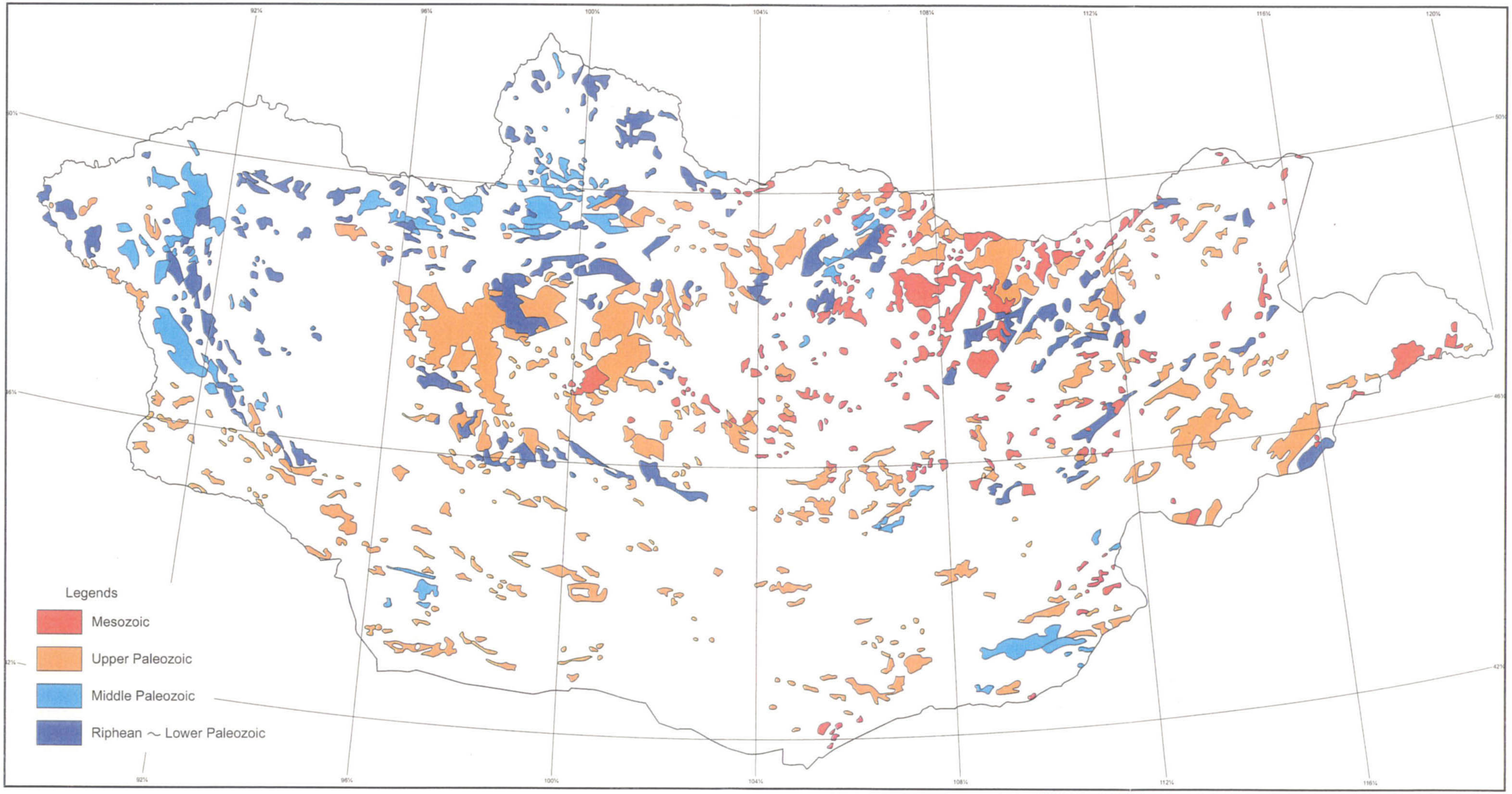
This is the accretionary wedge - magma arc formed in connection with the subduction at the margin of the North China craton. This unit having the basement of amphibolite of 2,535 Ma, clastic rocks affected by metamorphism of granulite and green schist facies of 706 Ma and carbonate rocks, etc. has developed as the accretionary wedge - magma arcs toward the northern side.

3.1.3 Igneous activities

In Mongolia, since there were many active events such as the subduction in island arcs with magma arcs from the Riphean through Paleozoic and the collision of continents in the Mesozoic, a great amount of igneous rocks which formed in association with the events exist. After the Cretaceous when the continents were stabilized, igneous activities continued in the plates. The distribution of plutonic igneous rocks based on the Geological Survey of Mongolia (1993) is shown in Figure I-3-4. In macroscopic order, the distribution is almost harmonic with the wide geological structure of the horseshoe opening toward the northeast as mentioned in the previous column and it is in a concentric circle centering Khangay - Khentiy Unit. Plutonic rocks of the Riphean through the early Palaeozoic distribute widely in the respective units except for South Gobi Unit and South Mongolian Unit which locate on the southern side from MML. This consists of mainly quartz diorite, tonalite, alkali granite and leucocratic granite. Particularly, the igneous activities of the early Palaeozoic occur widely in Tuva - Mongol Unit, which is characterized by calc-alkaline granite, tonalite and granodiorite. Effusive rocks consist of andesite and rhyolite of calc-alkaline. Especially, the granitoid complex which shows 450-445 Ma of Eastern Khuvsgul, Boroogol and others has become the host rock of the Pulton-related gold deposit. Those of the middle Paleozoic era are almost limited to Dzhida Unit, Darkhat Unit and South Mongolia Unit. The igneous activities of the late Palaeozoic did not exist in Kobdin Unit and Ozernaya Unit of the eastern part and Dzhida Unit and Darkhat Unit of the northern part, but they can be observed across Mongolia, which is characterized by calc-alkali to alkali rock series. In the area from the northern side of Tuva - Mongol Unit to Khangai - Khentiy Unit, the leucocratic granites which is called Khangai batholith distribute with granodiorite, granite, I type granite, granodiorite and syenitegranite. In the periphery of Khangai batholith, alkali rocks (trachybasalt, trachyandesite and trachyrhyolite) and non-alkali volcanic rocks occur widely. For the origin of the Khangai batholith, Gerel (1998) described that it occurred in the time of collision. On the other hand Takahashi et al. (1998) considered that it is connected with the subduction. From the early Paleozoic to early Mesozoic, igneous activities took place in a wide range in the area where plate converged in the South Mongol Unit and Tuva - Mongol Unit.

In Mongolian Altai, its composition changes systematically from the southwest to the northeast with tholeiite, calc-alkali and alkali rocks, and has a characteristic of subduction zone in which alkali increases toward the back arc side. In Bayanhokgor area, since the changes happen systematically from the southeastern side to the northwestern side or from the magnetite series to the ilmenite series, it is inferred that there was subduction from the northeast to the southeast (Takahashi et al., 1998). Thus, from the sporadic geological bodies, systematic change of igneous activities which suggests the subduction of the plate has been obtained. It is considered that, as mentioned above, the igneous activities from the early to late Paleozoic were resulted from the plate subduction beneath the island arcs (for example, Tuva-Mongol Arc: Sengor et al., 1996). Judging from the tectonic evolution, geological units formed before the early Mesozoic cannot be considered to be originated in igneous activities at their present sites.

Due to the closure of Mongol-Okhotsk Ocean Basin (Khangai - Khentiy Ocean) in the west by the approach of Angara craton and North China craton, the igneous activities with subduction gradually moved toward the east. Plutonic rocks of the Mesozoic occr to the east of 100° E of longitude. These igneous activities are considered to have occurred in the periods of collision and / or post collision in Angara craton and North China craton after the plate subduction in the island arc (Gerel, 1998), and they concentrate in the early Jurassic, late Triassic through early Jurassic and early Cretaceous. Two of the former activities mainly occurred in the eastern half of Northern Block, Khangai - Khentiy Unit and Tuva - Mongol Unit.



(Taken from MRAM,1993)

Fig. I-3-4 Distribution of granitic rocks of Mongolia (MRAM, 1993)

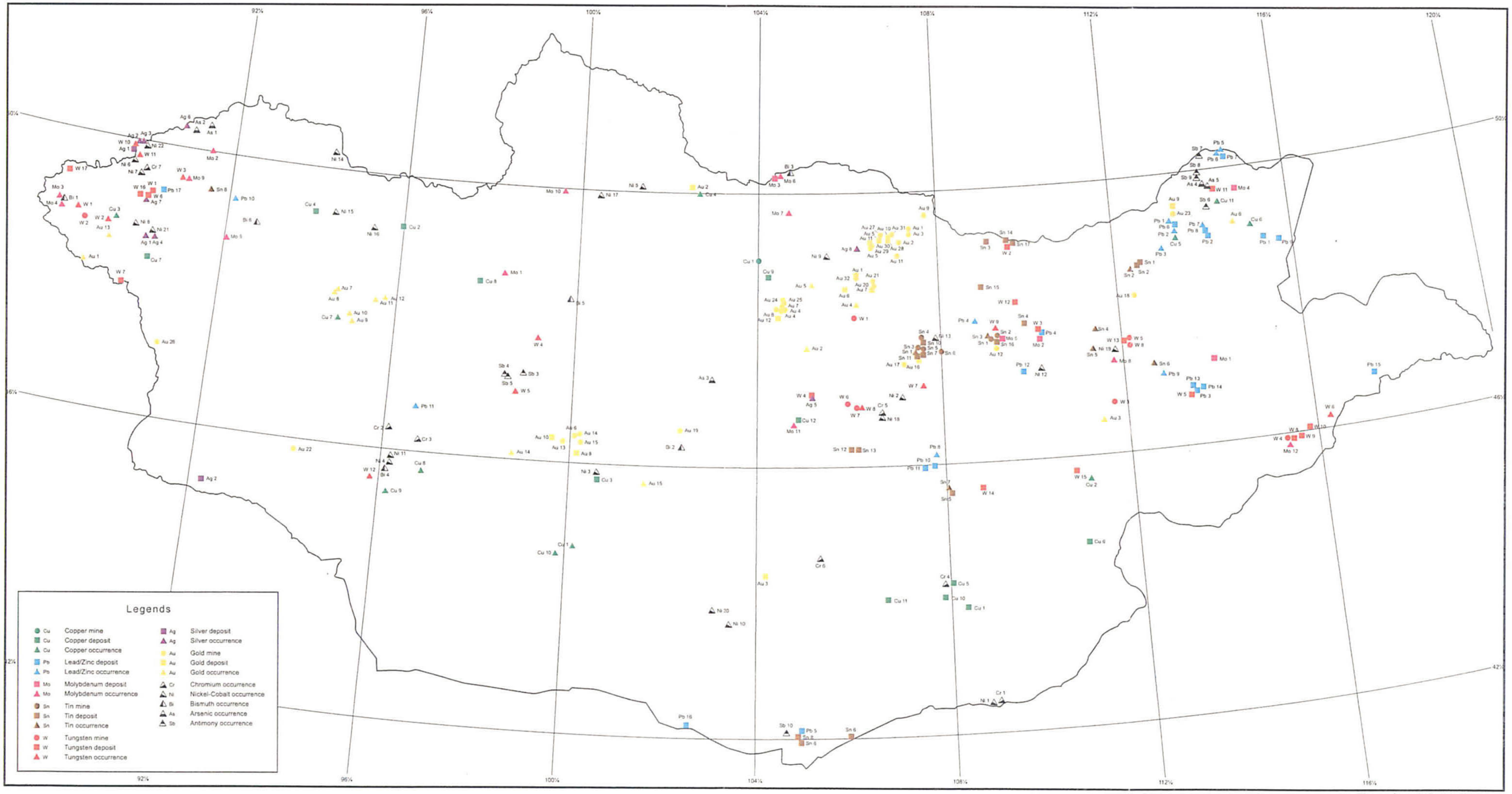
In the late Mesozoic, the area of igneous activities moved further toward the east and became smaller (Gerel, 1998). After the collision, igneous activities of alkali rock series, that is alkali basalt, trachyte, nephelinite, phonolite, Li-F granite and so forth, continued in the plates. The Erdenet Cu-Mo deposit is located at the Tuva - Mongol Unit. The Selenge complex which was the host rock of the deposit and the Erdenet porphyritic intrusive complex which was the igneous rock related to the mineralization have the same origin. Their active period is divided into three terms which show 250-245 Ma, 250-220 Ma and 205-195 Ma respectively (Berzina et al., 1999). This period is considered to be in the time of collision from the point of tectonic evolution of Mongolia. On the other hand, there is another interpretation that it was due to the subduction which took place before the continental collision (Takahashi, 1998).

3.1.4 Tectonic lines / Lineaments

In Mongolia, there are many E-W lineaments warped into the south and also NW-SE lineaments which diagonally cross them. The E-W lineaments are represented by Vitim Suture (Sengor et al., 1996) and Main Mongolian Lineament: MML (or Trans Mongolian Tectonic Lineament: TMTL). On the other hand, those of the NW-SE trend include faults which are bounded on the geologic body by Gorny Altai, Kobdin Unit, Ozernaya Unit and Tuva - Mongol Unit in the western part of Mongolia, and those from Erdenet of the central part to the south Gobi. The former being cut by MML does not extend to the south. On the other hand, the latter strides over MML and develops in the South Mongolia Unit also. The lineament of the E-W trend particularly is inferred to be formed during the formation of the strike-slip fault of the island arcs, at the time of bending and folding of the island arcs or later than those in the Carboniferous, and it does not seem that they reflect the structure of the basement before these events. The direction of the intrusive rocks which are related to the mineralization of the Erdenet deposit and its surrounding porphyry copper / molybdenum deposits is along the lineament of the NNW-SSE trend of the central part and this deeper fracture seems to have played an important role in the igneous activities and the mineralization (Sotnikov et al., 1984). Although the time has not been accurately acquired yet when the Tavt (Ereen) gold deposit zone was formed, it is located close to the NW-SE lineament which is relatively clear.

3.1.5 Mineral deposits

In Mongolia, there occur various types of ore deposits due to its complex geology mentioned above. Some are related with the magmatic activity caused by the subduction in the



(Taken from MRAM,1993)

Fig. I-3-5 Distribution of major base and precious metal deposits and occurrences in Mongolia (MRAM, 1993)

Table I-3-3 List of base and precious metal deposits in Mongolia (1/5)

COMMODITY	CATEGORY	NO.	NAME	DESCRIPTION
COPPER	MINES	Cu1	Erdenetin ovoo	porphyry copper/molybdenum stockwork
	DEPOSITS	Cu1	Tsagaan suvarga	porphyry copper/molybdenum stockwork
		Cu2	Ojut tolgoi	porphyry copper/nickel mineralization
		Cu3	Saran uul	copper molybdenum stockwork
		Cu4	Borts uul	ore bed in volcanics, copper/pyrite
		Cu5	Narin hudag	mineralized zone in volcanics and intrusive
		Cu6	Ojut	mineralized zone, lens in contact of diorite dike
		Cu7	Huh adar	mineralized shear zone, copper/pyrite
		Cu8	Naran bulag	ore lenses and beds in granite intrusive contact
		Cu9	Shand	stockwork
		Cu10	Hunguut	mineralized zone
		Cu11	Harmagtai	stockwork
		Cu12	Bayan uul	quartz zone in granitoid intrusive
	OCCURRENCES	Cu1	Shirt-1	mineralized zone, lens
		Cu2	Chandmana uul-3	skarn minealization in diorite intrusive contact
		Cu3	Ojut	quartz-carbonate metasomatic zone
		Cu4	Tsahir uul	skarn ore bodies
		Cu5	Temeen chuluut	quartz veins in granite intrusive contact
		Cu6	Lam chuluut	stockwork mineralization in granitoid intrusive
		Cu7	Nergui	epidote-garnet skarn and ore lenses in shale
		Cu8	Bituut	mineralized zone in gabbroid intrusive
		Cu9	Shar tal	silicified zone in shale
		Cu10	Hondloi	mineralized zone in milonite
		Cu11	Erdene tolgoi	silicified zone in skarn
LEAD/ZINC	DEPOSITS	Pb1	Tsav	multiple veins in intrusives, volcanics and metamorphics
		Pb2	Ulaan	mineralizd breccia pipes and fracture zones in volcanics
		Pb3	Tumurtin ovoo	stratabound skarn zinc deposit in roof pendant in granite massif
		Pb4	Mungun undur	hydrothermal alteration zone in sediments
		Pb5	Har tolgoi	mineralized shear zones in Proterozoic limestone
		Pb6	Bayandun-1	garnet-pyroxene skarn intrusive contact zone
		Pb7	Baits ovoo	altered zone in Mesozoic granite
		Pb8	Muhar	mineralized breccia pipes and fracture zones in volcanics
LEAD/ZINC	DEPOSITS	Pb9	Bayan uul	stockwork silicified zone and quartz veins
		Pb10	Haraat uul	magnetite skarn in granosyenite contact
		Pb11	Tumurtei	skarn zone in Mesozoic granite intrusive contact
		Pb12	Tugalgatain nuruu	hydrothermal alteration zones in sediment
		Pb13	Hol hudag	garnet-magnetite skarn lens intrusive contact
		Pb14	Salhit	stratabound skarn zinc deposit in roof pendant in granite massif
		Pb15	Modon-III	mineralized shear zone
		Pb16	Biluut ovoo	mineralized zone in sediments
		Pb17	Dulaan har uul	ore lenses and beds in volcanics
	OCCURRENCES	Pb1	Bayandun-III	pyroxene-amphibole skarn

Table I-3-3 List of base and precious metal deposits in Mongolia

COMMODITY	CATEGORY	NO.	NAME	DESCRIPTION
LEAD/ZINC	OCCURRENCES	Pb2	Sogoot uul	skarn body
		Pb3	Erdene tolgoi	skarn body
		Pb4	Muhar gutai gol	skarn body
		Pb5	Buun	hydrothermal altered zone in volcanics
		Pb6	Iher	quartz-sulfide veins in altered fracture zone
		Pb7	Namrin	mineralized zone
		Pb8	Zuun toirom	skarn bodies
		Pb9	Havtsgait	mineralized zone
		Pb10	Shiveen gol	mineralized zone in fracture
		Pb11	Nergui	altered and silicified limestone
SILVER	DEPOSITS	Ag1	Asgat	epithermal silver/gold veins in fracture zone
		Ag2	Nuhni Nuruu	mineralized shear zones in sediment
	OCCURRENCES	Ag1	Tolbo nuur	shear zone
		Ag2	Dund narin gol	silver veins in fracture zone
		Ag3	Dund narin gol	silver veins in fracture zone
		Ag4	Shar bureg	mineralized shear zone
		Ag5	Undur tolgoi	vein in aplite dyke
		Ag6	Mergenbulag	mineralized shear zone
		Ag7	Occurrence N 428	mineralized shear zone
		Ag8	Ujuu	mineralized zone
GOLD	MINES	Au1	Tolgoit	placer
		Au2	Ih adjir	placer
		Au3	Ih ulunt	placer
GOLD	MINES	Au4	Hailaast	placer
		Au5	Sharin gol	placer
		Au6	Muhar ereg	placer
		Au7	Bayangol	placer
		Au8	Tuul	placer
		Au9	Huder	placer
		Au10	Ulunt	placer
		Au11	Yalbag	placer
		Au12	Hadagtai	placer
		Au13	Bumbatin am	placer
		Au14	Ar chuluut	placer
		Au15	Jargalantin am	placer
		Au16	Baruun urt	placer
		Au17	Salhit	placer
		Au18	Salhit	placer
		Au19	Ult	placer
		Au20	Gachuurt	placer
		Au21	Biluut	placer
		Au22	Shar hooloi	placer

Table I-3-3 List of base and precious metal deposits in Mongolia (3/5)

COMMODITY	CATEGORY	NO.	NAME	DESCRIPTION
GOLD	MINES	Au23	Tsagaan chuluut hudag	placer
		Au24	Tosongin denj	placer
		Au25	Tsagaan chuluut bulag	placer
		Au26	Huurai salaa	placer
		Au27	Huiten	placer
		Au28	Tsamhag	placer
		Au29	Burhant	placer
		Au30	Havchuu	placer
		Au31	Harganat	placer
		Au32	Ih dashir	placer
	DEPOSITS	Au1	Boroo	altered breccia zones at granite-sediment contact
		Au2	Ereen (Tavt)	veins with alteration halos
		Au3	Oloon Ovoot	multiple veins in altered diorites and sediments
		Au4	Bumbat	veins in metamorphics
GOLD	DEPOSITS	Au5	Huiten	veins in altered metamorphics
		Au6	Narantolgoi	quartz veins in sediments, granites and metamorphics
		Au7	Sujigtei	quartz veins, mineralized zone
		Au8	Tsagaan tsahir uul	quartz veins in fault zone
		Au9	Tsagaan chuluut	veins and placer
		Au10	Huh bulagin hundiy	gold skarn
		Au11	Shaazgait	quartz veins in fault zone
		Au12	Narin gol	quartz veins in fault zone
	OCCURRENCES	Au1	Korumty (Chjamti Gol)	Placer
		Au2	Lun	stockwork
		Au3	Ulziit	veins in granodiorite
		Au4	Bayantsagaan	mineralized zone in granite
		Au5	Tsagaan gozgor	quartz veins mineralized zone
		Au6	Urlin ovoo	quartz veins mineralized zone
		Au7	Zuun shuvuu uul	quartzite bed, lens
		Au8	Shuvuun har uul	quartzite bed, quartz veins
		Au9	Bayan airag	quartzite bed, mineralized zone
		Au10	Nergui	mineralized zone
		Au11	Airag uul	mineralized zone
		Au12	Erdene hairhan	skarn, quartz vein zone
		Au13	Sagsai	quartz veins, metasomatite
		Au14	Buutsagaan	skarn
		Au15	Han uul	mineralized zone
CHROMIUM	OCCURRENCES	Cr1	Sulinheer group occurrences	magmatic chrome spinel deposit, lenticular chromite ore bodies in ultrabasics
		Cr2	Nogoon tolgoi	magmatic chrome spinel deposit, lenticular chromite ore bodies in ultrabasics
		Cr3	Jongin gol group occurrences	magmatic chrome spinel deposit, lenticular chromite ore bodies in ultrabasics
		Cr4	Ulhid	magmatic chrome spinel deposit, lenticular chromite ore bodies in ultrabasics
		Cr5	Onh hudag	magmatic, chromite ore in serpentinite

Table I-3-3 List of base and precious metal deposits in Mongolia

COMMODITY	CATEGORY	NO.	NAME	DESCRIPTION
CHROMIUM	OCCURRENCES	Cr6	Ongin zoo uul	magmatic, chromite ore in serpentinite
		Cr7	Havtsal	magmatic, chromite ore in serpentinite
NICKEL-COBALT	OCCURRENCES	Ni1	Sulinheer	mineralized zone in ultrabasics (serpentinite)
		Ni2	Duut uul	mineralized zone in ultrabasics (nontoronite-serpentinite)
		Ni3	Ulaan bulgin hundiy	mineralized zone in ultrabasics (serpentinite)
NICKEL-COBALT	OCCURRENCES	Ni4	Tsagaan gol	mineralized zone in carbonate rocks
		Ni5	Burhan tolgoi	mineralized zone in ultrabasics (serpentinite)
		Ni6	Nergui	mineralized zone in ultrabasics
		Ni7	Bor hag	mineralized zone in ultrabasics
		Ni8	Shar nuur	mineralized zone
		Ni9	Hutul	mineralized zone
		Ni10	Zulegt	mineralized zone
		Ni11	Nergui	silica-quartz veins in carbonate rocks
		Ni12	Tuntger har	serpentinite in gabbro
		Ni13	Har uzuur	metasomatic silicified zone
		Ni14	Sort tolgoi	altered zone
		Ni15	Jargalant	altered zone
		Ni16	Tsagduultin davaa	altered zone
		Ni17	Tsagaan burgas	altered zone
		Ni18	Tsahir uul	mineralized zone in ultrabasics (listvenite, sepentinite)
		Ni19	Herlen	mineralized zone in ultrabasics
		Ni20	Baruun saihan	mineralized zone
		Ni21	Teht	mineralized shear zone
		Ni22	Nergui	metasomatic zone
BISMUTH	OCCURRENCES	Bi1	Arshaan	mineralized zone
		Bi2	Nergui	mineralized zone
		Bi3	Hojuu ovoo	quartz vein
		Bi4	Tahilt uul	skarn zone
		Bi5	Tsagaan honh	mineralized shear zone, veins
		Bi6	Shar tolgoi	mineralized zone
ARSENIC	OCCURRENCES	As1	Tsamgin uul	silicified and skarn zone in granodiorite contact
		As2	Hairs	silicified and skarn zone
		As3	Baynzurh	mineralized shear zone
		As4	Zaagin hundiy	quartz veins
		As5	Tsagaan hundiy	quartz veins
ANTIMONY	OCCURRENCES	Sb1	Olonbulag	silicified shear zone, quartz-antimonite veins
		Sb2	Nergui	mineralized shear zone in granite-porphyry intrusive stock
		Sb3	Metegin ovoo	mineralized zone
ANTIMONY	OCCURRENCES	Sb4	Ar huvin am	quartz veins in shear zone
		Sb5	Urt am	quartz veins in shear zone
		Sb6	Modot undur	quartz veins in granite intrusive
		Sb7	Tsagaan chuluut	quartz antimonite veins

Table I-3-3 List of base and precious metal deposits in Mongolia (5/5)

COMMODITY	CATEGORY	NO.	NAME	DESCRIPTION
ANTIMONY	OCCURRENCES	Sb8	Baruun bulag	quartz antimonite veins
		Sb9	Tagin burd	quartz antimonite veins
		Sb10	Naran	mineralized zone

Note: NO. is coincident with Figure I-3-5. Mo, Sn and W are not listed.
Data source: MRAM (1963), Jargalsaihan et al. (1996)

Tuva - Mongol Island Arc, which accompanies the continental crust existed since the early Proterozoic. Some others are related with the magmatic activity caused by the collision of the Angara craton against the North China craton.

Among them, the porphyry copper/molybdenum mineralization related with acidic igneous activities in the magma arcs and the gold mineralization related with the plutonic rocks are considered to have more economic significance.

Distribution of major base and precious metal deposits and occurrences in Mongolia is shown in Figure I-3-5 and Table I-3-3.

(1) Porphyry type copper deposits

Major known porphyry type copper deposits (including mineral showings) in Mongolia are Erdenet, Bayan-uul, Tsagaan Suvarga, Oyu Tolgoi, Kharmagatai, Shuteen, Ikh and Shanhaicopper (Figure 1-3-5). Among these, only Erdenet is being operated at present and others are known as mineral showings or alteration zones related with porphyry copper mineralization .

The Erdenet deposit belongs to the Tuva-Mongol Unit, the Bayan-uul to the Khangai-Khenti Unit, and the Tsagaan Suvarga, Kharmagatai, Shuteen and Ikh Shanhai to the South Mongol Unit.

In general, the tectonic setting of porphyry copper mineralization in the world is classified as follows. The Andean type subduction zone, subduction zone of an island arc, the rift zone at the back arc of an island arc after subduction stopped, the rift zone in a continent and the rift zone within a collision zone (Sillitoe, 1980).

It is considered that among Mongolian porphyry type mineralization mentioned above, the Tsagaan Suvarga, the Kharmagatai, the Shuteen and the Ikh Shanhai in Southern Mongolia were obviously formed in the magmatic arc which was accompanied by the subuduction movement, judged from their ages.

On the other hand, the Erdenet and Bayan-uul deposits that occur in the Khentil uplift are considered to have formed during the collision phase in the Mesozoic time. The Khentil uplift which accompanies a large batholith of the Khangai-Khentil Unit was formed by the collision between the Angara and China cratons (Gerel, 1998). However, there are two other theories; one is that they were formed by the magmatic activity during the rift phase after the collision (Berzina et al., 1999) and another is that they were formed during the subduction phase (Takahashi 1998).

The Erdenet deposit is accompanied by the the Erdenet porphyritic intrusive complex which comprises granite porphyry and granodiorite porphyry of the late Permian to early Triassic. These intruded to the center of the uplift that had been caused by intrusion of the Selenge complex comprising acidic plutonic rocks of the late Permian age. The intrusive rocks of the Erdenet pohyritic inrusive complex occur approximately in a NW-SW direction at an intersection of structural lines of NW-SE, N-S and E-W. 5 mineralized zones including the Erdenet deposit have been discovered in a zone some 22km by 1.5km that extends in a NW-SE direction.

The age of mineralization indicates to be the late Triassic to Early Jurassic(207.4±2.5Ma: Lamb and Cox, 1998; 220Ma: Sotnikov et al., 1994) and approximately coincides with the age of the Erdenet porphyritic intrusive complex (250-245, 250-220, 205-195Ma: Berzina et al., 1999).

The Tsagaan Suvarga deposit was explored before the transition to the market economy. Here, copper mineralization occurs with molybdenum in a zone 0.8-3km by 10 km in an intrusive body of the Devonian to Permian age. Its geologic ore reserves are estimated at 240 million t with grades 0.53 % Cu and 0.018 Mo. The age of ore formation indicates the Carboniferous(313.0±2.9Ma: Lamb and Cox, 1998).

The Shuteen deposit develops in the volcanic and sedimentary rocks of the Carboniferous to Permian and accompanies the lithocap. Its geologic ore reserves are estimated at 12.6 million t with 0.31% Cu.

In the Kharmagatai deposit, mineralization occurs throughout sedimentary rocks of the Devonian, and diorite and granodiorite porphyry of the Carboniferous to Permian. Its geologic ore reserves are estimated at 13.9 million t with 0.25 % Cu.

A porphyry deposit named Bayan-uul was discovered by BHP Minerals Ltd at Oyu Tolgoi in the South Gobi Unit, some 125km southwest of the Tsagaan Suvarga deposit mentioned above (Mining Journal, September 4, 1998). The age of mineralization of the deposit is dated as the late Triassic (220-230 Ma: Lamb and Cox. 1998).

In general, each of these Mongolian porphyry deposits (including showings) has different characteristic features in type of hydrothermal alteration, related igneous rock, age of mineralization and so forth, however, all of them are related with potassic igneous activities (Sillitoe et al., 1996). Their another common feature is low in gold content, so that they are classified as porphyry copper/molybdenum deposits. Secondary enrichment zone does not develop so well except in the Erdenet deposit,.

(2) Gold deposits

Following types of gold deposits are recognized in Mongolia; placer, pluton-related, epithermal, metamorphogenic and sediment-hosted. There is a report that the potential gold reserves in Mongolia is 3100 t as metal (Mining Journal, February 28, 1997).

It is said that in Mongolian placer gold mining began in Zaamar and Altai Mountains in around mid-19th century. Even now operating gold mines are only placer deposits. The commercial-scale mining became active by the promotion policy of the Mongolian government after the transition to the market economy, and 8.5 t of gold were produced in 1997.

Major placer gold districts are Huder, Yuruu, Boroo and Zaamar in the northern Khentiy belt, as well as the Bayankhongor belt. The total reserves of placer gold are estimated at 130 t as metal (Jamasarandorj and Diatchkov, 1996). Among those districts, major producing mines are situated in a zone that extends from the western slope of the Zaamar mountains to the Tuul River, where gold occurs in the Neogene to Quaternary sediments on the basement of the early Permian. The source of the place gold is considered to be gold bearing quartz veins in the Zaamar mountains, which will be described later.

Pluton-related gold mineralization widely occurs in Mongolia associated with acidic plutonic rocks of the Altaids. Particularly, it occurs concentratedly to the north of the Khentiy Mountains and in the Bayankhongor belt that extend from the Russian border north of Ulaanbaatar to the east of Bulgan.

In the Boroo-Zuunmond and Erogol districts where Huder and Yuruu placer gold deposits occur, granite of the late Permian to Triassic is considered as the related plutonic rock for the lode type mineralization. Here, gently dipping quartz veins of several to several tens cm wide often occur. In the Boroo district which is about 130 km northwest of Ulaanbaatar, numerous gold-bearing quartz veins were recognized in a block 2.5 km long, 800 m wide and 300 m deep, and the gold reserves are estimated at about 40 t as metal.

Also in the Zaamar district, granodiorite and granite of the early Paleozoic are considered to be the related plutonic rocks as in Boroo. These plutons themselves and surrounding mudstone became the host rocks. Near about 150 gold bearing quartz veins with 10-20 g/t Au are recognized. At Bumbat north of Zaamar, development of a mine is likely being studied by a joint venture with a Canadian private company.

The Tavt (Ereen) deposit is located some 100 km northwest of Erdenet. There occur volcanic and sedimentary rocks of the Vendian to early Cambrian, and acidic plutonic rocks of the early Permian to early Jurassic intruded them. Here, a NW-SE lineament system develops, and about 100 quartz veins are concentrated within an area of 22 square km in accordance with this trend. Ore grades are quite fluctuated (Jargalsaikhan et al., 1996).

In the Bayankhongor district, gold-bearing quartz veins occur in the Cambrian granodiorite and migmatized crystalline schists of the Proterozoic. Quartz veins of both metamorphic and epithermal hydrothermal origins are present (Jargalan and Murao, 1998).

A weak gold mineralization with As and Sb is observed in the Permian limestone which abuts against the Solonker suture and was silicified by the intrusive rocks of the South Gobi Unit. This is interpreted as a showing of sediment-hosted gold deposit (Sillitoe, et al., 1996).

Sulfide poor gold-bearing quartz veins are known in the metamorphosed turbidite of accretionary prism in the South Mongolian Unit and are considered to be of metamorphogenic gold (Sillitoe et al., 1996). For reference, the Russian Far East region, which is the eastern extension of the Mongol - Okhotsk belt, is a prominent placer gold producing area and has a production record of about 1,000 t gold up to date As the source of the gold placer of this type, metamorphogenic gold deposits might be expected in an area where shale of accretionary prism predominates (Yakubchuk and Edwards, 1999).

A possible low-sulfidation type gold deposit Beli occurs in the rift zone of the late Jurassic of the Transbaikalia Unit, in Southern Russia. The doposit is situated about 180 km from the Mongolian border and has produced some 200 t of gold. Therefore, the same type deposits may be expected within the Mongolian extension of the Mongol - Okhotsk belt where a similar geological setting is present.

High sulfidation type gold deposits may also be expected some place above porphyry type copper deposits.

(3) Silver deposit

As to the silver deposits, two types of mineralization have been recognized so far: The Asgat type vein deposit and the Mungun Undur type polymetallic deposit. Besides these, silver is produced as a byproduct of an argentiferous base metal deposit and a porphyry copper deposit.

The Asgat deposit is located in the northwestern part of Mongolia some 170km north of Ulgii near the Russian border. It was discovered in 1976. Silver occurs as sulphosalts and accompanies copper, bismuth and antimony. The silver reserves are estimated at 6,900t as metal.

The Mungun Undur deposit is located some 310km east of Ulaanbaatar (Khentii province). It accompanies lead, zinc and tin besides silver. The silver reserves are estimated at 3,212t as metal.

(4) Lead and zinc deposits

Lead and zinc deposits distribute in Tsav, Ulaan, Muhar, Tumurtin Ovoo, Mungun Under and other districts which formed a small scale metallogenic province in the eastern part of Mongolia. There is no operating mine at present. They are classified into breccia pipe, vein, skarn and shear zone types (Jargalsaihan, 1996).

The breccia pipe type has a pipe-like shape which develops at the intersection of faults of NNW-SSE and E-W systems and extends in an area of 70 to 12 m by 120 to 650 m on a horizontal plane and continues over 800 m in vertical trend. The breccia consists of siliceous host rocks and crushed granitic porphyry dykes of the Jurassic and has quartz-fluorite-sulfide and quartz-sulfide. Ulaan deposit which is a typical deposit of this type is located 110 km northwest of Choibalsan and its ore reserves are estimated to be 68 Mt grading 2.0 % Zinc, 1.2 % Pb, 53 g/t Ag and 0.21 g/t Au.

A typical vein deposit is Tsav deposit which is dominated by pinnate faults of NW-SE and N-S strends. The strike extension is 350 to 2,000 m, the dip extension is 200 to 600 m, the mean width is 0.8 m and ore grades fluctuate (0.12 - 49.5 % Pb, 0.05 - 28.0 % Zn, 0.02 - 1.19 % Cu and 20.5 - 27.35 % Ag).

The shear zone type deposit is represented by Altan tolgoi deposit and it is limited to the boundary between granite and crystalline schist. It consists of sphalerite, galena, pyrite, chalcopyrite, tetrahedrite, bismuthinite, arsenopyrite and other minerals which accompany with quartz stockwork of the shear zone.

The skarn deposit is represented by Tumurtiin Ovoo deposit which is located 180 km southwest of Choibalsan of Dornod Province in the eastern part of Mongolia. Its host rocks are volcanic rocks and sedimentary rocks of the Devonian (roof pendant of the Permian granites) and its ore reserves are estimated to be 7.7 Mt grading 11.5 % Zn.

(5) Tin, tungsten and molybdenum deposits

Mineralization zones of tin and tungsten are mainly located in the central and the eastern parts of Mongolia and belong to two zones which extend to northeast - southwest.

The tin deposits occur with leucocratic granite from the late Triassic to Jurassic. There are many small scale deposits, but they are mainly placer deposits. The placer deposits have been generated during the Pliocene to Pleistocene and occurred in alluvium of Modot or Janchivlan districts (near Banganuur coal mines).

Tungsten mineralization zones have been confirmed over a wide area which often accompanies molybdenum. There are a vein type, a stockwork type and a greisen type of deposit. Ondor - Tsagaan tungsten and molybdenum deposits are located 70 km from Ondorkhaan of Khentiy Province in the eastward of Ulaanbaatar, and its ore reserves is 186 Mt grading 0.17 % WO3 and 0.2 % Mo. Molybdenum can be also found in porphyry deposits like the Erdenet deposit and the Aryn Nuur deposit which is located 600 km southeast of Ulaanbaatar.

(6) Rare earth minerals deposit

The rare earth minerals deposits distribute in the western, the southern and the northern parts of Mongolia with the mid to late Paleozoic and Mesozoic leucocratic granites, but there is no operating mine. Halzan - Buregtei deposit is located 50 km north of Khovd which is the center of Western Khovd Province. It is a disseminated deposit of rare earth minerals accompanied with fluorites grading 0.2 % Nb_2O_5, 0.05 % Ta_2O_5, 1.5 % ZrO_2 and 0.35 % Y_20_3. In Lugiingol deposit in Dornogov Province of the southern Gobi Desert, 17 carbonatite veins which were accompanied with alkali rocks and disseminated with rare earth minerals were confirmed. The grade of the rare earth oxide is 3.2 %. Mushgain hudag deposit which is located 100 km north of Dalanzadgad which is the center of Omnogov Province of the southern Gobi Desert is a rare earth deposit accompanied with carbonatite and apatite. The ore grade is

0.02 to 0.42 % La, 0.02 to 0.59 % Ce, and 0.03 % Sm.

(7) Chromium and platinum deposits

Although there is no production record so far, they are expected to be in harzburgite and dunite of ophiolite, and as placer deposits around ophiolite.

(8) Uranium deposits

As uranium deposits, vein and stockwork types (Dornot, Gurvanbulag, Mardain-gol and Nemer deposit) and a sandstone type (Haraat and Nars deposits) are known.

3.2 Outline of geological features and ore deposits in the survey area

3.2.1 Geology and structure

(1) Outline

A simplified geologic map that covers the investigated area is shown in Figure I-3-6 , which was compiled from the 1:1,000,000 Degital Geologic Map published in Mongolia in 2000. Geotectonically the investigated area is divided into the Tuva-Mongol Unit on the south of the Vitim Suture and the Darkahat, Sangilen and Dzihida Units on the north of it. The Suture is a large tectonic line running in an E-W direction approximately along the north 49^{th} parallel (Sengor et al., 1996). Generally speaking, Precambrian metamorphic rocks and components of accretionary prism predominate to the north of the Vitim Suture, while occurrences of these are limited to the south.

Phanerozoic granitc rocks occur less to the north of the 50^{th} parallel, but predominate to the south. Volcanic rocks of the Permian to Triassic occur in the eastern part of the investigated area such as in the vicinities of Erdenet and Bulgan cities, which are located to the south of the Selenge river, and along the Vitim Suture zone in an E-W direction.

The Vitim Suture is a prominent fracture zone (structural line) and accompanies numerous branch faults, which are observed to cut granitic rocks of the Permian and volcanic rocks of the Triassic to Jurassic on the geologic map (Figure I-3-6).

(2) Tectonic units and their geological features

To the north of the Vitim Suture, in the northern part of the Dzihida Unit on the east of the Khuvsgul lake (corresponds to the Uvs and Eg-Eur terranes by Tumutogoo, 1996) the fragmental blocks of the Precambrian continental crust (Baikalides) distribute and granitic rocks

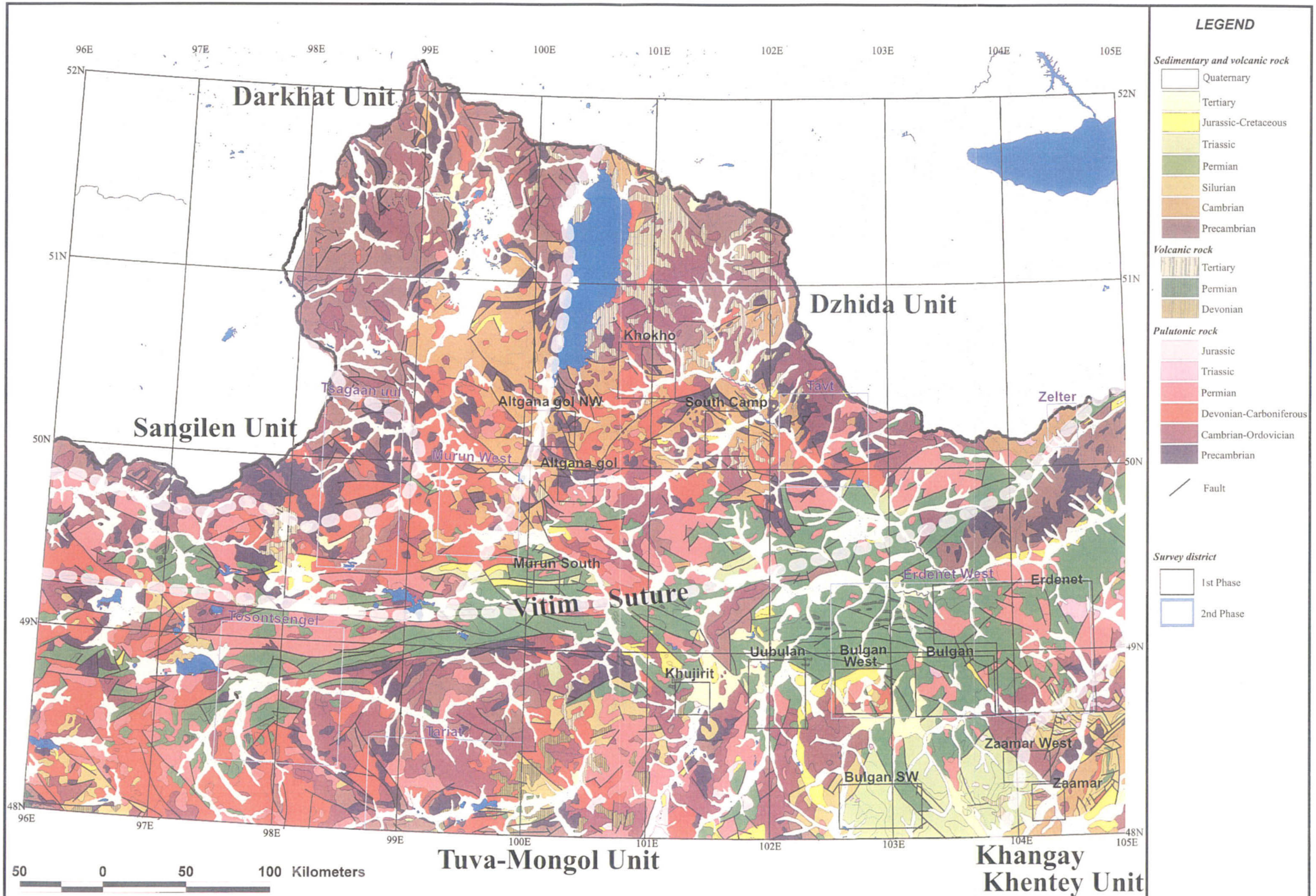


Fig. I-3-6 Geological map of the central north area of the Cambrian to Carboniferous intruded. The southern part (corresponds to the Eastern Khuvsgul Terrane by Tumutogoo, 1996) comprises the accretionary prism of the early Paleozoic which consists of dismembered ophiolite such as flysch sediments, limestone etc. and volcanic rocks of the island arc such as basalt, andesite, rhyolite etc. Granitic rocks of the Cambrian to Carboniferous intruded as same as in the northern part.

On the other hand, the Darkhat Unit (corresponds to the Tes-Darhadt Terrane by Tumutogoo, 1996), which distributes around the Khuvsgul lake and in the western part of it, comprises gneiss and schists of the early Precambrian as well as terrestrial sediments and island arc volcanics of the Riphean. Overlying these, neritic limestone, apatite, bauxite and dolomite of the Vendian to lower Carboniferous and calcareous flysch sediments of the Cambrian occur (Segor et al., 1996).

To the south of Vitim Suture, the Tuva-Mongol Unit (Tumutongo, 1996) (the Ulziit Terrane or the North Mongolia Tectonic Zone in unpublished "Crystalline Core" by MRAM) is considered as a magmatic arc that was formed by accretiom due to the subduction in the Vendian to Permian time, accompanying the continental crust as its core. The core consists of granulite, amphibolite and tonalite resembling the Angara craton. In the southwestern to eastern part in the investigated area, Precambrian metamorphic rocks, which are fragmental blocks of the continental crust of the Tuva-Mongol Unit sporadically distribute to form the basement of the area to the south of the Vitim Suture.

To the north of Erdenet city in the eastern part of the investigated area, Precambrian granites and metamorphic rocks distribute for about 150km in a NW-SW direction with a width of about 50 km. The zone is described as an independent zone named the Mongol-Ubur Baikal Tectonic Zone in a unpublished MRAM report. Similar to this, Precambrian metamorphic rocks distribute within an area some 100 by 100 km in the southwestern part of the investigated area. They are sometimes described as an independent zone named the Tarvagtai Terrane (Badarch and Tomurtogoo, 1997).

In the eastern part of the investigated area, clastic rocks of the Silurian to Permian and granitic rocks of the Permian to Triassic distibute in the same zone where the metamorphic rocks of the Precambrian age occur as mentioned above. Also in the southeastern part, granitic rocks of the Cambrian to Ordovician distribute in the same zone the metamorphic rocks Precambrian age occur. In an area that extends from the vicinities of Bulgan and Erdenet cities to the north of the Selenge river, volcanic rocks of the Permian to Triassic (ex. The Mogod deries) widely occur.

In this report, the same formation names that MRAM uses are adopted. They are listed below along with their geologic features and settings.

Zed formation (middle Jurassic to early Cretaceous): Continental rift. Pyroclastics

Khangai formation (late Permian to early Jurassic): Active continental margin.
Volcanic / plutonic magmatism
Khangai-Khenty formation (early Paleozoic to early Mesozoic): Plutonic magmatism
Orkhon-Selenge formation (early Paleozoic): Pyroclastics
Ider formation (Paleozoic): Basic to alkaline magmatism
Khenty of North Khenty formation (early Paleozoic): Active continental margin.
Metamorphic rocks
Near Khuvsgul formation (early Proterozoic to early Paleozoic): Continental rift.
Sedimentary and metamorphic rocks
Tariat-Selenge formation (Proterozoic to early Paleozoic): Metamorphic rocks
Buteeliin uruu formation(Archaean to early Proterozoic): Mirocontinent.
Metamorphic Rocks.
Tuva-Mongol formation (Archean to Proterozoic): Metamorphic rocks

3.2.2 Characteristic features of granitic rocks

Distribution of granitic rocks thoroughout the investigated area is shown in Figure I-3-7. The granitic rocks are classified by Pavlov et al (1985) and Garam(1991) into three types depending on their ages (Figure I-3- 7. Table 1-3 -4).

Granitic rocks that were active and formed in the early Devonian are named as the Tess complex, which includes leucocratic granite, granodiorite, granosyenite and so forth. They distribute from slightly north of the central part of the investigated area to the south of the Khuvsugul Lake. Petrologically they have characteristics of sub-alkaline rocks and ,as related mineralization, quartz veins and stockworks that accompany tungsten and molybdenum are described.

Syenite, granosyenite and so forth, which were active and formed in the middle Permian are named as the Zuun Khangai complex and occur in the areas slightly east of the central part of the investigated area, as well as in the western part of it. Petrologically they have characteristics of alkaline rocks and, as related mineralization, pegmatites accompanying rare metals and rare earths are described.

Monzonite, dirorite, granodiorite, granosyenite, granite which were active and formed from the middle to late Triassic are named as the Selenge comples, and occur in the eastern part of the investigated area from the proximity of Bulgan and Erdenet cities to the Selenge river. However, in various reports the same name "the Selenge complex " is also used to designate similar granitic rocks which are supposed to be of the Permian. Petrologically the Triassic rocks have characteristics of calc-alkaline rocks and, as the related mineralization, porphyry

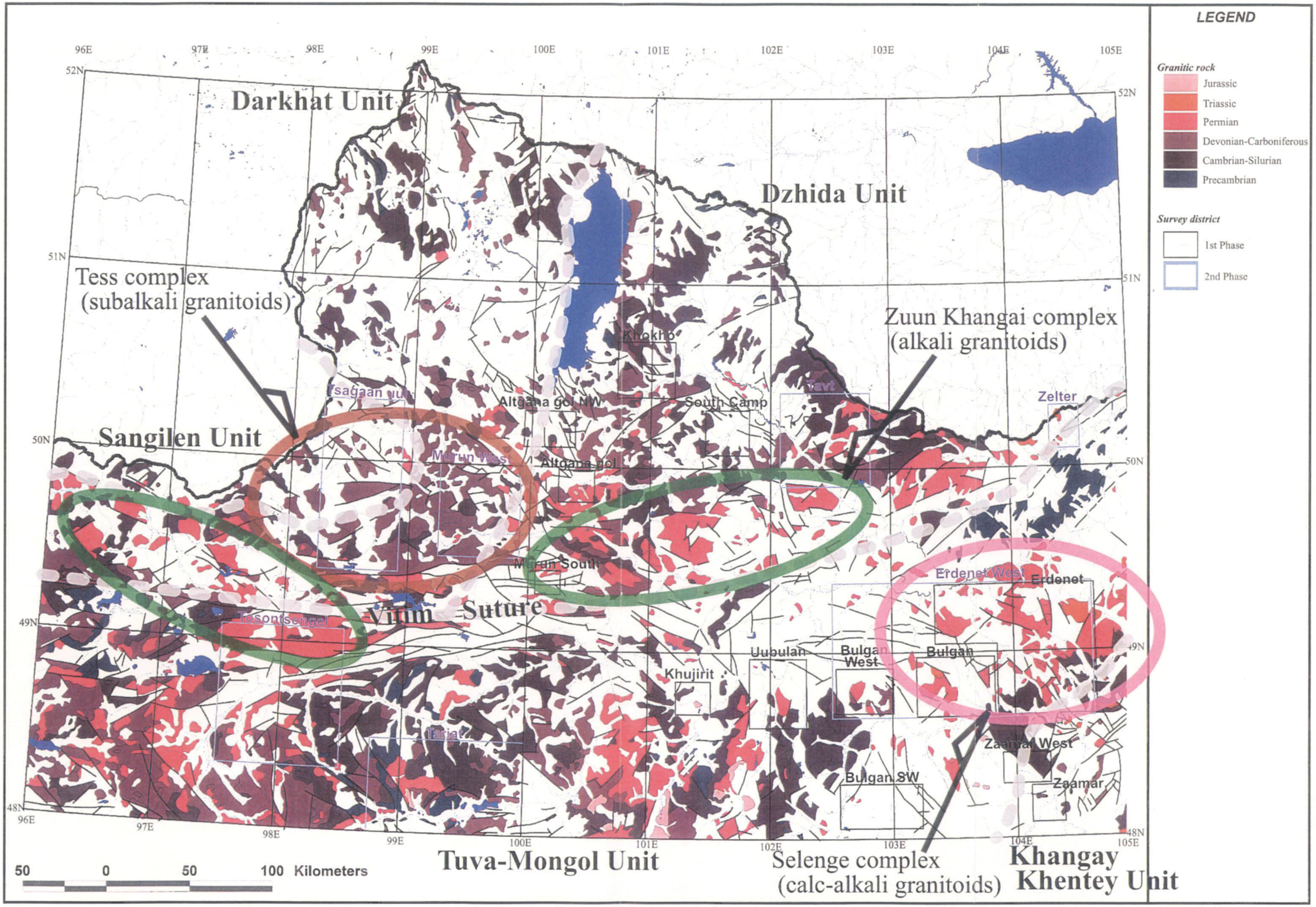


Fig. I-3-7 Distribution of granitic rocks in the central north area

Table I-3-4 Characteristics of middle and late Paleozoic granitoid intrusive complex distributed in the central north area (1/2)

Complex	Type of massif	Structural position	Age of rocks	Peculiarity of structure
Subalkali leucocratic granite (Tess)	Tess, Arbulag, Tsagaan uul, Muren gol, Bulnain, Budjir	It is concentrated at the area of early Caledonides, gravitated to the zone of fault joined with projections of Precambrian basin	It is cut volcanogenic- terrigenic formartions of the Bor nuur suite (D1-2); gravel of granites is located at the sedimentaries of lower Carboniferous; intruded by rocks of Permian Zuum Khangai complex; radiometric age is 360-340 Ma.	Multiphase plate- like plutones of size from ten to several thousand square km
Syenite-alkali granite (Zuun Khangai)	Zuun Khangai, Arkhustain, Teshig, Numrug, Tosontsengel, Khulan uul	It is related to the system of Khan Khukhii, Khangai and Selenge faults and feathered fractures	It is cut volcanic rocks of lower Permian; intruded by dykes of dolerites and leucogabbro (P22); radiometric age is 262-254 Ma.	Varied for sizes mulltiphase intrusions of area from ten to several hundreds square km, rarely- small stocks.
Calc-alkali granitoid (Selenge)	Erdenet, Ikh Tulburiin gol, Nariin, Tulburiin gol, Khujirtiin gol, Balga gol	It is concentrated at inner part of the Orkhon Selenge trough among the volcanogenic zone of upper Permian trachybasalt series, gravitated to cross depth faults	It is cut series of Permian volcanic rocks of the Khanui series; covered by Abzog suite (T2-3); radiolmetric age is 240- 220 Ma.	Various sized (from one to ten of square km stock or dyke like bodies of simple single-phase or complicate multiphase structure with typical vein series of porphyry rocks

Table I-3-4 Characteristics of middle and late Paleozoic granitoid intrusive complex distributed in the central north area

	Characteristic indications			
	Petrographic	Petrochemical	Geochemical	Metallogenic
Subalkali leucocratic granite (Tess)	Predomination of leucocratic to monospar granites (early phase); from large-grained to small- grained (late phase); here and there exiting of contact- reaction granodoirites and granosyenites. Minerals: main (potassium feldspar (usually microcline), quartz, plagioclase , biotite, natural hornblende); accessory (magnetite, pyrite, apatite, zircon, rarely fluorite, sphen, monazite and cassiterite); Dyke series is presented as aplites, granophyries, lampporphyries; Post magmatic processes: potassium spathization, greissenization.	Belonging to subalkali Na- K petrochemical series ($K_2O > Na_2O$); high aluminum oxid, saturation by SiO_2, poor for feldspar.	Clark level of concentrations of Zr, Nb, Ta, Li, Rb, Be; Accumulation at late differentiates and hydro-thermalites W, Mo, Pb, Sn	Tungsten- bearing greisens (Tsagaan uul massif) and quartz stockworks with molibdenite (Tsagaan tolgoi mineral occurrence)
Syenite-alkali granite (Zuun khangai)	Combination of syenites (phase I) with granosyenite and alkaline granites (phases II-III). Minerals: main (perthizated K-Na feldspar, plagioclase, aegirine- diopside, aegirine, riebeckite, quartzite); accessory (sphen, orthite, monazite, xenotime, thorite, bastnaesite, tantalum- niobates and others). Post magmatic processes: potassium spathization, albitization.	Domination of alkaline series $Na_2O \geq K_2O$; poor for calcium and magnesium.	Heightened concentration of Zr, Ta, PR, Be, Cu; lower grade Cu and Zu	Rare metal pegmatites with heightened concentration of rare and rare earth elements (Numrug, Zuun khangai and other massifs)
Calc-alkali granitoid (Selenge)	Rocks of gabbro- monzonite series (phase I), diorites and granodiorites (phase II), granosyenites, granites (phase III), granodiorite- and granoporphyries (phase IV). Main minerals of rocks: phases I-II (hornblende, plagioclase, biotite, rarely microcline- perthite, in more basal rocks are appeared augite); phase III- IV (plagioclase , perthitizated anorthoclase, green hornblende, biotite, and quartz; accessory (titan-magmatite, sphen, zircon, apatite). Post magmatic processes: potassium spathization, albitization, amphybolization, and silicification.	Belonging to calc- alkali K-Na series; differed by heightened concentration of CaO, MgO, and FeO.	Heightened concentration of Cu (diorites, granosyenites) and Mo (granites and granoporphyry)	Mineral occurrences and deposits of Cu-Mo porphyry type (Erdenet deposit, Khujirtyn gol and others)

(Taken from Garam, 1991)

copper/molybdenum mineralization is described. The Selenge complex plays a role of the host rocks of the Erdenet deposit and the mineralization is believed to have been brought by the Erdenet porphyritic intrusion complex which was the latest phase of the activity of the Selenge complex.

3.2.3 Ore deposits and mineral occurences

(1) Characteristics and distribution of mineral occurrences

Metallogenic provinces by the MRAM internal document, which are in the investigated area, are shown in Figure I-3-8, and the description of them is given in Table 1-3-5. Also the location map corresponding to the list of the mineral occurrences that MRAM keeps is shown in Figure1-3-9.

Copper occurrences are slightly concentrated in the eastern part of the investigated area from the proximity of the Erdenet mine to the west of Bulgan city. This area corresponds metallogenically to the Umard Mongol (North Mongolia) province and has a possibility that deposits related with the Mesozoic igneous activity such as porphyry type copper/molybdenum and vein types may occur, as there are descriptions of the alteration zones and veins accompanying copper mineralization.

Also copper occurrences are slightly concentrated in a zone from the center to the west of the investigated area, where volcanic and granitic rocks of the late Mesozoic distribute along the Vitim Suture. The zone corresponds to the Ider-Selenge metallogenic province and has a possibility that porphyry type copper/molybdenum and vein type deposits related with the Mesozoic igneous activity may occur as well.

Numerous copper-gold occurrences distribute in the southwestern part of the investigated area where the Tuva-Mongol Unit and the Khangai batholith occur. This corresponds to the Tarbagatain metallogenic province and there are descriptions on veins, alteration zones and skarns which accompany copper-gold mineralization. Therefore, it is considered there may occur vein and skarn type deposits related with plutonic igneous activity.

As to gold occurrences, a gold bearing quartz vein zone is known, which extends from Khunder and Togit (west of Darkhan) via Boo up to the Zaamar mountains in the southeastern part of the investigated area. Here gold showings of vein type and placer occur concentratedly. This zone corresponds to the Khoid Khenty (North Khenty) metallogenic province. At present in Zaamar, mining operation is being carried on mainly for placer gold.

Gold or gold-copper mineralization represented by the Tavt (Ereen) deposit occur concentratedly in a zone to the east of the Khuvsugl lake in the northern part of the investigated area . The zone corresponds to the Egiin gol (Teshig) metallogenic province and has a

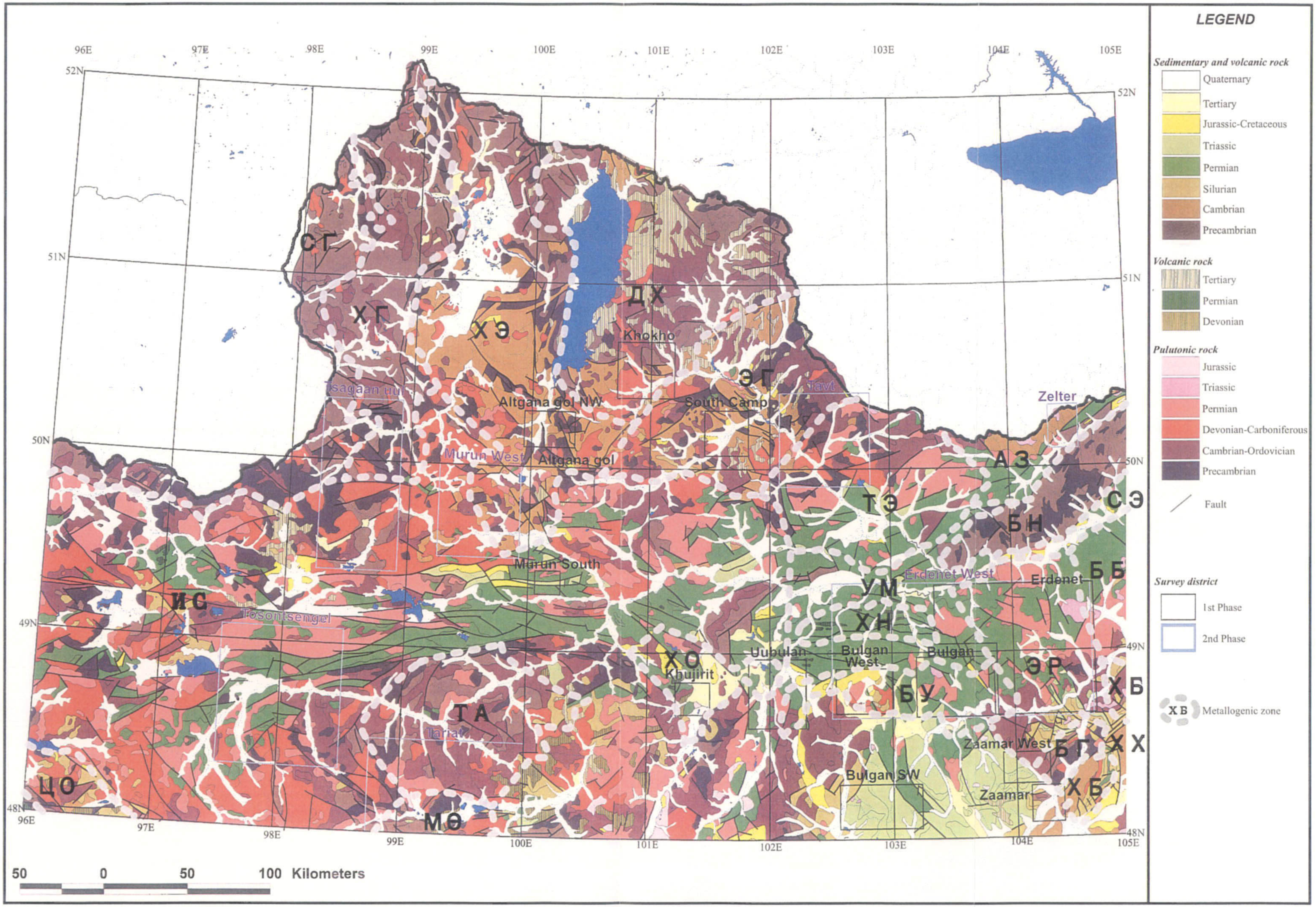


Fig. I-3-8 Geological and metallogenic map of the central north area

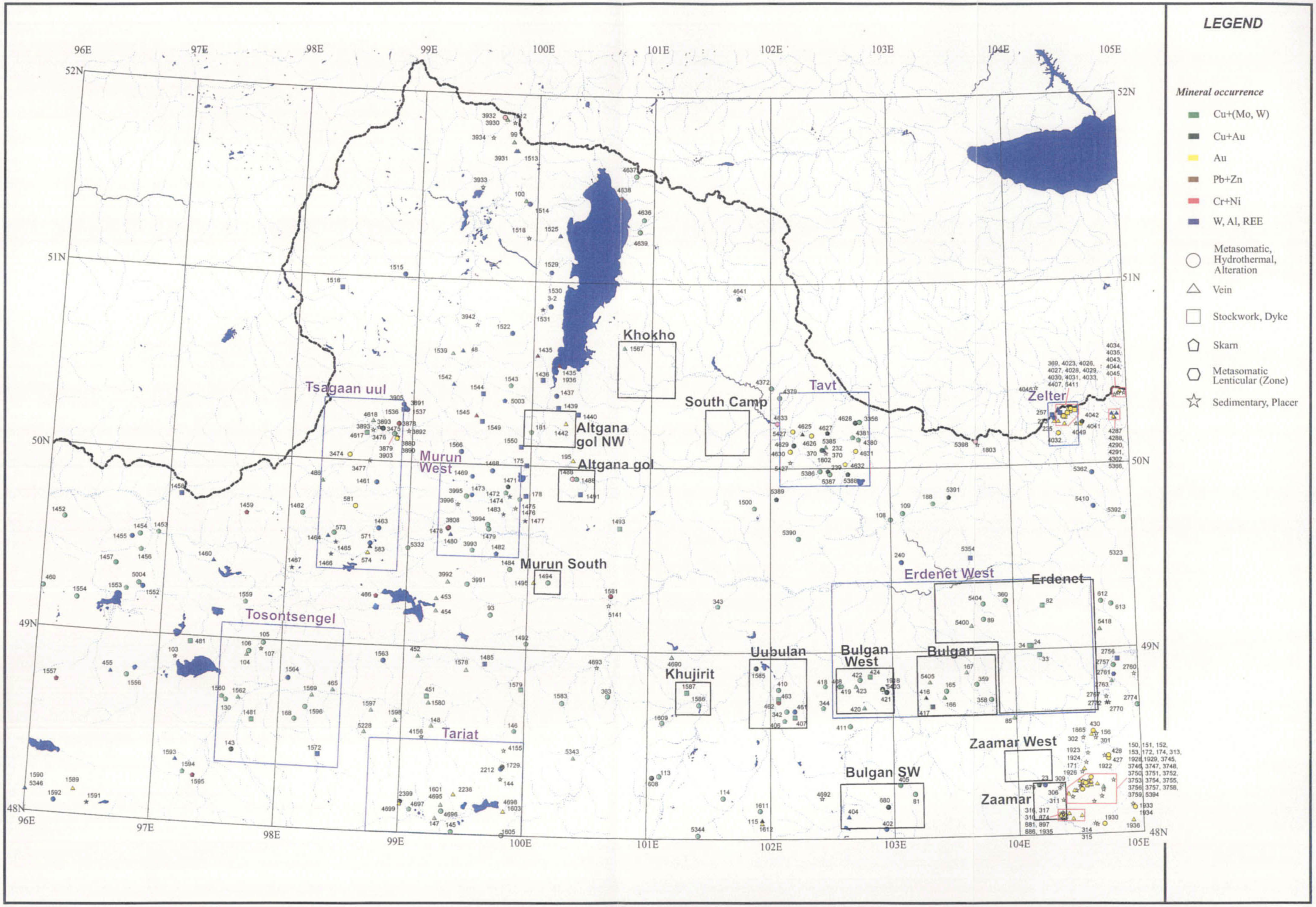


Fig. I-3-9 Location of ore deposits, mineral occurrences and geochemical anomalies in the central north area

Table I-3-5 Metallogenic classifications of the central north area

No.	Metallogenic belt	Geological characteristics	Tectonic environment	Ore district (short name)	Metallogenic characteristics
1	Ider-Selenge (И С)	Porphyritic plutonic rocks	Continental rift	---	The molybdenite-quartz/copper hydrothermal vein, copper and iron skarn, quartz-fluorite and copper-nickel mineralization, related to early-late Paleozoic gabbro-granodiorite and granite.
				Kho-ulaan (Х О)	The copper-molybdenium porphyry type mineralization, related to late Paleozoic porphyritic intrusion.
2	Tarbagatain (Т А)	Plutonic rocks-andesitic volcanism	Continental margin arc	Tarbagatain (Т А)	The iron-quartzite, muscovite, iron skarn, copper hydrothermal vein type mineralization, related to Proterozoic-early Paleozoic quartz pegmatite, diorite-granodiorite-plagiogranite (Telmen complex) and the molybdenum deposits, related to late Paleozoic granitoid complex. Middle paleozoic wolframite-molybdenite, molybdenum and gold mineralization.
		Metamorphic system	Micro continent	Must uul-Khajuugiin gol (М θ)	The titanomagnetite (ilmenite) mineralization, related to Proterozoic gabbro-anorthosite complex (Tarbagatai complex).
3	Sayan (С Г)	Metamorphic system	Micro continent	---	---
4	Khugiin gol (Х Г)	Continental volcanism-sedimentary system	Continental rift	---	The gold-quartzite, graphitic shale bed, nephrite and asbestos deposit, related to Riphean metamorphic system (shale-quartzite, gneiss-shale and hyperbasite complex).
5	Khubsgul (Х Э)	Plutonic rocks-andesitic volcanism	Continental margin arc	---	The copper skarn, iron-manganese, vanadium chemogenic sedimentary, phosphorium biogenic sedimentary, bauxite reaccumlation, nepheline-syenite, neobium-zircon-torium pegmatite and albetite deposits, related to early-middle Paleozoic shale, sandstone, aleurolite, carbonate-terrigenois and alkaline syenite-granite.
6	East Khubsgul Potential (Д Х)	Ultramafic magmatism, porphyritic plutonic rocks	Continental margin arc or rift	Dulaan khan	The chromite and tin groups deposits, related to Riphean hyperbasite complex. The early-middle Mesozoic copper-molybdenum porphyry, copper skarn and gold-polymetatlic hydrothermal vein type deposits.

Table I-3-5 Metallogenic classifications of the central north area

No.	Metallogenic belt	Geological characteristics	Tectonic environment	Ore district (short name)	Metallogenic characteristics
7	Egiin gol (Jid) (Э Г)	Ultramafic and mafic rocks, autometasomatism	Island arc	---	The chromite (platinum), asbestos and nephrite deposits, related to early Paleozoic Egiln gol hyperbasite complex.
		Plutonic rocks-volcano	Continental rift	Teshig (Т Э)	Early Mesozoic gold-copper and wolframite skarn, gold-copper hydrothermal vein type deposits.
8	Buteeliin nuruu (Б Н)	Metamorphic system	Micro continent	Buteeliin nuruu (Б Н)	The sillimanite, disthen, titanum, tantalum-niobium, lazulite and scheelite deposits, related to Archean-Proterozoic deposits.
9	Umard Mongol (North Mongolia) (У М)	Ultramafic and mafic magmatism	Continental rift	Khanuin (Х Н)	The titanomagnetite deposit, related to late Paleozoic intrusive complex.
		Porphyritic plutonic rocks		Bulgan (Б У)	Late Mesozoic copper skarn and hydrothermal vein type, gold-wolframite vein type deposits.
				Erdenet (Э Р)	The copper-molybdenum deposit, related to early Mesozoic porphyry complex.
		Continental volcano-sedimentary system		Baruun buren (Б Б)	The copper porphyry type mineralization, related to early Mesozoic intrusive complex.
10	Zavkhan-Tsagaan olom	Sedimentary-hydrogene system	Continental margin	Tsagaan olomiin (Ц О)	The iron-zinc skarn, copper and molybdenum vein type dmineralization, related to upper Paleozoic intrusive complex.
11	Bayan gol (Б Г)	Plutonic rocks-calcalkali volcanism	Continental margin arc	Ulziit	The copper mineralization, related to early Paleozoic basite and iron (copper mineralization in the alteration zone).
				Orkhon-tuul	Early Paleozoic iron, copper, asbestos mineralization and earlier mesozoic copper, wolframite mineralization.
				Khutul	The copper and nickel veins, related to early Paleozoic basite (gold, copper mineralization in the alteration zone).
				Tumur tolgoi	The iron and copper mineralization in the early Paleozoic skarn.

Table I-3-5 Metallogenic classifications of the central north area

No.	Metallogenic belt	Geological characteristics	Tectonic environment	Ore district (short name)	Metallogenic characteristics
12	Khoid Khenty (North Khenty) (X X)	Plutonic rocks-andesitic volcanism	Continental magin arc	Eruu gol	Early Paleozoic gold mineralization in the vein and metamorphic zone; upper Mesozoic gold, tin and wolframite mineralization.
				Boroo-Zuun mod	Early Mesozoic gold mineralization.
				Zaamar (X Б)	Early Paleozoic and early Mesozoic gold mineralization; wolframe and muscovite in Mesozoic pegmatite.
				Sharlin	The iron-manganese mineralization in the early Paleozoic sediments.
				Bayan tsogt	The gold, iron, manganese and copper mineralization in the early Paleozoic quartzite; copper, gold and polymetallic mineralization of earlier Mesozoic formation.

possibility that vein and skarn type deposits related with plutonic igneous activity may occur, as there are descriptions on vein and skarn type mineralization. As to the Tavt deposit, there is an information that 100 to 130t of gold are expected (Mining Journal, Feb, 28, 1997).

Other than these, gold occurrences are comparatively concentrated near the northeastern periphery of the investigated area in the proximity of Zelter at the Russian border, where there are descriptions on alteration zones and quartz veins carrying gold.

Occurrences of gold, copper, tungsten, molybdenum, nickel,, chromium and so forth are described in the Sangilen and Darkhat Units from the northern to northwestern parts in the investigated area. These correspond to the Khubsgul, Khugiin gol and Sayan metallogenic provinces. In this area, there is a possibility that deposits of nickel, chromium and platinum group may occur, which are related with ultrabasic rocks in the ophiolite of the early Paleozoic as well as pegmatite deposits which are related with the granitic rocks being active in the early Paleozoic.

(2) Outline of the Erdenet deposit

In the proximity of the Erdenet mine, 5 copper mineralized zones have so far been recognized, having the mine as the center. They occur in an area extending in a NW-SE direction for about 22km with a width of about 15 km.

The Erdenet deposit is situated to the south of the Orkhon-Selenge basin, which elongates in a NE-SW direction and has the matamorphic rocks derived from sedimentary rocks of the early Cambrian and late Paleozoic as its basement. The Orkhon-Selenge basin mainly comprises sedimentary and volcanic rocks of the Permian and accompanies sedimentary and volcanic rocks of the Triassic and Jurassic.

The Khanuin series (volcanics such as basalt, andesite, rhyolite etc) of the Permian and the Selenge complex of the late Permian (granitic rocks such as diorite, monzonite, granite etc.) form a large scale dome structure with a fracture system trending mainly in NW-SE, which provides the locus of mineralization of the deposit. The dome structure is recognized as a ring (diameter: approx. 50 km) with complex arc structures (Gavrilova et al., 1989).

Mineralization(copper and molybdenum) was brought by the intrusion of the Erdenet porphyritic intrusion complex (granite porphyry and granodiorite porphyry) (Table 1-3-6) , which is thought to be of the late Permian to early Triassic, into the intersection of structural lines of NW-SE, N-S and E-W in the dome structure. 5 mineralized zones are aligned in a NW-SE direction (Gavrilova et al., 1989; Naio and Sudo, 1999). After the formation of the ore deposits, activity of the Jurassic volcanic rocks such as trachyandesite, dacite, rhyolite etc. occurred in the mineralized zones and dykes of these intersected the deposits in a N-S direction.

As to the alteration zoning of the deposit, the zones of chlorite-epidote, sericite-chlorite and quartz-sericite occur from the periphery of the ore body towards the center in this sequence.

Table I-3-6 Characteristics of Selenge complex and Erdenet porphyritic intrusive complex distributed around Erdenet mine

Stage	Rocks	Morphology	Structure	Mineral association
V	B. quartz and sericite-quartz vein, sometimes accompanying K-feldspar alteration A. mesocratic granodiorite-porphyry, granodiorite-porphyry, dacite, hornblende-biotite andesite and diorite-porphyry	Rare parallel dikes, magmatic breccia	Local fractures, mainly steeply dipping	Pyrite-quartz, Molybdenite—quartz, Chalcopyrite-pyrite-quartz, Superimposed bornite-chalcocite-covillitic
IV	B. thin sericite-quartz vein A. quartz-biotite-plagioclasic and leucocratic porphyr, plagio- porphyry and dacite, mesocratic plagio-porphyry, amphibole-biotite andesite-dacite, andeiste			Pyrite-quartz, Molybdenite-quartz, Chalcopyrite-pyrite-quartz with sphalerite, Superimposed bornite-chalcocite- covellitic
III	B. sericite-quartz metasomatite and veins, quartz vein with chlorite, in the deep horizons quartz vein with secondaryl biotite and anhydrite	Predominately systems of parallel dikes sublatitude vertical, rarely netted stockwork and breccia	Systems of thin parallel fractures with steeply dipping and rarely gently dipping. Distributed along all vertical clack.	Pyrite-quartz, Molybdenite-quartz, Chalcopyrite-pyrite-quartz with sphalerite and bismuth
	A. 1.granodiorite-porphyries, biotite-plagioclasic porphyries, plagioporphyries, dacites 2. leucocratic granite-porphyry, quartz-plagioclase porphyry, rhyodacite and rhyolite	Predominantly sublatitude steeply dipping dikes, in the central part of the deposit-stock autobreccia structure, gently and steeply dipping bodies.		Superimposed bornite-chalcocite-covellitic
II	Structural reconstruction			
	B. 1.quartz-K-feldspar, aplitic, graniteporphyry dyke 2. quartz-sericite metasomatites, quartz breccia, metasomatite and veins	Stockwork, veins, zones, columns		Pyrite-quartz Molybdenite-quartz Chalcopyrite-pyrite-quartz
	A. granodiorite-porphyrry, granite-porphyry	Stocks, dikes, laccolith		Superimposed bornite-chalcocite-covellitic
I	B. main stage metasomatosis and mineralization. 1.quartz-K-feldspar metasomatite 2. quartz-sericite metasomatite, secondary quartzite, locally greisen, in the higher horison and NW flange tourmaline bearing rocks	Netted stockwork in the upper and middle horizons of the deposit; in the deeper local zones, columns	Veins and zones steeply, inclined, gently dipping; columns, "Rubble" veins	Pyrite-quartz, Molybdenite-quartz
	A. 1.granodiorite-porphyry, dacite 2.dacites 3.leucogranite, aplite	Stocks, dikes, stockwork, coarse rubbled eruptive breccia	Breccia, gently sheeting, vertical inclined, subhorizontal, injection	Chalcopyrite-pyrite-quartz, Superimposed bornite-chalcocite-covellitic
Before mineralization	Quartz-K-feldspar metasomatosis	Gently and steeply dipping fractures, bulk metasomatosis		Locally chalcopyrite

(Taken from Gavrilova et al., 1989)

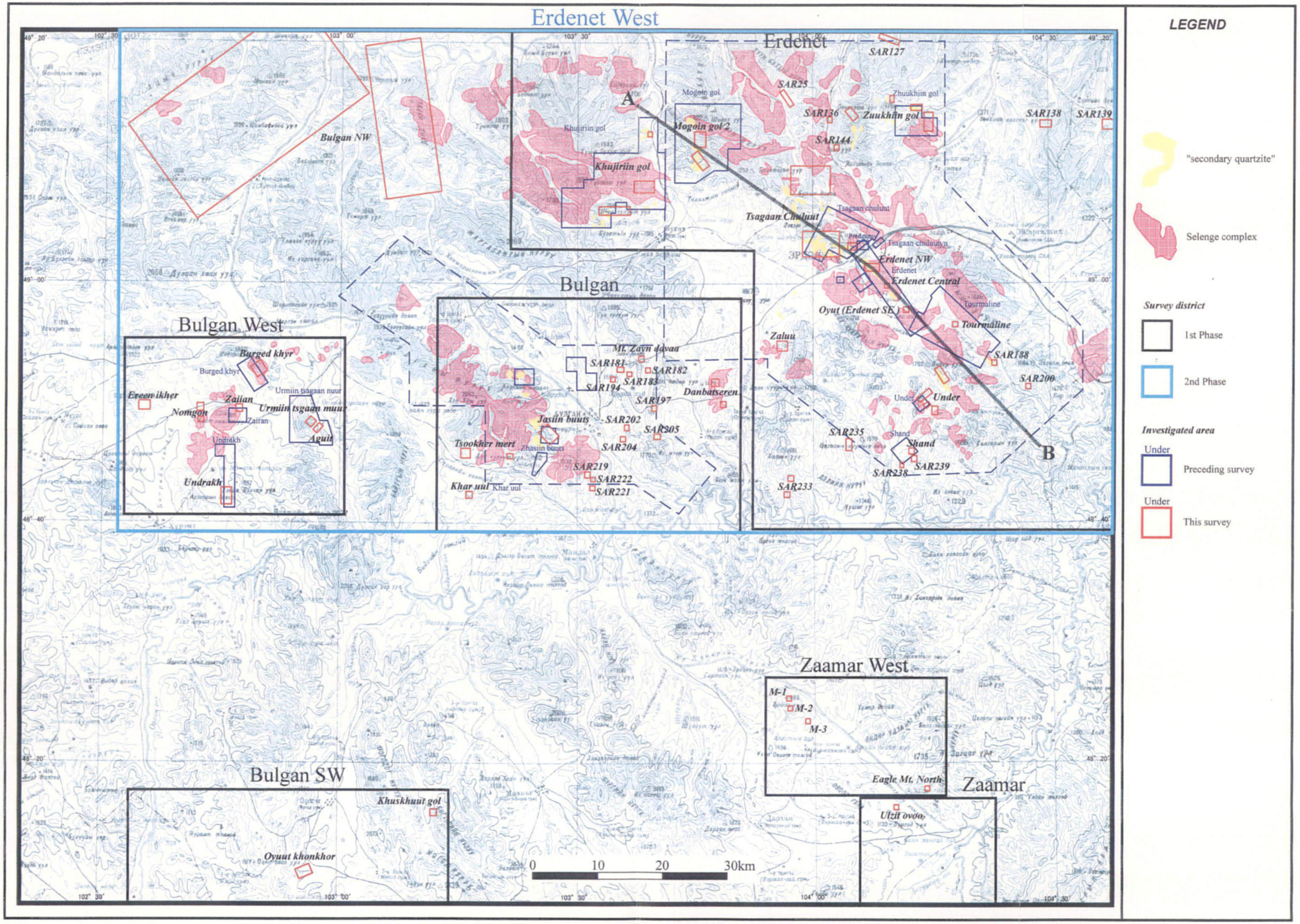


Fig. I-3-10 Distribution of "secondary quartzite" and Selenge complex in the Erdenet West district

Strong silicification and greisenization occur at the center.

Among the deposits, currently operating one is the Northwest deposit, which is the second from the northwest extremity. Within the ore body, the oxidized/leached zone occurs near the surface, the secondary enrichment zone that comprises chalcocite, bornite, covelline and oxide copper occurs underneath the former, and further downwards the primary zone occurs, which comprises chalcopyrite, bornite and pyrie with a minor amount of molybdenite. The oxidized/leached zone has already been stripped, and at present open pit mining is being carried on within the secondary enrichment zone.

(3) Unique alteration observed in the Erdenet West area

An alteration type described as "secondary quartzite" is widely observed in the geologic map prepared by MRAM that covers the proximity of the Erdenet ore deposits (Fig.1-3-10). According to Sillitoe(1995) the "secondary quartzite" is a geologic term often used in the former Soviet block and is a synonym of "advanced argillic alteration" in a porphyry system. He mentions that attention should be paid to this alteration in regard to the exploration for deposits related with a porphyry system. In our present study we have tried to reveal its distribution, as well mineralogical and geochemical characteristics with regard to evaluation of a porphyry system.

(3-1) Definition of "secondary quartzite"

According to a Russian dictionary (Геологиуеский), the "secondary quartzite" is defined as follows.

The "secondary quartzite" is an alteration product by hydrothermal or mesothermal origin. Its principal constituent minerals are quartz, sericite, alunite, pyrophyllite, andalusite and diaspore and its accessory minerals are corundum, dumortierite, topaz and tourmaline. Besides these, rutile, pyrite and hematite are sometimes contained. It is sometimes called "alumoquartzite, when it contains more aluminous minerals than quartz.

The "secondary quartzite" was formed being accompanied by acidic rocks, and rarely by alkaline rocks. Although it is very rare, sometimes the rock was formed being accompanied by the sedimentary and metamorphic rocks that were placed under the hydrothermal condition. Korjinsky (1954) considered that the "secondary quartzite" had been formed by the contact leaching which subvolcanic intrusion of granitic rocks brought and that the leaching had occurred near the boundary between the intrusives and host rocks(cap of volcanic rocks). On the other hand, Nakovnic (1954) considered that the "secondary quartzite" had been formed related with volcanic rocks on and near the surface

Other than these theories, the "secondary quartzite" is believed to be related with the non-metallic deposits such as alunite, pyrophyllite, andalusite and so forth, and with the metallic deposits such as gold, copper-molybdenum, polymetallic and copper-pyrite.

(3-2) Characteristic features of lithocap

The lithocap is an alteration zone defined by Sillitoe(1995), which is approximately equivalent to the "advanced argillic alteration" of a porphyry system that occurs at a shallow depths.(Fig.1-3-11). Its characteristic features and genesis are thought as follows.

The lithocap comprises advanced argillic alteration at its center and argillic alteration at its periphery, and was formed between the paleo-surface and an intrusive body at shallow depths. At the center of the advanced argillic alteration, chalcedonic quartz and crystalline alunite occur. Towards its periphery, kaolinite, dickite, sericite, pyrophyllite and diaspore become to occur, and also minor amounts of zunyite, dumortierite and topaz become to precipitate as well. In the ledge at the upper part of the lithocap, porous residuals and vuggy silica predominantly occur. At a place where the hydrothermal fluid activity was comparatively strong, there the ledge is observed to comprise quartz and alunite, and to accompany hydrothermal breccia .

Principal constituent sulfide minerals of the lithocap are pyrite and marcasite. The portion where gold, silver and copper are concentrated is characterized by the presence of enargite and luzonite, and is observed in residual silica and breccia .

The lithocap is formed by the reaction of the strongly acid and oxidized fluid with the rocks that occur at the upper part of a mineralized subvolanic body. The acid fluid is formed by contact of magmatic volatile components that contains SO^2 and HCl with porous rocks or their mixing with meteoric water. The fluid rich in sulfates formed alunite, while the fluid rich in halogens formed zunyite and topaz.

The regional extent of lithocap is developed by the lateral flow of the acid fluid that flows following the hydraulic gradient within a volcano.

(3-3) Comparison of lithocap and "secondary quartzite"

Comparison of the definition of the "secondary quartzite" with the characteristic features of the lithocap mentioned above indicates that both of them are the alteration products originated from acid hydrothermal fluid. From their constituent minerals and occurrences, the "seconday quartzite" is regarded as an equivalent of the lithocap defined by Sillitoe (1995) . Therefore it is necessary to investigate the "secondary quartzite" as a shallow expression of a porphyry system. However, not all the "secondary quartzite" described in the investigated area are equivalent to the lithocap. Therefore, it is required to decide whether it is a true equivalent or not, from both its occurrence in the field and mineral assemblage determined by the laboratory tests.

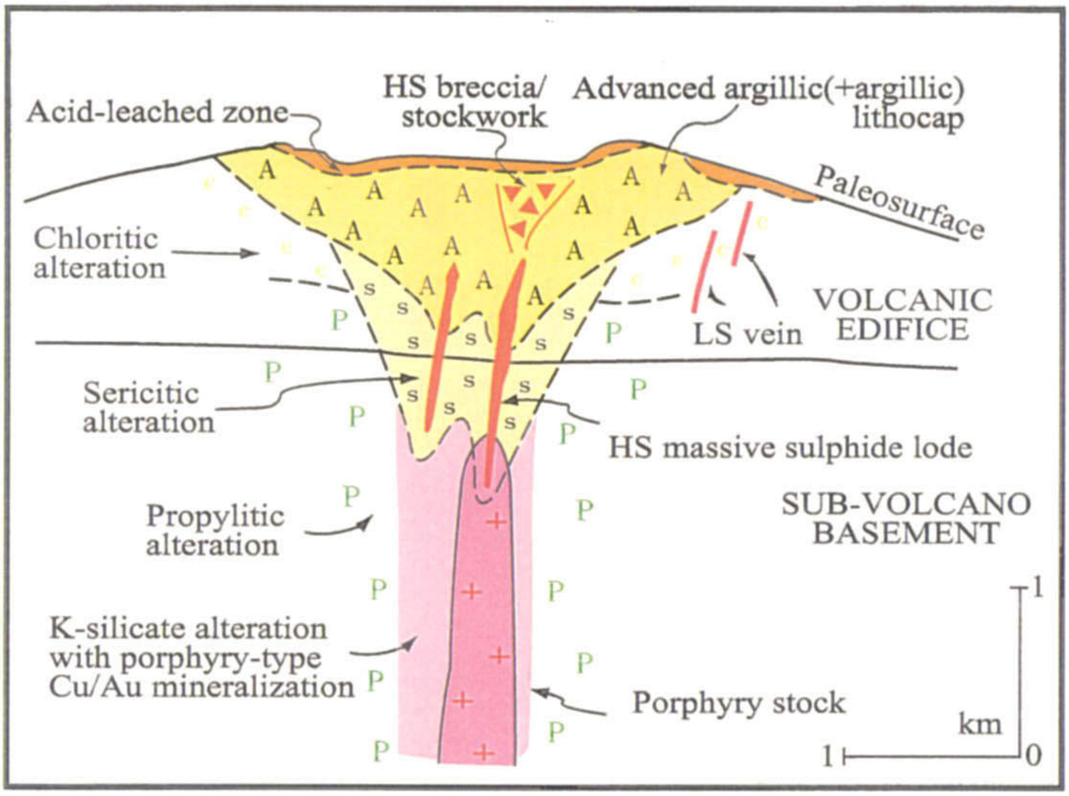


Fig. I-3-11 Idealized advanced argillic alteration (lithocap) and underlying porphyry Cu/Au deposit taken from Sillitoe 1995

3.3 Recent mining industry

The Guide to the geology and mineral resources of Mongolia (1996) and Japan Mining Engineering Center for International Cooperation (1998) gives full information about the recent mining industry of Mongolia. On the basis of them and with some data obtained afterward, an outline of the mining industry of Mongolia is reviewed as follows.

3.3.1 History of mining industry

In general, the history of the mining industry of Mongolia can be divided into three periods: the period before socialism, the period during socialism and the period from democratization onward. When looking into the history, it is understandable that the foundation of the Mongolian mining industry was built up during the period of socialism.

(1) Before socialism (-1923)
1901: Exploitation of gold began.
1912: Exploitation of coal began.

(2) During socialism (1924 - 1989)
1939: Systematic geological surveys and mineral exploration under cooperation of the former Soviet Union and eastern European countries began.
1940s: Activities of the modern mineral industry began.
1943 -: 1948: Operation of tungsten mines (Yugzur, Tumentsogt and Burentsogt) began.
Exploitation of fluorite began.
1950: Development of Zuunbayan oil field began (Mongol-oil).
Note: Since its reserves are small, its production was stopped in mid-1960s.
1970s - 1980s:
- The mining industry developed greatly owing to the financial and technical support by Council of Mutual Economic Association (CMEA) of COMECON countries. During this period, a large scale development of copper and fluorite began.
- The deposits developed during this period were Modot placer tin deposit, Tolgoit placer gold deposit, Khajuu-Ulaan/Khar-Airag/Urgen/Chuluut Tsagann del/Bor-Undur/Berkh fluorite deposit, Erdenet copper- molybdenum deposit and Baganuur coal deposit.

(3) From democratization onward (since 1989)
1989: With the transition to the democratization and the market economy, foreign investments were introduced to the mineral occurrenceing and mine development.

1994: New Mining Law was enacted.

1997: New Mining Law (Revised edition) was enacted.

3.3.2 Mining in general

Major metals and minerals of Mongolia are summarized below.

Table I-3-7 Production of Cu, Mo and Au in Mongolia

	1990	1991	1992	1993	1994	1995	1996	1997
Cu in Concentrate (10^3t)	123.9	90.1	104.6	117	120.2	121.9	123.04	124.4
Mo in Concentrate (t)	1978	1747	1540	2053	2066	1823	2202	1992.3
Au (kg)	810.8	722.6	775.6	1117	1789.5	4080	5997.8	8000

(1) Gold

Many gold deposits were discovered in early 1900s in North Khentiy area (eastern Khentiy Province) where is the major gold producing area in the 20th century. Between 1909 and 1919, a Mongol-Russia joint venture which was called "Mongolor" produced 9.3 t of gold from the Irogol placer deposit. Its production had been once stopped due to political reasons, but for four years from 1939, 693 kg of gold was produced in Bayankhongor district (Bayankhongor Province, Gobi desert). Up to 1970s digging was conducted with man power.

For the first time in 1974, a Mongol-Russia joint venture (Mongol Ros Tsvetmet) conducted mining with dredge at Tolgoit placer deposit and produced about 10 t of gold in North Khentiy Province. In 1984 the Mongolian Government began a joint venture with Bulgaria in Bayankhongor district and produced 1 t of gold between 1984 and 1990. In North Khentiy area between 1990 and 1993 after democratization, Mongolian mining companies produced 1 t of gold in total.

The amount of gold produced since 1990 is shown in Table I-3-7. Gold production in

1997 became 7 times as large as that in 1993. Gold production in 1998 was 9.9 t and that in 1999 was expected to be 11t (Mining Journal, November 12, 1999). The accumulated production of gold in Mongolia up to 1995 was 23.5 t, of which nearly 95 % was produced from placer deposits. Major placer deposits under operation at present are located in Zaamar district (Tov Province).

(2-1) Copper

The most important deposit type in copper production in Mongolia is the porphyry type copper/molybdenum deposit, and the Erdenet mine is being operated at present..

(a) Erdenet Mine

The Erdenet mine is located 165 km west-southwest of Darkhan (Bulgan Province) and is being operated by Erdenet Mining Corporation, which is a Mongolia-Russia joint venture (share: Mongolia 51 %, Russia 49 %). Total number of mine workers is 7,000 and 22.6 million t of ores were mined in 1998 (0.695 % Cu, 0.021 % Mo. Cu content: 126,000 t, mill recovery 82.5 %). In 1999, 22 million t of ores were scheduled to be produced (0.695 % Cu, 0.019 % Mo, Cu content: 126,000t, mill recovery 82.5 %). Due to low copper price and decrease of ore grades and so forth, the operation of the mine faces some difficulties at present.

[History of Exploration and Development]

In 1941, outcrops of the minerealized zone in Erdenet area were first described by Soviet geologists. Between 1958 and 1959, they compiled a 1:500,000 geologic map of this area. Between 1964 and 1969 a joint study by Czechoslovakia and Mongolia was carried out, which included detailed geological mapping, geophysical survey (SP, IP and resistivity), geochemical survey and drillings. As a result, 512 million t of ore reserves with 0.84 % Cu and 0.016 % Mo were outlined. Between 1971 and 1972, the feasibility study was carried out by the USSR/Mongolia joint team, and in 1973 an agreement for joint development was concluded between the two governments. Construction of mine facilities started in 1974 and operation commenced in 1978 with a production rate of 4 million t ore/y .

[Geology]

In the vicinity of the mine, volcanic and sedimentary rocks of the early Permian and Selenge complex (granite, grandiorite, syenite, diorite, gabbro and others) of the late Permian widely distribute, the latter of which intruded the former.

In a central zone of upheaval caused by the intrusion of the Selenge complex, the Erdenet porphyritic intrusive complex (granite porphyry and granodiorite porphyry) of the late Permian to early Triassic intruded at the intersection of tectonic lines of NW-SE, N-S and E-W trends to bring the copper/molybdenum mineralization. Five mineralized zones (deposits) distribute in an area some 22 km by 1.5 km that extends in a NW-SE direction

Currently the Northwest deposit, which is the second mineralized zone from the northwest extremity is being mined. In the deposit, the oxidized/leached zone occurs near the surface, under which the secondary enrichment zone that comprises chalcocite, bornite, covelline, copper and so forth occurs. Further downwards, the primary sulfide zone occurs, which comprises chalcopyrite, bornite , pyrite and a minor amount of molybdenite.

[Open pit]

Operation is being carried on 3 shifts/day(8h/shift), 7 days /week and 365 days/y. Dimension of the pit is 2.5 km (NW-SE) by 1.5 km (NE-SW) at present. The highest point of the original topography in the pit was 1,605 m above sea level and the lowest working bench is 1,340 m asl at present. The bench height is 15 m

25 haulage trucks of 3 types are being used: (2 x 78 t Komatsu, 3 x 136 t Mitsubishi /Caterpillar, and 20 x 125 t Russian Belaz).

[SX-EW (solvent extraction/electrowinning) plant]

Under the joint venture of the USA and Mongolia, the plant has been operated since June 1997. Oxide ores and waste from the open pit (below cutoff grade 0.25% Cu) and tailing from the mill are being processed by heap leach: Materials are stacked and irrigated with dilute sulfuric acid. The resulting copper laden liquor (CuSO4) is mixed with an organic solvent such as Kerosene to thicken copper content. The copper is transferred into solution once again, which is put under electrolysis. The cathode is made of stainless steel and the anode is lead. Copper plated onto the anode is stripped once a week. 8 tons of electric copper grading 99.99 % Cu are produced per day.

[Mill plant]

Sulfide ores are processed at the mill: 3 stages of crushing and grinding are adopted. Flotation is carried out using flotators made in India, China, Russia and Finland (Outokumpu).

Copper concentrate (28-30 % Cu, recovery: 82.5 %) and molybdenum concentrate (50 %, Mo recovery: 45 %) are recovered by flotation.

(2-2) Other copper deposits

The Tsagaan Suvarga porphyry type copper and molybdenum deposit is located 164 km southwest of the Zuun bayan railway station in Dorngovi Province, southeastern part of Mongolia. Its mineable reserves are estimated at 220 to 240 nillion t with 0.54 % Cu and 0.19 % Mo.

The Oyut tolgoi porphyry type copper and gold deposit is located in Omnogoh aimag 80 km north from the border of China. Recently BHP reported around 750 million tons of copper ore was discovered.

Mineralizations of skarn type (with chalcopyrite), copper-nickel type and sandstone copper type are known, but no sufficient study has been carried out as yet.

(3) Fluorite

In 1946 production of fluorite started in Berh district. Around the middle of 1970s a Mongolia-USSR joint survey team which was called "Mongolsovtsvetmet" was organized. From 1980 a Mongolia-Czechoslovakia joint business entity had made efforts to increase the production efficiency and the output in the year of 1989 was 1 Mt.

Currently fluorite is produced in districts of Berh, Har-Airag, Urgen, Chuluut tsagaan del and Bor-Ondor, respectively. The largest scale among them is Bon-Ondor which is being operated by "Mongolsovtsvetmet". At the open pit 400,000 t of 31-34 % fluorite is produced annually. The reserves of fluorite in Mongolia, 18.4 Mt, rank fifth in the world. Its output in recent years occupies 4 % of the world production.

(4) Phosphorite

The surroundings of Lake Khuvsgul in the northern central part of Mongolia has high phosphorite potential and its reserves are estimated to be 2,400 Mt. Since environmental deterioration in the surroundings which might occur with the operation is deeply concerned, start of the development is still pending.

(5) Coal

In Mongolia, more than two hundred coal deposits and occurrences have been found in ten sedimentary basins. 20 % of 50,000 Mt reserves in total is hard coal and 80 % is brown coal. Forty-two deposits of them have been investigated and proved reserve was 3,000 Mt.

Production in a comparatively large scale is carried out in four coal fields, Baganuur, Sharyngol, Shivee Ovoo and Nalaikh. Baganuur coal field, 125 km eastward of Ulaanbartar, produces about 4 t of brown coal annually. Sharyngol coal field, 240 km northward of Ulaanbaartar, produces about 1.5 Mt annually. Shivee Ovoo coal field, 240 km southward of Ulaanbartaar, produces 500,000 t annually. In Tavantolgoi coal field, 540 km southward of Ulaanbaartar, 1,500 Mt of raw coal and 3,500 Mt of steam coal have been proved for reserves.

(6) Petroleum

Many oil showings have been discovered by explorations which took place during the period of more than sixty years. Zuunbayan field was found in 1941 and the Mongolian-Russian joint venture conducted exploration and development. After that, in major sedimentary basins of Mongolia, preliminary geological surveys and geophysical exploration have been conducted.

Between 1989 and 1990, a national petroleum company named Mongol Gazryn Tos (MGT) with BP Company and Phillips Petroleum Company re-estimated results of exploration conducted in early days. In 1991 and 1992 exploration took place in eastern, central and southern parts of Mongolia. In 1993, for the development of Zuunbayan and Tsagaan Els field, MGT and Nexcor Energy of the USA concluded a contract on distribution of the product.

In 1994 Mongolian government gave the permission of exploration in the eastern Mongolia to Snider Oil Corporation. The Corporation drilled four holes from 1995 to 1996 and proved 500 to 1,000 Mbbl of recoverable crude oil.

3.3.3 Mining law and mining concession

In 1989 Mongolia was democratized and shifted to the market economy, and at the same time it began to accept investment of foreign capitals for exploration and mining. In September 1994 the government enacted new Mining Law and revised it in April 1995. The new Mining Law was further modified in 1997, enacted as Mining Law (revised version) and executed in July of the same year.

The present Mining Law (English version) is accessible by Internet web site (http:// www.mram.mn). In the Reports for Evaluation and the Research of Development Project of Mongolia in Fiscal 1997 (Japan Mining Engineering Center for International Cooperation, 1998), whole provisions of the Mining Law is also described. Outlines of the Minin law is summarized in a report of Mineral Resources Authority of Mongolia (1999).

3.3.4 Recent activity of exploration and development

The recent exploration activity in Mongolia is summarized as follows.

Exploration activity in Mongolia reached the peak in 1997. Currently exploration expenditure by foreign mining company has reduced to a half of the peak. Due to the stagnant market, exploration activities have decreased sharply all over the world, which has affected Mongolia also. Expenditure in exploration in Mongolia in the last three years is shown below:

- 1997: US$20 million
- 1998: US$10 million
- 1999: US$ 8 million

Overseas mining companies which are performing exploration activities in Mongolia at present are five which are listed below:

- Harrods Minerals Ltd. (USA) at eastern and southern Gobi

- Troy Resources NL (Australia) took over exploration by Rio Tinto
- Quincunx (Canada) hold concession of gold in the central Gobi
- Cascadia (Canada) at northern part of Mongolia
- BHP (Australia) at southern Gobi
- China starts developping Zn deposit at Uudam tal district

Chapter 4 Outline of Survey Results

4.1 Analysis of the existing data

In Mongolia, the data concerning the domestic geology, ore deposits and prospecting had been solely controlled by the government before its economy was converted into a market economy in 1991, but the control of the data, especially that of the wide area data, are still solely controlled by the government. The existing data were collected from Geology and Geological Information Center of the Mineral Resources Authority, the Ministry of Trade and Industry of Mongolia. The information on the geology and the ore deposits in the vicinity of Erdenet mine was obtained from the mine. The information was also obtained as far as possible from the retired mining engineers of the mine and the technical staffs of the Geological Information Center through the direct hearing from them. Further, the published literatures were retrieved through the JICST. The geological maps in 1:50,000 scale and 1:200,000 scale covering the surveyed area and the survey report are almost completely available, and the data sheets of the ore deposits and mineral occurrences prepared by the government of Mongolia are also available. In the site, the information on mineral occurrences was analyzed and integrated based on the previously digitized geological map in 1:50,000 scale and the GIS software (Arc View of ESRI Corp.), and the obtained data was studied together with the existing geological data and the SAR image which had been prepared based on the result of the present research project to select mineral occurrences and districts to be checked.

4.2 Analysis of satellite images

There is a wide distribution of the coniferous forests called taiga in the survey area, and is usually covered with the snow and the ice for a long period of a year since being situated in a cold district. Being under such geological condition, it was hard to obtain effective remote sensing data via optical sensor such as LANDSAT TM and the like. For this reason, the satellite image was analyzed according to the SAR (Synthetic Aperture Radar) data of the JERS-1.

The JERS-1/SAR data covering the survey area (200,000 km^2) comprises 130 scenes in total, and the mosaic image based on this data was produced according to the procedure given below. First, the SAR data was processed for the bit conversion, trend correction, calculation of relative position, scene conjunction and adjustment of gray level to complete a digital mosaic image. Next, the digital mosaic image and the topographic map were compared to assign a geographical coordinates system to the image. Images were cut out into a sheet of 1° in north-south by 1.5 ° in east-west. Finally, the individual images (22sheets in total) were stitched to make a mosaic image covering the subject area. Each image was prepared into a drawing in 1:200,000 scale, while the mosaic image covering the whole area was prepared into an image of 1:1,000,000 scale.

The image was interpreted and analyzed in terms of the division into geologic unit, interpretation and analysis of the geologic structure including the lineament. In dividing the area into the geologic units, criteria were established in terms of the photographic characteristic and the topographic characteristic, which are the elements of the photogeologic interpretation, but the importance was attached to the resistivity to the erosion and the density of the drainage systems for the topographic characteristic. Further, for the interpretation and the analysis of the geologic structure, the lineament (including the dislocation) and the ring structure were sampled.

The result of the analysis and the distribution of mineral occurrences were compared, and the 6 districts given below were selected as the areas of interest in terms of the analysis of the SAR image.

(1) Central to southern parts "Reshaant", "Hutag", "Bulgan" image sheets.,

Commodity: Copper and gold.

Occurrence: Porphyry type and vein type.

Fracture: NW-SE direction

Others: Neighboring part of the Egiyn River flowing the central part of the area, and the ring structure lying in the southeastern part of the area shown in the "Hutag" image sheet were selected as the areas of interest.

(2) Southern part Southern part shown in "Jarganant" image sheet

Comodity: Copper.

Occurrence: Stockwork and quartz vein

Ring structure: Existing in hilly area, with caldera-like depression at the center being observable.

(3) Central part Southern part shown in "Altraga" image sheet

Commodity: Gold and copper.

Occurrence: Stockwork and quartz vein.

Fracture: E-W direction, NE-SW direction, high density.

Others: There are ring structures, up to about 6 km in diameter, lying in northeastern part to southwestern part (granitic rocks belonging to the Devonian).

(4) Southern central part Northern part shown in "Tosontsengel" image sheet

Commodity: Gold, copper and molybdenum

Occurrence: Stockwork and quartz vein

Fracture: Fracture in E-W direction and derivative fractures

Others: Existing of ring structure, 10 km in diameter (Granitic rocks belonging to the Lower Proterozoic and the Devonian)

(5) Southeastern part Southeastern part shown in "Dzurh" image sheet

Commodity: Copper

Occurrence: Stockwork and quartz vein

Fracture: Intersection of fracture in E-W direction and fracture in N-S direction.

Others: Fracture zone in N-S direction is formed with the fractures in NW-SE direction and NE-SW direction.

(6) Northern Central Southern part shown in "Hatgal" image sheet

Commodity: Gold and copper

Occurrence: Fracture, skarn, greisen, stockwork and quartz vein.

Fracture: Intersection of the fracture zones in NE-SW and NW-SE directions.

Others: There is a concentration of indefinite ring structures, less than 5 km in diameter. (Granitic rocks belonging to the Lower Proterozoic)

4.3 Ground truth

According to the results of the analyses of the existing data, the analysis of the satellite image, hearing the opinions of the counterparts, selection of the prospective spots of the ground truth from the state of access, 13 districts and 80 mineral occurrences/points were selected and conducted ground truth in the first year survey and 8 districts and 35 mineral occurrences/points in the second-year survey respectively.

The data and samples collected through the surveys of various mineral occurrences/points have been analyzed, and the results thereof have been made up into the reports such as those of "Representative latitude and longitude", " Topography and vegetation", "Infrastructure and access", "Preceding survey", "Geology and structure", "Mineralization and alterations", "Laboratory Test" and "Evaluations" as the data for evaluating the potentiality the existence of ore deposits and rooms for further exploration.

4.4 Geological structure and mineralization

In studying the genesis of the ore deposit, it is important to understand the development of the geological structure of the area concerned. However, the development of the geological structure in Mongolia has not been clarified in detail so far, and there is different opinions to discuss. For instance, the geologic bodies are sometimes classified into the Terrane (Unit), but, at present, there are different opinions of different researchers. Therefore, we have estimated the prospective ore deposits within the survey area in terms of the kinds and types of mineral occurrences distributed in the survey area , based on the classification by Sengor et al., 1996, which was published relatively recently and summarized in Chapter 1 Overview. Concerning the types of the ore deposits, the ore types proposed by USGS and Geological Survey of British Columbia were referred.

The geology in Mongolia is characterized by a series of orogenic movements (Sengor et al., 1996) including (1) the formation of accretionary prism in the peripheral area of the continent and the activity of the island arc magmatism, (2) collision of the Siberian craton and Sino-Korean massif and (3) formation of stable massif, and so the formations of various types of ore deposits occurred during this process of geologic development are expected. The geological features and distribution of the Terrane (Unit) known in the survey area, and the types of ore deposits and the kinds of ores expected existence are given below

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(1) Darkhat Unit and Sangilen Unit

[Distribution in the survey area]

Darkhat Unit and Sangilen Unit distributes in the northern part of Vitim Suture and the west side of Khuvsugl Lake where is located in the northern part of the survey area.

[Outline of the geology]

The geology consists of a continental crust of Pre-Baikald and the Riphean magma arc-accretionary prism complex. Further, the geology also comprises the gneiss, schist belonging to the Lower Precambrian, which forms a basement, basalt, rhyolite, tuff and terrigenous sediment, which were produced from the magma arc of the Riphean. There are distributions of the shallow marine limestone, dolomite, phosphate rock, bauxite and the calcic flysch belonging to the Medium to the Cambrian, which irregularly cover previously mentioned geologic constituents. There distribute the metamorphic rock of the green schist facies and the ophiolite in the eastern part of the Unit, which is considered to be accretionary prism complex accompanying the subduction. In the southern part of the Unit, there observed the activity of the granitic rocks belonging to the Lower Paleozoic.

[Expected ore deposit]

The list of the known mineral occurrences/points includes the mineral occurrences of gold, copper, tungsten, molybdenum, nickel, chromium, etc., and this indicates that there are possibilities of the existences of nickel, chromium and platinum group ore deposits relating to the ultrabasic rock in the ophiolite and the pegmatite ore deposit relating to the granitic rocks which were active during the Lower Paleozoic.

(2) Dzhida Unit

[Distribution in the survey area]

Dzhida Unit distributes in the eastern side of the Khuvsugal Lake in the northern part of the survey area.

[Outline of the geology]

The Dzhida Unit consists of the magma arc and accretionary prism belonging to the Lower Paleozoic. There are distributions of the island arc basalt and the boninite covering the ophiolite, which is the magma arc belonging to the Vendian to the Lower Cambrian. These geologic constituents are further covered with basalt, andesite, rhyolite, tuff, sandstone and calcic rock. Accretionary prism includes ophiolite, turbidite, chert and a tectonic block consisting of turbidite and reef limestone.There are distributions of granitic rocks, which were active during the Lower to Upper Paleozoic in this southern part of the Unit.

[Mineral occurrences/points]

Since the presence of the magma arc formed during the period ranging from the Upper Proterozoic to the Palaeozoic was observed, the existences of nickel, chromium and platinum group ore deposits can be expected. Further, the Tavt ore deposits situated in this Unit, and there is the possibility that the vein type gold and copper deposits occur within the distribution area of granitic rocks, which were active during the Middle to the Upper Paleozoic.

(3) Tuva-Mongol Unit

[Distribution in the survey area]

Tuva-Mongol Unit distributes widely in the southern part of Vitim Suture and the central-southern parts of the survey area.

[Outline of the geology]

Tuva-Mongol Unit comprises the continental crust prior to the formation of Altaids and magma arc belonging to the Vendian to the Permian. The continental crust forming basement of the island arc comprises migmatite similar to Angara craton, grranitie, anorthosite, granulite, etc. Further, there is the distribution of the high grade metamorphic rock belonging to the Archean, which was divided by ophiolite during the Vendian to the Lower Cambrian. The magma arc comprises ophiolite of the Vendian to the Lower Cambrian and the island arc volcanic rock of the Riphean. In the central to western parts of the survey area, there are wide distributions of crushed rocks and volcanic rocks of the Lower to the Middle Paleozoic, and alkali-calc alkalic granitic rocks of the Lower to the Middle Paleozoic. In the eastern to central parts of the survey area, the distribution of sediment rocks and volcanic rocks of the Middle to the Upper Paleozoic is predominant, although there is also the distribution of calc-alkali granitic rocks of the Upper

Palaeozoic. Concerning the origin of this Unit, there is an interpretation that the collision of the micro continents formed the micro continent of the Tuva-Mongol, while accretionary prism and the magma arc developed with the development of the subduction along the periphery of the Tuva-Mongol micro continent (Tumurtogoo, 1996).

[Mineral occurrences/points]

In the central to western parts of the survey area, the existences of the porphyry type, vein type and skarn type copper-molybdenum, lead-zinc and gold deposits relating to granitic rocks which were active during the Lower to the Middle Paleozoic are expected.In the central to eastern parts of the survey area, because of Erdenet deposit being located therein, the existence of the porphyry type copper-molybdenum deposit relating to granitic rocks which were active during the Permian to the Triassic can be expected. Further, the existences of the high sulfidation and low sulfidation type epithermal gold deposit, polymetallic vein type deposit and skarn type deposit can also be expected.

(4) Khangay-Khentiey Unit

[Distribution in the survey area]

Khangay-Khentiey Unit distributes in the southeastern end to southern end in the survey area .

[Outline of the geology]

Khangay-Khentiey Unit consists of accretionary prism and the magma arc. The unit comprises ophiolite, serpentinite mélange, chert, limestone and shale of the Upper Riphean(?) to the Lower Cambrian; turbidite, basic-neutral volcanic rock, tuff and chert of the Lower Paleozic to the Carboniferous; turbidite, gabbro and basalt of the Carboniferous to the Triassic. There observed the existence of fragments of some island arcs, the fragments having polarity becoming younger towards the northeastern direction.This Unit shows the evidences of its activity of the granitic rocks during the Permian, the Triassic and the Jurassic.

[Mineral occurrences/points]

As the Zaamar gold deposit is situated in this Unit, the existence of the vein type gold deposit relating to plutonic rock accompanying the activity of granitic rocks is expected, and the existence of porphyritic type ore deposit and skarn type ore deposit can also be expected.

4.5 Potentiality of mineral deposits and selection of promising districts, and mineral occurrences/points

(1) Potentiality of existence of ore deposits

The Geological evolution of Mongolian is characterized by the formation of magmatic arc and accretionary prism since the Vendian, and collision of the Angaraa Craton and Northern China Craton afterwards (e.g., Sengor et al., 1996). Regionally, the survey area is consisted with remnants of various kinds phenomena happened at plate convergence area. It is expected that various types of ore deposit formed in the plate convergence area such as porphyry type copper, gold, and molybdenum deposits, skarn type copper, lead, and zinc deposits, epithermal type gold ore deposits, pluton-related gold deposits, and *kuroko* discovered under the tectonic environment of magmatic arc. Also, Cyprus type copper deposits and chromium/platinum group deposits may be expected in ophiolite under the such tectonic environment as an accretionary prism (Mitchell and Garson, 1981). Main deposit types in the survey area are porphyry type copper/molybdenum deposits, skarn type copper/lead/zinc deposits, epithermal type gold deposits, skarn type copper gold deposits, and pluton-related gold deposits. The potential of each ore deposit type is described below.

①Porphyry type copper/molybdenum deposit

A typical deposit of the survey area is the Erdenet deposit. The mineral occurrences related to this type of mineralization are the Tsagaan chuluut, Mogoin gol 2, Zuukhiin gol, Danbatseren, Tourmaline, Shand, Oyut, and Undrakh mineral occurrences in the Erdenet West district and the Naranbulag mineral occurrence in the Tososntsengel district. The Erdenet West district belongs to the Tuva – Mongol unit consisting of volcanic arc igneous rocks. Volcanic rock and granite classified as calc-alkaline rock of the Permian to Triassic are distributed over the Erdnet West district, which satisfies the tectonic environment which forms porphyry copper/molybdenum deposits.

The formation of the Erdenet deposit is considered to have accompanied the Erdenet porphyritic intrusion complex that intruded into the Selenge complex.
The radioactivity ages of the Erdenet Porphyritic Intrusion Complex and the Erdenet deposit range between 196 ± 4 and 253 ± 28 Ma and 202 ± 4 and 240 ± 0.8, respectively (Figure I-4-1). In particular, magmatic activity in this period is thought to be important for formation of mineralization.

The Erdenet deposit consists of the Erdenet NW deposit in operation, the untapped Erdenet Central deposit, the Oyut (Erdenet SE) mineralized zone, the Intermediate mineralized zone, and the Tsagaan chuluut mineral occurrence, which are distributed in the NW-SE direction. Macroscopically, the Selenge complex including the Mogoin gol 2, Khujiriin gol, Tourmaline, Danbatseren, and Shand mineral occurrences are also distributed in the NW-SE direction like the Erdenet deposit.

In porphyry systems, it is generally thought that a hydrothermal system that formed porphyry type deposits forms advanced argillic alteration (lithocap) at shallow depth. High sulfidation type gold deposits are formed inside it and porphyry deposits are formed at deep

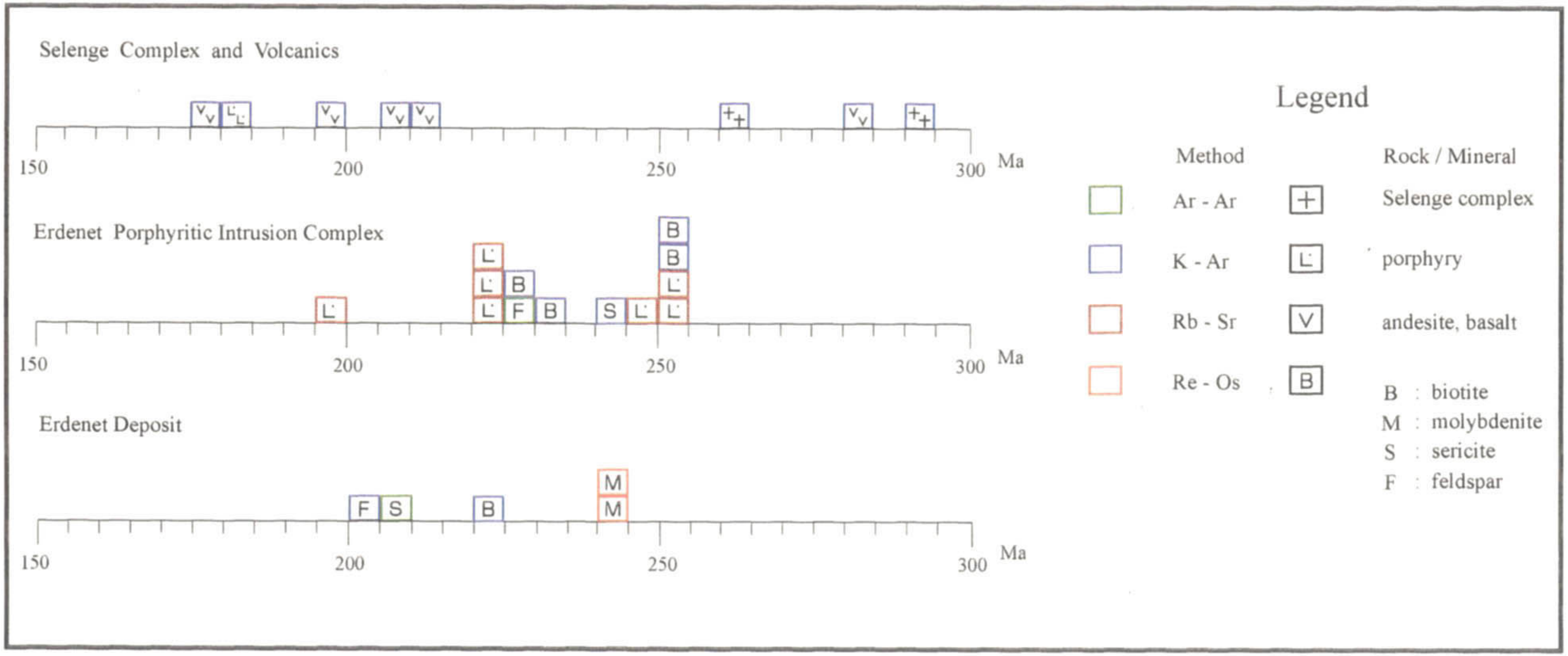

Fig. I-4-1 Radiometric age of Selenge complex, Erdenet porphyritic intrusion complex and Erdenet deposit (taken from Sotnikovetal., 1995; Berzina et al., 1999; Watanabe and Stein, 2000; JICA-MMAJ, 2000) depth (Figure I-3-11). Consequently, if there is little denudation of the magmatic hydrothermal system, advanced argillic alteration remains at present surface. If the denudation advances, the porphyry deposits itself eventually crops out. Since the denudation of magmatic hydrothermal system has advanced in the Erdenet deposit, the deposit cropped out.

The Erdenet deposit is considered to be inclined toward the northwest. A "secondary quartzite" corresponding to advanced argillic zone develops in the Tsagaan chuluut and Mogoin gol 2 mineral occurrences in the northwestern part of the Erdenet deposit. Figure I-4-2 shows a conceptual superimposition of porphyry systems over a geologic profile in the NW-SE direction that connects the Erdenet deposit and the Mogoin gol 2 mineral occurrence. Andalusite was identified at some points of the advanced argillic alteration zone in the Mogoin gol 2 mineral occurrence. Compared to the Tsagaan chuluut mineral occurrence, it is assumed that a relatively deep area crops out. Consequently, porphyry type copper/molybdenum deposits and/or high sulfidation type gold deposit are expected to exist below andalusite. The Danabatseren mineral occurrence is situated in the west of the Erdenet deposit. Similarly, the upper part of the advanced argillic alteration zone appears at present surface in the Tsagaan chuluut mineral occurrence and porphyry type copper/molybdenum deposits and/or high sulfidation type gold deposit are expected to exist below the alteration zone.

On the other hand, in the Zuukhiin gol mineral occurrences oxide copper crops out in potassic alteration zone. An ore body for SX-EW is expected to exist at shallow depth. In the Khujiriin gol mineral occurrence, the outcrop of potassic alteration zone is caused by the hydrothermal alteration of another stage because the homozenization temperature of fluid inclusions of quartz veins accompanied with copper oxide were as low as 142 – 239 ℃. For this reason, it was concluded that the Khujiriin gol mineral occurrence is barren of porphyry type copper/molybdenum deposits.

The Tososntsengel district belongs to the Tuva-Mongol unit. Plutonic rock of the Precambrian to the Permian and volcanic rock of the Permian to the Triassic are distributed near the Naranbulag mineral occurrence in this district. Since granite is chemically composed of volcanic arc calc-alkaline, the Tososntsengel district is in a tectonic setting similar to that of the Erdenet West district. Since the granite underwent potassic alteration and copper oxide ore can be seen, it may indicate a relatively deep level of the porphyry system. Like the Zuukhiin gol mineral occurrence, the development into copper oxide deposit in the lower part is expected.

②Skarn type copper/lead/zinc deposit and skarn type gold deposit

The Ulzit ovoo mineral occurrence in the Zaamar district, the Holboo ovoo mineral occurrence in the Uubulan district, the Skarn mineral occurrence in the Altgana gol NW district, the Hurilt gol mineral occurrence in the khokhoo district, 20 a point, and 20 d point are classified as a skarn type copper/lead/zinc deposit in the survey area. Meanwhile, the Teshig

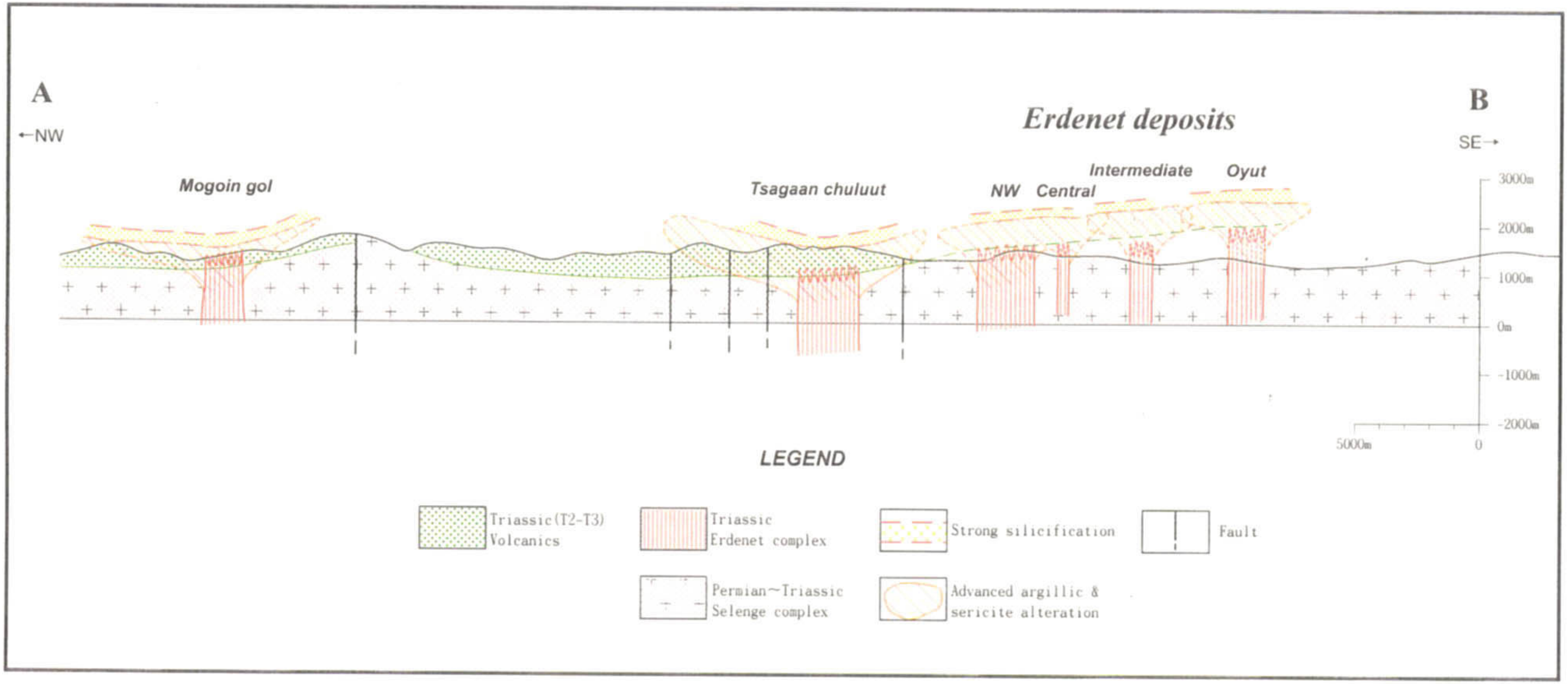

Fig. I-4-2 Geological cross section along the Oyut - Erdenet NW -Tsaggan chullut - Mogoin gol 2 deposits and mineral occurrences in the Erdenet West district mineral occurrence in the Tavt district is classified as a skarn type gold deposit.

The skarn of the Ulzit ovoo mineral occurrence was determined by boring which followed the magnetic exploration and IP method electric exploration. Its extension is not known. A Mongolian private company is now exploring the Teshig prospect and estimates the amount of geologic resources of gold at 4 t. A value of Au: 0.125 – 0.0051 g/t was obtained from the chemical analysis of skarn of the Teshig mineral occurrence in the this survey. Generally speaking, the skarn type mineral occurrences other than the Teshig mineral occurrence are thought to be small scale and some of them could not be discovered even through the field survey. It is concluded that there is little possibility that a deposit having an economic value exists. However, if carbonate rock is distributed near a porphyry system, a skarn deposit is most likely to be formed. In future, it is advisable to pay attention to this point all over the survey area where the plutonic magmatism was active.

③Epithermal gold/silver ore deposit

The Oyuut Khonkhor mineral occurrence in the Bulgan SW district and Tsookher mert mineral occurrence in the Erdenet West district are classified as an epithermal type gold/silver deposit in the survey area. Both of them belong to the Tuva – Mongol unit.

In the Oyuut khonkhor mineral occurrence, 8.8 g/t Au was recorded in brecciated rhyolite through the Mongolian scientific research. Though the gold grade was low, quartz veins (float) and gossans were found in this survey. The extension of silicification/argillization (Sericite > kaolinite) was discovered. Hydrothermal breccia is present. These findings indicate that there was neutral pH > acid hydrothermal activity at least at the present surface level.

On the other hand, in the Tsookher mert mineral occurrence of the Erdenet West district, an analysis value of 285.4 g/t Au was obtained from a quartz veinlet zone (analysis width: 30 cm) in granite through the this survey. In addition, 0.395 – 6.29 g/t Au was obtained from a chip sample. The existence of high grade auriferous quartz vein is expected in granite near this mineral occurrence. In particular, as described above, signs of hydrothermal activity related to the porphyry system remain in the southeastern part of the survey area including the Erdenet West district. It is most likely that this type of gold deposit will exist around that place.

④Plutonic rock related gold ore deposit

The Ereen mineral occurrence of the Tavt district which belongs to the Tuva – Mongol unit is classified as pluton- related gold deposit in the survey area. Numerous gold mineral occurrences are known in the Zaamar massif including Sudal N117 prospect of the Zaamar district. The area along the Tuul River is considered to be an alluvial gold deposit source. In the present survey, Sudal N117 mineral occurrence was considered to be an epithermal ore deposit. However, it is likely to be pluton- related gold deposit because there are few signs of volcanic activity around that area.

The Ereen mineral occurrence has auriferous quarts veins that develop in the shear zones in granite. Within the range of 5 km x 5 km, ten ore bodies of the NE-SE trending system (approximately 100 quartz veins containing gold) are known. In this survey, a value of 54.14 g/t Au has been obtained from a quartz vein chip sample. An existing document describes that the grade ranges between 0.1 g/t Au and 250 g/t Au. According to the Mining Journal (1997), the estimated amount of gold is 100 to 130 tons. A Mongolian private company is now exploring gold. It is reported that the amount of gold in these ore bodies including No. 3 ore body, the major vein, is estimated at 8 tons. The whole area around the Ereen mineral occurrence has a high potential of existence of gold ore deposits, but sufficient survey has not been conducted yet.

⑤Platinum group deposits associated ophiolite

Ultramafic rock that accompanies with ophiolite is distributed in the eastern part of the Khuvsgul Lake (for example, the Altagana gol district and the south camp district selected in this survey) corresponding to the Dzhida unit. Around that place, a small-scale platinum group alluvial deposit originated from the ultramafic rock may exist. Though distant and small in scale, a platinum group deposit of high value can be considered as an important ore deposit type in Mongolia poor in infrastructure because there will be an increasing demand in catalyst in the future.

(2) Selection of promising districts and mineral occurrences/points

With respect to the mineral occurrences/points where ground truth was conducted, ten mineral occurrences were selected as promising ones judging from the tectonic setting, size/dimension and characteristics of alteration and mineralization zone, and multivariate analysis of geochemical data, where further surveys are desirable (Table I-4-1, Figure I-4-3). For evaluation of the selected 103 mineral occurrences/points, refer to Appendix. The mineral occurrences/points selected for further exploration and reasons for their selection are shown as follows.

① Tsagaan chuluut mineral occurrence in Erdenet West district

This is a mineral occurrence adjacent to the Erdenet NW Deposit. Secondary quartzite showing advanced argillic alteration is widely distributed in its vicinity. As a result of geochemical analysis, this mineral occurrence was found to show characteristics of advanced argillic alteration. Although the score of the seventh principal component related to Cu/Mo mineralization is low, the score of the second principal component is high in its correlation with

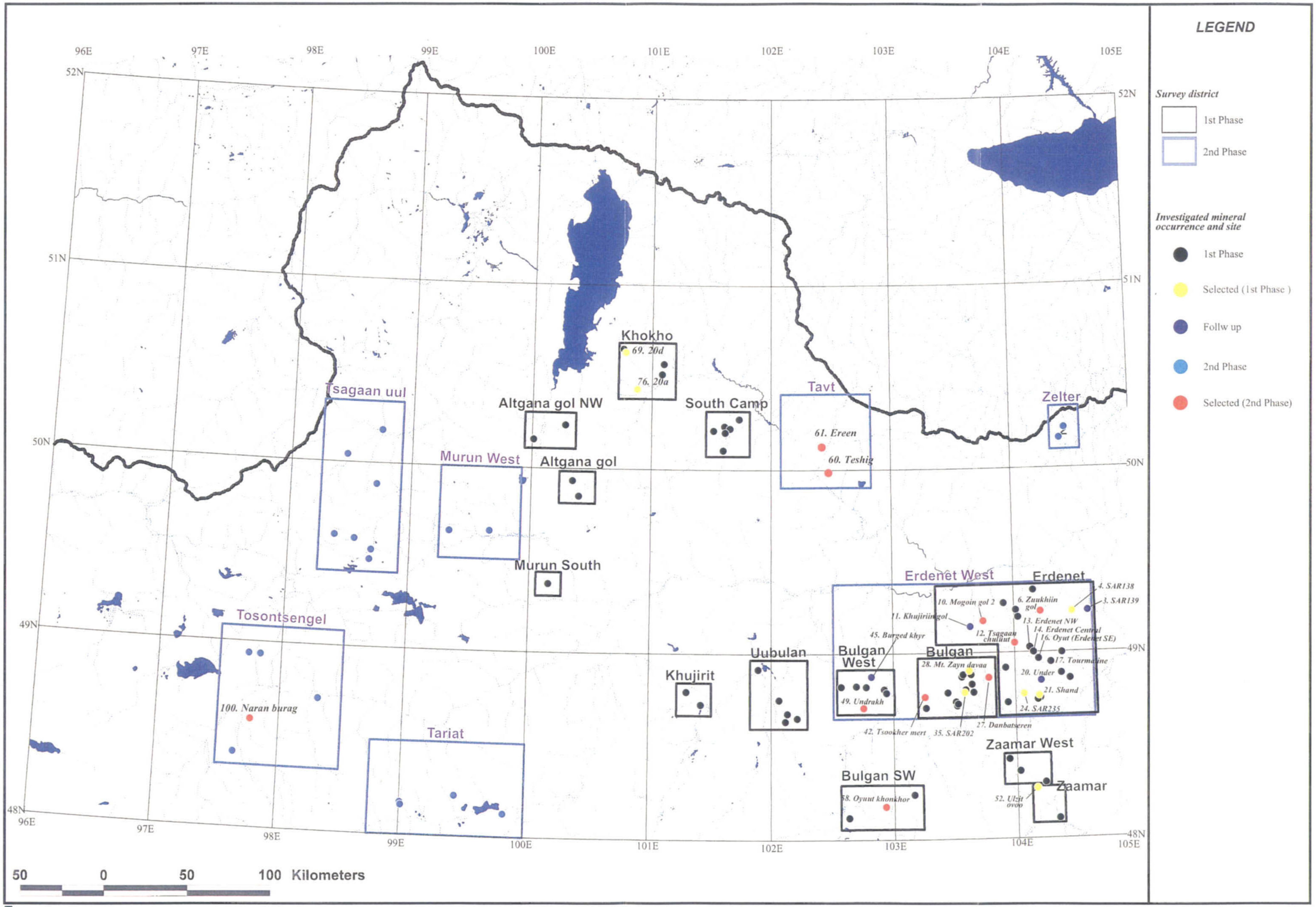

Fig. I-4-3 Selected mineral occurrences and sites in the central north area

Table I-4-1 Selected promising mineral occurrences of the central north area

Region	Mineral occurrence	Expected deposit type	Results of previous survey	Geology	Alteration		Mineralization	PC[*2]	Remarks
					Characteristics	Alteration mineral assemblages			
Erdenet West	Zuukhiin gol	Porphyry Cu・Mo	Cu:0.11-0.17%, Mo:0.003-0.007% (drill core), 21 drill holes	Selenge complex, micro diorite, dacite-andesite porphyry, dacite and andesite volcanics	Potassic alteration		Oxide copper	C	Oxide copper deposits are expected beneath the surface at shallow
	Mogoin gol	Porphyry Cu・Mo, Epithermal Au	Cu:0.034-0.074%, Mo:0.002-0.018% (ore sample), FE:6%(IP method)	Selenge complex, Permian volcanics, late Triassic-early Jurassic volcanics	"secondary quartzite"(2km*4km) with sericite, alunite, andalusite and kaolinite	Quartz+Serisite+Alunite+Kaolinite, Quartz+kaolinite±Andalusite	Oxide copper	A	Epithermal Au deposits are expected within "secondary quartzite" and porphyry Cu・Mo deposits are expected beneath it at deep
	Tsagaan chuluut	Porphyry Cu・Mo, Epithermal Au	Cu:0.75% (drill core length 15m)	Selenge complex, Permian-Triassic volcanics,	"secondary quartzite" (12km*4km) with sericite, alunite, andalusite and kaolinite	Quartz+Kaolinite+Alunite, Quartz+Sericite+Kaolinite±Andalusite		A	Epithermal Au deposits are expected within "secondary quartzite" and porphyry Cu・Mo deposits are expected beneath it at deep
	Danbatseren	Porphyry Cu・Mo, Epithermal Au	High resistivity and FE detected by IP method, weak geochemical anomaly (Cu, Pb, Zn, Mo, Au)	Selenge complex, rhyolite intrusion	"secondary quartzite" (0.5km*0.3km) with sericite, alunite, pyrophylite, andalusite and kaolinite	Quartz+Serisite+kaolinite Pyrophyllite±Andalusite		B	Epithermal Au deposits are expected within "secondary quartzite" and porphyry Cu・Mo deposits are expected beneath it at deep
	Tsookher mert	Epithermal Au	Cu:0.02-0.3%, Au:3-10g/t, Ag:20-500g/t (quartz vein)	Selenge complex, dacite intrusion	Wall rock alteration (silicification, sericite)	Quartz+Kaolinite, Quartz+Sericite	Quartz veinlet with oxide copper, spharelite and etc., Au:285.4g/t, Ag:950g/t, Cu:624ppm, Pb:8.99%, Zn:0.101% (width: 30cm)	C	High grade auriferous quartz veins are expected beneath the surface at shallow
	Undrakh	Porphyry Cu	Cu:0.5-0.7% (point samples)	Selenge complex, aplite	Potassic alteration (300m*150m+)		Oxide copper, chalcopyrite,	B	Primary and oxide copper deposits are expected beneath the surface at shallow
Tavt	Ereen[*1]	Pluton related Au	Au reserve: 8t	Cambrian-Ordovician granitoids, Permian-Triassic granitoids and sedimentary rocks	10 Au deposits in 100km^2	Muscovite+K-feldspar	around 100 quartz veins in granitoids, strongly controlled by NW-SE fracture, Au:6.3g/t	D	Besides No.1 No.2 and No.3 ore bodies, more gold deposits are expected around the Ereen prospect
	Teshig[*1]	Skarn Au	Geological Au resource: 4t, Au:10g/t-30g/t in skarn	Vendian-Cambrian sediments, Devonian plutonic rocks		Epidote+Magnetite skarn	Au:0.05g/t-0.125g/t in epidote and magnetite skarn	D	More gold deposits are expected around the Teshig prospect
Bulgan SW	Oyuut khonkhor[*1]	Epithermal Au	Au:4.4g/t, Ag:0.2g/t (drill core)	Volcanics of the Mogod formation, granitic dyke	Neutral pH>acid argillic alteration and silicification	Quartz+Sericite±Kaolinite±Alunite	Au:0.45g/t, Ag:10.2g/t (float of quartz vein)	C	Epithermal Au deposits are expected beneath the surface at shallow
Tosontsengel	Naranbulag	Porphyry Cu・Mo	Estimated reserve: 22,000,000t, Cu:0.28%, Mo:0.001-0.015%	Lower Permian volcano-plutonic rocks	Potassic alteration	Quartz+Sericite±Kaolinite	Oxide copper	D?	Primary and oxide copper deposit are thought to be expected beneath the surface

[*1] Under exploration by the Mongolian private company
[*2] Principal Component, see Table II-4-1, II-4-2 and II-4-3 in details

Al and P, which is a characteristic of advanced argillic alteration. Moreover, also taking into consideration the result of powdery X-ray diffraction of silicified rocks, those with high scores of the second principal component correspond to the samples which contain alunite and kaolinite, and this suggests advanced argillic alteration. Further, andalusite was detected, showing a characteristic of relatively deep level of advanced argillic alteration. From these, although no mineral showings is observed on the surface, existence porphyry type copper/molybdenum deposits at deep depth and high sulfidation type gold deposit at shallow depth is expected, whose types are similar to those in the Erenet Deposit. Although detailed status is unknown, mineralization of copper (Cu: 0.75%) was captured near the depth of 275 m through boring survey conducted in this mineral occurrence, and this fact supports the above expectation.

② Mogoin gol 2 mineral occurrence in the Erdenet West district

This mineral occurrence is located approximately 30 km to the northwest of the Erdenet Deposit. Like Tsagaan chuluut mineral occurrence, “secondary quartzite” is distributed here; with geochemical data indicating the characteristics of advanced argillic alteration, and silicified rocks accompanying andaulsite has been identified. Consequently, existence of porphyry type copper/molybdenum deposits of the same type as that of Erdenet deposit is expected at deep depth. Further, since copper oxide exists on the surface, the depth where the deposit may exist is presumed as shallower level than that of Tsagaan chuluut mineral occurrence.

③ Zuukhin gol prospect in Erdenet West district

This is a mineral occurrence located approximately 20 km to the north-northeast of Erdenet Deposit. Copper oxide cropped out in potassic alteration zone, and existence of ore body for SX-EW is expected.

④Danbatseren mineral occurrence in Erdenet West district

This mineral occurrence is located approximately 40 km to the southwest of Erdenet Deposit. “secondary quartzite” accompanying andalusite is distributed here, and existence of porphyry type copper/molybdenum deposit at deep depth and/or high sulfidation type gold deposit at shallow depth is expected.

⑤ Undrakh prospect in Erdenet West district

This mineral occurrence is located approximately 100 km to the west-southwest of Erdenet Deposit. Potassic alteration zone accompanying copper oxide developed, and existence of copper oxide deposit at shallow depth is expected.

⑥ Tsookher mert mineral occurrence in Erdenet West district

This mineral occurrence is located approximately 70 km to the west-southwest of Erdenet Deposit. 285.4 g/t Au was obtained from a quartz veinlet zone in granite (analysis width: 30 cm), and existence of high-grade auriferous quartz vein deposit at shallow depth is expected.

⑦ Oyuut khonkhor mineral occurrence in Bulgan SW district

This mineral occurrence is located approximately 120 km to the southwest of Erdenet Deposit. As a result of this survey, analysis value 0.45 g/t Au was obtained from quartz vein (floats). As a result of an academic examination in Mongolia, 8.8 g/t Au was obtained from brecciated rhyolite. Also, 4.4 g/t Au was obtained from a boring survey. In view of the fact that the mineral occurrence incurred neutral pH >acidic argillization, existence in its periphery of auriferous quartz vein deposit is expected. A Mongolian private company obtained a mining right last year and commenced it exploration.

⑧ Ereen prospect in Tavt district

This mineral occurrence is located approximately 150 km to the northwest of Erdenet city. A Mongolian private company started its exploration in 1995, and 10 ore bodies (about 100 auriferous quartz veins) were captured so far within a range of 5 km x 5 km. There is a high possibility where a deposit of similar type exists in the vicinity of Ereen prospect.

⑨ Teshig prospect in Tavt district

This mineral occurrence is located approximately 120 km to the northwest of Erdenet city. A Mongolian private company is now conducting an exploration, and 4 t is presumed as the amount of geological resource of gold. There is a high possibility where a deposit of similar type exists in the vicinity of Teshig mineral occurrence.

⑩ Naranbulag mineral occurrence in Tosontsenegl district

This prospect is approximately 40 km to the southeast of Tosontsengel town. Potassic alteration zone accompanying copper oxide developed, and existence of oxide copper ore at shallow depth expected. However, taking into account the infrastructure for mining operation, preference of execution of detailed survey in this mineral occurrence is lowered.

The following mineral occurrences/points which were determined as promising in the Phase-I survey were excluded from promising mineral occurrences as a result of review of characteristics and extension of alteration and mineralization, and assay result:

Erdenet district: SAR 138, 139 and 235 points ,Burget Khyr, Mt.Zain gobaav, Under

Bulgan district: SAR 204

Zaamar district: Ulzit

Khokhoo district: 20a and 20d

Chapter 5 Conclusion and Recommendation

5.1 Conclusion

Geology of the investigated area is characterized by the formation of the magmatic arc and accretionary prism, and the collision between the Siberian and North China cratons which took place from the Vendian of the Proterozoic time on. From this tectonic development history, the potential of following types of mineralization is expected in the area: ① porphyry copper/molybdenum, ② epithermal gold/silver, ③ pluton-related gold, ④ skarn, ⑤ volcanogenic massive sulfides and ⑥ chromite or platinum group in ophiolite.

According to the information provided by MRAM, 398 mineral occurrences have been located within the investigated area and they are classified into following types; porphyry, skarn, hydrothermal and metasomatic.

The results of the ground truth for 103 mineral occurrences/investigation points, which were selected by the analyses of the existing data and satellite imageries, have confirmed the presence of mineralization of following types; porphyry copper/molybdenum, epithermal gold/silver, pluton-related gold, skarn type copper/lead/zinc and skarn type gold, and have revealed they are promising. Among them, following 10 occurrences have been selected as the candidates for further follow-up.

Erdenet West district

- Tsagann chuluut mineral occurrence
- Mogoin gol 2 mineral occurrence
- Zuukhiin gol mineral occurrence
- Danbatseren mineral occurrence
- Undrakh mineral occurrence
- Tsookher mert mineral occurrence

Bulgan SW district

- Oyuut khonkhor mineral occurrence

Tavt district

- Ereen mineral occurrence
- Teshig mineral occurrence

Tosontsengel district

- Naranbulag occurrence

5.2 Recommendation for the future investigation

Based on the results of the survey for two years, following are recommended.

Further detailed study is recommended in the Erdenet West district, especially in its eastern part where promising mineral occurrences are concentrated. However, the effectiveness of surface investigation such as geological mapping and geochemical sampling (either soil or stream sediments) is limited here. The reason is as follows; in most of the district, the topography is very gentle and the surface is covered with vegetation (steppe and taiga = boreal forest), exposure of the bed rock is poor, alluvium beds widely occur and overburden is very thick, and development of drainage system is poor and running water is scarce except some large rivers.

Therefore, it is recommended to carry on a high resolution airborne magnetic survey prior to the geologic mapping. The survey should be carried on taking the Erdenet deposit as a standard, in order to find the structural factors that localize the deposit and lithocap, factors that control the formation of deposit such as distribution of intrusive rocks and demagnetized zones that suggest the alteration zones. Based on findings from these, it is recommended to select the new targets for the further detailed exploration.

As to the individual promising occurrences which have already been selected in the district, it is recommended to obtain further detailed information on alteration and mineralization, by carrying on geological survey simultaneously with the high resolution airborne magnetic survey.

Promising targets selected in other districts are as follows.

①The areas where "secondary quartzite" distribute （Tsagaan chuluut, Mogoin gol 2, and Danbatseren mineral occurrences）, since high sulfidation type epithermal gold and porphyry type copper/molybdenum minerlization are expected.

② The areas where oxide copper distribute (Undrakh and Zuukhinn gol mineral occurences), since porphyry type copper/molybdenum mineralization is expected at depths.

③ The area where epithermal gold mineralization is expected (Tsookher mert mineral occurrence).

Recommendations for the target areas listed above are as follows.

For group ①, following works are recommended as there is no prominent mineralization on the surface: Detailed geological survey(rock geochemistry and study of alteration zones) , in order to find the characteristics of the hydrothermal system (scale, characteristics and locating the activity center) , though outcrops are limited here. IP geophysics in order to check the presence of the sulfides at depths.

For group ②, following works are recommended, as denudation is advanced here and the ore level is considered to crop out : Detailed geological survey (soil and rock geochemistry and study of alteration zones) in order to estimate the extent of oxide copper mineralization and possibly to guess presence of leached cap. IP geophysics in order to check the presence of the sulfides at depths including the secondary enrichment zone.

For ③, following work is recommended: Detailed geological survey(soil geochemistry and study of alteration zones), in order to find the extent of gold mineralization and nature of alteration (scale and denudation level) and further to infer the bonanza zone. Diamond drilling after the targets have been located by the study mentioned above.

For Naranbulag in the Tosontsengel district, it is recommended to carry on the same works as described for ②.

For Oyuut khonkhor in the Bulgan West district (epithermal gold.), and Ereen (pluton-related gold) and Teshig (skarn type gold) in the Tavt district, we would watch what are going on hoping that good results will be obtained, since the exploration works are currently being carried on by Mongolian private companies.

It is suggested to carry on following works, although these are not applied to the present scheme of "Cooperative Exploration for Mineral Development" by JICA /MMAJ.

In order to promote the foreign investment in Mongolia, it is suggested to bring existing data and documents including geologic maps in better state based on standardized format. Particularly it would be desirable to make 1:200,000 geologic maps ready for GIS use, which have already been prepared in almost whole the area of Mongolia as shown in Appendix. For this purpose, it would be important to use bilingual notation written in both Mongolian and English. Also it would be necessary to prepare the data base of the inventory of ore deposits/mineral occurrences and to prepare geochemical maps based on the results of the geochemical survey (sample location, assay results etc.). Besides these, it is considered that clarification of the metallogenic and tectonic provinces based on the analysis of the terrane would contribute for the future exploration.