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Introduction to Geology of Mongolia

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Abstract: Mongolia, situated between the Siberian platform and Sino-Korean massif, is divided into two large blocks by the Ural-Mongolian Lineament: North and South Large Blocks. The North Large Block is composed of Ulaanbaatar and North Mongolian Folded Systems. Each folded system contains several folded belts. The South Large Block consists of Inner Mongolian and South Mongolian Folded Systems. These systems are composed of some folded belts, but the detail has not known yet. The Khangai-Khentii Megazone, one of the megazones in the North Mongolian Folded System, hosts the Kherlen Depression where intense metallic mineralizations are noticed. The Mongon-Ondor and Ondor-tsagaan deposits were dated to be 174-175 Ma, but there is no information for the age of other mineral deposits.

1. Introduction

Recently, Mongolia has come to the attention of mining geologists by her political change (e.g., Dorian, 1991) but the geological information on Mongolia presented in public is not enough. Thus the authors will give a brief summary about geology of Mongolia and introduce the mineralization of "Kherlen Depression" which is one of the target for the ITIT project of MITI.

2. Geology of Mongolia

Mongolia is situated in the center of Asian continent. Geologically, it is sandwitched by the Siberian platform in north and Sino-Korean massif in south, and is roughly devided into two "large blocks" by the "Ural-Mongolian Lineament" which is the largest overthrust fault in the country (Fig. 1).

2.1 The North Large Block

This block occupies large area of the nation and is composed of two folded systems: "North Mongolian" and "Ulaanbaatar" Folded Systems (Fig. 2 and Table 1).

The North Mongolian Folded System is of Caledonian orogeny and is composed of "Central Mongolian Median Mass", "Nuur-Altai Megazone", "Shishkhid-Zedin Megazone" and "Khangai-Khentiin Megazone". The Central Mongolian Median Mass, occupying the central part of the North Mongolian Folded System, consists of polymetamorphic folded stratum of upper Archean to lower Proterozoic age and those of Precambrian to early Cambrian age. The Nuur-Altai Megazone is widely developed in the west of the Central Mongolian Median Mass. This megazone includes "Nuuriin" and "Altai (or Mongol-Altai)" folded belts. The Nuuriin folded belt consists of ophiolite complex (upper Riphean), spilite, keratophyre, carbonate rocks and terrigenous sedimentary

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Keywords: Mongolia, Ural-Mongolian Lineament, Kherlen Depression, Mongon-Ondor prospect, Ondor-tsagaan mine.

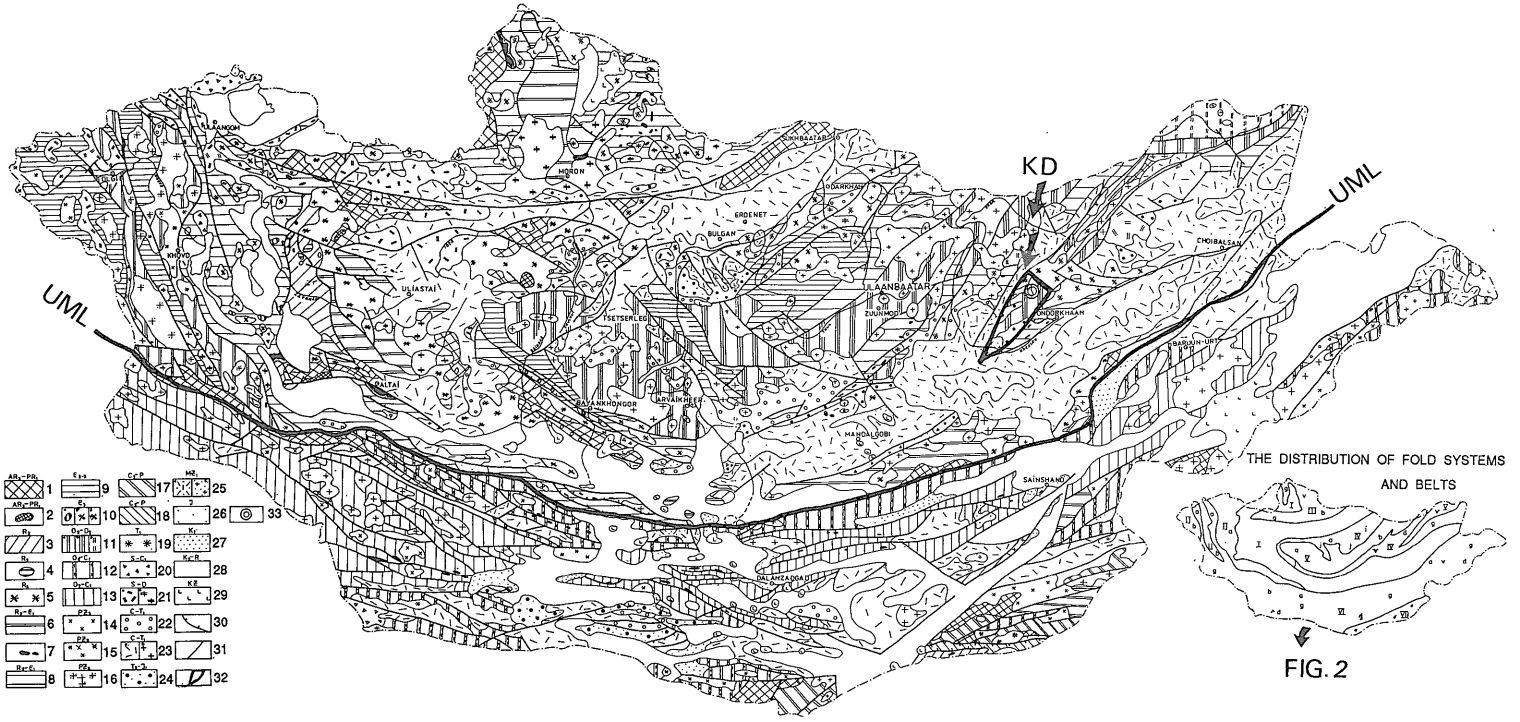

Fig. 1 Tectonic map of Mongolia. (After Yanshin, 1974)
1 : Precambrian basement ; 2 : Precambrian anorthosite etc. ; 3 : Ripheian strata ; 4 : Middle Ripheian ophiolite ; 5 : Middle Ripheian tonalite and plagiogranite ; 6 : shelf and graben facies of Middle Ripheian to early Cambrian age ; 7 : ophiolite of various ages and relic oceanic crust ; 8 : late Ripheian to early Cambrian strata ; 9 middle to upper Cambrian system ; 10 : early Cambrian system ; 11 : middle Ordovician, Carboniferous, Permian and Triassic strata ; 12–13 : middle Ordovician to lower Carboniferous rocks ; 14 : Paleozoic tonalite and plagiogranite ; 15–16 : middle Paleozoic granitoids ; 17 : middle Carboniferous to Permian marine sediments 18 : middle Carboniferous to Permian rocks of micro-continents and island arcs ; 19 : lower Triassic granitoids ; 20 : molasse of Silurian to lower Carboniferous age ; 21 : Silurian to Devonian volcano-plutonic complex ; 22 : molasse of Carboniferous to lower Triassic age ; 23 : volcano-plutonic complex of Carboniferous to lower Triassic age ; 24 : molasse of middle Triassic to lower Jurassic age ; 25 : Mesozoic granitoids ; 26 : Jurassic strata ; 27 : lower Cretaceous strata ; 28 : strata of upper Cretaceous to Paleogene age ; 29 : Cenozoic basalt ; 30 : overthrust and thrust ; 31 : other faults ; UML : Ural-Mongolian Lineament ; KD : Kherlen Depression.

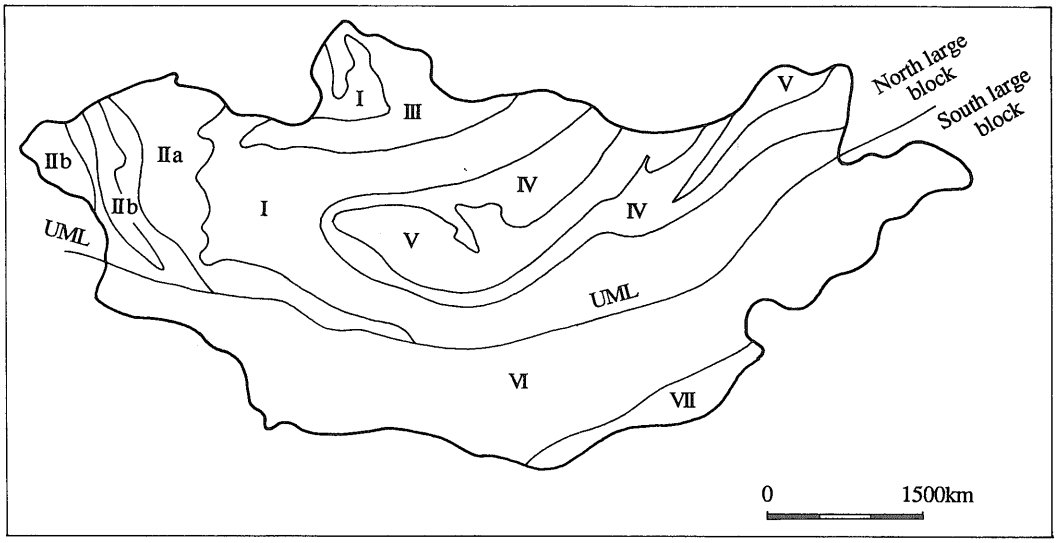

Fig. 2 Schematic map showing major tectonic units of Mongolia.
I : Central Mongolian Median Mass ; II a : Nuriin Folded Belt ; II b : Altai Folded Belt ; III : Shishkhid-Zeddin Megazone ; IV : Khangai-Khentiin Megazone ; V : Ulaanbaatar Folded System ; VI : South Mongolian Folded System ; VII : Inner Mongolian Folded System ; UML : Ural-Mongolian Lineament.

rocks (upper Riphean to lower Cambrian), carbonate and volcanic formation (lower Cambrian) and tuff and terrigenous sedimentary rocks (lower to middle Cambrian). The Altai Folded Belt is composed of middle to upper Cambrian flysh. The Shishkhid-Zediin megazone is of Caledonian orogeny and is distributed north of the Central Mongolian Median Mass, (Tes, Shishkhid, Eg and Uuriin basins), and also in the eastern side of the Khovsgol sea. The structure and geologic history are similar to those of the Nuuriin Folded Belt of the Nuur-Altai Megazone. Khangai-Khentiin Megazone of Caledonian orogeny is situated north-east of the Central Mongolian Median Mass and is composed of seven folded belts : "Tariat-Darkhan", "Bayankhongor", "Adaatsag", "South Khentii-Onon" "Kherlen", "North Kherlen" and "Zag-Kharaagiin" Folded Belts. The Zag-Kharaagiin is located in the central part of the Khangai-Khentiin Megazone. Ophiolite formations with overthrust and thrust structures are observed at Bayankhongor, Adaatsag and Kherlen folded Belts.

Ulaanbaatar Folded System is of Variscan orogeny and is subdivided into some smaller units such as Tsetserleg Folded Belt, Ulaanbaatar Folded Belt and Dochiin gol Depression. But the system is not well understood yet. In the Dochiin gol Depression, Permian to lower Triassic sediments are distributed.

2.2 The South Large Block

The South Large Block covers the entire region of the Govi area and generally has linear structures. Two folded systems, "South Mongolian" (Variscan) and "Inner Mongolian" (late Variscan), have been recognized in this block but the detail of the geology has not been well understood yet. These two folded systems accompany smaller uplifted bodies of Caledonian time.

The South Mongolian Folded System is elongated from the west (Baruun-Khurain Depression) to the east (Khalkhiin gol of the country and is divided into the following folded belts : "Khovd-Baruun-Urt", "Edren", "Asgat (or Khalzan)", "Goviin (or Govi)", and "Govi-Tjanshan-Uul-Nukhet-davaa" belts. In the Khovd-Baruun-Urt and Govi-Tjanshan-Uul-Nukhet-davaa Folded Belts, volcanic rocks,

Table 1 Tectonic framework of Mongolia.

Late Variscan Orogeny	South Large Block	Inner Mongolian Folded System	?	?	Luugiin-gol Folded Belt
					Sulenkheer Folded Belt
Variscan Orogeny		South Mongolian Folded System	?	?	Khovd-Bruun-Urt Folded Belt
					Edren Folded Belt
					Asgat(Khalzan) Folded Belt
					Goviin(Govi) Folded Belt
					Govi-Tjanshan-Uul-Nukhet-davaa Folded Belt
		Ulaanbaatar Folded System		?	Tsetserleg Folded Belt
					Ulaanbaatar Folded Belt
					Dochiin-gol Depression
Caledonian Orogeny	North Large Block	North Mongolian Folded System	Central Mongolian Median Mass	Zavkhan Megazone	Some Depressions (e.g., Khovsgol, Tsagaan-Olom, Bayanshargalan)
				?	
			?	Nuur-Altai Megazone	Nuuriin Folded Belt
					Altai(or Mongol-Altai) Folded Belt
				Shishkhid-Zediin Megazone	Tes-Egiin gol Folded Belt
					Zediin Folded Belt
					Darkhat-Khovsgol Folded Belt
					Shishkidiin Folded Belt
				Khangai-Khentiin Megazone	Tariat-Darkhan Folded Belt
					Bayankhongor Folded Belt
					Adaatsag Folded Belt
					Omno Khentii-Onon Folded Belt
					Kherlen Folded Belt
					Khoit Kherlen Folded Belt
					Zag-Kharaagiin Folded Belt

carbonate rocks and terrigenous sediments of middle Ordovician to lower Carboniferous age are underlain by the older folded basement. Mongolian geologists believe that an original continent was separated into some smaller blocks during the Caledonian orogeny. These orogenic belts are marked by thrust and over-thrust structures and carry various kinds of

rock. For example, in Edren and Asgat Belts, carbonate and volcanic rocks (middle Ordovician to lower Cambrian) of island arc and volcano-sedimentary formations are seen, but in Goviin Folded Belt, ophiolite formation, volcanic rocks of island arcs, tuff of middle Ordovician to lower Carboniferous age are noticed.

In the Inner Mongolian Folded System, the autochthonous formation of middle Carboniferous to Permian age and allochthonous ultrabasic rocks of unknown age are distinguished. The geology of this folded system has not been well studied yet.

2.3 Superimposed Structures

In additon to the structures mentioned above, "super imposed structures" are observed in Mongolia. This word includes (a) intra-deep basins and depressions filled with mollasse and volcanic rocks ; (b) "Ulaanbaatar Variscan System" ; and (c) deep faults. Type (a) is

Table 2 Fault system of Mongoila.

FAULT OF NORTHWEST SYSTEM	1: Turgen-gol, 2: Tolbo-nuur, 3: Khovd, 11: Bajankhongor, 15: Edren, 37: Orkhon, 38: Ulaanbaatar, 39: Barkh
FAULT OF NORTHEAST SYSTEM	6: Agardag, 18: Khoit-Totoshan, 20: Bargiin-Ovoo, 21: Modon-Ovoo, 24: Dund-govi, 25: Matat, 26: Delger, 27: Khoit-govi, 28: Kherlen, 29: Ulz, 30: Onon, 31: Omno-Khentii, 32: Yoroo-gol, 33: Bajan-gol, 34: Selenge, 35: Zelturiin, 36: Argiin-gol
FAULT OF SUBLATITUDINAL SYSTEM	7: Khan-khokhii, 8: Tamirgol, 9: Shargiin, 10: Bulgan, 12: Ukh-Bogd, 13: Altain-tsaadakh 14: Gurbansaikhan, 16: Tsagaan-Bogd, 17: Sulenkheer, 19: Manlai, 22: Saikhan-dulaan, 23: Ondor-shil
FAULT OF SUBMERIDIONAL SYSTEM	4: Deluun-sagsai, 5: Tsagaan-shiveet, 40: Khovsgol, 41: Darkhat, 42: Zavkhan

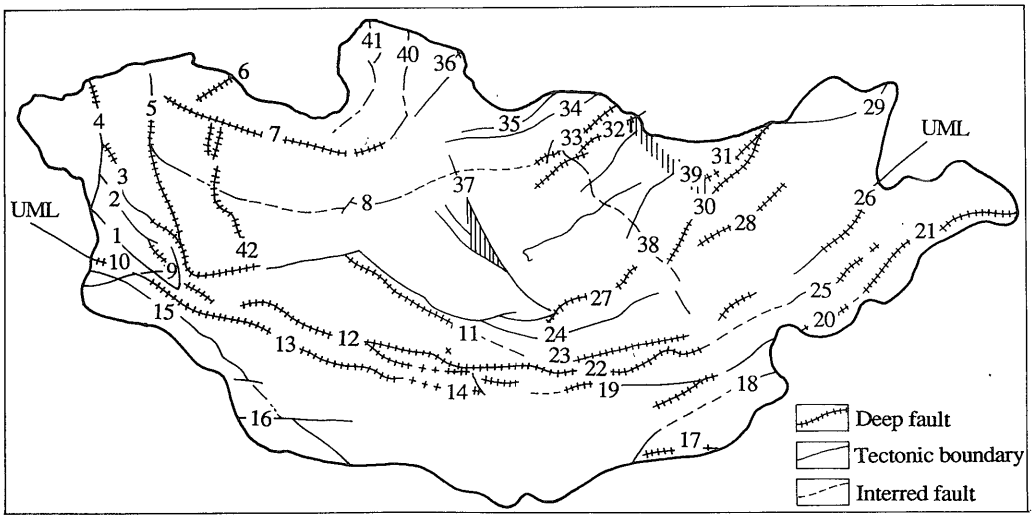

Fig. 3 Fault system of Mongolia. Numbers correspond to those in Table 2.

observed in most portion of the central Mongolia and south Mongolia. The crustal movements responsible for these types took place in Devonian, late Paleozoic and early Mesozoic age. Type (b) is seen around Ulaanbaatar and in southern Mongolia and is composed of intra-deep depressions and volcano-plutonic belt of Carboniferous and early Triassic ages. Type (c) includes upthrust, displacement faults and jointing. One of the distinctive characters of this structure is the exsistence of ultrabasic rocks. In Mongolia, identified are the following fault systems (Fig. 3 and Table 2) : North-West ; North-East ; sublatitudinal ; and submeridional systems. The North-West system is developed in the Nuur-Altai Megazone with the length of ca. 600 km. This system is active from the Paleozoic age until present, and is characterized by basic and ultrabasic magmatism. The sublatitudinal fault system has following peculiarity : (a) the faults run mostly parallel to the longitude in the central

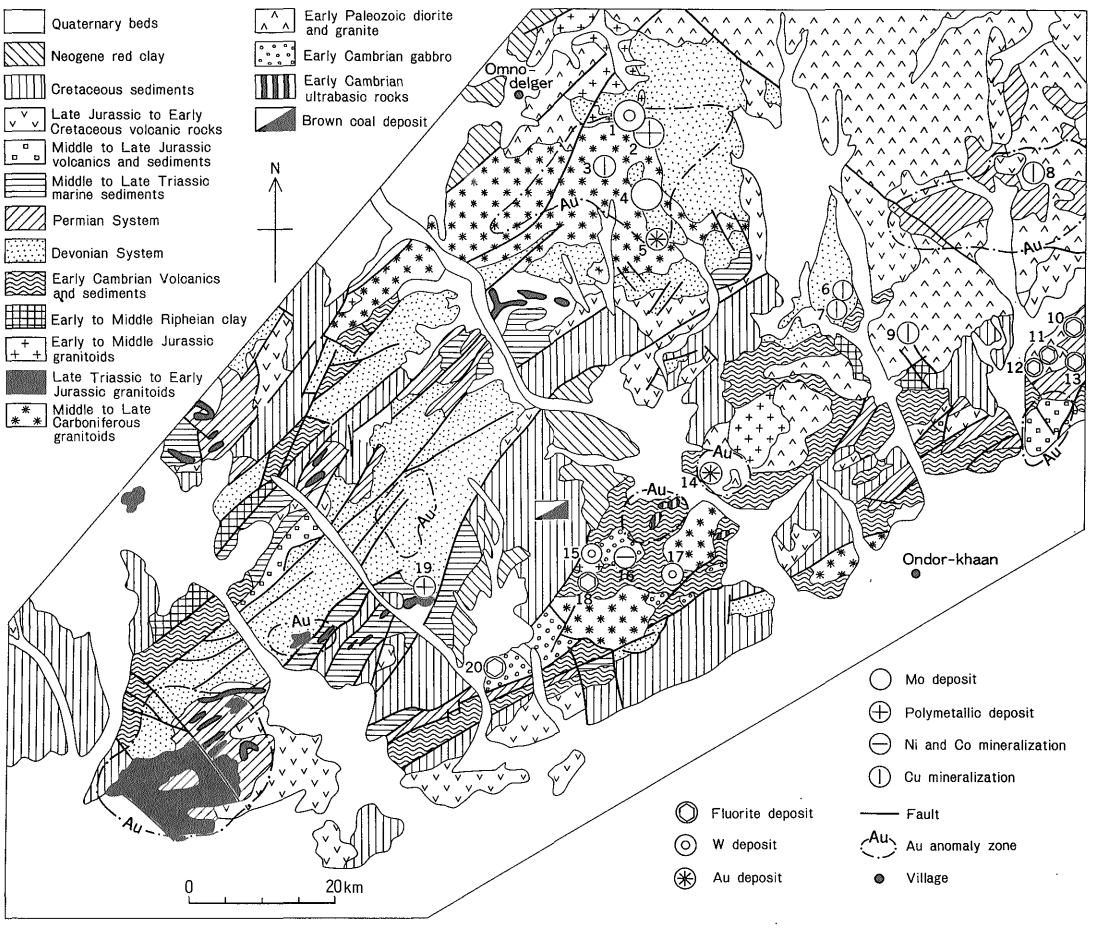

Fig. 4 Geologic map of the Kherlen Depression.
1 : Ondor-tsagaan mine ; 2 : Mongon-Ondor prospect ; 3 : Mandaliin khuree deposit ; 4 : Tsagaan-tschuluut deposit ; 5 : Khoer zotlig deposit ; 6 : Okhaash deposit 7 : unnamed ; 8 : Uuluun raschaan deposit ; 9 : unnamed ; 10-13 : Nergui area ; 14 : Ulaan-Ondor deposit ; 15 : Tsagaan-Ovoo deposit ; 16 : Tuntger deposit ; 17 : Olziitbulag deposit ; 18 : unnamed ; 19 : Tugalgatain-nuruu deposit ; 20 : unnamed.

part of the nation but bend to north direction at the periphery ; (b) metamorphic rocks (mica schist, amphibolite, garnet-bearing gneiss) are distributed along the faults ; (c) most of the faults are overthrusts ; and (d) sometimes breccia zone is developed along faults.

2.4 Characters of Kherlen Depression

The Khangai-Khentiin Megazone of the North Mongolian Folded System includes the "Kherlen" Depression which is bounded by the Onon, Kherlen and Barkh faults, and has the area of ca. 130 km by 10–20 km (Figs. 1 and 4). The depression exhibits synclinorium with NE-trending fold axes, and is composed of the following geologic bodies : metamorphic rocks of upper Proterozoic age, terrigenous and volcanic rocks of lower Cambrian age, gabbro and granitoids of lower Paleozoic age, terrigenous sedimentary rocks of lower to middle Devonian age, volcanogenic molasse formation of lower Permian, Triassic and middle to upper Jurassic ages, and granitoids of upper paleozoic to Mesozoic ages. The Devonian terrigenous sedimentary unit is called "Kherlen Group" and contains clayey schists, siltstone, sandstone (Fig. 5), diabase, gabbro and fine-grained green rocks of intermediate composition. These green rocks are deformed. Into the Kherlen Group, late Paleozoic and Mesozoic granitoids have been intruded. The former is called "Tsenkher gol complex", while the latter is designated "Bor-Ondor complex". The Tsenkher gol complex is mainly distributed at the marginal area of the depression and is composed of coarse to medium-grained granodiorite and medium-grained biotite granite (Figs. 6 and 7). The Mesozoic granites occur along faults and are mainly classified into late Triassic to early Jurassic alkali granite and early to middle Jurassic leucogranite. No petrochemical data nor radiometric-age data have been known for these granitoids but for one chemical analysis of the sample from the Ondor-tsagaan mine (Table 3).

3. Mineral Deposits in the Kherlen Depression

In the Kherlen Depression, there are a lot of metallic ore deposits and mineralized areas (Fig. 4). They are Pb veins, Zn veins, Pb-Zn-Ag veins (Fig. 8), Mo-W veins or stockworks (Fig. 9), Cu-Mo of porphyry type, hydrothermal Au and so on. Most of the deposits have not been studied yet from the geological, mineralogical and geochemical point of view. Tectonics of the depression has not been studied well neither.

Some of the metallic deposits seem to be distributed near the contact between the Kherlen Group and Paleozoic Tsenker gol

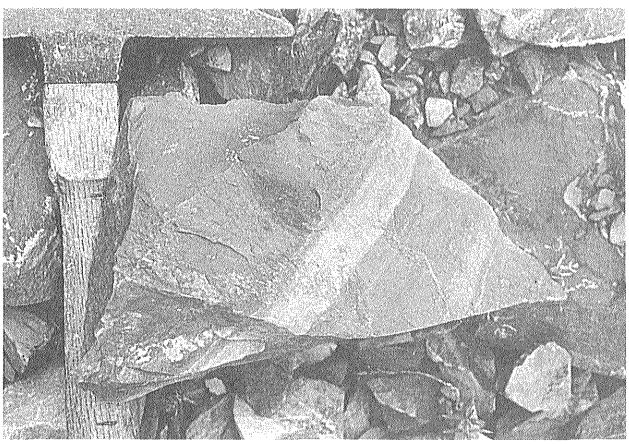

Fig. 5 Sandstone (light-color band) and mudstone (dark-color portion) of the Kherlen Group.

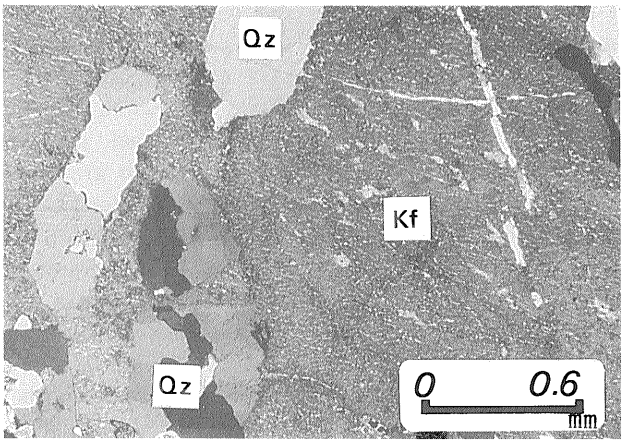

Fig. 6 Microphotograph of a Paleozoic granite from Tsagaan-tschuluut area. No. 0824-1. Qz : quartz ; Kf : alkali feldspar.

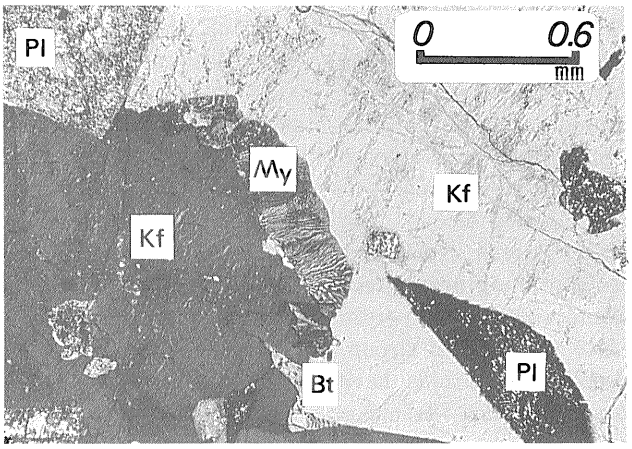

Fig. 7 Microphotograph of a granite of the Tsenkher gol Complex. No. 0824-13. Qz : quartz ; Pl : plagioclase ; Kf : alkali feldspar ; My :myrmekite ; Bt : biotite.

Complex, which implies the genetic relation between the deposits and the complex. But the K-Ar dating of the mica concentrate from a W-Mo stockwork (Ondor-tsagaan mine) and a quartz-phlogopite vein (Mongon-Ondor prospect) revealed that these deposits were developed during the Jurassic time (174-175 Ma : Murao *et al.*, in preparation). Thus detailed petrochemical study and radiometric age dating of the granites and ore deposits are necessary to establish the guidline for the mineral exploration in the region.

4. Concluding Remarks

In Mongolia, two large blocks are recognized. These large blocks consist of several folded systems. Each of them is subdivided into some megazones and folded belts. Most of the tectonic units have not been well researched. One of the tectonic units, Khangai-Khentii megazone includes the Kherlen Depression which is an expected area for mining.

In the Kherlen Depression, intense mineralizations of various kinds of useful metals are

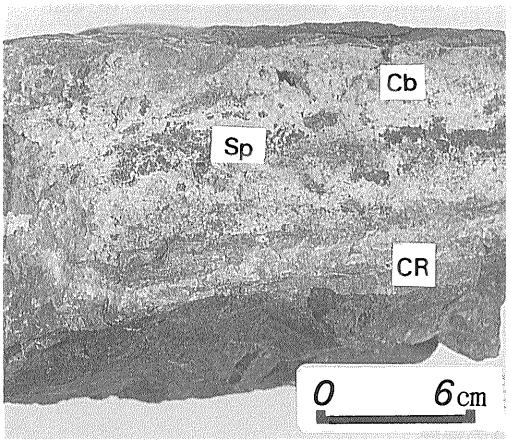

Fig. 8 Pb-Zn-Ag-carbonate vein from the Mongon-Ondor prospect.
Sp : sphalerite ; Cb : carbonate ;
CR : country rock.

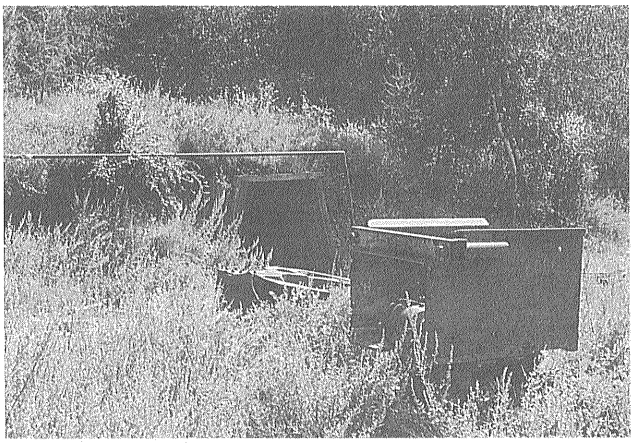

Fig. 9 Adit of the Ondor-tsagaan mine.

Analytical Result		Normative Constituent	
SiO_2	73.1	il	0.61
TiO_2	0.3	ap	6.05
Al_2O_3	13.1	or	26.16
Fe_2O_3	0.9	ab	33.03
FeO	1.2	an	3.34
MnO	0.05	C	0.71
CaO	1.2	mt	1.39
Na_2O	3.9	hy	2.13
K_2O	4.4	Q	26.12
P_2O_5	0.8		
Ig.Loss	0.1	Total	99.54 w%
Total	99.55 %	D.I.	85.31

Table 3 Chemical analysis of a granite from a drilling core at the Ondor-tsagaan ore field.

observed. Most of them are hydrothermal deposits which are genetically related to acid magmatism. But there is mostly no information on the regional geology, mineral deposits and granitoids. Basic studies such as geological field survey, microscopic observation, petrochemical analyses and radiometric dating are required to discuss the mineralization and to capture high-grade ore bodies in this depression.

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モンゴル国の地質区分の概要

T. ツェデン ・ 村尾 智 ・ D. ドルジゴトフ

要 旨

モンゴル国の地質区分について概説した．同国は基本的にウラル-モンゴリアリニアメントによって北ラージブロックと南ラージブロックに区分され，これらはさらに小さな地質単位（folded system, megazone, median mass, folded belt）に分けられる．しかし各単位は経験的に設定されており定義があいまいである．また，各単位の相互関係のほとんどは不明である，北ラージブロック内のKhangai-khentiin Megazone には Kherlen Depression と呼ばれる陥没地域があり，Au, Ag, Pb, Zn, Mo などの金属鉱化作用がみられる．本地域は ITIT プロジェクトの対象区域であり，1991年度の成果として，オンドルツァガンおよびモンゴンオンドル鉱床は 174–175 Ma の生成である事が明らかになっている．他の鉱床の詳細は不明である．

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