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A Geochemical Study on Trace Elements in the Granitic Rocks in relation to Mineralization in the Limestone Area of the Taebaegsan Basin

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Abstract: Various skarn ore deposits of Pb-Zn, Fe-Cu, W-Mo and others are widely distributed in the study area which consists mainly of Cambro-Ordovician calcareous rocks. The ore deposits are all in close association with specific types of granitic rocks of mid-late Cretaceous age according to the kinds of ores: Fe-Cu deposit with granodiorite-quartz monzodiorite, Pb-Zn deposit with granite-granodiorite, W-Mo deposit with granite, and Mn deposit with quartz porphyry.

The granitic rock of Fe-Cu deposit has lower content in K and higher in Ca than those of Pb-Zn deposits. On the contrary, the granitic rock of W-Mo deposit has much higher content in K and lower in Ca in comparison to those of Pb-Zn deposits. However, the granitic rock of Mn deposit shows similar variation to those of Pb-Zn deposits.

Lithophile trace elements of Sr and Rb tend to vary in close relation with major elements of K and Ca, respectively. In good contrast, chalcophile elements of Cu, Pb, Zn, W and Mo are enriched in the granitic rocks of their ore deposits, and other trace elements of Ni and Co show a trend to vary in relation with Mg, Fe and Cu, which have the same replacement index (0.14) as Ni and Co. Average K/Rb and Ca/Sr ratios of the granitic rocks range nearly within 300~150 and 150~40, respectively, and the distribution pattern of the ratios is different according to the kind of ore deposits: Fe-Cu deposit is plotted toward K-Rb poor region whereas Pb-Zn and W-Mo deposits toward K-Rb rich region. In contrast, Fe-Cu and Fe deposits are plotted toward Ca-Sr rich region whereas Pb-Zn deposit toward Ca-Sr poor region. The variation trend of chemical elements of the mid-late Cretaceous granitic rocks in the study area is similar to that of the Cretaceous granitic rocks in the Gyeongsang Basin. Therefore, this geochemical result may be applicable to determining what kinds of ore deposits a Cretaceous granitic rock is favourable for, and whether it is productive or non-productive for systematic geochemical exploration works.

INTRODUCTION

In the Taebaegsan Ore Belt which consists mainly of the Cambro-Ordovician calcareous rocks in the southern part of the Taebaegsan Basin, skarn ore deposits of Pb-Zn, Fe-Cu and W-Mo are widely distributed from the western to the eastern margin in the area in close association with the mid-late Cretaceous granitic rocks (Yun and Silberman, 1979; Yun, 1983), and it is expected that blind ore deposits might exist at the contact zones of the calcareous country rocks with the granitic rocks at certain depths. Therefore, the limestone area including the Taebaegsan Ore Belt was selected for this study.

Active mineral exploration works have been carried out in the Taebaegsan Ore Belt by applying geochemical and geophysical prospecting methods to find blind ore deposits. As for geochemical exploration works a great number of stream sediments, heavy mineral concentrates (Lee, 1969), soil samples have been chemically analysed to investigate the secondary dispersion

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patterns of pathfinders, which are useful to find anomalies of the blind ore deposits. In spite of these active exploration works, however, primary dispersion patterns of trace elements in the granitic rocks have not been investigated so far in relation to mineralization, although it is important and fundamental not only for geochemical exploration but also for research works in lithochemistry and economic geology.

As certain kinds of ore deposits are associated with specific types of plutonic rocks, and the association has been used for mineral exploration, it is also possible to explore ore deposits by using the primary dispersion patterns of certain elements in the plutonic rocks. Therefore, it has been the focus of attention to determine the characteristics of the dispersion patterns in the mid-late Cretaceous granitic rocks according to various ore deposits of Fe-Cu, Pb-Zn and W-Mo in the Taebaegsang Ore Belt. Interesting geochemical results had already been obtained from similar geochemical study on the Cretaceous granitic rocks in the Gyeongsang Basin (Lee, 1984).

Fortunately, a number of analytical data of the granitic rocks have been collected from geochemical and lithochemical works in the limestone area, and these data make it possible to carry out this geochemical study in the Taebaegsan Ore Belt and its vicinity of the area.

In this context the investigation on content of major and trace elements in the granitic rocks in relation to mineralization has a significant importance. Therefore, in this study the content of major (Na, K, Ca, Mg) and trace (Rb, Sr, Cu, Pb, Zn, W, Mo, Ni and Co) elements were compared between the granitic rocks associated with various ore deposits of Mn, Fe-Cu, Pb-Zn and W-Mo, and this work was focussed on finding geochemical difference between the granitic rocks of Fe-Cu and Pb-Zn deposits.

As various ore deposits are associated with the mid-late Cretaceous granitic rocks in the area, the results of the geochemical study may be useful to determine whether a Cretaceous granitic intrusive would be productive or non-productive, and favourable or unfavourable for

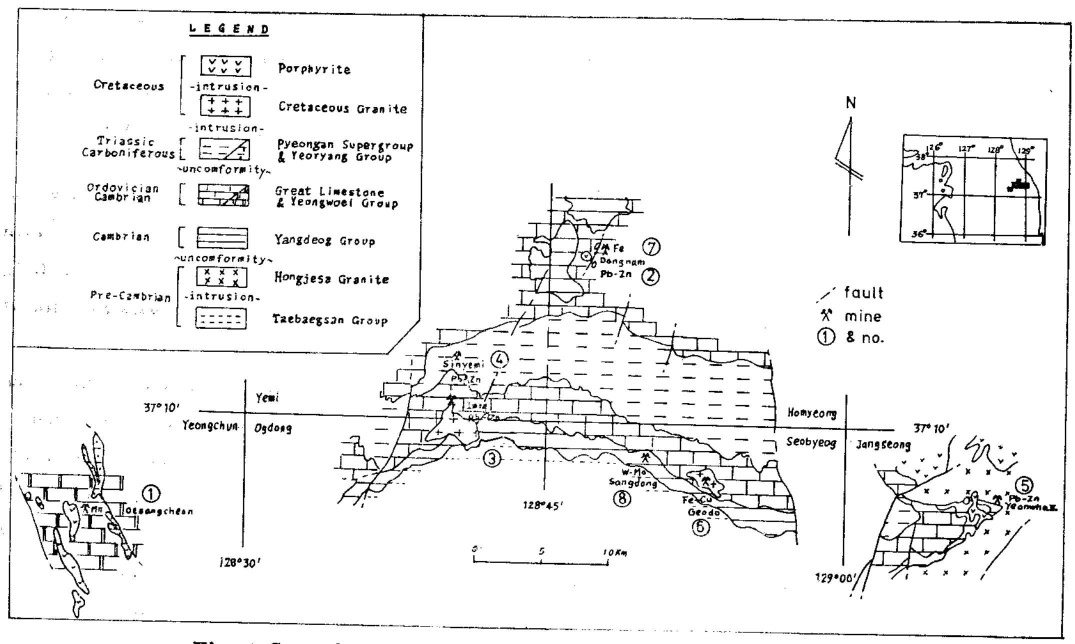

Fig. 1 General geology of the Taebaegsan zone with mine localities.

certain ore deposits by comparing with the Cretaceous granitic rocks from the Gyeongsang Basin.

GENERAL GEOLOGY

The Taebaegsan Ore Belt is located in the northeastern part of the Ogcheon Fold Belt, which is one of the four main geologic provinces including Gyeonggi Massif, Ryeongnam Massif and Gyeongsang Basin. The two massifs composed of Pre-cambrian schist and granite form the basement for the Ogcheon Fold Belt (Reedman and Um, 1975).

The northeastern zone of the Ogcheon Fold Belt is a non-metamorphic and Neo-geosynclinal, while the southeastern zone is a metamorphic and Paleo-geosynclinal. The former is composed of terrain of the Cambro-Ordovician calcareous rocks (The Great Limestone Group and Yeongweol Group) and sandstone-shale of the Carboniferous to Triassic age (Pyeongan System), which were all intruded by the mid-late Cretaceous granitic rocks forming various skarn deposits (Fig. 1). On the contrary, the latter consists predominantly of deformed schist, gneiss, quartzite, limestone, and dolomite of the late Proterozoic age.

Most of the deformation in the Ogcheon Fold Belt is known to be related to the major orogeny of Jurassic age, which involved the emplacement of north-northeast trending Daebo granites, and the two zones display differences in the geological structure (Yun, 1979a).

The non-metamorphic zone is highly folded, and has numerous high angle thrust faults and zones of imbrication. The folds are more commonly concentric than in the metamorphic zone, and the strata have brittle fractures. In good contrast, the metamorphic zone is characterized by major similar folds and ubiquitous penetrative minor structures resulting from intensive plastic deformation, and axial plane, crenulation foliation and a variety of types of tectonic lineation are found in the the strata (Reedman and Um, 1975; Yun, 1979a).

METALLOGENY

Most mineral deposits in South Korea are closely associated with the Mesozoic granitic rocks of the mid Cretaceous - early Tertiary Bulgugsa granites and masanites, and Jurassic Daebo granites (Kim, 1971; Lee, 1972).

The major mineral deposits related to the Cretaceous granitic rocks occur as hydrothermal vein or breccia pipe deposits in the Gyeongsang Basin, in which the ore deposits are distributed in metallogenic pattern of Cu-Fe, Pb-Zn and W-Mo from the southeastern coast to inland (Sillitoe, 1977; Min et al., 1980).

In good contrast, the major mineral deposits related to the Cretaceous granitic rocks occur as

Table 1 A brief geological description of mines.

Id. No.	Mines	Main ore metals	Intrusive	Country rock	Main ore minerals
1.	Oesangcheon	Mn	Quartz porphyry	Calcareous rocks	Mn-oxides
2.	Dongnam	Pb-Zn	Quartz porphyry	Calcareous rocks	Galena/Sphalerite
3.	Imog	Pb-Zn	Granite	Calcareous rocks	Galena/Sphalerite
4.	Sinyemi	Pb-Zn	Granite	Calcareous rocks	Galena/Sphalerite
5.	Yeonwha Ⅱ	Pb-Zn	Quartz monzonite porphyry	Calcareous rocks	Galena/Sphalerite
6.	Geodo	Fe/Cu	Granodiorite-Quartz monzodiorite	Calcareous rocks	Magnetite/Chalcopyrite
7.	Dongnam	Fe	Diorite	Calcareous rocks	Magnetite
8.	Sangdong	W-Mo	Granite	Calcareous rocks	Scheelite/Molybdenite

contact metasomatic or replacement deposits in the study area of the Cambro-Ordovician calcareous rocks in the Taebaegsan Basin.

The major important ore minerals are Mn-oxides and rhodochrosite for Mn ore deposits sphalerite and galena for Pb-Zn skarn ore deposits, magnetite and chalcopyrite for Fe-Cu ore deposits and scheelite and molybdenite for W-Mo ore deposits. These ore minerals are associated with various other sulphides. Most deposits are characterized by various types of hydrothermal alteration, and the skarn minerals are arranged in a zonal pattern from the intrusives toward fresh calcareous rocks.

According to the ternary diagram of Rb-Ba-Sr, most intrusives were partly altered to anomalous granitic rocks and resemble base-metal mineralized calc-alkaline palingenic granodiorite (Yun, 1979b).

The representative ore deposits related to the granitic rocks in the study area are as followings (Table 1):

Mn Ore Deposits

Oesangcheon Mine: Secondary enriched Mn-ore deposits are developed near surface along north-westerly trending fault in the Ordovician calcareous rocks of Samtaesan Formation.

Supergene enrichment of Mn-oxides has resulted from oxidation of pre-existing Mn-carbonate, chiefly of rhodochrosite which was mineralized in close association with the Cretaceous quartz porphyry. Most of associated sulphides of galena and pyrite were removed during weathering, and the resulting Mn-oxides are chiefly of manganite, pyrolusite and cryptomelange(Lee and Hwang, 1984).

Pb-Zn Ore Deposits

Yeonwha Mine: Ore bodies occur in association with skarns in the Cambro-Ordovician calcareous rocks of Myobong, Pungchon and Hwajeol Formations (Han, 196 & 1972).

The ore minerals, sphalerite and galena are associated with clinopyroxene at the upper part and with clnopyroxene-garnet at the lower part of the Wolam I ore body at Yeonwha I. The pyroxene-garnet zone is in pipe-type at depth but branches to rhodochrosite-pyrite veins toward the surface in an area of quartz porphyry dikes. Skarns at Yeonwha II display higher garnet/pyroxene ratio and occur as stratabound lenses and irregular massive at or near contacts with larger bodies of quartz monzonite (Yun, 1983).

Although rhodochrosite occurs in association with Pb-Zn ores at Yeonwha deposits, it was not as much oxidized as the Oesangcheon supergene Mn deposit.

Sinyemi Mine: Ore bodies are developed in the Maggol limestones of Cambro-Ordovician age in close association with Cretaceous quartz monzonite porphyry. They occur in the skarnized carbonate beds at the west side and as pipe-like or irregular veins at the east side of the ore bodies. The Maggol limestone beds are selectively replaced by hydrothermal solution under control of geologic setting. The west ore bodies might be formed in an early stage of mineralization (Kim et al., 1981).

The hydrothermal alteration of the ore-related granitic rocks includes sericitization of feldspar and biotite near ore body, and propylitization of calcic plagioclase and biotite toward fresh host carbonate. Argillic alteration of feldspar and silicification of host calcareous rocks is observed in some zones.

Sphalerite and galena are main ore minerals. Chalcopyrite, pyrrhotite, pyrite and arsenopyrite are associated with them.

Imog Mine: Ore bodies are emplaced in Dumudong argilliceous limestone near the contact zone with Imog granite. Ore lodes are about 100m long and 0.2~1.0 m wide, and dip 70° westly striking NS-N15°E. Sphalerite and galena are associated in the lodes as main ore minerals with other sulphides of chalcopyrite, pyrrhotite, pyrite and arsenopyrite (Seo, 1985).

Fe and Pb-Zn Ore Deposits

Dongnam Mine: There are three types of ore deposits. One is magnetite deposit which was formed at the contact zone of the Cambro-Ordovician calcareous rocks with diorite, and another one is hydrothermal veins of galena, sphalerite and rhodochrosite which were formed by quartz porphyry along NS faults, and the last is stockwork of molybdenite in the diorite. Mn-oxides are enriched at surface by supergene oxidation of the rhodochrosite (Seo and Lee, 1983).

Most calcareous rocks are thermally metamorphosed at the contact zone of the intrusive rocks. Albite-epidote-hornfels are formed from pelitic Myobong slate and hornblende-hornfels from Pungchon limestone. The quartz porphyry also shows wallrock alteration of epidote-chlorite-calcite and kaolinite-muscovite-chlorite facies.

Fe-Cu Ore Deposits

Geodo Mine: There are two kinds of ore deposits of iron skarn and copper skarn ores at the contact zones of the Cambro-Ordovician calcareous rocks with quartz monzodiorite (Chang and Park, 1982; Ko and Kim, 1982). The Iron skarn ore deposit (Jangsan ore body) is located along the southern margin, and the upper skarn ore deposit (78 ore body) along the northern margin of the quartz monzodiorite. Skarn minerals are zonally arranged at both deposits (Yun, 1983).

The iron skarn ore deposit is hosted in the quartz monzodiorite as a typical endo-skarn type, and shows a skarn zoning from center of the ore body toward outer side: magnetite zone, magnetite-garnet zone, garnet-clinopyroxene zone, and clinopyroxene-epidote-plagioclase zone. Magnetite is associated mainly with the garnet.

The copper skarn ore deposit is hosted in the calcareous rocks and shows a zoning from the quartz monzodiorite toward the countryrock: orthoclase-epidote zone, epidote-clinopyroxene zone, and clinopyroxene-garnet zone. Chalcopyrite is associated mainly with the clinopyroxene-garnet.

W-Mo Ore Deposits

Sangdong Mine: W skarn ore deposit is enriched in the imbedded limestone in the Myobong slate and the lower parts of the Pungchon Limestone Series of Cambro-Ordovician age.

The ore deposit is of metasomatic replacement type which was formed by ascending mineralizing fluid probably derived from an inferred magma within 1km below the present Sangdong ore deposit (Moon, 1984). Later Sangdong granite was found within the depth as ore-relating intrusive (Kim, 1986).

The ore deposit shows an unusual zonal distribution of skarn of quartz-mica, amphibole and pyroxene-garnet from its central part toward unaltered limestone. This indicates that ore deposit was formed inward from the outer contacts with limestone (Moon, 1974).

Scheelite is a main ore mineral, but molybdenite occurs with other sulphides such as bismuthinite and chalcopyrite (Moon and Hang, 1980).

GRANITIC ROCKS

The granitic rocks are distributed in close spatial association with ore deposits in the study area, and have been investigated to be mostly related to the mineralization of the ore deposits (Yun, 1979b; Chang and Park, 1982; Seo and Lee, 1983; Lee and Hwang, 1984; Kim, 1986).

The content of trace elements in the granitic rocks at Imog, Geodo and Yeonwha II also indicate that the granitic rocks are similar to Tauson's palingenic calc-alkaline granitoids, which has potential ore capacity of, and genetically related to the mineralization of Cu, Pb, Zn, W, Mo, Sn and Au (Yun, 1979b).

Chemical Composition

The granitic rocks with high silica contents are generally high in alkalies, but low in lime, magnesia and iron oxides; whereas the granitic rocks with low silica content are high in lime, magnesia and iron oxides, but low in alkalies in the study area, This regular variation of major oxides against SiO_2 coincides with the statistical proportion of those in common plutonic rocks.

The granitic rocks fall in categories of granite (or quartz porphyry), granodiorite and diorite on the basis of SiO_2 content, which is relatively consistent with the classification based on modal compositions.

According to SiO_2 content and modal compositon, granodiorite-quartz monzodiorite of Geodo Fe-Cu mine ranges 51~64% in SiO_2, which decreases to 50~54% for quartz monzodiorite in contact with Cu-bearing deposit. In good contrast, diorite of Dongnam Fe mine has also low SiO_2 content of 53~58% similary to Geodo mine. However, granite-granodiorite of various Pb-Zn mines including Dongnam Pb-Zn deposit has high SiO_2 content of 64~70%, which increases to 73~75% for granite (quartz porphyry) at Oesangcheon Mn mine. SiO_2 content is also very high (70~76%) for Sangdong granite, which is, however, much altered near the contact. In the comparison with other granitic rocks, this alteration must be considered.

The granitic rocks in the study area were fractionally crystallized in the order of Geodo granodiorite, quartz monzonite porphyry and Imog granite from co-magma (Yun, 1985), showing low K and high Ca at Geodo mine, and high K and low Ca at Imog mine. This order, however, is not well reflected in K/Rb and Ca/Sr ratios. But the fractional crystallization of Imog granite is indicated by the variation patterns of K/Rb and Ca/Sr ratios toward the central part of the intrusive.

According to the AFM diagram (Fig. 2) the chemical composition of the granitic rocks in the study area shows a trend to change from intermediate to felsic with close relationship to types of ore deposits. This variation is broadly analogous to that in the Gyeongsang Basin (Lee, 1984).

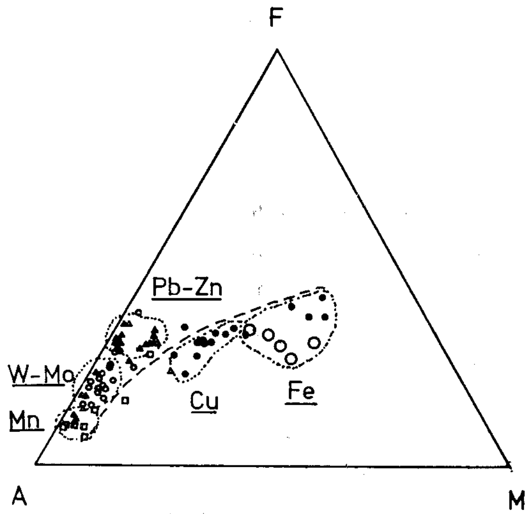

Fig. 2 Chemical variation of granitic rocks in relation to types of ore deposits.
• (Fe-Cu), ▵ (Pb-Zn) ∘ (W-Mo)
▫ (Mn), ○ (Fe)

Mineralogical Composition

The granitic rocks are classified mainly into granite, granodiorite, quartz monzonite and

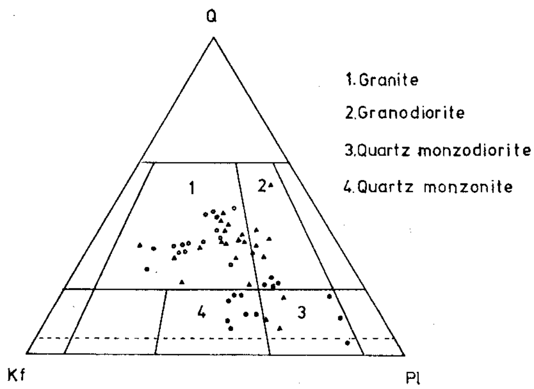

Fig. 3 Classification of granitic rocks from the study area. Symbols are the same as Fig. 2.

quartz monzodiorite according to the ternary diagram of modal composition (Fig. 3), which normative composition largely coincides with, and is only slightly richer in orthoclase.

The general variation trend of normative composition(Fig. 4) displays magmatic differentiation from granodiorite to granite, and strongly indicates that kinds of ore deposits are associated with specific types of granitic rocks in the study area. This variation is broadly analogous to that of the crystallization path of the Cretaceous granitic rocks in the Gyeongsang Basin (Jin et al., 1982), and changes from plagioclase toward quartz-orthoclase side of the diagram.

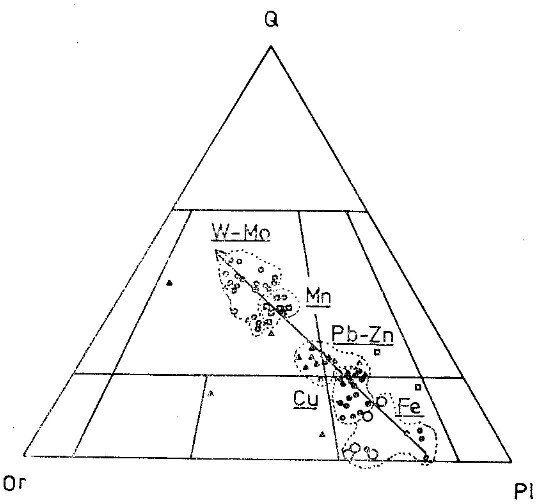

Fig. 4 Variation of normative composition in granitic rocks. Symbols are the same as Fig. 2.

GEOCHEMISTRY

Major Elements

As major elements play an important role chemically and petrochemically in the variation of trace elements, it is necessary to investigate the variation trend of some important major elements which are related to the variation of trace elements.

Content of major elements shows a characteristic difference between granitic rocks of various deposits of Mn, Pb-Zn, Fe-Cu, and W-Mo in the study area.

Granitic rock of the Fe-Cu deposit at the Geodo mine has content lower in K and higher in Ca than those of Pb-Zn deposits at the Imog, Yeonwha II and Sinyemi mines. On the contrary, granitic rock of the W-Mo deposit at the Sangdong mine has content much higher in K and lower in Ca in comparison to those of Pb-Zn deposits. However, granitic rock of the Mn deposit at the Oesangcheon mine shows similar variation trend to those of Pb-Zn deposits. This may be due to mineral association of galena and sphalerite to rhodochrosite at the Oesangcheon mine, from which Mn-oxides were formed by supergene enrichment.

In contrast to K, Na content shows some irregular variation trends. For instance, it is lower at the Dongnam Pb-Zn deposit than at

Table 2-a Major elements of the granitic rocks.

No.	Name of mines	Na	K	Ca	Mg	Nos. of samples
1.	Oesangcheon	2.49～5.01(3.17)	1.02～4.41(3.31)	0.18～1.70(0.60)	0.01～0.76(0.35)	8개
2.	Dongnam(Pb-Zn)	0.17～2.78(1.90)	4.05～6.48(4.95)	0.16～0.88(0.44)	0.12～0.24(0.18)	4개
3.	Imog	2.44～2.61(2.49)	3.20～3.57(3.39)	1.66～2.34(2.07)	0.48～0.81(0.72)	10개
4.	Sinyemi*	2.58～3.26(3.02)	2.81～5.05(4.06)	1.97～2.69(2.32)	0.08～0.14(0.12)	4개
5.	Yeonwha II**	2.52～2.92(2.71)	3.65～4.02(3.83)	1.19～1.97(1.72)	0.11～0.28(0.16)	6개
6.	Geodo	1.67～3.26(2.48)	2.44～4.49(3.01)	2.30～4.21(2.96)	1.45～2.74(2.03)	9개
7.	Dongnam(Fe)	1.67～2.47(2.04)	2.07～2.93(2.56)	3.59～5.43(4.58)	2.88～5.81(4.14)	5개
8.	Sangdong***	0.84～2.35(1.78)	3.50～4.65(4.10)	0.41～1.08(0.80)	0.08～0.59(0.23)	32개

Data from *(Kim, K.H. et al., 1981), **(Yun, S.K., 1979), ***(Kim, K.H., 1986)
unit=%, ( )=average

the Geodo Fe-Cu deposit.

According to the variation trend of major elements there is a trend that the granitic rock related to Cu mineralization has content lower in Na and K, and higher in Ca in comparison to the granitic rocks related to Pb-Zn mineralization, because the Cu deposit occurs in close association with less differentiated granitic rocks than Pb-Zn deposits.

Thus, the difference in the content of major elements between granitic rocks of various deposits seems to be reflected more clearly in K and Ca (Table 2a).

This variation trend of major elements may be useful in distinguishing types of granitic rocks and determining favorable mineralization of the mid-late Cretaceous granitic rocks in the study area.

This variation trend between various ore deposits of Fe-Cu, Pb-Zn and W-Mo is compared with that between the metallogenic provinces of Fe-Cu, Pb-Zn and W-Mo in the Gyeongsang Basin.

Sodium: There is not a clear difference in Na content between granitic rocks of various deposits

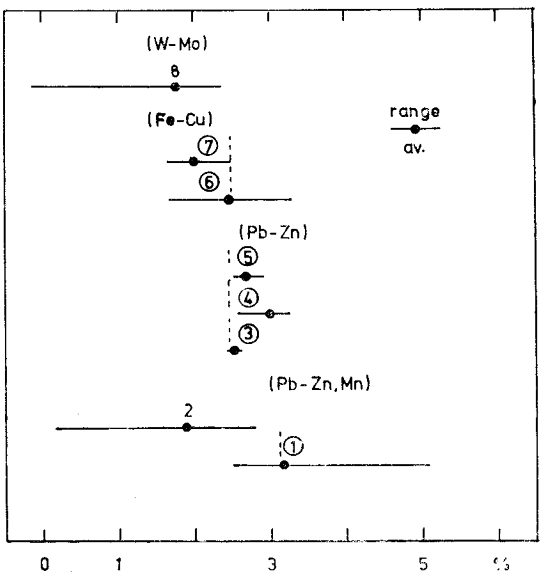

Fig. 5 Variation of Na in granitic rocks.

in the study area. However, Na shows a weak variation trend decreasing in the order of Mn deposit>Pb-Zn deposit>Fe-Cu deposit>W-Mo deposit.

This difference in Na content is displayed better by its average content (Fig. 5) ; The average is lower at the Geodo Fe-Cu deposit (2.48%) than at the Pb-Zn deposits of Yeonwha II(2.71%) and Sinyemi(3.02%) except Dongnam (1.90%). However, this low average of the Dongnam mine is slightly higher than that of the Sangdong mine (1.78%). This is due to anomalous alkali content (low Na/high K) of Sangdong granite, which was altered near the contact (Kim, 1986). The highest in the study area is 3.17% at the Mn deposit. This is due to the variation trend of Na which is concentrated more in felsic rocks during fractionation.

This variation trend of the averages, slightly higher at the Pb-Zn deposits than the Fe-Cu deposits is consistent with that of the Gyeongsang Basin, where Na is 2.97% in Pb-Zn province against 2.40% in Cu province. However, the lowest value is obtained from the W-Mo deposits although Mo province has highest average (3.1%) in the Gyeongsang Basin (Lee, 1984).

Potassium: There is a clear difference in the K content between granitic rocks of various deposits in the stdudy area, showing a variation trend that K decreases in the order of W-Mo deposit>Pb-Zn deposit>Fe-Cu deposit. However, the difference between W-Mo and Pb-Zn deposits is not so clear, and Mn deposits has a wide range of variation which covers most of the other ore deposits.

Similarly to Na, the difference in K content is clearly displayed by its average content (Fig. 6) ; The average is lower at the Geodo Fe-Cu deposits (3.01%) than at the Pb-Zn deposits of Imog (3.39%), Yeonwha II (3.83%), Sinyemi (4.06%) and Dongnam (4.95%). It is much lower in comparison to the Sangdong W-Mo deposits (4.10%).

The variation trend of K content, higher at the Pb-Zn deposits than at the Fe-Cu deposits also coinsides with that of the Gyeongsang Basin, where K is 2.90~4.79% (av. 3.59%) in Pb-Zn province and 1.43~4.31% (2.59%) in Cu province. But the tendency that the W-Mo deposits has higher K content than the Pb-Zn deposits is in opposite relation to the Gyeongsang Basin, where K is 2.21~4.10% (av. 3.13%) in Mo province against 2.90~4.79% (av. 3.59%) in Pb-Zn province (Lee, 1984).

Calcium: There is also a clear difference in Ca content between granitic rocks of various deposits in the study area. Ca decreases in the order of Fe deposit>Fe-Cu deposit>Pb-Zn deposit>Mn, W-Mo deposit. However, the difference between Mn and W-Mo deposits is not clear.

This opposite variation trend of Ca content to K is more clearly displayed by its average (Fig. 7) ; The average is higher at the Geodo Fe-Cu deposits (2.9%) than at the Pb-Zn deposits of Yeonwha II (1.72%), Imog (2.7%) and Sinyemi (2.32%), and it is much higher than those of the Sangdong W-Mo deposit (0.80%) and the Oesangcheon Mn deposit (0.60%).

This variation trend of Ca content between the Fe-Cu, Pb-Zn and W-Mo deposits is consistent with that of the Gyeongsang Basin, where Ca is 1.63~5.49% (av. 2.9%) in Cu province and 0.33~2.55% (1.03%) in Pb-Zn province and 0.33~2.18% (0.97%) in Mo province (Lee, 1984).

Magnesium: There is a clear difference in Mg content between granitic rocks of Fe-Cu and other ore deposits in the study area showing a variation trend that Mg decreases in the order of Fe deposit>Fe-Cu deposit>Pb-Zn, Mn, W-Mo deposits. There is not a distinguishable difference between Pb-Zn, Mn and W-Mo deposits.

The difference in Mg centent between the Pb-Zn, Mn and W-Mo deposits is not displayed even by its averages (Fig. 8) ; The averages are all less than 1% except those of Dongnam Fe deposit (4.14%) and the Geodo Fe-Cu deposit (2.03%).

The variation trend between the Fe-Cu and Pb-Zn deposits coinsides with that of the Gyeongsang Basin, where Mg content is higher

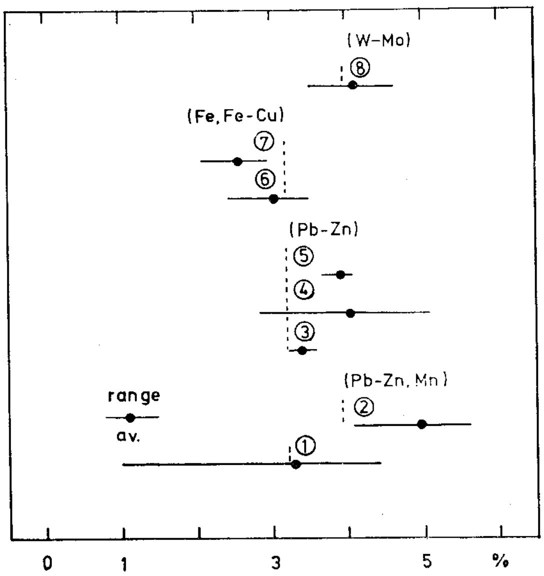

Fig. 6 Variation of K in granitic rocks.

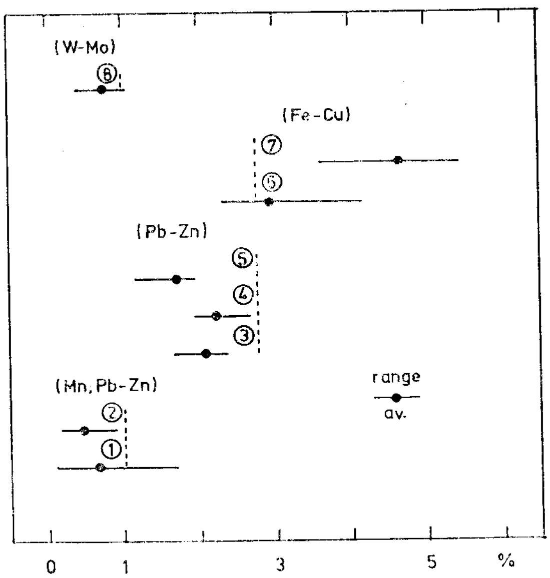

Fig. 7 Variation of Ca in granitic rocks.

Table 2-b Trace elements of the granitic rocks.

No.	Name of Mines	Rb	Sr	Cu	Pb	Zn	Ni	Co	Mo	W
1.	Oesangcheon	—	—	15~30 (20)	10~30 (16)	24~62 (45)	10~25 (16)	10	1~5 (3)	5
2.	Dongnam (Pb-Zn)	—	50~170 (98)	5~7 (6)	40 (40)	100 (100)	5	10~13 (11)	5~8 (7)	—
3.	Imog	123~164 (141)	85~185 (117)	10~40 (18)	35~70 (43)	90~140 (115)	9~20 (14)	10 (10)	1~7 (3)	10
4.	Sinyemi	(147)	(168)	24~48 (34)	35~40 (37)	95~130 (111)	25~60 (40)	45~50 (48)	—	—
5.	Yeonwga II	87~236 (165)	350~520 (423)	10~105 (41)	35~96 (53)	22~35 (32)	—	—	3~9 (7)	—
6.	Geodo	110~171 (139)	525~827 (640)	10~95 (52)	13~50 (30)	43~111 (72)	30~75 (47)	—	4~15 (8)	5~7 (6)
7.	Dongnam	—	240~530 (400)	5~25 (15)	40~85 (49)	100 (100)	4~25 (11)	20~65 (34)	5~25 (11)	—
8.	Sangdong	238~360 (283)	41~187 (108)	2~25 (12)	9~98 (40)	7~100 (39)	5~7 (39)	—	1~34 (14)	11~182 (43)

unit=ppm, ( )=average.

in Cu province than in Pb-Zn province (Lee, 1984). This variation trend is consistent with the general variation pattern of Mg because a Fe-Cu deposit is related to less felsic rocks in comparison to a Pb-Zn deposit.

Trace Elements

The content of certain trace elements also shows characteristic difference btween the granitic rocks of various ore deposits, especially of Fe-Cu and Pb-Zn in the study area.

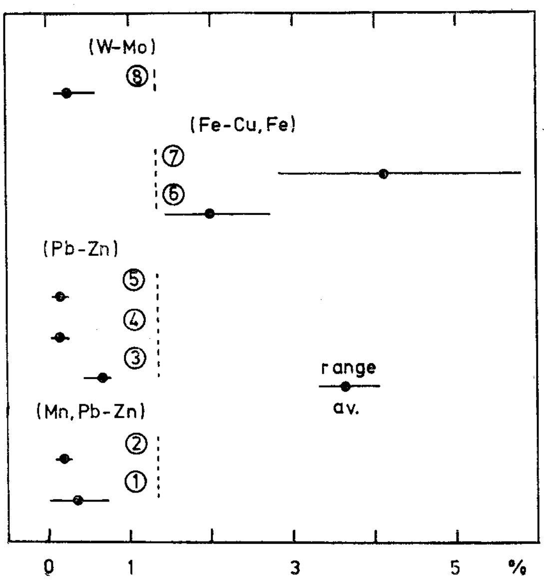

Fig. 8 Variation of Mg in granitic rocks.

Lithophile trace elements of Rb and Sr tend to vary in close relation with major elements of K and Ca. In contrast, chalcophile elements of Cu, Pb, Zn, W and Mo are enriched in the granitic rocks of their ore deposits, and other trace elements of Ni and Co show a trend to vary in relation with Fe, Mg and Cu due to their similar replacement index (0. 14) between them (Table 2b).

Most trace elements were taken up by the crystallizing silicates during the differentiation of the granitic magma, substituting for major elements. However, ore metal markedly disimilar to major elements were concentrated in the residual melt of the granitic magma, and enriched in the productive granitic rocks in the study area.

The variation trend of trace elements in the study area is also compared with that in the Gyeongsang Basin (Lee, 1984).

Rubidium: There is a slight difference in Rb content between the granitic rocks of various ore deposits in the study area. Rb decreases in the same order of W-Mo deposit>Pb-Zn deposit>Fe-Cu deposit as K. For instance, Rb content is 110-171ppm at the Geodo Fe-Cu deposit which is lower than 87-236ppm of the

Yeonwha II Pb-Zn deposit and much lower than 238-360 ppm of the Sangdong W-Mo deposit.

This difference of Rb content is reflected more clearly by its average content (Fig. 9) ; The average of Rb at the Geodo Fe-Cu deposit (139 ppm) is apparently lower than those of the Pb-Zn deposits at the Yeonwha II (165 ppm), Imog (141ppm) and Sinyemi (147ppm), and considerably lower in comparison to the Sangdong W-Mo deposit (283ppm).

This variation trend of Rb similar to K is due to its affinity to K. Rb content increases with K content by being admitted into K-minerals such as biotite and potash feldspar in the granitic rocks. This coinsides with K variation in the study area, where K content is higher at the Yeonwha II Pb-Zn deposit and Sangdong W-Mo deposit than at the Geodo Fe-Cu deposit.

This distinguishable content difference between various ore deposits is largely consistent with that of the Cretaceous granitic rocks between the provinces of Fe-Cu, Pb-Zn and W-Mo in the Gyeongsang Basin, where Rb is 75~190ppm (114ppm) in Fe-Cu province which is lower than 70~230ppm (149ppm) in Pb-Zn province and 95-220ppm (152ppm) in W-Mo province.

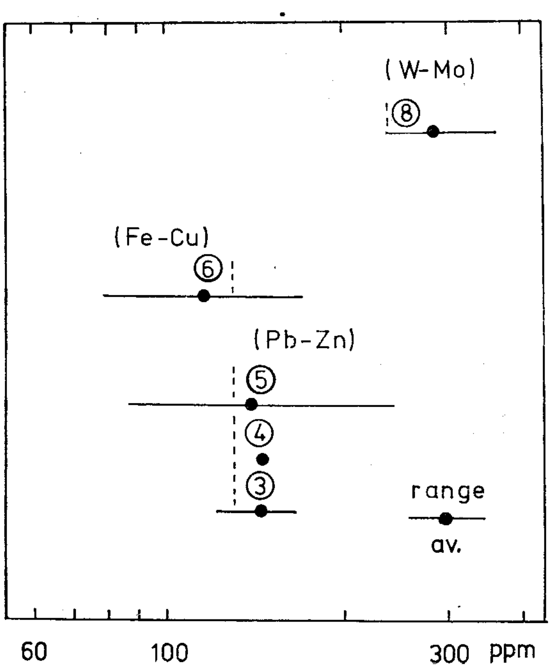

Fig. 9 Variation of Rb in granitic rocks.

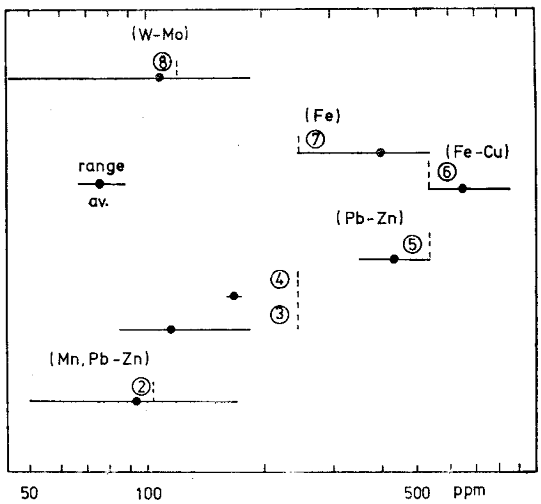

Fig. 10 Variation of Sr in granitic rocks.

Strontium: There is a clear difference in Sr content between the granitic rocks of various ore deposits in the study area, showing a variation trend similar to Ca. Sr decreases in the order of Fe-Cu deposit>Pb-Zn deposit>W-Mo deposit.

This difference of Sr content is displayed more clearly by its average content like Rb (Fig. 10) ; The average at the Geodo Fe-Cu deposit (640 ppm) is higher than those of the Pb-Zn deposits at the Yeonwha II (423ppm), Imog (117ppm) and Sinyemi (168ppm), and much higher than 108ppm at the Sangdong W-Mo deposit.

This variation trend of Sr is similar to Ca, because Sr is incorporated mostly in plagioclase or potash feldspar being admitted into Ca-minerals or captured by K-minerals. This is consistent with Ca variation in the study area, where Ca content at the Geodo Fe-Cu deposit (2.30~4.21%) is clearly higher than those of the Pb-Zn deposits at the Yeonwha II (1.19~

1.97%) and Imog (1.66~2.34%) mines.

Therefore, this variation trend of Sr in the study area coinsides with that in the Gyeongsang Basin, where Sr content is 50~465ppm (294 ppm) in Fe-Cu province, which is higher than 95~320ppm (185ppm) in Pb-Zn province and 25~435ppm (157ppm) in province.

Potassium-Rubidium: There is a clear difference in K/Rb ratios between the granitic rocks of various ore deposits in the study area. Fe-Cu deposit is plotted toward K-Rb poor region under about 3% K whereas Pb-Zn and W-Mo deposits toward K-Rb rich region above the K value (Fig. 11).

According to the distribution pattern of average K/Rb ratios the ore deposits may be further devided by the K/Rb ratios. The Geodo Fe-Cu deposit falls in the central part of K/Rb ratios within the K-Rb poor region, and the Imog and Yeonwha II Pb-Zn deposits fall toward the higher limit (300) whereas the Sangdong W-Mo deposit toward the lower limit of K/Rb ratios within the K-Rb rich region.

It is interesting that the K/Rb ratios fall nearly within same upper and lower limits of 300 and 150 as that of the Gyeongsang Basin (Lee, 1984), and the distribution pattern of K/Rb ratios is also similar to that of the Gyeongsang Basin, where Fe-Cu province is plotted in the K-Rb poor region and Pb-Zn province in the K-Rb rich region. However, there is a trend that Fe-Cu and Pb-Zn deposits are plotted toward the opposite limits of K/Rb ratios from Fe-Cu province and Pb-Zn province, respectively. This indicates a possibility that productive or nonproductive granitic rocks may be distinguishable by the distribution pattern of K/Rb ratios within the limits. It is because the granitic rocks in the study area are productive, and compared mostly with nonproductive ones from the Gyeongsang Basin.

Calcium-Strontium: There is also a clear difference in Ca/Sr ratios between the granitic rocks of various deposits in the study area. Fe-Cu and Fe deposits are plotted toward Ca-Sr rich region above about 2.2% Ca whereas Pb-Zn deposits toward Ca-Sr poor region under the Ca value. From the Pb-Zn deposits W-Mo and Mn deposits can be devided by lower Ca content of approximately 0.9%, under which they are plotted in the Ca-Sr poor region (Fig. 12).

According to the distribution pattern of average Ca/Sr ratios the ore deposits may also be further devided by the Ca/Sr ratios as well as the K/Rb ratios. The Geodo Fe-Cu deposit, Sangdong W-Mo deposit and Oesangcheon Mn deposit fall toward the lower limit (40) of Ca/Sr ratios,

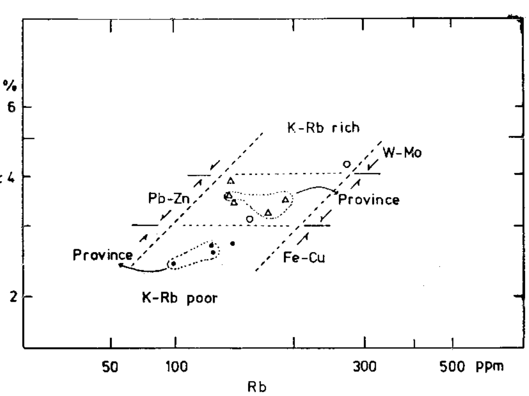

Fig. 11 Plot of average K/Rb in granitic rocks. Symbols are the same as Fig. 2.

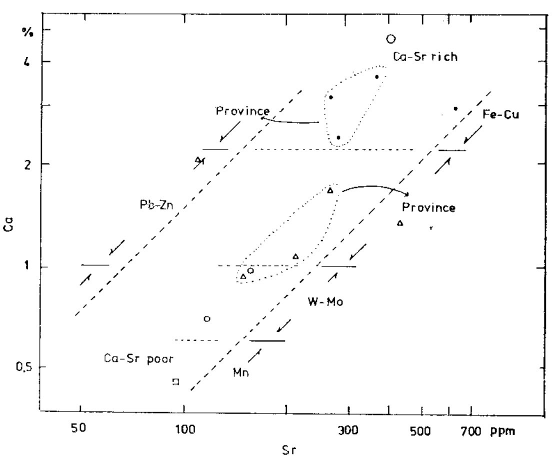

Fig. 12 Plot of average Ca/Sr in granitic rocks.

whereas the Dongnam Fe deposit and the Pb-Zn deposits of Imog and Sinyemi except Yeonwha II(<40) mines are scattered along the higher limit (150) of the Ca/Sr ratios.

Though the Ca/Sr ratios show a little wider limits than 150~40 of the Gyeongsang Basin (Lee, 1984), the distribution pattern of Ca/Sr ratios is also largely similar to that of the Gyeongsang Basin, where Fe-Cu province is plotted in the Ca-Sr rich region and Pb-Zn deposits toward the Ca-Sr poor region.

It is interesting that Fe-Cu and Pb-Zn deposits are plotted toward opposite limits of Ca/Sr ratios from Fe-Cu province and Pb-Zn province as in the case of K/Rb ratios, showing a possibility that productive or nonproductive granitic rocks may also be devided by the distribution pattern of Ca/Sr ratios.

Copper: There is a clear difference in Cu content between the granitic rocks of Fe-Cu deposit and other ore deposits in the study area, showng a variation trend that Cu decreases in the order of Fe-Cu deposit>Pb-Zn deposit>Mn deposit>W-Mo deposit.

This difference in Cu content is displayed clearly by the average content (Fig. 13) ; The average at the Geodo Fe-Cu deposit (52ppm) is higher than those of the Pb-Zn deposits at Yeonwha II (41ppm), Sinyemi (34ppm) and Imog (18ppm), and than that at Oesangcheon Mn deposit (20ppm). It is much higher in comparison to those of the Sangdong W-Mo deposit (13ppm) and Dongnam Fe deposit (12 ppm).

This variation trend of Cu is consistent with that of the Gyeongsang Basin, where Cu is slightly higher in Fe-Cu province (17ppm) than those in Pb-Zn province (13ppm) and W-Mo province (12ppm), and increase much higher at Ilkwang Cu deposit (40~220ppm).

Cu is known to be incorporated more in plagioclase, apatite and Fe-minerals than other silicate minerals, by substituting for Ca and Fe. This incorporation of Ca in rock forming minerals coinsides with the fact that Ca content is generally higher at Geodo mine than at Imog, Sinyemi and Yeonwha II mines.

Lead: There is a clear difference in Pb content between the granitic rocks of Pb-Zn deposits and other ore deposits in the study area. Pb tends to decrease in the order of Pb-Zn deposit>Fe-Cu deposit>Mn deposit. However, W-Mo deposit does not show a clear relation

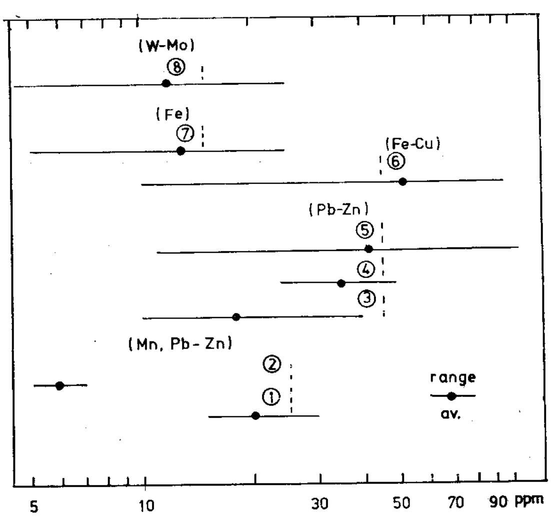

Fig. 13 Variation of Cu in granitic rocks.

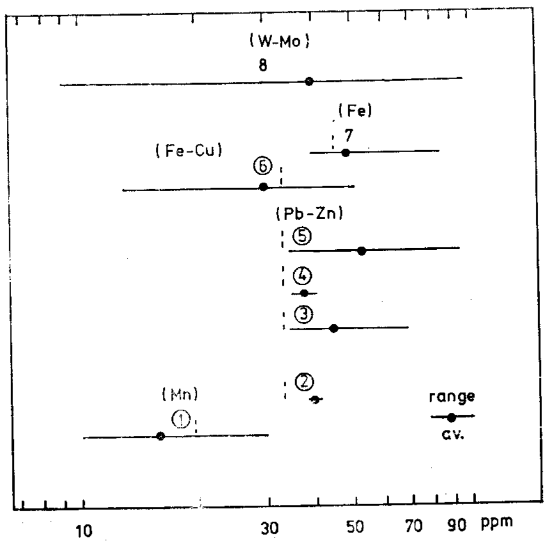

Fig. 14 Variation of Pb in granitic rocks.

with other ore deposits.

This difference of Pb content is displayed clearly by its average content (Fig. 14) ; The average of Pb at the Geodo Fe-Cu deposit (30 ppm) is lower than those of the Pb-Cu deposits at Yeonwha II (53ppm), Sinyemi (37ppm) and Imog (43ppm) mines but higher in comparison to that at the Oesangcheon Mn deposit(19ppm).

This normal variation trend of Pb, however, is not consistent with that in the Gyeongsang Basin, where Pb content is rather slightly higher in Fe-Cu province (34ppm) in comparison to Pb-Zn province (27ppm). Therefore, this may indicate that Pb is not increased in the all granitic rocks in the Pb-Zn province (Lee, 1984) although it is increased in the granitic rocks of Pb-Zn deposit.

Pb is incorporated in potash feldspar, being captured or admitted by K-minerals. This coinsides partially with the fact that K content is lower at the Geodo Fe-Cu deposit in comparison to those of the Pb-Zn deposits at Imog, Sinyemi and Yeonwha II mines. However, high Pb content is related mainly to its mineralization of the granitic rocks.

Zinc: There is also a clear difference in Zn content between the granitic rocks of various deposits in the study area, showing a variation trend that Zn decreases in the order of Pb-Zn deposit>Fe-Cu deposit>Mn deposit>W-Mo deposit. However, W-Mo deposit does not show a clear relation with Mn deposit as it is in the case of Pb.

This difference of Zn content is also displayed well by its average content in a similar pattern to Pb due to their mineralogical association(Fig. 15) ; The averages of the Pb-Zn deposits at Imog (115ppm) and Sinyemi (111ppm) mines are higher than that of the Geodo Fe-Cu deposit (72ppm), but an unusual low average (32ppm) was obtained at the Yeonwha II Pb-Zn deposit, which is much lower than that of the Oesang-

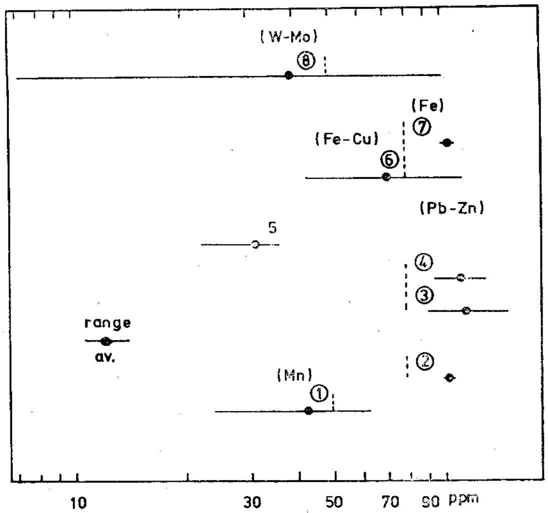

Fig. 15 Variation of Zn in granitic rocks.

cheon Mn deposit (45ppm).

Although Zn content is generally higher at the Pb-Zn deposits, it is abnormally lower (22~35ppm) at the Yeonwha II Pb-Zn deposit even in comparison to the Mn or W-Mo deposits. However, a similar variation trend was also found in the Gyeongsang Basin, where Zn content is higher at Dongrae area (23~110ppm) in Fe-Cu province than at Oenyang area (23~60ppm) and Daeyul area (30~80ppm) in Pb-Zn province (Lee, 1984). This may indicate that Zn content is not always increased in the granitic rocks related to Pb-Zn deposits.

Zn apparently enter biotite in preference to other minerals, and also enter feldspar as minute grains of sphalerite (Tauson and Kravchenko, 1956). However, high Zn content is also related to its mineralization in the Pb-Zn productive granitic rocks.

Tungsten and Molybdenum: There is a difference in W and Mo content between the granitic rocks of W-Mo deposit and other ore deposits in the study area, showing a variation trend that Mo decreases in the order of W-Mo deposit>Fe, Fe-Cu deposit>Pb-Zn, Mn deposit, but that W does not decrease regularly.

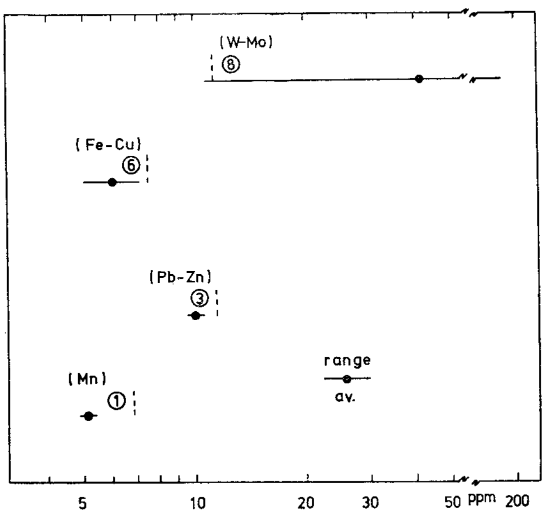

Fig. 16 Variation of W in granitic rocks.

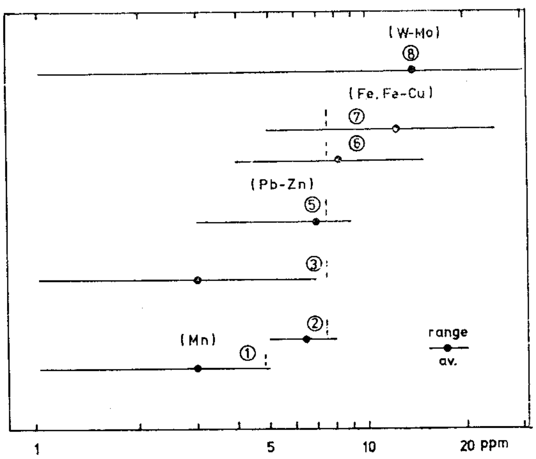

Fig. 17 Variation of Mo in granitic rocks.

This difference of W content is displayed well by its considerably high content (11∼182ppm) at the Sangdong W-Mo deposit which is higher than those of the Geodo Fe-Cu deposit (5∼7ppm), Imog Pb-Zn deposit and Oesangcheon Mn deposit (<5ppm) (Fig. 16).

In contrast to W, Mo shows less clear difference. Mo content at the Sangdong W-Mo deposit (1∼34ppm) is only slightly higher in comparison to those of other deposits, and relatively high Mo content was obtained at the Dongnam Fe deposit (5∼25ppm), and Geodo

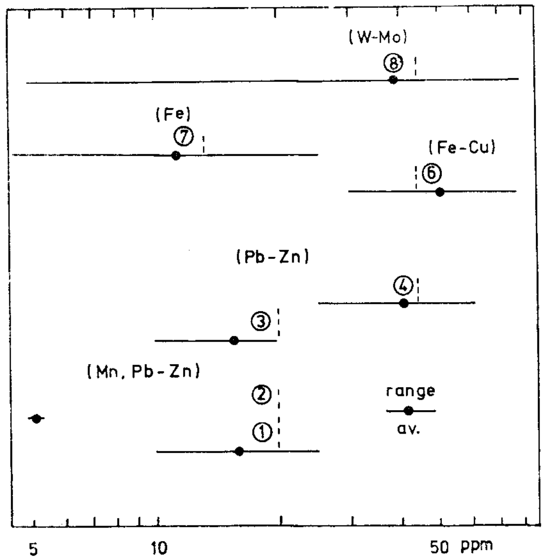

Fig. 18 Variation of Ni in granitic rocks.

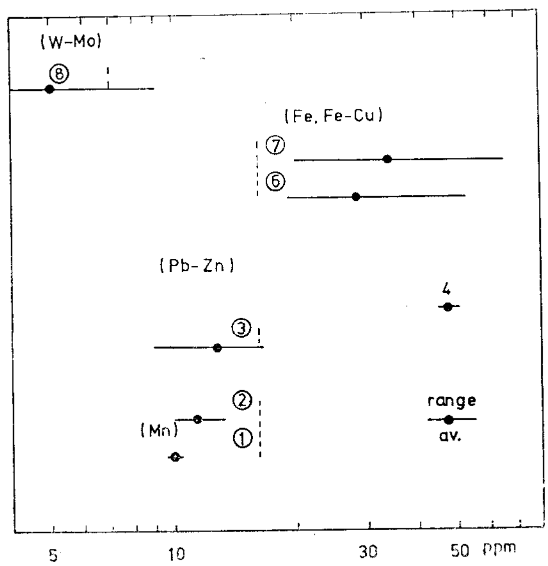

Fig. 19 Variation of Co in granitic rocks.

Fe-Cu deposit (1∼15ppm) as shown in Fig. 17.

This relatively high Mo content may be related to molybdenum, which occurs in the diorite of the Fe deposit at Dongnam mine (Seo and Lee, 1983), and high Mo content was early found at the Geodo mine by geochemical exploration of heavy minerals (Lee, 1969).

Nickel and Cobalt: There is a difference in

Ni and Co content between the granitic rocks of Fe-Cu deposit and other ore deposits in the study area, showing a variation trend that Ni decreases in the order of Fe-Cu deposit>W-Mo, Pb-Zn deposit>Fe deposit, and that Co decreases in the order of Fe, Fe-Cu deposit>Pb-Zn, Mn deposit>W-Mo deposit.

This difference of Ni content is displayed better by its average content in a pattern similar to Cu due to their close association in ores (Fig. 18). The average at the Geodo Fe-Cu deposit (47ppm) is slightly higher than those of the Sangdong W-Mo deposit (39ppm) and Sinyemi Pb-Zn deposit (40ppm), and clearly higher in comparison to those of the Imog Pb-Zn deposit (14ppm), Dongnam Pb-Zn (5ppm), and Oesangcheon Mn deposit(16ppm).

The difference of Co shows a similar pattern to Ni, and is well displayed by its background as well as average content (Fig. 19). However, the Fe-Cu deposit is not distinguishable from a Fe deposit by Co content. But it shows a clear difference between deposits of Fe-Cu and W-Mo.

Ni and Co are easily incorporated in ferromagnesian minerals owing to the same replacement index (0. 14) as Fe and Mg. Therefore, higher Ni and Co content at the Geodo Fe-Cu and Dongnam Fe mines may be related to higher Mg content of the mines, and Cu mineralization in the case of the Dongnam mine. Cu has the same replacement index as Ni and Co.

SUMMERIZATION AND CONCLUSION

1. The mid-late Cretaceous granitic rocks in the study area are classified into granite, granodiorite, quartz monzonite and quartz monzodiorite by modal composition (Fig. 3). Normative composition (Fig. 4) coincides with it.

2. Mineralization is in close association with the types of the granitic rocks. For instance, the Pb-Zn deposit is related to granite and the Fe-Cu deposit to quartz monzodiorite respectively according to the Q—Kf—Pl diagram (Fig. 3).

3. Major elements of Na, K, Ca and Mg show distinguishable differences in content between the granitic rocks of various deposits (Fig. 5~8). Na and K are low, and Ca and Mg are high at the Fe-Cu and Fe deposits than at the Pb-Zn deposits and other deposits of Mn and W-Mo. The general variation trend between the deposits are as following:

Na : Mn deposit>Pb-Zn deposit>Fe, Fe-Cu deposit>W-Mo deposit

K : W-Mo deposit>Pb-Zn deposit>Fe-Cu deposit

Ca : Fe deposit>Fe-Cu deposit>Pb-Zn deposit>Mn, W-Mo deposit

Mg: Fe-Cu, Fe deposit>Pb-Zn, Mn, W-Mo deposit

4. Lithophile Rb and Sr tend to vary in close relation with K and Ca content respectively due to their chemical affinities. This may indicate why the Geodo Fe-Cu mine shows background low in Rb (110~171ppm) and high in Sr (525~827ppm).

5. Most granitic rocks in the study area fall nearly within the same K/Rb (300~150) and Ca/Sr (150~40) ratios limits (Fig. 11 & 12) as the Gyeongsang Basin, and show very similar variation patterns.

6. Thus, it seems to be possible to distinguish some ore deposits by the distribution pattern of the K/Rb and Ca/Sr ratios; The Fe-Cu deposit is plotted toward K-Rb poor region under about 3% K, whereas the Pb-Zn and W-Mo deposits toward K-Rb rich region above the K value. In good contrast, the Fe-Cu and Fe deposits are plotted toward Ca-Sr rich region above about 2% Ca, whereas Pb-Zn deposit toward Ca-Sr poor region under the Ca value.

7. The variation patterns of ore metals in the granitic rocks seem to be related to petrochemical characteristics and mineralization of the rocks, and each element shows relatively high

content in the granitic rocks of its related ore deposits (Fig. 13~19); Cu (chalcopyrite) at Fe-Cu deposit, Pb and Zn (galena and sphalerite) at Pb-Zn deposit, W and Mo (scheelite and molybdenite) at W-Mo deposit. This variation pattern is similar to that of the Gyeongsang Basin.

8. Therefore, some metallogenic difference of the study area from the Gyeongsang Basin seems to be related mainly to chemical composition and physical-geotectonical properties of the country rocks, whick consist mainly of calcareous rocks.

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REFERENCES

Chang, H.W. and K.H. Park (1982) Petrogenesis of Fe-Cu bearing skarn at Keodo (in Korean). Kor. Inst. Eng. and Resources. Report on Geoscience and Mineral Resources, 14.

Han, K.S. (1968) Geology and ore deposits of Yeonwha mine (in Korean). J. Kor. Min. Geol., v. 2, No. 3, p. 47-57.

Han, K.S. (1972) Geologic report of the Second Yeonwha mine, Kangwon province, Korea (in Korean). J. Kor. Min. Geol., v. 5, No. 4, p. 211-220.

Jin, M.S., et al. (1982) Lithogeochemistry of the Cretaceous granitoids with relation to the metallic ore deposits in southern Korea. J. Kor. Min. Geol., v. 18, p. 119-131.

Kim, H.J. (1986) Geochemical characteristics of Imog granite and relation of mineralization (in Korean). Kyungpook Nat. Univ. M.S. thesis.

Kim, K.H. (1986) Petrology and petrochemistry of Sangdong granite (in Korean). M.S. thesis, Kyungpook Nat. Univ.

Kim, K.H., et al. (1981) A mineralogical study of the skarn minerals from the Shinyemi lead-zinc ore deposits, Korea (in Korean). v. 14, No. 4, p. 167-182.

Kim, O.J. (1971) Metallogenic epochs and provinces of South Korea. J. Geol. Soc. Kor., v. 7, No. 1, p. 37-59.

Ko, J.D. and S.J. Kim (1982) Mineralogy and genesis of Fe-Cu and Au-Bi-Cu deposits in the Geodo mine, Korea. J. Kor. Min. Geol., v. 15, No. 4, p. 189-204.

Lee, J.Y. (1969) Geochemical study in Ogdong, Seobyeogri and Gyesangchon quadrangles. J. Geol. Soc. Kor., v. 5, No. 3, p. 211-227.

Lee, J.Y. (1984) Geochemistry on major and trace elements in the granitic rocks from the Gyeongsang Basin in relation to mineralization. J. Kor. Min. Geol., v. 20, No. 4, p. 326-344.

Lee, J.Y. and D.H. Hwang (1984) Geochemistry of the country rocks at Eosangcheon mine. J. Kor. Min. Geol., v. 17, No. 1, p. 17-34.

Lee, S.M. (1972) Granites and mineralization in Gyeongsang Basin (in Korean). Memoirs in celebration of 60th birth day of Prof. Son, C.M., p. 195-219.

Min, K.D., et al. (1981) Applicability of plate tectonics to the post-late Cretaceous igneous activities and mineralization in the southern part of South Korea (I) (in Korean). Kor. Inst. Min. Geol., v. 15, No. 3, p. 123-154.

Moon, K.H. and H.J. Hang (1980) A study on the molybdenum in scheelite of Sangdong tungsten ore bodies. J. Kor. Min. Geol., v. 13, No. 2, p. 117-127.

Moon, K.J. (1974) Study on mineral paragenesis in Sangdong scheelite deposit. J. Kor. Min. Geol., v. 7, No. 2, p. 45-62.

Moon, K.J. (1984) Geochemistry of main gangue minerals at the Sangdong tungsten deposit. J. Kor. Min. Geol. v. 17, No. 2, p. 17, No. 2, p. 79-90.

Reedman, A.J. and S.H. Um (1975) The geology of Korea. Geol. Min. Inst. Kor., p. 139.

Seo, J.R. (1985) A study on geology and ore deposits of the regional mineralization in the Ogdong sheet (in Korean). Kor. Inst. Energy and Resources, Report on metallic ore deposist, p.75-121.

Seo, J.R. and J.Y. Lee (1983) Geology and ore deposit of Dongnam mine (in Korean). J. Natur. Sc. Kyungpook Nat. Univ., v.2, p.69-107.

Sillitoe, R.H. (1977) Metallogeny of an Andean type continental margin in South Korea. Implication for opening of the Japan Sea. Maurice Ewing Series, Am. Geophys. Union, v.1, p.303-310.

Tauson, L.V. (1974) The geochemical types of granitoids and their potential ore capacity. In: U. Stemprok (ed.) Metallization associated with acid magmatism. Geol. Survey, Prague, p.221-227.

Yun, H.S. (1985) Petrochemical study on the granitic rocks in the southern Hambaeg Basin and its basement area (in Korean). Yonsei Univ., Ph.D. thesis.

Yun, S.K. (1979a) Structural and compositional characteristics of skarn zinc-lead deposits in the Yeonwha-Ulchin mining district, southeastern Taebaegsan region, Korea. part II: the Yeonwha II mine. J. Kor. Min. Geol., v.12, No.3, p.147-176.

Yun, S.K. (1979b) Petrochemistry, hydrothermal alteration, and trace element geochemistry ore related igneous rock along southern margin of the Taebaegsan Basin, Korea. J. Geol. Soc. Kor., v.15, No.2, p.141-167.

Yun, S.K. (1983) Skarn-ore associations and phase equilibria in the Yeonhwa-Keodo mines, Korea. v.16, No.1, p.1-10.

Yun, S.K. and M.L. Silberman (1979) K-Ar geochronology of igneous rocks in the Yeonwha-Ulchin zinc-lead district and southern margin of the Taebaegsan Basin, Korea. J. Geol. Soc. Kor., v.15, No.1, p.89-100.

화강암류중 미량원소와 태백산분지내 석회암지역 광화작용과의 지구화학적 관계

이 재 영

요약 : 태백산 광화대에는 연-아연, 철-동 및 중석-휘수연 등의 스카른광상이 캠브리아-오도비스기의 석회질퇴적암을 주 모암으로 하여 중-후기 백악기의 화강암류와 밀접한 관계를 갖고 발달하여 있다.

이들 광상들의 화강암류와의 수반관계를 보면 철-동광상은 화강섬록암-석영몬조니암, 연-아연광상은 화강암-화강섬록암, 중석-휘수연광상은 화강암, 그리고 망간광상은 석영반암에 수반되는 경향이 있다.

화강암류의 화학조성을 보면 철-동광상과 관련된 화강암류는 연-아연광상과 관련된 것보다 K은 낮고 Ca은 높은 함량을 보이며 반대로 중석-휘수연광상과 관련된 화강암은 연-아연광상과 관련된 것보다 K은 높고 Ca은 낮은 함량을 보인다. 그러나 망간광상과 관련된 화강암은 연-아연광상과 관련된 것에 유사한 변화를 보인다.

미량원소중 친석원소인 Rb과 Sr은 K과 Ca에 관련된 변화를 보이며 이와는 대조적으로 친동원소인 Cu, Pb, Zn, W 및 Mo은 이들 원소의 광상과 관련된 화강암류에서 그 함량이 높고 기다 Ni과 Co는 교대지수(0.14)가 같은 Mg, Fe 및 Cu와 관계된 변화를 보인다.

화강암류의 평균 K/Rb 및 Ca/Sr 비가 보이는 범위는 각각 300∼150 및 150∼40내에 속하는데 K-Rb함량이 낮은 영역에는 철-동광상이 그리고 K-Rb 함량이 높은 영역에는 연-아연 및 중석-휘수연광상이 점시되고 대조적으로 Ca-Sr함량이 높은 영역에는 Fe-Cu 및 Fe광상이 그리고 Ca-Sr함량이 낮은 영역에는 연-아연광상이 점시된다.

태백산 광화대내 백악기 화강암류중 원소가 보이는 함량변화는 경상분지내 백악기 화강암류의 것과 대체로 유사한 경향을 보이고 있으므로 본 지화학적 연구의 결과는 어느 한 지역에서 백악기 화강암류와 관련된 광상을 대상으로 지화학탐사를 실시할 때 그 화강암체의 광종과 생산성여부를 결정하는데 유용하게 활용될 수 있을 것으로 기대된다.