Bulletin of the Geological Survey of Japan, vol. 49 (6), p. 249-255, 1998

K-Ar dating of granitoids and hydrothermal micas from the northern part of Kherlen Depression, Mongolia

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Satoshi MURAO, Danjindorjiin DORJGOTOV and Tsagaanbilegiin TSEDEN (1998) K-Ar dating of granitoids and hydrothermal micas from the northern part of Kherlen Depression, Mongolia. *Bull. Geol. Surv. Japan*, vol. 49 (6), p. 249-255, 6 figs., 1 table.

Abstract: We have determined the K-Ar ages for micas of granitoids and hydrothermal deposits in the Kherlen Depression, one of the prospective regions of eastern Mongolia. According to geologic evidences, the granitoids belong to Triassic, Jurassic or Carboniferous in age, and are accompanied by many hydrothermal deposits. Some large stocks are considered to have developed during the Carboniferous or Triassic Period, while small plugs show evidences of Jurassic-time intrusion. Among the hydrothermal deposits in the depression, the Öndör tsaggan (Mo-W-Be) and Möngön-Öndör polymetallic (Zn-Sn-Pb-Ag) deposits within the Öndör tsagaan ore field were selected for the age determination. The result showed that a granitic plug near the Öndör tsaggan ore field has 191 Ma, while hydrothermal micas from Öndör tsagaan deposit and Möngön-Öndör deposit show the age of 174 and 175 Ma respectively. In addition to these, two ages for igneous mica from a Carboniferous complex were obtained to be 273 and 308 Ma.

Mineral deposits in the depression are distributed along the boundary between Devonian sedimentary rocks and Carboniferous granitoids, which implies that mineralization mainly took place during the Carboniferous Period being related to large-size stocks. But our geochronology indicates that several mineralization episodes were existed in the Kherlen Depression and especially Jurassic magmatism was important for polymetallic mineralization.

Also it is noteworthy that the Mo-W-Be and Zn-Sn-Pb-Ag zones (deposits) of the Öndör tsagaan ore field have mostly the same age, 174 and 175 Ma. This fact indicates that two zones in this ore field are probably a product of single pulse solution from a felsic magma. In addition geologic setting indicates that a polymetallic ore field, 10-20 km^2 in dimension, could be formed around the apex of such small plug. In eastern Mongolia, fractionated small plugs must be examined with attention to explore polymetallic and other type of mineral deposits.

1. Introduction

The Kherlen Depression in eastern part of Mongolia is one of the most prospective regions for rare metal deposits. Especially its northern part including the Öndör tsagaan ore field hosts many polymetallic deposits with high-grade ore of Mo, W, Be, Zn, Sn, Pb and Ag. The depression has a dimension of 80 km by 150 km, and is situated in the Khentii Aimag, ca. 300 km east from Ulaanbaatar, the capital of the nation (Fig. 1). The projected Ulaanbaatar-Öndörkhaan highway will improve the infrastructure of the region. In spite of such advantageous position in economy, mineral exploration has not been progressed much in this region due to the paucity of geochronologic information. Thus we have surveyed the area, collected some rock and ore specimens, and determined the K-Ar ages for representative specimens. The aim of this note is to present the data, and discuss exploration strategy based on the geochronology.

2. Kherlen Depression

The Kherlen Depression is a basin-like structure in eastern Mongolia which is mainly composed of Devonian sedimentary unit, Kherlen Group, and granitoids of Carboniferous, late Triassic and Jurassic ages (Fig. 2). These granitic rocks intrude the Kherlen Group (Tseden *et al.*, 1992). A granitic complex of the Carboniferous age, designated "Tsenkher gol Com-

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Keywords: Mongolia, Kherlen Depression, Möngön-Öndör deposit, Öndör tsagaan deposit, Tsagaan chuluut deposit, Tsenker gol Complex, Bor-Öndör Complex, radiometric age, monoascendent zoning, polymetallic ore.

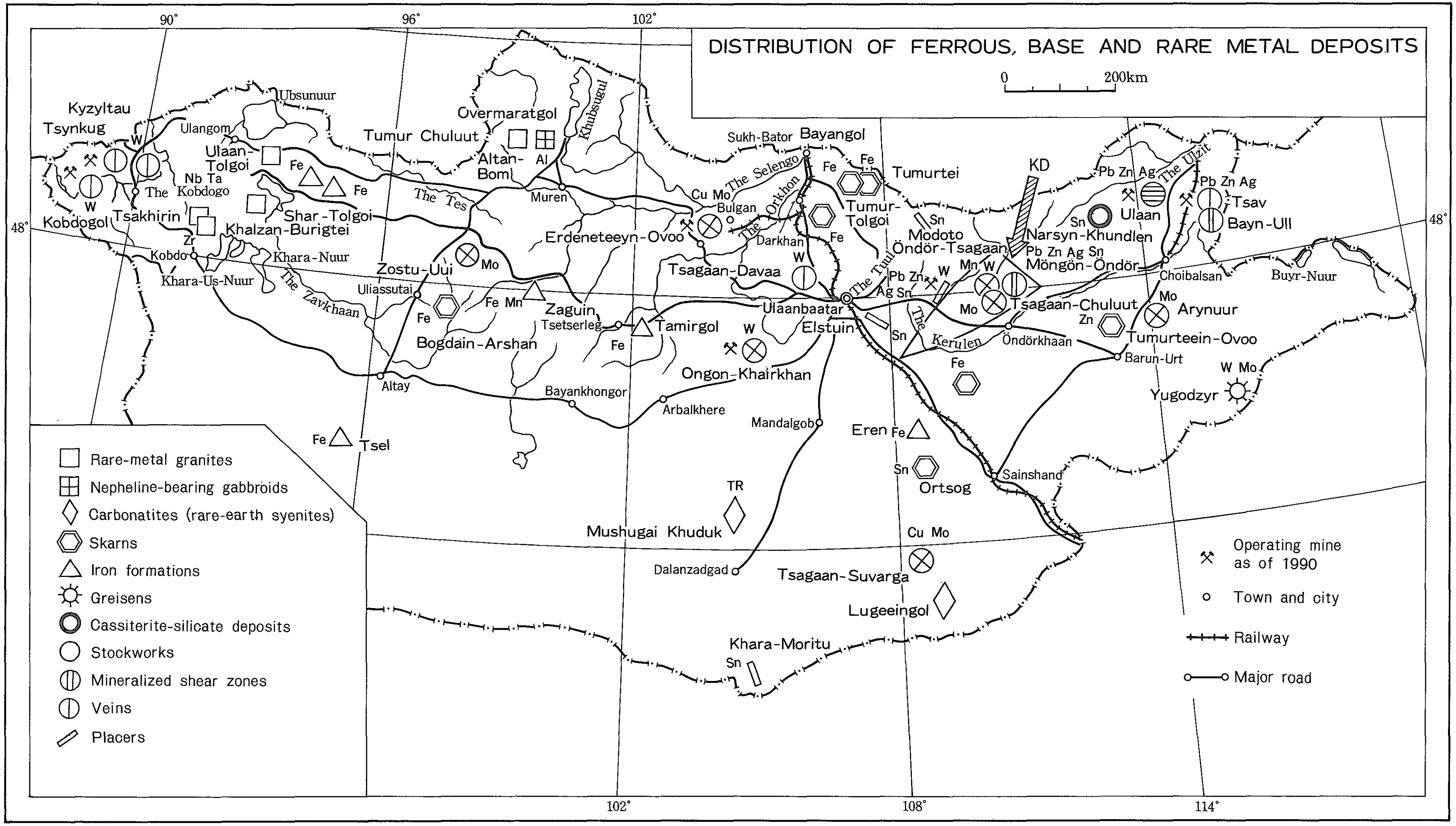

Fig. 1 Representative mineral deposits in Mongolia. Gold deposits are not shown in the figure.

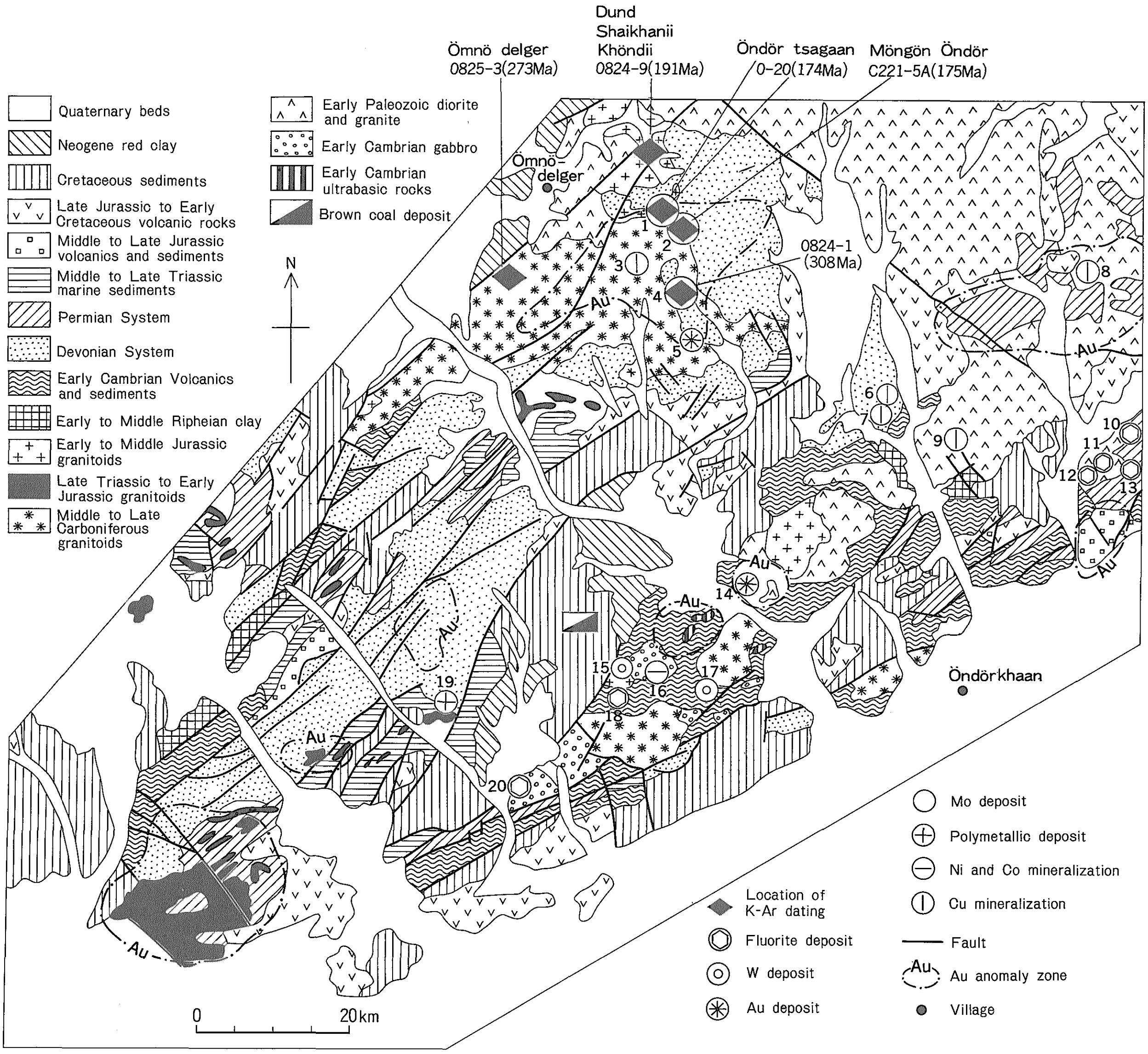

Fig. 2 Map showing the geology of the Kherlen Depression and the locality of K-Ar dating (modified from Tseden *et al.*, 1992). 1: Öndör tsagaan deposit; 2: Möngön Öndör deposit; 3: Mandaliin khuree deposit; 4: Tsagaan chuluut deposit; 5: Khoyor zotig deposit; 6: Okhaash deposit; 7: unnamed; 8: Uuliin rashaan deposit; 9: unnamed; 10-13: Nergui area; 14: Ulaan-Öndör deposit; 15: Tsagaan-Ovoo deposit; 16: Tuntger deposit; 17: Olziitbulag deposit; 18: unnamed; 19: Tugalgatain-nuruu deposit; 20: unnamed.

plex", and another of late Triassic to early Jurassic, called "Bor-Öndör Complex", are the representative large-size stocks in this depression. In addition to these stocks, small granitic plugs, mainly of Jurassic age, are often observed in the depression.

The Tsenker gol Complex is composed of hornblende gabbro, diorite, granodiorite, and granite. Three phases can be recognised in this complex: (1) gabbro and diorite; (2) biotite-hornblende granodiorite, tonalite, adamellite and hornblende-biotite/biotite granite; and (3) biotite leucogranite. Borzakovskii *et al.* (1973) determined the K-Ar ages for biotite from the complex between 263 and 318 Ma, but details about his experiment and specimen are not recorded in his report. In our study, two specimens were collected from the phase (2) to determine the age of the most active period of the magmatism.

The Bor-Öndör Complex is represented by granite, granosyenite, leucogranite, alaskite, and granite porphyry. According to Borzakovskii *et al.* (1973), these rock types show high silica and high alkaline chemistry (74.6-76.8 wt. % and 8.6-9.8 wt. % respectively); it is characterized by high concentration of Zn, Sn, Ta and Nb; and the K-Ar ages of biotite range from 194 to 235 Ma. No other geochemical work has been performed on this complex.

The northern part of the depression includes several ore fields which seem to be distributed along the boundary between the Kherlen Group and Tsenkher gol Complex (Fig. 2). Among the ore fields, the Öndör tsagaan ore field and Tsagaan chuluut ore field were selected for this pilot study. The Öndör tsagaan ore field is of rare metal bearing polymetallic mineralization, while the Tsagaan chuluut ore field is of simple molybdenum mineralization.

The Öndör tsagaan ore field is composed of granitoids of Paleozoic and Mesozoic ages, Devonian green rock and sedimentary rocks, and Cretaceous sedimentary rocks. Petrological features of the rocks have not described yet in detail in this region. In this ore field, mineral deposits are distributed around a granitic plug which intruded the Kherlen Group and the zoning on the order of ore field can be established: Mo-W-Be zone; Pb-Zn-Sn zone; Pb-Zn-Ag zone; and Ag zone from the center outward. The Mo-W-Be zone is of porphyry type and is designated the Öndör tsagaan deposit, while Pb-Zn-Sn, Pb-Zn-Ag and Ag zones are of polymetallic vein type. The boundary between the three zones is artificial and each zone grades each other. The area which include these three zones designates Möngön-Öndör deposit. The Öndör tsagaan deposit is mainly hosted by a strongly altered porphyritic granite (plug) and partly by the Kherlen Group, while the Möngön-Öndör orebodies are embedded in the Kherlen Group.

The Tsagaan chuluut deposit, located at 17 km south of the Öndör tsaggan area, is of stockwork molybdenum mineralization. The ore bodies are found in greisenized granitoid of Carboniferous age. Within this granitoid, the molybdenum mineralization is found in and around small granite-porphyry dykes which crosscut the granitoid.

3. Sample description

Samples were collected from the Öndör tsagaan, Möngön-Öndör, and Tsagaan chuluut deposits, and from the granitic outcrops at Dund Shaikhanii Khöndii and Ömnö delger. The outcrop at Dund Shaikhanii Khöndii represents Jurassic plugs in the region, while that of Ömnö delger is a part of the Carboniferous Tsenkher gol Complex.

At Öndör-tsagaan, samples were collected from stockwork of quartz-muscovite-beryl. The sample No. O-20 contains veinlets of a few millimeters to a few centimeters in width, and carries molybdenite, wolframite, beryl, muscovite and small amount of sphalerite. At Möngön Öndör, sphalerite-galena ore, No. C221-5A, was sampled. The specimen is a veinlet of a few centimeter wide in slate in which quartz and phlogopite are coexisted with sulfides.

The granite sample from the Tsagaan chuluut, No. 0824-1 (Fig. 3), is hornblende-biotite granite. A small aplite veinlet of a few centimeters wide cuts the rock. The granite is medium-grained and equigranular in texture. Hornblende is subhedral grain, homogenous and shows pale green in Z-axial color. Biotite is also subhedral and the X=Y axial color is greenish brown to tan.

The sample from Dund Shaikhanii Khöndii, No. 0824-9 (Fig. 4), is biotite-hornblende tonalite. It is medium-grained and equigranular. Hornblende is subhedral in shape, and shows bluish green in Z-axial color. Biotite is also subhedral in shape and the X=Y axial color is greenish brown to tan. Plagioclase shows weak zoning. Epidote, apatite, zircon and opaque minerals occur as accessory phases. Most of the quartz is dynamically recrystallized, and all of the biotite grains show strong wavy extinction. This suggests that the rock was deformed after crystallization.

The specimen from Ömnö delger, No. 0825-3, is two-mica bearing granitic rock. This specimen shows granoblastic texture, and is mainly composed of quartz, muscovite, plagioclase, and biotite. Muscovite occur as large grains with wavy extinction (Fig. 5), ranging from 1 to 1.5 mm in diameter. Biotite occurs as small euhedral grains of X=Y axial color in dark brown to green. Plagioclase is usually observed as saussuritized subhedral grains. Zircon and apatite are accessory minerals.

4. K-Ar dating of micas

The ore specimens from the Öndör tsagaan ore field were roughly crushed in an iron mortor. Phlogopite, polytype 3 T, of the sphalerite-galena ore and muscovite, polytype 3 T, of the stockwork were carefully hand picked under a binocular microscope. To decide the ages of granitoids, the rock chips were crushed and muscovite and biotite were concentrated with an isodynamic separator. After this procedure, the quality of each concentrate was examined under a binocular microscope: the purity of the concentrate was estimated to be more than 99%. All of the micas were fresh having K content more than 6%. The ages were determined 174 ± 9 for Öndör tsagaan and 175 ± 9 Ma for Möngön Öndör. The biotite of the Tsagaan chuluut granite gave an age of 308 ± 15 Ma. The tonalite from Dund Shaikhani khöndii was dated to be 191 ± 10 Ma, while the two-mica-granite from Ömnö delger, 273 ± 14 Ma (Table 1 and Fig. 6).

5. Discussion

The granite samples from Ömnö delger and Tsagaan chuluut belong to the Tsenker gol Complex. Their radiometric ages are included in the range of the complex, 263-318Ma, that was reported by Borzakovski *et al.* (1973). Molybdenum dissemination at Tsagaan

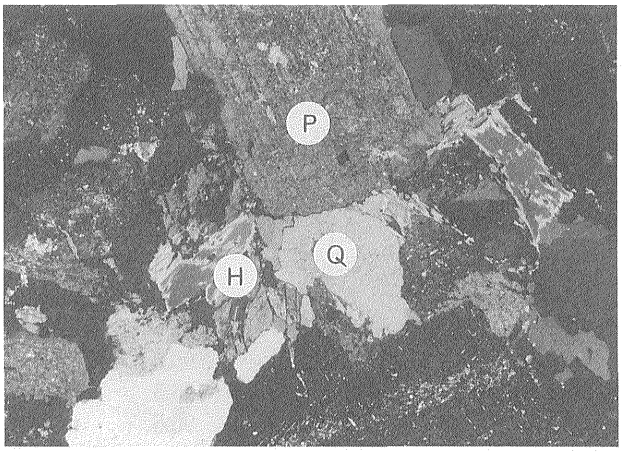

Fig. 3 Photomicrograph of a granite from Tsagaan chuluut. Sample No. 0824-1; P: plagioclase; H: hornblende; Q: quartz. Field of view, ca. 2 mm.

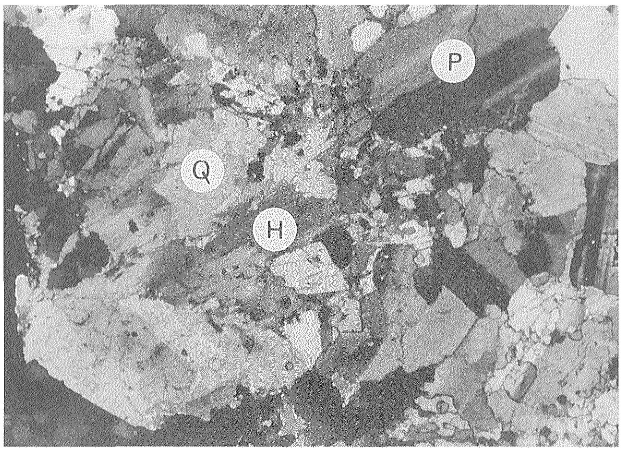

Fig. 4 Photomicrograph of a tonalite from Dund Shaikhanii Khöndii. Sampe No. 0824-9; P: plagioclase; H: hornblende; Q: quartz. Field of view, ca. 2 mm.

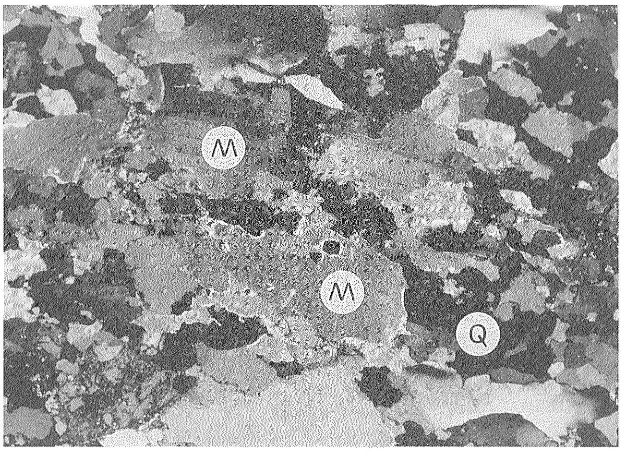

Fig. 5 Phtomicrograph of two-mica-bearing granitic rock from Ömnö delger. Sample No. 0825-3; M: muscovite; Q: quartz. Field of view, ca. 2 mm.

chuluut deposit is closely asscociated with this granite and thus it must be distinguished from the molybdenum mineralization at Öndör tsagaan.

On a geologic map around the Kherlen Depression, mineral deposits are distributed along the boundary between sedimentary rocks and Carboniferous granitoids. But the geologic setting and radiometric ages for micas of Möngön-Öndör and Öndör tsagaan revealed that the mineralization took place in the middle Jurassic time at the apex of a small plug. When carefully examined the geologic map, some small plugs of Jurassic age at the vicinity of polymetallic deposits are noticed (Fig. 2). Our study clarified that one of them, a small plug at Dund Shaikhanii khöndii, has on age of 191 Ma. This age corresponds to those of mineralization ages, 174 and 175 Ma, within analytical errors. Usually poymetallic deposits are found at or close to the apex of highly fractionated acidic intrusions (e.g., Murao *et al.*, 1991, 1995). Thus such small intrusion of middle Jurassic age is considered to be a possible source for polymetallic mineralization. One noteworthy fact is that the Mo-W-Be zone (Öndör-tsagaan deposit) and Zn-Sn-Pb-Ag zone (Möngön Öndör deposit) have mostly the same age, and thus the zonality at Öndör tsagaan seems to be of monoascendent type. There have been controversies on zonal arrangement of polymetallic ore bodies (e.g., Kutina, 1965; Nakamura and Miyahisa, 1976; Murao, 1988; Furuno *et al.*, 1992). The observation this time implies that such zonality can be developed mostly at the same time in a hydrothermal histroy and that an ore field of 10–20 km^2 in dimension can be formed around a small felsic plug.

6. Conclusion

Mineralization at Öndör tsagaan ore field is of polymetallic mineralization and the deposits are possibly the product of single pulse of hydrothermal solution. The zoning from the Mo-W-Be zone to the Zn-Sn-Pb-Ag zone is considered to be of monoascendent feature.

Jurassic granitic rocks are small in size and have less-distinct surface expression compared to Carboniferous granitoids, but they could be more important for the rare metal exploration. As stated before, in the Kherlen Depression, many deposits seems to be distributed along the boundary between Carboniferous granitoids and Devonian sedimentary rocks but the real distribution might be controlled not only by the boundaries but also by localities of small Jurassic plugs. It might be necessary to inspect the apex of highly fractionated small stocks of Jurassic age to explore such ore bodies rather than to work on a large batholith or to simply extend the prospect from an existed mine site.

Based on the geochronology in this region, there

Table 1 Potassium-argon age determinations on micas from granitoids and ore samples. Analyst: Teledyne Isotopes.

Sample No.	Locality	Material analyzed	Isotopic age (Ma)	$^{40}Ar^*$ (scc/gm$\times 10^{-5}$)	%$^{40}Ar^*$	%K
O-20	Öndör tsagaan	muscovite	174±9	5.60	97.1	7.84
				5.53	96.7	7.85
C 221-5 A	Möngön Öndör	phlogopite	175±9	5.06	97.2	7.17
				5.11	96.7	7.11
0824-9	Dund Shaikhanii	biotite	191±10	5.50	94.2	7.13
	Khöndii			5.65	94.6	7.09
0825-3	Ömnö delger	muscovite	273±14	8.89	97.6	7.73
				8.93	96.8	7.80
0824-1	Tsagaan chuluut	biotite	308±15	8.00	96.5	6.04
				7.80	96.6	6.06

$^{40}Ar/^{36}Ar_{\text{atomosphere}}=295.5$: Steiger and Jäger (1977).
Equation to calculate the age: Dalrymple and Lanphere (1969).

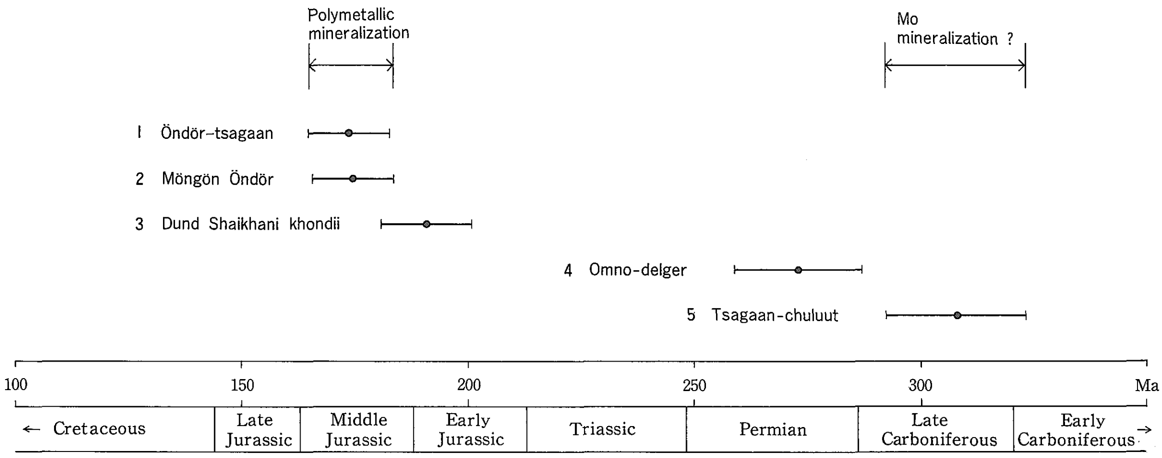

Fig. 6 Summary of K—Ar ages of igneous and hydrothermal mica minerals from eastern Mongolia

are at least two mineralization events, one of Mo, W, Sn, Be, Zn, Pb, Ag at Jurassic time and the other of Mo dissemination at Carboniferous time. Thus systematic geological survey and radiometric dating of rocks are vital to perform effective exploration and exploitation in this region.

Acknowledgments: Secretarial assistance and advise for the field survey was provided by Dr G Dejidmaa. Dr S Harayama gave SM technical advise on K-Ar dating of minerals.

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Received January 14, 1998
Accepted March 18, 1998

モンゴル国ケルレン陥没帯の花崗岩類および熱水性雲母の K-Ar 年代測定

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要　旨

モンゴル東部ケルレン陥没帯に産する花崗岩類と鉱床の熱水性雲母類の年令を K-Ar 法によって測定した．域内には地質学的な産状から三畳紀，ジュラ紀，石炭紀と判断される花崗岩類が分布し，多数の鉱床を随伴している．一般的に三畳紀，石炭紀花崗岩類は規模が大きく，ジュラ紀のものは小さい．本研究では陥没帯内オンドルツァガーン地域の小規模花崗岩体，その近傍に存在するMo-W-Be及びZn-Sn-Pb-Ag 鉱床の雲母類を測定し，それぞれ 191 Ma，174 Ma，175 Ma の結果を得た．また石炭紀花崗岩類の黒雲母を測定し 273 Ma と 308 Ma の結果を得た．以上より，ケルレン陥没帯の地質図では一見デボン系と石炭紀花崗岩類の境界付近に鉱床が集中するようにみえるが，実際にはジュラ紀の小規模花崗岩体が探査対象として重要であると結論した．