K-Ar Ages of Some W-Mo Deposits and Their Bearing on Metallogeny of South Korea

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Abstract: K-Ar ages were determined on eight specimens from five W-Mo deposits in South Korea. Muscovites purified from tungsten ore and pegmatitic quartz vein of the Ssangjeon W deposits give ages of Proterozoic. Although biotite in pegmatitic quartz vein of the Ogbang W mine yields much younger age, the occurrences of the deposits in both mines are so similar that the Ogbang deposits seem to have been formed at almost the same time as the Ssangjeon deposits. Muscovites from the Garisan W-Mo and Jangsu Mo deposits give ages of about 170 Ma, and confirm wide distribution of W-Mo mineralization at early Jurassic time. The results for sericites from the Cheongyang W deposits are around 80 Ma, and are almost same as those of the Daehwa W-Mo and Sangdong W-Mo-Bi deposits. In South Korea, W-Mo mineralization is prior to Au-Ag mineralization in Jurassic time, whereas vice versa in Cretaceous time. At the northeastern end of the Ryeongnam massif, tin (~1800 Ma), tungsten (~1500 Ma) and gold (~1100 Ma) mineralizations are overlapped in Proterozoic time.

Introduction

The Korean peninsula is famous for its large production of tungsten as well as gold. In South Korea, for example, the Sangdong mine is one of the most productive tungsten mines in the world. In his excellent pioneer work on the metallogeny of South Korea, KIM (1971) thought that most W-Mo deposits were formed in Jurassic time with genetical relation to Daebo granitic rocks. Recent age determinations, however, have revealed that some major W-Mo mineralizations are related genetically to Cretaceous Bulgugsa granitic activity. They include such as the Sannae W-Mo (65 Ma; FLETCHER and RUNDLE, 1977), Ilgwang Cu-W (66–81 Ma; FLETCHER and RUNDLE, 1977), Sangdong W-Mo-Bi (81–84 Ma; FARRAR et al., 1978), Shinyemi Zn-Pb-Mo (75 Ma; SATO et al., 1981), Daehwa W-Mo (89 Ma; SHIBATA et al., 1983) (88 Ma; So et al., 1983a) (85 Ma; KANEOKA et al., 1983), Geumseong Mo (157–179 Ma; SHIBATA et al., 1983), and Garisan (171 Ma; KIM and SEO, 1986) deposits. The first two deposits are situated in the Gyeongsang basin, which is covered by thick accumulations of Cretaceous sedimentary rocks with intermediate volcanic rocks. One more occurrence of tungsten is known in the basin, that is, the Ulsan Fe-W deposits. Although no direct age determination has yet been carried out, the deposits are thought to have been formed with genetical relation to Gadaeri granodiorite (PARK and PARK, 1980), which is dated as 58 Ma (LEE and UEDA, 1977). Those given above are all the data so far appeared in the literature, on the formation age of W-Mo deposits in South Korea.

Formation age data on Au-Ag deposits in South Korea have been also accumulated in recent publications, and three epochs, Precambrian, Jurassic and Cretaceous, are clearly recognized (SHIMAZAKI et al., 1986). In the present paper, five W-Mo deposits situated out-
side the Gyeongsang basin, were selected for the K–Ar age determination to shed more light upon the tungsten and molybdenum metallogeny of South Korea. Differing from the deposits in Japan, mineralizations of tungsten and molybdenum in South Korea are usually associated more or less with each other (Gallagher, 1963; Farrar et al., 1977; Ishihara et al., 1981; Shimazaki et al., 1981). Therefore, both mineralizations will be discussed together in the present paper.

**Brief Description of Studied Deposits and Samples**

The outline of geological setting of hydrothermal mineral deposits in South Korea is given elsewhere (i.e. Kim, 1971; J. H. Kim, 1977; Lee, 1981; Shimazaki et al., 1981). Eight specimens from five W-Mo deposits were selected for the K–Ar age determination. The approximate location of each deposit is given in Figure 1 with the distribution of Jurassic and Cretaceous granitic rocks and tectonic divisions.

**Ssangjeon and Ogbang W mines:** These mines are situated near the northeastern end of the Ryeongnam massif, a part of the Taebaegsan area, as shown in Figure 1. Not only tungsten, fluorite was produced from the Ogbang mine. Peculiar occurrences of the deposits attracted the notice of many previous workers such as Lee (1967), Youn (1979), Youn and Park (1982), So et al. (1983b) and Park and Lee (1984). These works reveal that the occurrence of the deposits is almost identical in both mines. The area mainly consists of two Precambrian rock units, the Weonnam series of biotite and biotite-garnet gneiss, and the Buncheon granite gneiss. The mines are located at the boundary of these two units. Along the boundary so-called amphibolite occurs in association with pegmatitic quartz veins, which contain scheelite, wolframite, fluorite and minor sulfide minerals such as arsenopyrite, pyrite, chalcopyrite and pyrrhotite. The origin of the amphibolite has been much debated. Many investigators supposed that it is an intrusive with a genetical relation to the tungsten mineralization, whereas So and Kim (1975) and So et al. (1983b) classified the rock as a hornblende schist, a member of the Weonnam series, of mafic tuff origin.

For the K–Ar age determination, three specimens were selected as follows. Fine-grained muscovite was separated from a wolframite ore (KR–945) of the Ssangjeon mine. The mineral is closely associated with large wolframite crystals and quartz. Another muscovite was from a pegmatitic quartz vein (KR–952) of the same mine, which consists of coarse-grained muscovite, aggregates of coarse-grained muscovite, and minor amounts of fluorite and wolframite. From a pegmatitic quartz vein (KR–937) of the Ogbang deposit, biotite was separated. Under the microscope, the biotite is slightly chloritized, and is associated with quartz, partly sericitized sodic plagioclase, K-feldspar and a considerable amount of apatite.

**Garisan W-Mo mine:** The mine is situated about 20 km east of Chuncheon City, Gangweondo Province. The mining area is a part of the Gyeonggi massif, and is occupied by Precambrian gneissose rocks with a small
granitic intrusion, which is colored as Jurassic in the geologic map of 1/250,000 scale published by Korea Institute of Energy and Resources (KIER). The W-Mo deposit occurs in quartz vein associated with intense greisenization. Molybdenite, wolframite, scheelite, sphalerite, galena, chalcopyrite, pyrite, muscovite and fluorite are observed with quartz in the vein. Recently Kim and Seo (1986) published K-Ar age data of muscovites from granite and quartz vein in the mine as 170 and 171 ± 4 Ma, respectively.

Muscovites from two specimens were provided for the K-Ar age determination in this study. One (HS81060803) is a greisen contacting with quartz vein. Muscovite was separated from the greisen, which includes quartz, sodic plagioclase, and minor K-feldspar, fluorite, zircon, sphene, chalcopyrite and sphalerite, besides muscovite. The other sample (HS81060804) was taken also at the boundary between greisen and quartz vein. Almost mono-mineralic muscovite aggregate along the boundary was used for the experiment.

Jangsu Mo mine: The mine is located about 45 km east-southeast of Jeonju City, and has once been one of the largest molybdenum mines in Korea (Gallagher, 1963). Molybdenite occurs in quartz-rich pegmatite dikes, which cut a granitic mass classified as Jurassic in the geologic map by KIER. According to Gallagher (1963), molybdenite-bearing pegmatite dikes include quartz, muscovite, orthoclase, scanty fluorite, and trace of biotite and chalcopyrite. The formation age of both Garisan and Jangsu deposits are assigned to Cretaceous in the metallogenic map of Korea compiled by Kim and Hwang (1983).

Muscovite was separated from a pegmatite specimen (KR-733) containing quartz and pink orthoclase (perthite).

Cheongyang W mine: The mine is located near the southwestern end of the Gyeonggi massif. The production of beryl is also recorded from the mine (Gallagher, 1963). The mining area consists of Precambrian biotite gneiss, which is intruded by a small stock of granite porphyry and several dikes of quartz porphyry. Several wolframite-bearing quartz veins occur in the granite porphyry stock with the same trend as the quartz porphyry dikes. Some quartz veins are observed outside the stock along the contact between the gneiss and dikes. Wolframite is scattered in pods and lenses throughout the quartz veins. Beryl, molybdenite, scheelite, pyrite, chalcopyrite, galena, bismuthinite, native bismuth, arsenopyrite, pyrrhotite, sphalerite, fluorite, rhodochrosite and calcite are observed in the veins (Gallagher, 1963; K. H. Kim, 1977).

For the K-Ar dating, sericite is separated from two specimens. One (HS81061701) is from altered pegmatitic dike running parallel to quartz vein. Sericite occurs as very fine-grained aggregate among K-feldspar and quartz crystals. The other (HS81061708) is a quartz vein specimen composed of quartz, radial aggregate of sericite and a small amount of wolframite.

Results and Discussion

The age determination was carried out at Geological Survey of Japan. The analytical method is given in Shibata and Nozawa (1978), and the constants used in the age calculation are: \( \lambda_0 = 4.962 \times 10^{-10}/y \), \( \lambda_e = 0.581 \times 10^{-10}/y \), \( ^{40}\text{K}/^{40}\text{Ar} = 0.1167 \text{ atm\%} \). The obtained results are listed in Table 1. In the present paper, age data given by previous workers are taken without recalculation.

Muscovite from wolframite ore in the Ssangjeon W mine gives 1480 Ma, whereas muscovite from pegmatitic quartz vein in the mine gives 1700 Ma. Judging from the occurrence of the former muscovite, that is, close association with the tungsten mineral, the former value seems to be more reliable as the formation age of the deposit. As stated before, tungsten (plus fluorite) mineralization in the Ogbang mine seems to have occurred under similar geologic environment to that of the Ssangjeon deposit, with marked spatial relation to so-called amphibolite. Biotite from pegmatitic quartz vein in the Ogbang mine, however, gives much younger age than those for the Ssangjeon deposit. The reason is not clear at present. Quartz porphyry of probably Cretaceous age occurs as a mass in the western
area of the Ogbang mine, and also as dikes scattered in the mining area (Lee, 1967; Youn, 1979), and might have reset the isotopic ages of surrounding rocks. Anyhow, the present data confirm the tungsten mineralization of Proterozoic time in the Taebaegsan area, prior to Cretaceous intense tungsten mineralization typified by the Sangdong deposits.

The obtained data for the Garisan deposit, 177 and 170 ± 5 Ma, are exactly the same as those given by Kim and Seo (1986) within the range of error, indicating that the both data are reliable. The results on the Garisan W–Mo and Jangsu Mo deposits, together with the published data of the Geumseong Mo deposits (Shibata et al., 1983), show that tungsten and molybdenum mineralizations also occurred at early Jurassic time widely in South Korea. The Cheongyang W deposits have been formed at late Cretaceous time. It is worthy to note that all Cretaceous tungsten-molybdenum deposits so far studied have similar formation ages of about 75 ± 10 Ma. Among them, typical W–Mo deposits in South Korea, such as the Sangdong, Daehwa and Cheongyang deposits, are formed at about 85 Ma, Zn–Pb dominant deposits in the Taebaegsan area, such as the Shinyemi and No. 2 Yeonhwa (Yun and Silberman, 1979), are at about 75 Ma, and the W–Mo deposits in the Gyeongsang basin are at about 65 Ma. Occurrences of beryl, fluorite and stanniferous minerals from the Cheongyang and Daehwa (So et al., 1983a; H. I. Park et al., 1985) deposits strongly suggest that both deposits have been formed with genetical relation to the igneous activity of ilmenite series, although Cretaceous Bulguga granitic activity is thought to have in general the characteristics of magnetite series (Ishihara et al., 1981).

The relation between the ages of W–Mo and Au–Ag mineralizations in Cretaceous and Jurassic time in South Korea, could be summarized as shown in Figure 2. Only reliable age data so far published are plotted in the figure. The Ulsan Fe–W deposit could be included in the figure, if it was really formed with relation to the granitic activity of 58 Ma as mentioned before. Kaneoka et al. (1983) reported the formation age of the Holgol Au–Cu deposit as about 130 Ma, which is located about 150 km north-northwest of Seoul City. The data could also be included in the figure. It is demonstrated in this figure that W–Mo mineralization occurred prior to Au–Ag mineralization in Jurassic time, whereas vice versa in Cretaceous time. The relation given in the figure probably indicates the sequence of mineralizations brought by long evolution of granitic magmatism in one region such as the Daebo and Bulguga ones, occurred at two different, deeper (Jurassic) and shallower (Cretaceous), levels. Further detailed study is

### Table 1 K–Ar Ages of Minerals from W–Mo Deposits in South Korea

<table>
<thead>
<tr>
<th>Name of mine</th>
<th>Specimen No.</th>
<th>Mineral and host rock</th>
<th>K2O(%)</th>
<th>Ar rad (10^-4 mIqSTP/g)</th>
<th>Atm. Ar (%)</th>
<th>Age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saengjeon</td>
<td>KR–945</td>
<td>Muscovite in wolframite ore</td>
<td>9.64</td>
<td>698 / 723</td>
<td>0.7 / 1.0</td>
<td>1440 ± 50 / 1490 ± 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1480 ± 40 / 1700 ± 50</td>
</tr>
<tr>
<td>Ogbang</td>
<td>KR–952</td>
<td>Muscovite in pegmatitic quartz vein</td>
<td>9.55</td>
<td>870 / 68.1</td>
<td>0.6 / 2.7</td>
<td>257 ± 8</td>
</tr>
<tr>
<td>Garisan</td>
<td>HS81060803</td>
<td>Muscovite in greisen contacting with quartz vein</td>
<td>10.63</td>
<td>63.7 / 61.0</td>
<td>4.3 / 6.2</td>
<td>177 ± 5</td>
</tr>
<tr>
<td>Jangsu</td>
<td>KR–733</td>
<td>Muscovite in pegmatite vein</td>
<td>10.64</td>
<td>62.2 / 29.6</td>
<td>7.2 / 17.1</td>
<td>170 ± 5</td>
</tr>
<tr>
<td>Cheongyang</td>
<td>HS81061701</td>
<td>Sericite in altered pegmatitic vein</td>
<td>10.81</td>
<td>26.9 / 17.1</td>
<td>5.7 / 85.9 ± 2.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HS81061708</td>
<td>Sericite in quartz vein</td>
<td>9.85</td>
<td>28.0 / 5.7</td>
<td>28.0 / 85.9 ± 2.7</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 2 Histogram of formation ages of mineral deposits in South Korea (Mesozoic only). Locality map is given in Figure 3. Name of deposits and data source are as follows:


necessary to solve this problem from the viewpoint of metallogeny of the Korean peninsula.

In Figure 3, all deposits with reliable age data are plotted. It is confirmed that tungsten and molybdenum mineralization has at least three epochs in south Korea, as well as gold (SHIMAZAKI et al., 1986). The present compilation, however, reveals that age data on base metal and fluorite mineralizations are almost lacking. Especially the latter is one of the features characterizing the metallogeny of South Korea, and has a significant role in the correlation to the metallogeny of Japan.

Precambrian mineralization seems to be limited in the northeastern end of the Ryeongnam massif. This area is also known as the area only where remarkable tin mineralization is recognized in South Korea (PARK, 1982). All deposits so far exploited are cassiterite-bearing pegmatites in Precambrian gneiss and schist.

YUN (1983) reported the age of 1773–1792 Ma on muscovites from pegmatites occurring near the Soongyeong mine, one of the representative tin deposits in this area. Unfortunately, however, it is not clear in his paper whether those pegmatites are mineralized or not. If it is the case that tin-bearing pegmatite was formed at about 1800 Ma, tin (∼1800 Ma), tungsten (∼1500 Ma) and gold (∼1100 Ma) mineralizations are confirmed to have been overlapped in this area. Not clear yet is the reason why this area was so intensely mineralized in Proterozoic time, and has been preserved at the present erosion level.

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韓国におけるいくつかの W-Mo鉱床の K-Ar年代と
その鉱床生成論における意味

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要旨：韓国の5つのW-Mo鉱床からの8つの試料について、K-Ar年代測定を行った。双田W鉱床の鉱石とベグマタイト質石英脈から分離された白雲母は原生代の年代を与えた。玉房W鉱床のベグマタイト質石英脈中の黒雲母はより若い年代を与えたが、両鉱床の産状が酷似していることから、玉房も双田と同時代に生成されたと考えられる。加里山W-Moおよび長沢Mo鉱床からの白雲母は、およそ170 Maの年代を与え、ジュラ紀初期の広範なW-Mo鉱化作用があったことを示す。青陽W鉱床の綿雲母の結果は、およそ80 Maであり、大華W-Moや上東W-Mo-Bi鉱床と同時期である。韓国では、ジュラ紀ではW-Moの鉱化が、Au-Agの鉱化に先立って起こっているが、白亜紀でのこの逆である。嶺南陸塊の北東隅では、鎧(〜1800 Ma)・タンクステン(〜1500 Ma)・金(〜1100 Ma)の鉱化が、原生代に重複して起こっている。

(地名)