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Description of The Geology of The Sangdong Tungsten Deposit with Suggestions for Further Exploration Using Geochemical Techniques

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Abstract: The Sangdong tungsten (mostly scheelite) mine is located on the southern limb of a major syncline, the Hambaeg syncline, in a thick sequence of lower Paleozoic sedimentary rocks in the mideastern part of south Korea.

Productive scheelite mineralization in Sangdong area is confined to one single formation, the Myobong Slate. Four major ore beds, which have an lateral extension over than 1 km and were not heavily subjected to spatial disturbance, are developed in the Myobong Formation. The original materials of the ore-comprising horizones were probably of either calcareous or silceous sediments. The four ore beds, especially in the case of Main ore bed, display both lateral and vertical zoning. Association quartz-mica-scheelite is predominant in the central, while association hornblende-quartz-diopside-scheelite, diopside-garnet and wollastonite-garnet are developed in this order towards the periphery of the ore beds.

Petrologically, two phases of thermometamorphism are recognized. The first phase is represented by the association wollastonite-garnet and diopside-garnet, while the second phase by the association hornblende-quartz-diopside-scheelite and quartz-mica-scheelite. The associations of the second phase do constitute prodctive ore.

The high background value of tungsten in the area surrounding the Sangdong mine reveals that the area can be considered a geochemical zone enriched in tungsten.

Studies on the trace element patterns were carried out to draw useful criteria for the purpose of future geochemical exploration in the area. The increasing trend of the ratio Rb (x1000)/K_2O of the Myobong Slate towards the known mineralization area proved to be indicative for the presence of tungsten mineralization.

1. Introduction.

The Sangdong mine is one of the world's largest tungsten producers since 1951, with an annual output of about 2000 tonnes of tungsten metal against a world output of about 40,000 tonnes. Various geological investigations have been undertaken in the mine area. Most of the studies have been concentrated upon field and underground mapping, mineralogical studies and ore genesis. Large scale exploration surveys have not been undertaken. A few mineralized bodies of small size have been found by small scale geophysical investigations and drilling; most of them proved to be non-economic. The author, who has been particiated in various prospecting programs at the mine, likes to give his views on the feature of the deposit and ideas on the ore genesis. A regional exploration tool that uses hard rock geochemistry is proposed as the result of the study on primary dispersion patterns at the area.

The objectives of the study can be summarized as follows: (a) to distinguish acid igneous bodies in the Sangdong and adjacent area into some geochemical types, which are favorable and nonfavorable for mineralization (b) to investigate trace element patterns and ratios in the host rock of the Sangdong tungsten deposit in relation to mineralization (c) to present the author's observations on the deposit and notes on the ore genesis. 27 rock samples were collected from 5 acid igneous bodies, from an undergr-ound crosscut and from a borehole. 2 samples were taken from each igneous body.

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To study possible differentiation stages, one sample of each igneous body was taken near the center of the outcrop and the other was taken near the margin. The remaining 17 samples were collected from the country rock and ore beds of the deposit. They consist mainly of footwall and hanging-wall slate of Main ore bed, skarnfels of ore beds and limestones of the Pungchon Formation. Samples were analysed by X-ray fluorescence, atomic absorption spectrophotometry and colorimetry at the Mining Department of Delft University. Seven major oxides, SiO_2, Al_2O_3, FeO (total Fe), MnO, MgO, CaO and K_2O were measured quantitatively in the X-ray fluorescence. The major oxides, MnO, FeO (occasionally) and Na_2O and the trace elements Li, Ni, Cu, Zn and Pb were measured by AA spectrophotometer (Perkin Elmer model 300).

2. General features of the Sangdong tungsten deposit.

2.1 Regional geology

The regional geology of the mideastern part of south Korea comprising the study area is very well known (Geological survey of Korea, 1965). This subject is not discused in this paper.

2.2 Location of mineralization.

Productive scheelite mineralization in Sangdong area is confined to one single formation of a large lateral extend and some 140 m thickness. The formation is referred to as the Myobong Formation (see Fig. 2-1). No mineralization is present both in the upper limestone and lower quartzite formation. Within the Myobong Formation, the mineralization corresponds with a number of parallel beds and a main wolfram-

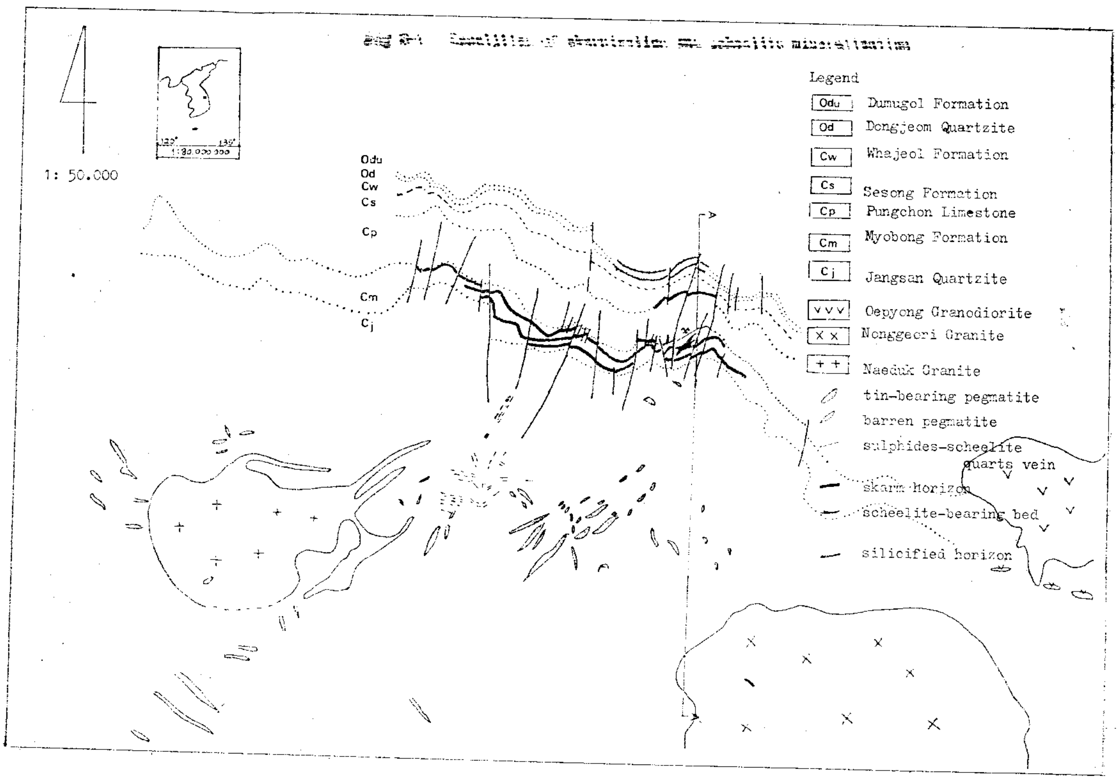


Fig 2-1. Location of skarnization and scheelite mineralization

ite-bearing quartz vein(Fig. 2-2); all of them are being mined. In addition, there are swarms of scheelite-bearing quartz veins which especially occur near mineralized beds. The quartz veins are normal or parallel to the bedding of the formation and occur both near ore beds as well as near silicified horizons. An oblique skarnfels vein protrudes into the Pungchon Limestone from the uppermost ore bed (Fig. 2-2). The swarms of quartz veins and the skarnfels vein represent potential ore reserves.

a. Ore Beds.

Four ore beds are known in the Myobong Formation. They are referred to as the Hanging-wall ore bed, the Main ore bed, the Footwall No. 1 ore bed and the combined Footwall No. 2 & 3 ore beds. They appear in this order from top to bottom (Tab. 2-1, Fig. 2-3). In the present paper Footwall No. 2 and No. 3 ore beds are combined because it is uncertain whether the beds can be mined separately. In addition to the four ore beds there are a couple of mineralized horizons. These are discontinuous and seldom form ore.

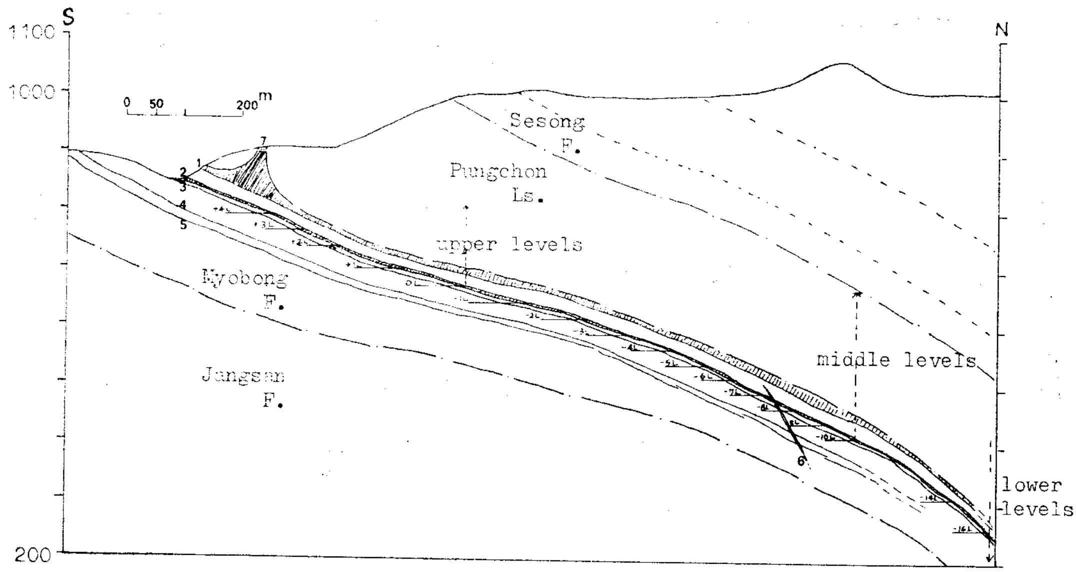


Fig 2-2. A schematic section along N-S direction at the Sangdong Mine
1: Hanging-wall Ore bed
2: Main Ore bed
3: Footwall No. 1 ore bed
4: Footwall No. 2 ore bed
5: Footwall No. 3 ore bed
6: Main wolframite-bearing quartz vein
7: Oblique skarn vein

The Hanging-wall ore bed is developed along a shear zone at or near the contact of the Myobong Formation and the Pungchon Limestone. A vertical skarnfels vein penetrates the Pungchon Limestone between the 2nd and 3rd incline of the +2L of the Hanging-wall ore bed.

The Main ore bed occurs at about 20m below the floor of the Hanging-wall ore bed. It is traced for more than 1 km on the surface and for 1.5 km along dip. The mineralized part of the bed is made up mainly of skarnfels and cherty rock. The horizon of the bed grades into a barren limestone horizon.

The Footwall No. 1 ore bed is a skarnfels

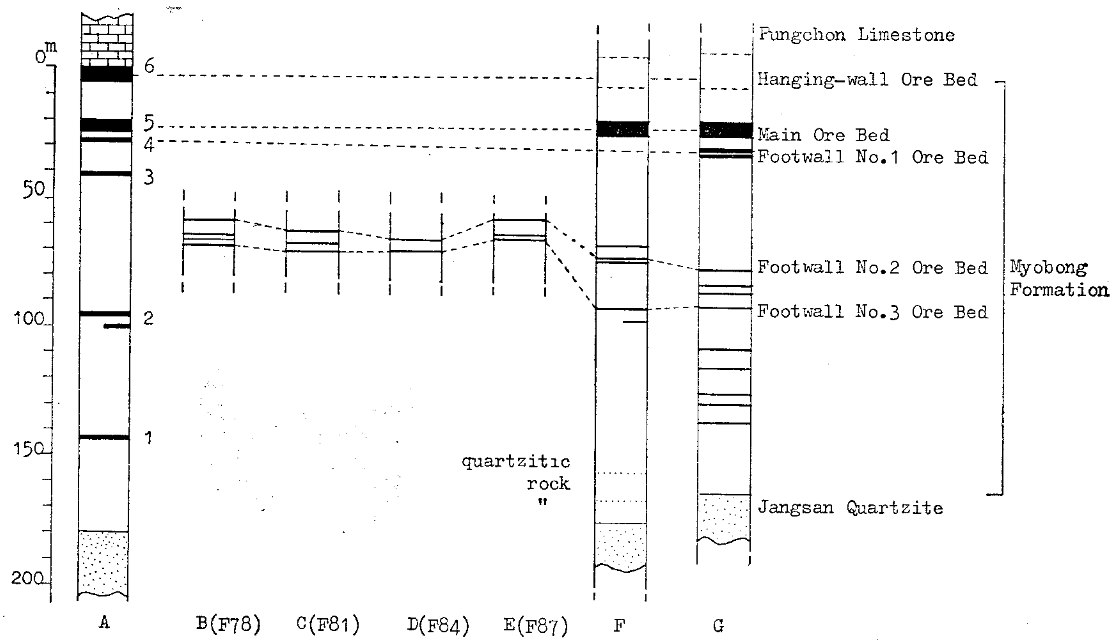


Fig. 2-3. Schematic columns showing mineralized horizons in the Myobong Formation.
A: after So (1968) G: observations at a crosscut on 6L
B. C. D. E: after a company drilling report —: skarn or silicified horizons
F: observations at a crosscut on-10L

sheet with fairly regular thickness. The outcrop of the bed is obscured due to weathering. Moreover parts of the outcrop are covered by mining waste. Underground observations reveal that the bed is positioned at 3–7 m (average 4m) below the floor of the Main ore bed. Its width varies from 0.2 m to 1 m; the average is 0.5 m. Its dimensions along strike and dip exceed 1 km and 1.5 km respectively. The horizontal projection on the Main ore bed and the Footwall No. 1 ore bed largely overlap one another.

The Footwall No. 2 & 3 ore beds occur at 30~50 m below the floor of the Main ore bed. They consist of two continuous beds and a couple of intermittent mineralized horizons (Fig. 2-3 B–G). Their continuation is traced as far as 3 km from the present mine. In the

Tab. 2-1. A list of the ore beds and vein

Name	Approx. depth below top of the Myobong Formation	Lateral length	Dip length	Average thickness
Hanging-wall ore bed	10m	over than 700m	over than 1000m	10m
Main ore bed	40m	〃 〃 1000m	〃 〃 1500m	5m
Footwall No. 1 ore bed	50m	〃 〃 1000m	〃 〃 1000m	0.5m
Footwall No. 2&3 ore bed	85-95m	〃 〃 400m	〃 〃 1000m	0.5 & 0.5m
Main wolframite bearing quartz vein	10-?	〃 〃 300m	〃 〃 80m	0.4m

eastern part of the mine, both beds are 0.6 m thick and are made up of a skarnfels with sulphides of Bi, Cu and Zn and scheelite in brecciated host slate. In the western part, the beds consist mainly of skarnfels and silicified slate with minor scheelite.

b. Other mineralized horizons.

Another two mineralized beds are known to occur at the bottom of the Myobong Formation, within 40 m above its floor. Extensive prospecting has revealed that these beds are hardly having any underground extension. The upper one of the two beds appears in a crosscut between the 1st and 2nd incline in the 0L and consists of hornblende, quartz and diopside. It extends about 20 m and grades into silicified slate at both its margins. The low content in scheelite and relatively thin thickness of the bed causes the bed not to be an economic proposition. The author was not able to study the lowermost bed; it is not properly exposed in the underground workings. The bed, however, may well relate to a discontinuous skarnfels bed of 1 km lateral extension that is observed at the same horizon, at some 3 km distance west of the mine. Exploration has shown that the latter bed has no economic significance.

2.3 Zoning.

a. At a large scale, the four beds display some zoning in mineral paragenesis. Before discussing this zonation, we shall define the following mineral associations:

(1) associations rich in calc-silicates
- (a) wollastonite-garnet; <0,1% WO_3
- (b) diopside-garnet; 0.1 WO_3±
- (c) garnet-calcite-fluorite-quartz; 0.2 WO_3±
- (d) hornblende-fluorite-diopside-scheelite; 1 ~2% WO_3±
- (e) hornblende-quartz-diopside-scheelite; 1 ~3% WO_3±

(2) associations rich in silica
- (f) quartz-mica (mainly biotite & muscovite)-scheelite; 3~25% WO_3±
- (g) quartz-plagioclase (=cherty hornfels); 0.5% WO_3±.

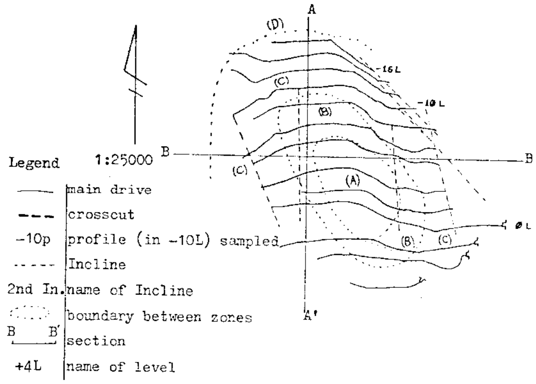


Fig 2-4. Zoning of the Main ore bed with reference to the horizontal projection of the Sangdong mine.
(A): Zone of the mica-quartz-scheelite
(B): Zone of the hornblended-quartz-diopside-scheelite
(C): Zone of the diopside-garnet
(D): Zone of the garnet-wollastonite

The WO_3% are indicative only. Magnetite is very subordinate. The above zoning largely controlls the grade distribution in space. The productive part of the beds is given by the spatial position of the assemblages quartz-mica-scheelite, hornblende-quartz-diopside-scheelite and quartz-plagioclase.

Hornblende-fluorite-scheelite occurs only in the Hanging-wall ore bed and also important as ore.

The zones are easily distinguished megascopically by colour and texture.

b. The zoning at a large scale is displayed in figure 2-4, 2-5 and 2-6. The Hanging-wall ore bed reveals no zoning. With reference to horizontal and vertical projections of the other beds, the following features are seen:

(1) the association quartz-mica-scheelite is predominant in the central part.

(2) in between the central part and the periphery of the ore beds. the mineral parag-

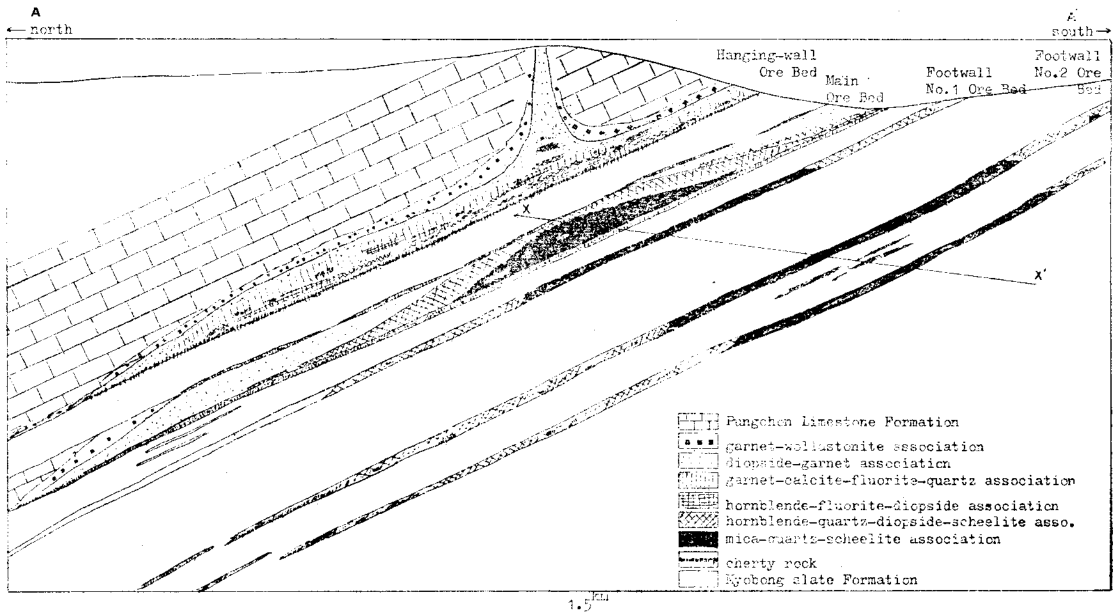


Fig 2-5. A schematic section showing zoning in ore beds (along A-A′ direction of Fig. 2-4)

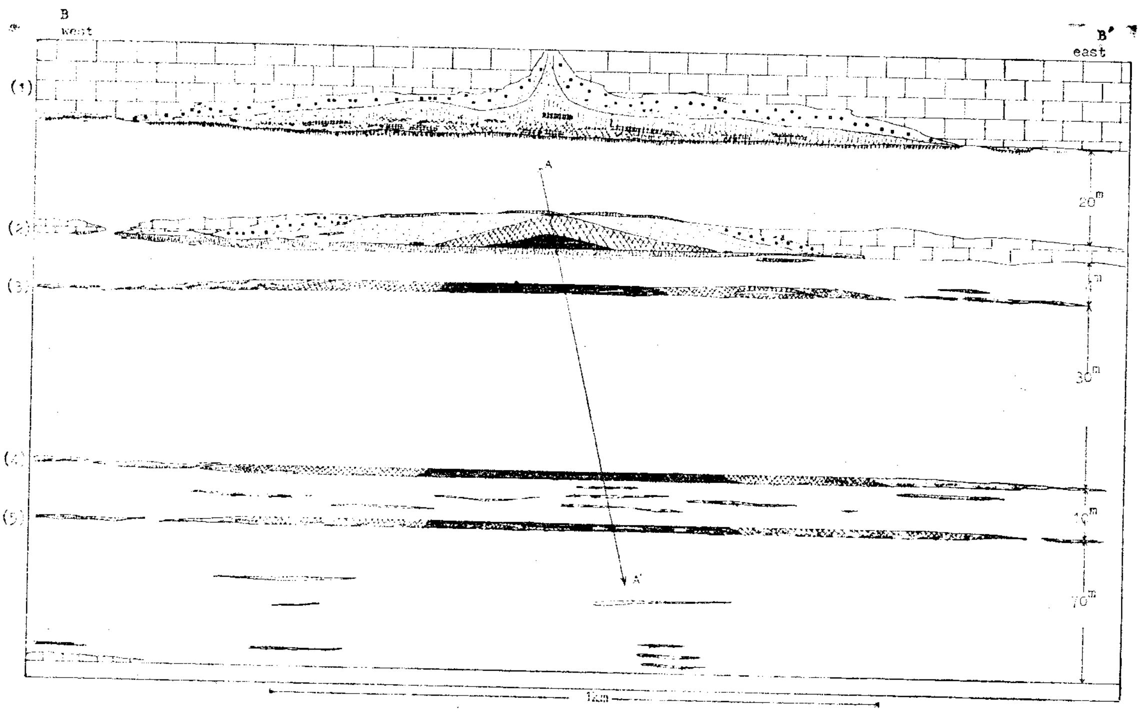


Fig 2-6. A schematic section showing zoning in ore beds along B-B′ direction of Fig 2-4. (Legend refer to Fig 2-5)
(1) Haning-wall ore bed, 10m thick
(2) Main ore bed, 5m thick
(3) Footwall No. 1 ore bed, 0.5m
(4) Footwall No. 2 ore bed, 0.5m
(5) Footwall No. 3 Ore bed, 0.5m

enesis is represented by the association hornblende-quartz-diopside-scheelite.

(3) the mineral assemblage cherty hornfels occurs typically at the periphery. This is especially the case in the Footwall ore beds.

c. The distribution of mineral association at the detailed scale is as follows.

The Hanging-wall ore bed does not show a conspicious zoning, although some mineral association like cherty rock, hornblende-quartz-diopside-scheelite and hornblende-fluorite-diopside-scheelite are most common in the lower part of the ore bed. The cherty rock lies mostly underneath the skarnfels and has an irregular boundary with the host slate. Some cherty rock occurs also in the skarnfels area. Garnet-rich associations occupy the largest part of the bed.

The Main ore bed shows the most conspicious zoning among all ore beds. The bed consists of quartz-mica-scheelite, hornblende-quartz-diopside-scheelite, diopside-garnet and cherty rock. In general, fluorite is subordinate. However it is the next abundant mineral to garnet & diopside in the association diopside-garnet. The wollastonite-garnet appears only in the marginal zone. It is mainly appear at the uppermost part of the bed at the underground workings lower than -11 level. Chery rock appears at the floor as well as the top of the bed. The occurrence of cherty rock is more irregular at the lower levels than at the middle and upper levels.

Until now, mineral zoning within the Footwall ore beds has not been studied properly; it is exposed only in the upper levels. However, referring to drilling logs, a similar zoning to that of the Main ore bed is assumed. The central part mainly comprise quartz-mica-scheelite. The outer part is mainly represented by hornblende-quartz-diopside-scheelite. Cherty rock increases towards the marginal zones. However the limits of the above zones are not well defined; particularly the distribution of the association diopside-garnet is erratic in the Footwall No. 2 & 3 ore beds. The area of scheelite enrichment, corresponding with the quartz-mica-scheelite and hornblende-quartz-diopside-scheelite association, is wider than the Main ore bed.

2.4 Alteration.

a. Alteration in the ore bèds.

Retrogressive metamorphism is present. The general sequence is garnet→diopside→amphiboles→biotite, muscovite, phlogopite→chlorite→sericite.

The alteration of garnet to diopside is very extensive.

b. Wall rock alteration.

We distinguish 3 zones:

(1) cherty rock immediately outside the ore beds,

(2) slate up to 10 m from the ore beds,

(3) slate at more than 10 m distance from the ore beds.

The cherty rock is assumed to be a silicified slate. Its appearance is especially conspicious near the floor of the Main ore bed. It mainly consist of quartz and plagiclase with lots of veinlets of quartz, diopside and hornblende. The rock contains subworkable grade of scheelite. Scheelite is mainly associated with the hornblende and quartz veinlets.

Slate in the zone up to about 10 m from the Main ore bed and in between Footwall No. 2 & 3 ore beds is heavily altered. Numerous quartz veins as well are intruded along fractures, cracks and bedding planes. The altered parts are consist mainly of silicified rocks with recrystallized biotite, chlorite and skarns (diopside, hornblende). The skarns are developed in forms of veinlet and band, which presumably represents a sedimentary structure. These skarns are partly subjected to retrogressive metamorphism whose sequence is the same as the one in the ore bed. The altered horizones are so numerous that one can hardly find fresh slate in the zone.

Slåte at more than 10 m distance from the ore beds have largely remained unaltered.

2.5 Structure.

The Myobong Formation in the study area occurs at the southern limb of the asymmetrical Hambaek syncline, whose axial plane is 15°/80°. Major structures in the formation are shear zone, thrust fault, various fractures and normal faults. The direction and the dip of thrust faults is 0°/35°~60°, of normal faults mostly 270°~300°/40°~65°. Fractures are roughly parallel to thrusts, shear zones and normal faults.

Most of the normal faults are clearly later than the mineralization; some normal faults and many of the thrust faults are believed to have formed earlier. The age relation between the latter faults and mineralization, however, is uncertain, because there is no practical way to prove a fault of pre-mineralization. The presence of a brecciated shear zone along the boundary between the Myobong Formation and the Pungchon Limestone and at the floor of the Main ore bed was reported already; this zone is believed to have been the channel way of mineralizing solutions.

2.6 Mineral generations.

The paragenesis of ore and gangue minerels is presented in figure. 2-7. A minimum of three stages are distinguishable in ore beds, namely an early high-temperature, a late medium-temperature and a further late hydrothermal stage. Retrogressive metamorphism are seen in the minerals of the high and medium-temperature stage to indicate a great time interval between the stages.

Wollastonite, garnet, clinopyroxene, epidote, quartz and plagioclase appear to have mainly formed during the high-temperature stage. According to the results of chemical analysis, garnet seems to belong to Fe & Al-rich one with a general formula of $(Ca, Mg, Fe^{2+}, Mn)(Al, Fe, Ti)(SiO_4)_3$; average contents of cations are 2.65Ca, 0.08Mg, $0.27Fe^{2+}$, $0.05Mn^{2+}$, $0.55Fe^{3+}$, 1.22Al, 0.02Ti. However, andradite and grossularite were also reported. Most clinopyroxenes have been identified as diopside, while some chemical data of separated clinopyroxenes give a formula for hedenbergite. Extensive alterations of garnet to diopside, of diopside to hornblende are observed.

Amphiboles (mainly hornblende, partly tremolite-actinolite), biotite, muscovite, phlogopite, chlorite, fluorite and opaque minerals are main minerals formed in the medium-temperature stage. Alterations of hornblende to chlorite, of biotite to chlorite and muscovite, and of muscovite to sericite are observed.

Scheelite associates mainly with quartz, biotite, muscovite and hornblende, and occasionally with fluorite, apatite, diopside and opaque minerals.

Many quartz veins, including the main wolframite-bearing quartz vein, intersect the ore beds. The quartz veins might have formed during the medium temperature stage or much later, at the further late hydrothermal stage. Quartz veins formed in the latest stage are characterized by the content of comparatively large amount of wolframite, chalcopyrite and Bi-minerals.

Opaque minerals are mainly pyrrhotite, pyrite, chalcopyrite, arsenopyrite, bismuthinite, native bismuth, molybdenite and magnetite.

3. Summary of ore controls with present author's notes on ore genesis.

Some of the aspects of the environment and controls of the Sangdong depsit have been mentioned in the foregoing text. A comprehensive review is summarized below:

a. Stratigraphic controls.

The deposits exclusively occur in the Cambrian, more specifically in the Myobong Slate formation is embeded in between a quarzite formation at its base and a limestone formation at its top. From the stratigraphic point of view, the position of the Hanging-wall ore bed at the top of the Myobong Formation is well defined; the position of the 3 beds is vaguely defined.

b. Sedimentary controls.

The ore deposits are confined to skarnbeds within the Myobong Slate Formation. The horizons are, at present, rich in Ca-silicates. As some of the skarn beds grade into barren limestion, it appears reasonable to assume that at least some of the beds represent metamorphosed beds of calcareous sedimentary rock; metasomatism was then rather subordinate. In other instances the skarn beds grade via horn fels into slate. In the latter case the original composition of the bed is uncertain. Perhaps the skarn-forming sections of the beds might represent a facies change from siliceous sediments to calcareous ones. Otherwise the matter must be explained by processes of extreme metasomatism.

The original texture of the beds that are presently skarnitized probably deviated from the original texture of other beds of the Myobong Formation. However here, one enters a field of speculation.

c. Petrological and geochemical controls.

The entire region of Sangdong may be considered a geochemical zone enriched in W. Small scheelite mineralizations occur in rocks of various ages, from Precambrian age to Cambrian. Metamorphic sediments as well as granites carry high background values. It follows that the source of W of the Sangdong deposit may be any.

A very remarkable feature is that the slate of the Myobong Formation has been subjected to regional metamorphism of greenschist facies, while the skarn horizons are typical products

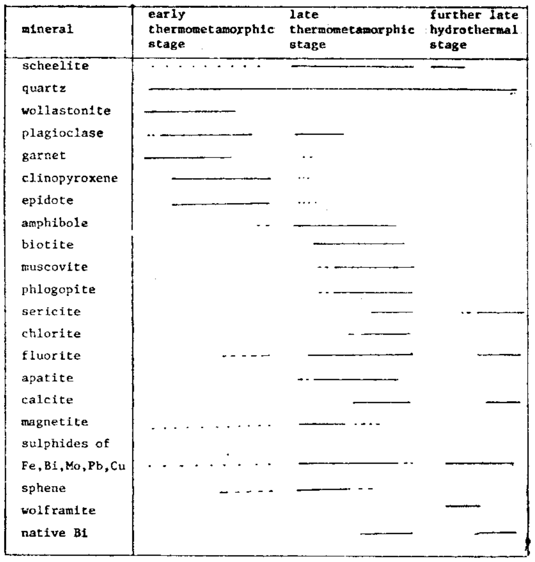


Fig 2-7 Mineral Paragenesis

of thermometamorphism. Skarn horizons that originally represented calcareous beds have probably been subjected to some degree of metasomatism, with introduction of silica and possibly FeO, Al_2O_3 and K_2O.

The observation that the present skarn horizons were formed by selective thermometamorphism must mean that these horizons at sometime were good heat conductors. In other words, those were accessible for a heat transporting medium. This medium could have been an aqueous silica phase above the critical temperature of water. The source of the heat is probably magmatic. However the source of the various components of the transporting medium may be any, even the Myobong Slate itself.

Two phases of thermometamorphism of selected horizons may be recognized. The first phase (high temperature phase) produced the association diopside-garnet and wollastonite-garnet. This phase has effected many beds and lenses over a large region of the Myobong Formation. The above associations carry high background W, but donot constitute ore. The second phase (medium temperatue phase) has been operative in limited areas only and has given cause to local replacement of the earlier formed associatians by new ones, namely hornblende-quartz-diopside-scheelite and quart-mica-scheelite. It also caused silification and hornfelsification of wall rocks and the formation of quartz stringers.

Economic W mineralization is confined to those sections of skarn beds, where high temperature associations have been replaced by medium temperature ones. There appears a geometric relation between the position of the above sections in beds at different levels (see axis X-X′ Fig. 2-5 & 2-6).

It appears obvious that economic W mineralization was introduced during the second phase of thermometamorphism. As late quartz stringers within the skarn beds are rich in W, the introduction of W probably took place mainly at the end of the second phase.

d. Structral controls.

The productive horizons of the Sangdong mine are situated in area that has permeable structure for transportation of heat and ore & gangue-forming solution.

The position of the Hanging-wall ore bed corresponds with a zone of shearing and overthrusting. The footwall of the Main ore bed consists of a breccia zone, that is heavily altered into cherty hornfels. The Footwall No. 2 & 3 ore beds represent breciated zones. Normal faults are relatively abundant in the mining area. Some of them off set the ore beds, others do not. It appears that normal faults have acted as main channels for heat transporting media. The position of productive beds is controlled by heavily fractured zones and mylonitized overthrust zones as well as by special sedimentary features of specific horizons of the Myobong Formation.

c. Concluding remarks.

In conclusion, it may be stated that the geological environment of W mineralization in the Sangdong area is complex, but rather well

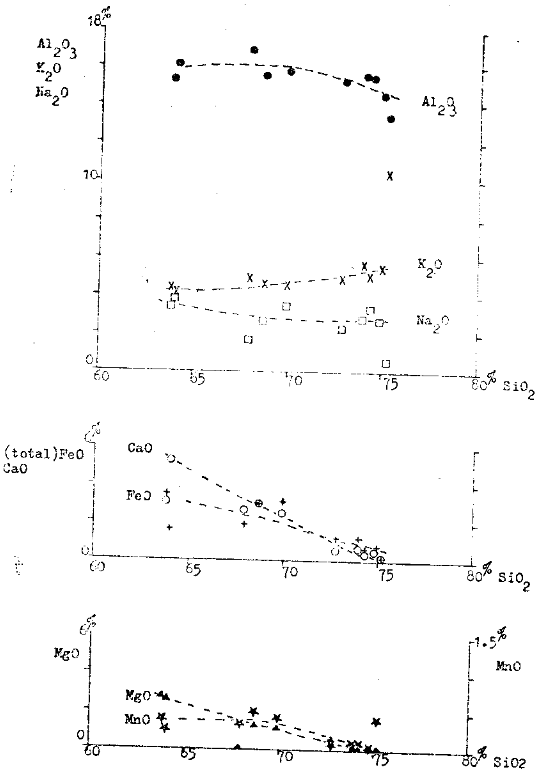


Fig 4-8 Variation Diagram for Igneous rocks in Sangdong area

defined. Prospecting should be based on mapping of the Myobong Formation with special attention to intensity of tectonization and character of thermomtamorphism in skarn horizons.

From the point of ore genesis the ore beds represent thermometamorphically altered horizons in regional metamorphic states of the Myobong Formation. Heat was probably provided by subsurface magmatic activities and transported by some medium through available ducts or channels. The origin of the ore constituents is probably complex; they may have derived from a variety of sources. Part of the material is bound to be autochtoneous whereas part may be metasomatic.

4. Discussion of some geochemical problems in Shinyemi-Oepyong zone.

4-1. Some geochemical data of igneous rocks along Shinyemi-Oepyong zone.

Seven major and minor oxides and seven trace elements, including W, were determined in ten samples (listed below) from Sangdong area.

OP 1&2; from the Oepying Granite
IM 2&3; from the Imog Granite
IM 1; from an intrusion known as Imog Granite
ND 1&2; from the Naeduk Granite
NG 1&2; from the Nonggeori Granite
SY 1: from the Shinyemi liparite

The analytical results are presented in table 4-2, 3.

a. Discussion of analyical results

● Major and minor oxides variation.

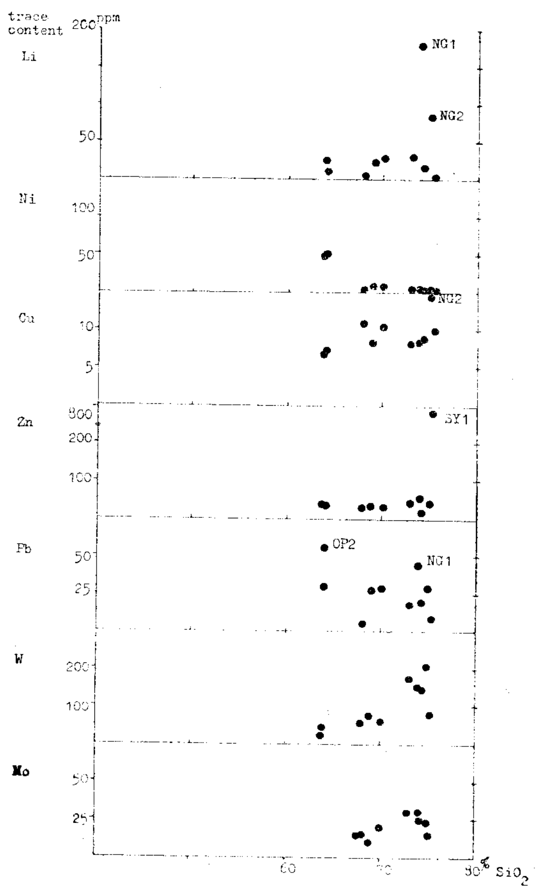


Fig 4-9 Trace elements variations according to SiO_2 content

Variation diagram of sampled Sangdong Graniotids is presented in figure 4-8. Estimation of trends of distribution of major and minor oxides, according to SiO_2 content, is shown with doted lines in the diagram.

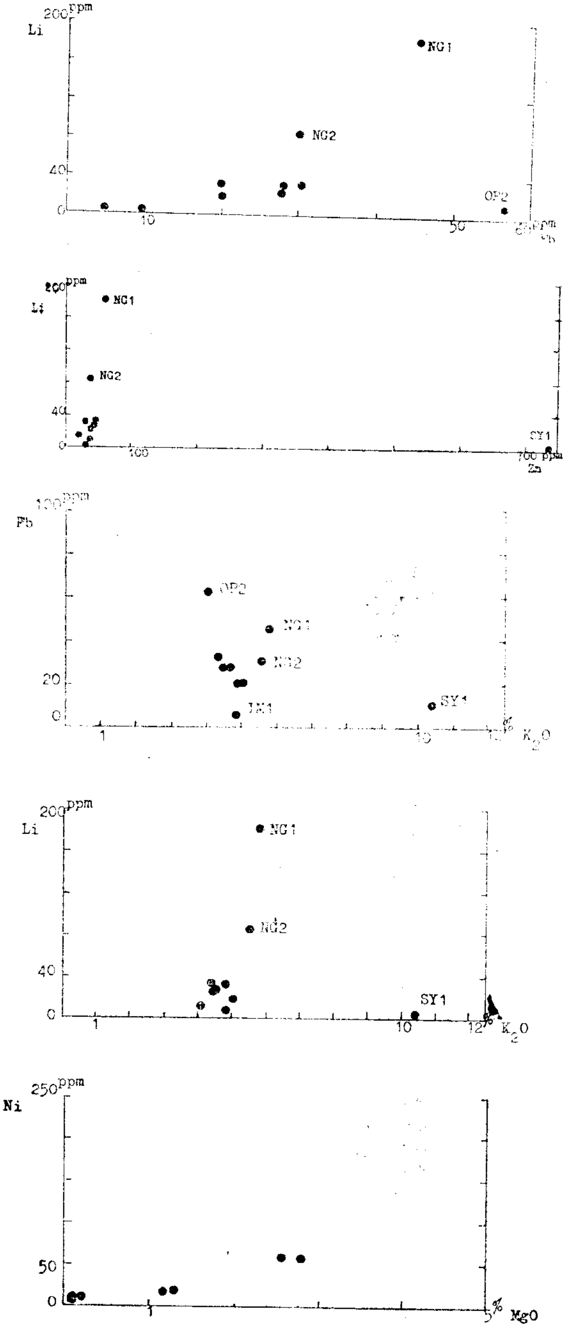


Fig 4-10 Rank correlations between selected elements

As shown in Fig. 4-8, only sample SY1 has a different major and minor oxides (relatively high K_2O and MnO, relatively low Na_2O), other samples follow, more or less closely, the linear pattern marked with dotted lines on the diagram.

● Trace elements patterns.

Trace elements variations according to SiO_2 contents, are shown in figure 4-9. Trace elements were used to distinguish the granitoids from each other. Rank correlations between Li & Pb, Li & Zn, Li & K_2O, Pb & K_2O, and Ni & MgO are shown in Fig. 4-10, and element ratios are presented in table 4-4. The ratios Rb/K_2O and Rb/Ba are estimated from the results of qualitative XRF analysis, and are therefore indicative only.

By trace element patterns, the discussed granitoids can be subdiveded as follows.

1) SY1; relatively high in Zn & Rb and low in Li with high Rb/K_2O and Rb/Ba and low Pb/K_2O, Li/K_2O and Li/Zn.

2) NG 1 & 2; relatively high in W, Li and Rb with high Li/K_2O, Li/Zn, Rb/K_2O, Li/Pb and Rb/Ba.

3) ND 1 & 2; relatively high in W and Rb with Rb/K_2O and Rb/Ba.

4) OP 1 & 2, IM 1 & 2 & 3 with no clearly distinguishable patterns.

Considering the major and minor oxides and trace element patterns, the following subdivision of the sampled rocks is suggested:

1) SY1, characterized by high K_2O, MnO, Zn, Rb contents with high Rb/K_2O, Rb/Ba and low Na_2O, Li contents with low Pb/K_2O, Li/K_2O, Li/Zn.

2) Other granitoids whose major and minor oxides variation show a regional trend. However those rock can be further divided into two groups according to trace element patterns.

a) NG 1 & 2 and ND 1 & 2, characterized by high W, Rb contents with high Rb/K_2O, Rb/Ba.

b) The rest of the group, whose trace element pattern shows a regular variation.

b. Some geochemical considerations about the mineralization possibilities in Sangdong area.

Some of the granitoids in Sangdong area are closely related to known mineralizations. For instance, the Shinyemi liparite to Zn mineralization, the Oepyong granite to Cu, Fe, Au and Bi mineralization. No studies on the relation between the tin-bearing pegmatites and W and/or sulphide-bearing qrtz veins on one hand and the Nonggeori Granite and the Naeduk Granite on the other hand have been performed. They are, however, closely associated geographically. The Imog Granite is generally known not to be connected with any economic mineralization. The characteristic features of those granites are summarized in table 4-4. From the table, the possible tendencies of the rocks for mineralizations may be concluded as follows.

The Shinyemi liparite which is believed to be responsible for Zn mineralization is characterized by high background of Zn and Rb and high Rb/K_2O and Rb/Ba ratios.

The Oepyong Granite which may be responsible for Cu, Fe, Au and Bi mineralizations has no high background values of those metals and show no characteristic geochmical properties in this direction.

If we assume that the Nonggeori Grante and the Naeduck Granite are associated with tin and/or tungsten mineralizations in form of pegmatites and quartz veins, then the high Sn, W and high Rb/K_2O and Rb/Ba of those granites may be a manifestation of the mineralizations.

The above criteria suggest that high content in ore metals and Rb and high Rb/K_2O and Rb/Ba ratios of a certain granite probably support its potential for mineralization.

The Oepyong Granite, however, reveals that mineralization of certain elements such as Cu, Fe, Au and Bi can be also associated with granitoids which show no specific geochemical properties. Therefore it my be tentatively concluded that:

(1) The Shinyemi liparite is a favourable rock for Zn mineralization and probably for some granitophile elements.

(2) The Nonggeori Granite and Naeduk granite are probly favourable for some granitophile elements such as W and Zn.

(3) The Oepyong Granite and Imog granite have similar geochemical properties. The association of the Oepyong Granite teochalcopyrite, magnetite, gold and bismuthinite mineralization of contact metasomatic skarn type suggests that the two granites can be held responsible for mineralizations when they meet favourable environmental conditions (at contact with lime stone etc,). In this instance, it may be said that mineralizations are indepenent by-products of magma generation rather than results of differentiation processes.

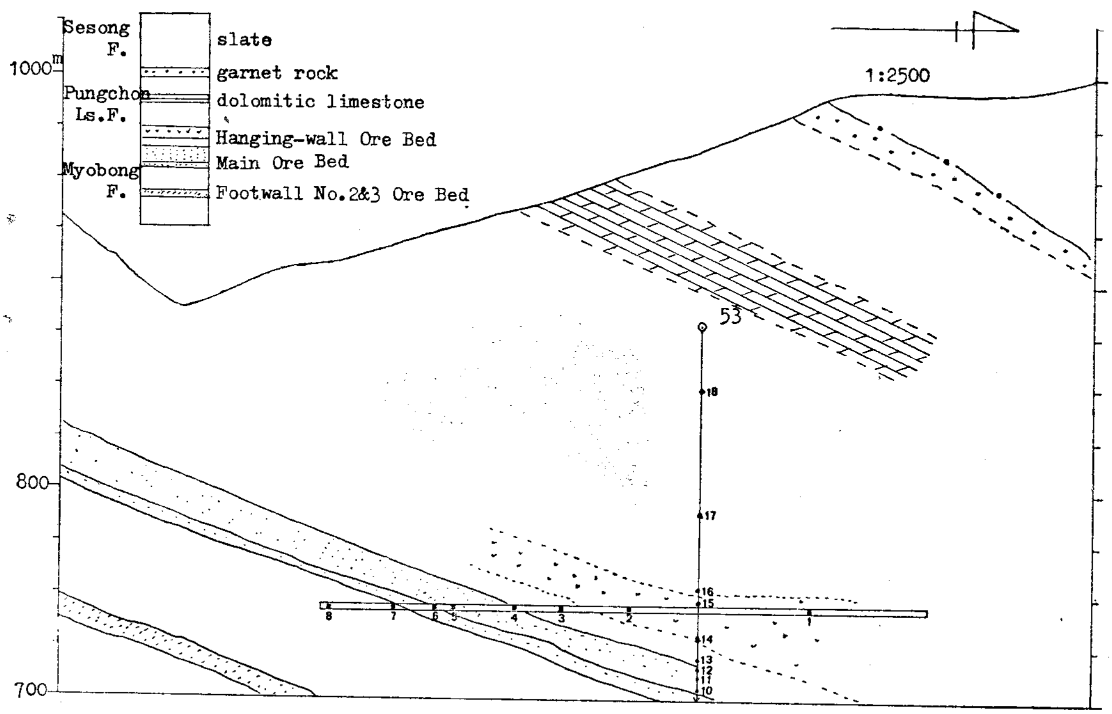


Fig 4-11 A section Showing sampling points

- Geochemical variation in individual igneous bodies.

No characteristic features are found. Presumably, the number of samples (2 from each intrusion) is too low for this purpose. The effect of differentiation is probably hidden behind individual point deviations.

c. Some element patterns of the Sangdong tungsten deposit.

Seventeen samples were taken from a crosscut of the Myobong Slate and ore beds and from a bore hole (No. 53) which pass through part of the Pungchon limestone and the Myobong Slate. Sampling points are marked in figure 4-11.

Seven major and minor oxides and seven trace elements were determined. Analytical results are presented in table 4-6, -7, -8,

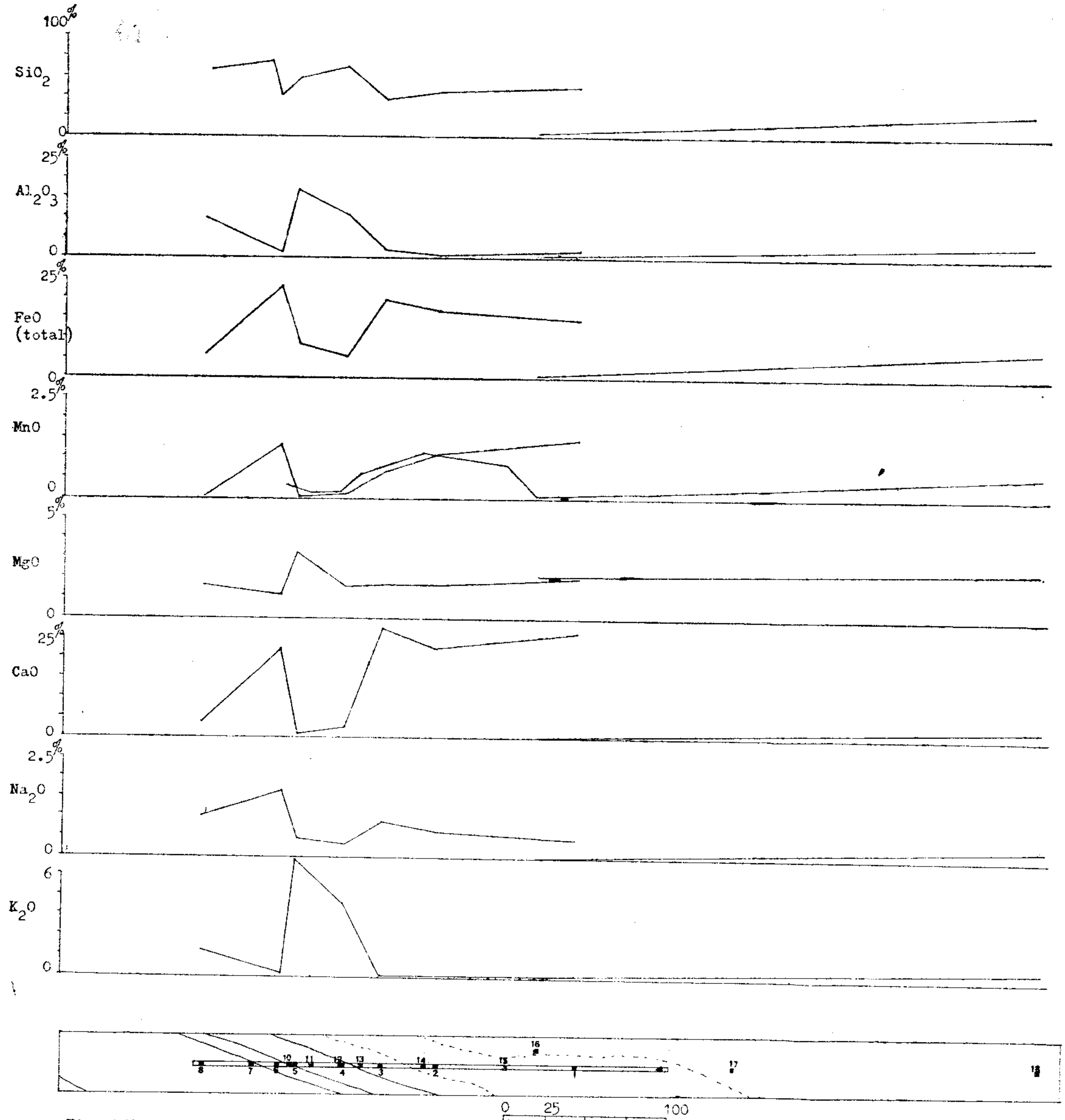


Fig. 4-12. Major element variation of ore beds, Myobong slate and Pungchon limestone.

Fig 4-12 Major element vaiation of ore besds, Myobong slate and Pungchon Limestone

● Major and minor oxides patterns.

As shown in figure 4-12, there are characteristic differences in major and minor oxides distribution between country rooks and ore beds.

SiO_2, Al_2O_3, MgO and K_2O contents decrease towards the ore beds, whereas total Fe, MnO, CaO and Na_2O increase. This is obviously connected with the presence of skarn minerals in the ore beds. Also the same may be responsible for the high SiO_2 content of BU 4 & 8. The host slate was subject to silicification in the proximity of the ore beds.

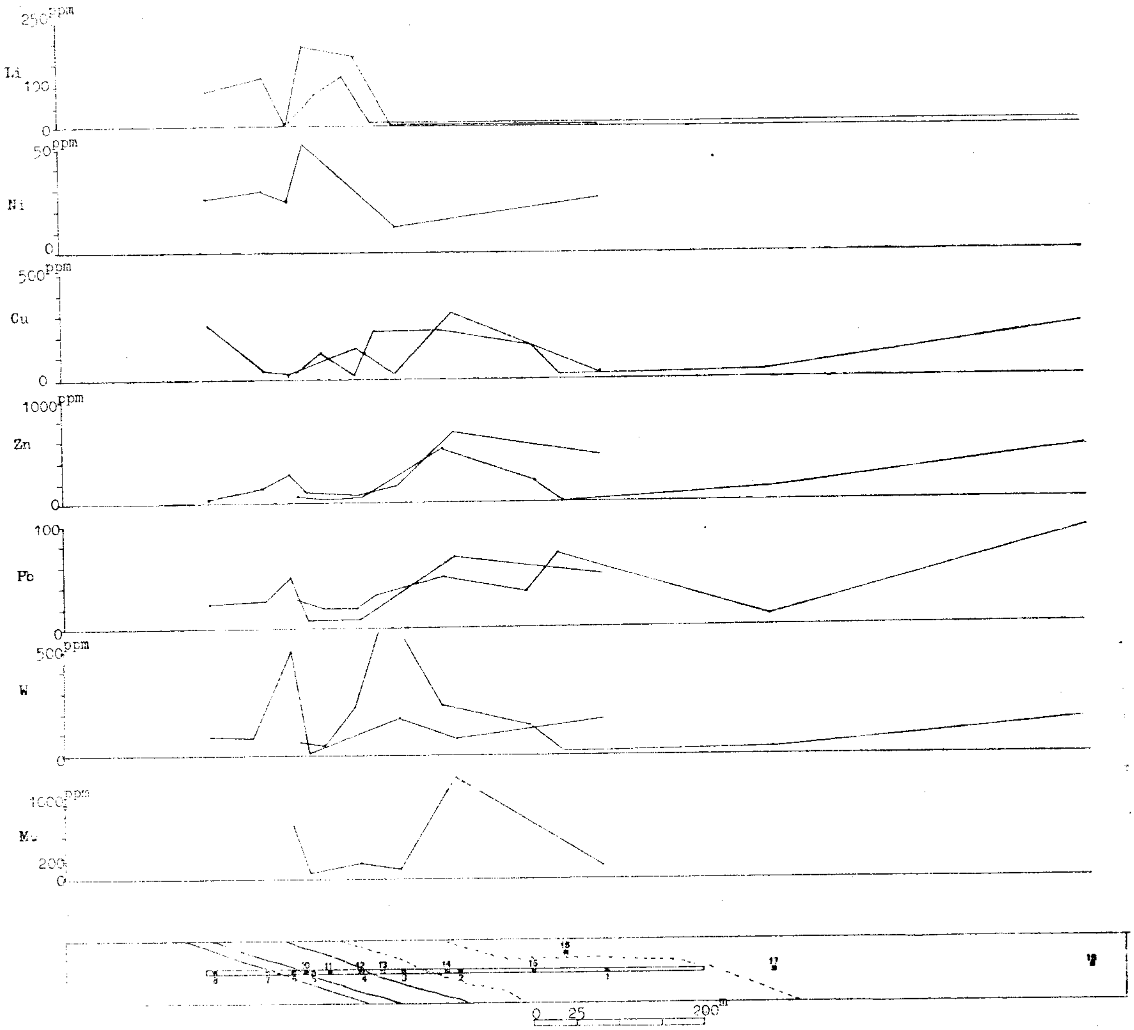


Fig 4-13 Trace elements variation of coundry rock and ore beds

●Trace element patterns.

Trace element variation of country rcok and ore beds are presented in figure 4–13. Discussion of the figures are summarized below.

(1) The Myobong Slates are fairly high in W& Mo and slightly high in Li, as compared with global abundance. Cu, Zn and Pb contents are generally the same as global abundances. This is largely supported also by other data.

(2) The Pungchon Limestone seems to have high background values of W. Other elements show generally the same background as global abundances. However, skarn-like part of this limestone shows anomalous W, Cu, Zn and Pb values.

(3) W, Mo, Zn and Pb contents increase towards the ore beds, whereas Li and Ni are depleted there. Cu seems to be depleted in and

near the main ore bed, Hower, the number of samples here is to small to investigate the dispersion of elements. This subject will be discussed in next chapter, using data taken from Kim (1976).

Tab. 4-2 Analytical results of igneous rocks along Shinyemi-Oepyong zone

		OP1	OP2	IM1	IM2	IM3	ND2	ND1	NG1	NG2	SYI
major elements	SiO_2	63.8	64.0	67.9	68.7	69.9	72.8	74.3	74.0	74.9	75.2
	Al_2O_3	15.3	16.0	16.8	15.5	15.7	15.2	15.4	15.5	14.5	13.3
	FeO	3.5	1.6	1.9	3.0	3.1	1.2	0.6	1.2	0.8	0.1
	MnO	0.04	0.03	0.04	0.05	0.04	0.01	0.01	0.01	0.01	0.04
	MgO	2.8	2.6	0.03	1.3	1.2	0.23	0.04	0.13	0.07	0.04
	CaO	3.1	5.3	2.7	3.0	2.5	0.60	0.49	0.65	0.63	0.10
	Na_2O	3.4	3.8	1.7	2.7	3.5	2.3	3.4	2.85	2.8	0.54
	K_2O	4.3	4.1	4.9	4.6	4,5	4,9	5.0	5.7	5.5	10.4
	total	96.2	97.4	96.0	98.9	100.4	97.2	99.2	100.0	99,2	99.7
minor elements	Li	26	10	4	24	30	32	18	180	83	3
	Ni	54	56	6	16	16	9	6	9	6	5
	Cu	6.8	7.3	12	7	11	7	8	7	16	10
	Zn	39	37	30	37	31	46	18	60	40	730
	Pb	31	63	5	28	28	20	20	45	30	10
	W	20	45	55	75	60	175	150	150	210	80
	Mo			15	10	20	30	25	30	25	15

unit; % for major, ppm for minor

Tab. 4-3. Analytical results of igneous rocks along Shinyemi-Oepyong zone

elements	OP1	OP2	IM1	IM2	IM3	ND2	ND1	NGI	NG2	SYI
Ti	10-1	(1-10)	<0.1	1-0.1	1-0.1	1-0.1	1-0.1	1-0.1	1-0.1	<0.1
P	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S	<0.1	<0.1	<0.1							
Cl	<0.1	1-0.1								
Cr			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Co	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
As		<0.1				<0.1	<0.1	<0.1	<0.1	
Rb	<0.1	<0.1	<0.1	<0.1	<0.1	1-0.1	1-0.1	1-0.1	1-0.1	1-0.1
Sr	1-0.1	1-0.1	1-0.1	1-0.1	1-0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Y			<0.1							
Zr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1(?)	<0.1	<0.1	<0.1
Nb				<0.1		<0.1	<0.1	<0.1		<0.1
Sn						<0.1		<0.1	<0.1	
Sb										<0.1(?)
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bi										

unit : %

analytical method: XRF

Tab. 4-4. Relative ratios between some elements.

OP 1	OP 2	IM 1	IM 2	IM 3	ND 2	ND 1	NG 1	NG 2	SY 1
Pb/K_2O	high	low							low
Li/K_2O							high	high	low
Li/Pb	low						high	high	
Li/Zn							high	high	low
Rb/K_2O					high	high	high	high	high
Rb/Ba					high	high	high	high	high

Tab. 4-5 Characteristic features of igneous bodies along Shinyemi-Oepyong zone

	OP 1&2	IM 1	IM 2&3	ND I&2	NG I&3	SY 1
Rock Type	granodioritic	granitic-granodioritic	granitic-granidioritic	granite (tourmaline rich)	granitic (muscovite -tourmaline)	rhyolitic (liparite)
Constituents	plagioclase, microcline, quartz, pyroxene, (Ca-bearing,) biotite, calcite	plagioclase, quartz, biotite, hornblende	plagioclase, K-feldspar quartz biotite	quartz, plagioclase, microcline, muscovite, tourmaline	quartz, microcline, plagioclase, muscovite, tourmaline	quartz, orthoclase, opaque, (sphalerite)
Characteristic trace elements		high Sr	high Sr	high Rb high W, Sn*	high Rb, Li high W, Sn*	high Rb high Zn
Characteristic ratios between some elemens				high Rb/K_2O high Rb/Ba	kigh Rb/K_2O high Rb/Ba high Li/Pb high Li/Zn	high Rb/K_2O high Rb/Ba
Known mineralization	Cu, Fe			(Sn, W?)	(Sn, W?)	Zn

*; After Kim (1976)

Tab. 4-6 Analytical results of samples from the Myobong slate and the ore beds

		BU 8	BU 7	BU 6	BU 5	BU 4	BU 3	BU 2	BU 1
Major elements	SiO_2	72.8		43.7	59.0	70.0	38.6	45.2	48.1
	Al_2O_3	10.0		1.4	16.8	10.6	1.6	0.7	2.2
	FeO	6.1		22.6	8.5	5.6	19.5	17.1	14.7
	MnO	0.08	0.07	1.3	0.09	0.1	0.67	1.10	1.48
	MgO	1.6		1.2	3.3	1.6	1.7	1.7	2.0
	CaO	3.9		22.6	1.1	2.9	28.0	22.5	26.4
	Na_2O	1.0		1.7	0.5	0.33	0.9	0.7	0.47
	K_2O	1.4		0.17	6.2	3.6	0.05	n.a.	n.a.
	tosal	96.6		94.7	95.5	94.7	91.0	89.0	95.4
Minor elements	Li	90	122	7	192	164	5	6	4
	Ni	25	30	24	52	30	13	16	26

	Cu	252	44	20	54	148	28	320	25
	Zn	57	76	325	130	105	190	690	460
	Pb	24	25	50	10	10	35	70	53
	W	95	90	510	15	100	180	80	190
	Mo			135	15	40	25	700	30

Tab. 4-7 Analytical results of samples from No. 53 bore hole core

		53-10	53-11	53-12	53-13	53-14	53-15	53-16	53-17	53-18
Major elements	SiO_2							2. 4		19. 8
	Ai_2O_3							0. 6		2. 1
	FeO	4. 85	6. 2	3. 1	13. 6	14. 5	17. 0	0. 2	1. 1	5. 2
	MnO	0. 30	0. 11	0. 18	0. 62	1. 16	0. 81	0. 09	0. 18	0. 41
	MgO							2. 3		2. 0
	CaO							50. 7		42. 2
	Na_2O							0. 5		0. 0
	K_2O							0. 4		0. 07
	loss							41. 4		22. 0
	total							98. 6		93. 8
Minor elements	Li	21	82	131	9	10	11	7	1	4. 7
	Ni	130	33	19	11	14	0	8	20	14
	Cu	16	134	15	217	266	172	12	20	245
	Zn	94	57	50	149	522	251	17	126	478
	Pb	32	22	24	34	55	37	68	12	92
	W	70	50	230	910	235	150	10	20	155

Tab. 4-8 Analytical results of some rocks from Myobong and Pungchon (qualitative)

Elements	BU8	BU6	BU5	BU4	BU3	BU2	BU1	53-16	53-18
Ti	10-1	<0. 1	10-1	10-1	1-0. 1	<0. 1	<0. 1		<0, 1
P	<0. 1	<0. 1		<0. 1	10-1	10-1	<0. 1	<0. 1	<0. 1
S	1-0. 1	<0. 1	<0. 1	1-0. 1	<0. 1	10-1		<0. 1	1-0. 1
Cl	<0. 1	<0. 1					<0. 1(?)	<0. 1	<0. 1
Cr		<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1		
Co	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	
As			<0. 1	<0. 1	<0. 1	<0. 1	<0, 1		
Rb	<0. 1	<0. 1	1-0. 1	1-0. 1					<0. 1
Sr	<0. 1		<0. 1	<0. 1		<0. 1			<0. 1
Y	<0. 1								
Zr	<0. 1	<0. 1	<0. 1	<0. 1			<0. 1		<0. 1
Nb			<0. 1		<0. 1				
Sn		<0. 1		<0. 1	<0. 1	1-0. 1	1-0. 1		<0. 1
Sb				<0. 1					
Ba		<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1		
Bi	<0. 1			<0. 1			<0. 1		

unit : %
analytical method: XRF (qualitative)

5. Suggestions on the Procedures for a Geochemical Exploration

5.1 Introcuction

This chapter reports on studies on the selection of characteristic elements or ratios for the purpose of geochemical exploration, using rock samples for finding W deposits in the Sangdong are. Suggestions are presented.

The data used in this chapter are confined to rock samples of the Myobong Slate and taken from Kim's thesis (1976, Tab. 6. 1-3 & 7. 1-3).

The data refer to 6 profiles across the Myobong Formation. The samples are distributed over the various profiles as follows.

Profile	No. of samples	Position of profile
2-8 profile	16	20 Km west of the mining area
2-5 〃	20	7 Km 〃
-6 〃	19	within the mining area
-10 〃	28	〃
-14 〃	11	〃
2-2 〃	18	500 m east of the mining area
total	112	

All samples were analyzed for six major oxides, five minor oxides and thirteen trace elements.

Suggestions presented at the end of this chapter are based on the following studies:

a. Visual inspection of profiles sampled by Kim. These profiles are at varying distance from known mineralization.

b. Statistical tests

c. Geostatistical computations to arrive at both an optimun spacing of sample profiles for future rock surveys in the Sangdong area as well as the optimum number of samples to be collected in each profile separately.

5.2 Features of geochemical profiles sampled by Kim.

A first glance at the geochemical profiles given by Kim (1976) across the Myobong Formation reveals that the various profiles of the different trace elements contain two kinds of values, namely background values and anomalous values. As far as profiles of W are concerned the anomalous values broadly fall into two groups; moderately anomalous values (group I)

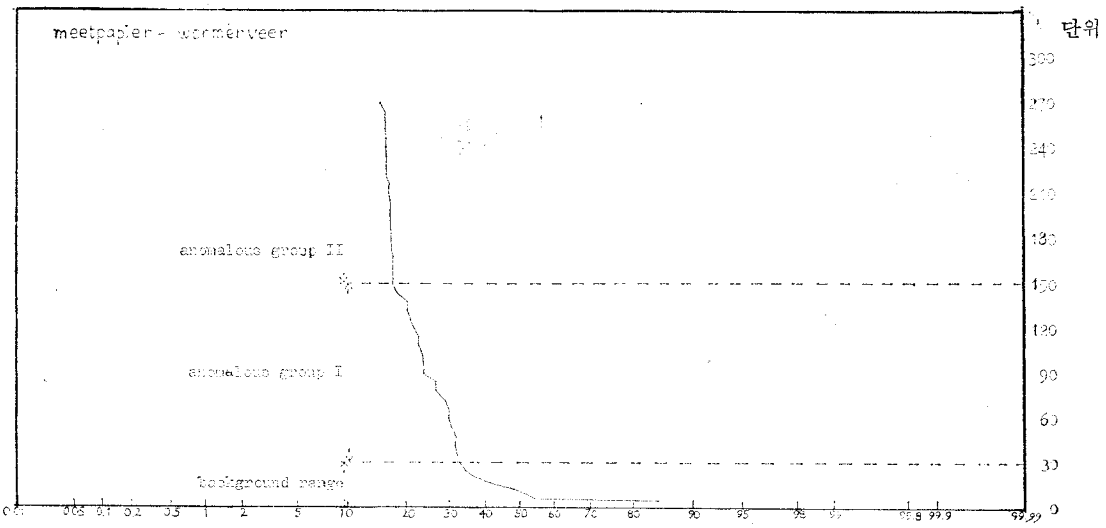


Fig. 5-14 Cumulative frequency percentile for W on a normal probability paper

and highly anomalous values up to ore-grade (group II). This is largely supported by frequency distribution of all data (Fig. 5-14).

A further qualitative inspections of the profiles shows that the number of anomalous W values both of group I and II increases from barren areas towards the area of known mineralization. Anomalous W values appear to be associated with high values of Sn and Zn; samples with anomalous W values are relatively enriched in Mn, Ca and Fe, but they are very low in Rb and K, In fact, the profiles indicate the element W on one hand and the elements Rb and K on the other are negatively correlated.

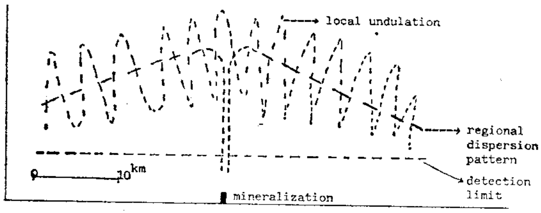
If samples with anomlous W values are excluded, then it appears that the values of some elements display a regional characteristic. This is notably the case for Rb and Y. Mean Rb values in profiles increase to wards the area of mineralization. Mean values of Zn, Cu, Sn, and Mn suggest similar trends of lesser significance. Mean values of other elements, including K, do not demonstrate and regional characteristic at all.

Based on the above qualitative observations three methods of geochemical exploration using rock samples are envisaged.

a. A method that makes use of the density distribution of number of anomalous W or Zn values at the regional scale. The occurrence of anomalous W and Zn values are about 10%, 20%, and 50% at distance of 8 km, 0.5 km and 0.1 to 0.2 km. Although this method opens some possibilities, the author prefers the other methods proposed below. Because the density distribution method needs a great number of samples.

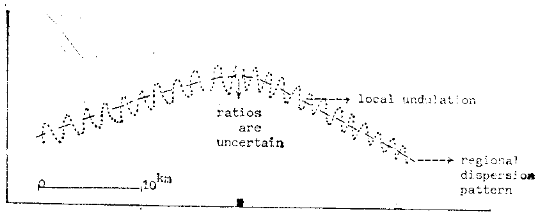
b. A method that makes use of the increase in Rb values in the background slate samples towards the area of mineralization. The term background samples refer to samples that carry W values within background range.

However, here we again face some problems. Main problem is high variance of Rb values at the local scale. It demands large numbers of samples. Minor problem arises if samples are collected right near a mineralization. This basic concept of the method is sketched below.



Sketch : model for Rb

c. A method that makes use of the increase in Rb/K_2O in the background slate samples towards areas of mineralization. Adopting the Rb/K_2O ratio instead of absolute Rb content, the above problem in second method can be largely overcome. The variance of Rb/K_2O ratio is considerably lower than the variance of absolute Rb content. This reduction in variance is due to the inter-element correlation between Rb and K_2O; this correlation only applies to the simultaneous fluctuations of the two elements at the local scale. Like the absolute Rb values, the Rb/K_2O ratio in space is presented in the sketch below.



Sketch : model for Rb/K_2O

As the ratio Rb/K_2O is the crucial parameter in the method of exploration proposed, a discussion on the correlation between both elements is justified. Figure 5-15 shows a scatter diagram of Rb and K_2O values in rock samples outside the mineralized area, near the mineralized area at distances of more than 10 m away from W beds and at the direct proximity of W beds. Samples of the first group fall in Field C and samples of the second group in Field B. Both fields are separated by the line T-T′. The regression line for values within field C is given by P-P′ and the regression line for values within Field B by R-R′. It is noted that the ratios within Field B are about 2 times higher than the ratios in Field C.

It appears that the ratio Rb/K_2O is a more stable quantity than are Rb values alone. The ratio is also less sensitive for the presence of anomalous W values. All of this obviously has a geochemical as well as a petrological reason. It seems fair to assume that K in biotite is progressively replaced by Rb in the direction of a mineralized area. W veins and beds themselves are largely deprived of biotite; nevertheless sparce grains of biotite present have similar high Rb/K_2O ratios as the country rocks.

5.3 Statistical tests

Some of the qualitative statements in the previ ous section have been tested statistically, The following computations were carried out.

a. Histograms

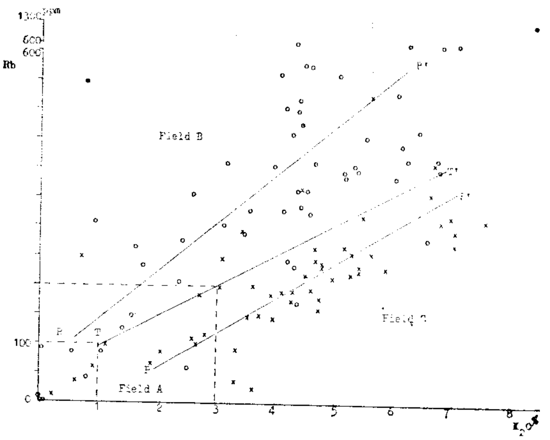


Fig. 5-15 plots Rb against K_2O
o : sample from area of mineralization
x : sample from area of nonmineralization

(1) Total data histograms of W, Pb, Sn, Zn, Cu, Sr, Y, Zr, Rb, K_2O, CaO and Fe_2O_3, MnO, TiO_2 and Rb (x 1000)/K_2O reveal that most of the values are positively skewed and show discontinuations. This gives cause to the following definitions for ranges of background distributions.

W; up to 30 ppm.,	Sr; up to 250 ppm
Pb; 〃 30 〃 ,	Y; 〃 150 〃
Sn; 〃 30 〃	Zr; 〃 300 〃
Zn; 〃 150 〃 ,	Rb; 〃 600 〃
Cu; 〃 200 〃 ,	MnO; 〃 5000 〃

(2) Histograms of values of seperate profiles were examined whether values in different profiles have different background ranges and whether there is a spatial discrimination in the distrib- ution of anomalous values. Conclusions are:
(a) Most of the anomalous of W and partly those of Cu and Zn occur in the profiles of the mineralization. Anomalous values of other elements occur rather randomly.

(b) The range of background values of Rb inthe mineralized area is larger than in the nonmineralized areas. The histogram of Rb of the mineralized area seems to contain two distributions. Most of the samples with very low Rb coincide with samples of anomalous W values.

b. Significant differences between mean values of prifiles.

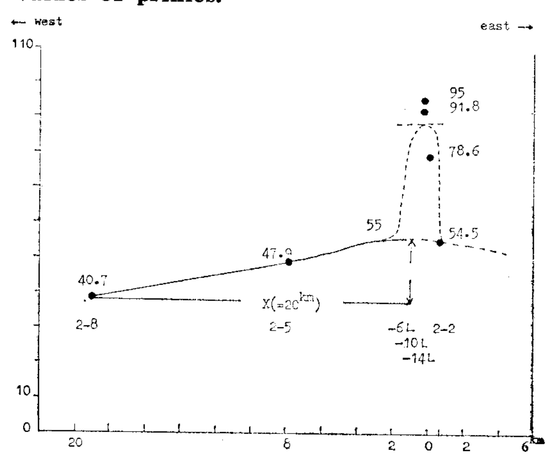


Fig 5-16 A model of distribution of mean value of Rb (x1000)/K_2O

Tab. 5-9 Parameters

Element	Profile	t Profile lenghth	N No. of samples	M (t) Mean	σ_0 Variance	C Correlation
W	2−8	75(M)	14	10.3	270	5(M)
	2−5	150	18	—	—	25
	−6	300	12	—	—	−(<15)
	−10	370	9	—	—	−(<35)
	−14	230	11	—	—	−(<20)
	2−2	150	14	—	—	−(<10)
Cu	2−8	75	14	61.2	1568	−(<5)
	2−5	150	17	522	1347	10
	−6	300	12	67.3	1246	50
	−10	370	23	76.9	3204	15
	−14	230	11	63.0	3080	30
	2−2	150	14	21.5	2070	−(<10)
Zn	2−8	75	16	63.9	829	10
	2−5	150	19	69.9	708	25
	−6	300	15	68.3	1043	30
	−10	370	25	82.6	882	25
	−14	230	10	79.4	1592	−(<20)
	2−2	150	14	78.6	847	25
Sn	2−8	75	16	10.9	17.6	−(<5)
	2−5	150	19	9.3	19.4	−(<10)
	−6	300	17	9.5	33.6	−(<20)
	−10	370	25	15.7	31.4	30
	−14	230	10	3.7	10.2	−(<20)
	2−2	150	14	15.5	30.3	10
MnO	2−8	75	15	0.14	0.02	25
	2−5	150	19	0. 4	0.006	25
	−6	300	17	0.22	0.0014	30
	−10	370	24	0.21	0.012	30
	−14	230	9	0.19	0.006	25
	2−2	150	15	0.15	0.005	−(<10)
Sr	2−8	75	15	21.2	58	10
	2−5	150	16	87.9	3745	−(<10)
	−6	300	16	102.1	3399	20
	−10	370	27	112.5	3364	10
	−14	230	10	135.7	7002	−(<20)
	2−2	150	16	106.8	5344	25
Rb	2−8	75	16	173	5455	20
	2−5	150	19	218	9746	20
	−6	300	17	400	20660	40
	−19	370	26	348	26171	−(<20)
	−14	230	11	350	24143	−(<20)
	2−2	150	14	230	7793	35

	2−8	75		14	40.7	7.3	15	
	2−5	150		14	47.6	77.2	10	
$Rb\ (\times 1000)/K_2O$	−6	300	210	17	91.8	1485.0	35	20
	−10	370		27	95.0	691.8	15	
	−14	230		10	78.6	666.5	40	
	2−2	150		13	54.5	66.4	10	

Tests on significant differences between means of Cu, Zn, Sn, MnO, Sr, Rb (x 1000) $/K_2O$ were done. W was excluded because about half of the background values is below detection limit and, hence, the calculation of statistical parameters is impossible.

(1) Calculation of parameters

Means and variances of separate profiles have veen calculatedand presented in table 5-16.

(2) t and F test

t and F test were carried out and results are summarezed as follows. For most elements means between profiles do not show significant differences. we refer to the tables quoted above. However, the means of Rb and ratio Rb (x 1000) K_2O show differences that are highly significant.

5.4 Estimation of optimum distance between profiles with minimum number of samples

It seems likely that the ratio Rb (x 1000) $/K_2O$ gives the best contrast between the mineralized and barren areas. We suggest this ratio to adopt as an indicator to mineralization in our hard rock exploration.

a. Optimum distance between profiles

For the determination of optimum distance between profiles, we first refer to the model of Fig. 5-16. The black spots represent the mean of Rb (x 1000) $/K_2O$ in various profiles. A-A′ represents an anticipated curve showing the regional change in mean values as obtained from actual measurements. In order to detect this regional dispersion pattern we need at least two profiles within 40km. If we take more profiles, then our estimated pattern will be more reliable. To arrive at the optimum number of profiles, we consider various cases as shown in Fig. 5-17. Fig. 5-17 A, B and C represent the sampling scheme where distance between profiles are 14km, 8km and 3.6km respectively. Fig. 5-17 A1, & B1 & C1 are the cases where one of our points coincides with a mineralized area. Fig. 5-17 A3 & B3 & C3 represent the cases where a mineralized area is located just middle between our profiles. Fig. 5-17 A2, B1 & in the C2 represent the situation between the other two.

We suggest that the case B whose diatance between profiles are 8km reflects the most reasonable sampling scheme. The reasons are as follows. In the case A, the maximum height of regional trend detectable seems very low (see Fig. 5-17 A3). Consequently we need a large number of samples in a profile to overcome local undulation. Therefore this sampling scheme is unpractical. As shown in the figure 5-17 B3 and C3, both the mean ratios 53.1 and 53.7 are reasonably high to overcome local undulation, with practical number of samples in a profile. However the case B is more economic than the C. Because the lower number of profiles in the case B reduces the total number of samples, although the case B need more samples in a profile. So we take 8 km for the distance between profiles.

b. Estimation of the number of samples in each profile.

According to a study by Botman, et al (1975), the optimum number of samples in a profile

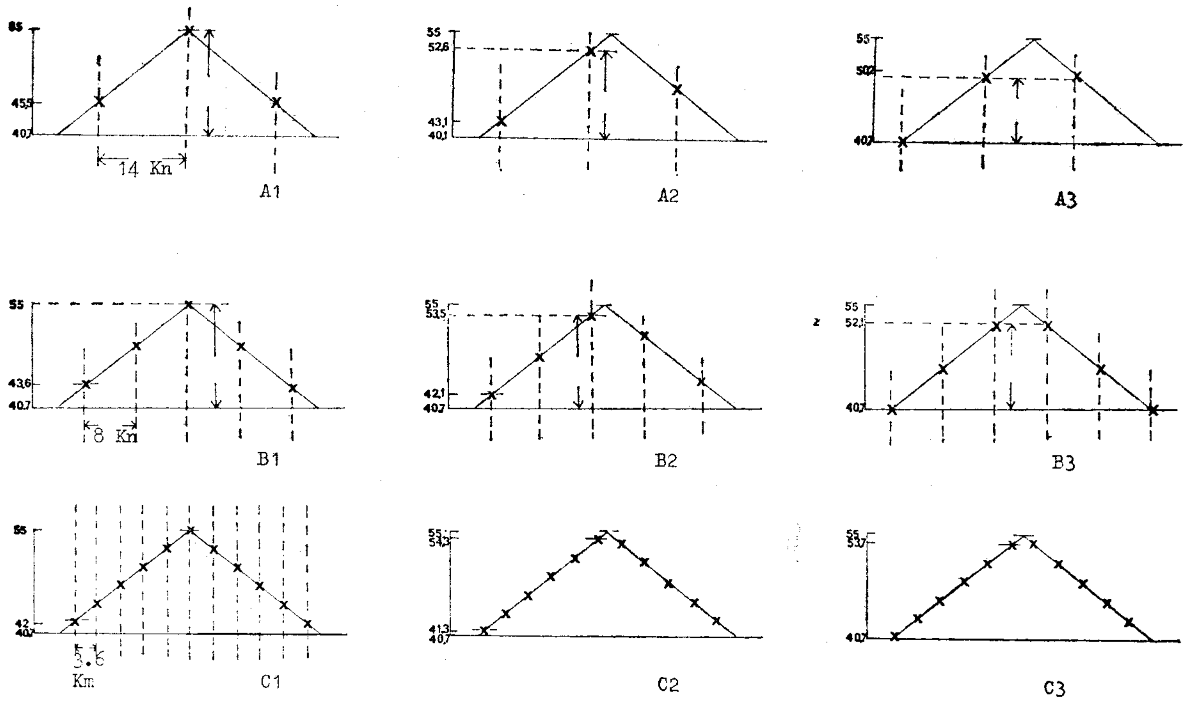


Fig 5-17 Various trend high according to sampling models

can be estimated by a certain ratio between variance of mean of sample values in profile and variance of individual sample values. This ratio is expressed by $k=\sigma m^2/\sigma_0^2$ where, σm^2 is the variance of mean of sample values in a profile,

σ_0^2 is the variance of individualvalues. Besides these, we should know D (control spacing), which is expressed by D=t/a=2t/c, where t is the length of the prolile

a is half the correlation distance

c is correlation distance.

In our instance, the optimum number of samples is estimated as follows, adopting the case B3.

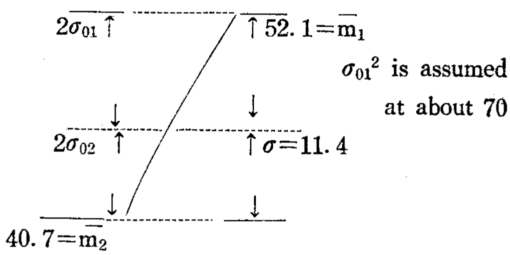
$\sigma m=\sigma/4=11.4/4=2.85$

$\sigma m^2=8.1$

$\sigma_0^2=39$ $(70+7.3)/2\fallingdotseq;39$, see sketch below)

σm and σ_0^2; referring to the sketh below.

according to figure 1 by Botman, et al (1975) (see appendix 1 of the present paper), the optimum number of samples then is 6



$\sigma_{02}=7.3$

$k=\sigma m^2/\sigma_0^2=0.21$

$D=t/a=2t/c=2x210/20=21.$

5.5 Remarks and suggestions

In naïure, Rb does not form minerals of its own, but it is disperesed especially in K-minerals. This comes from the character of Rb^+ with the same oxidation state and an similar ionic radius to that of Rb^+. The Myobong Slate consists mainly of quartz, biotite, chlorite and muscovite. If there happened hydrothermal invasions which gave rise to Rb enrichment in the country rock, biotite and muscovite probly accomodate the Rb. As a result, slate in the mineralized area which thought to be the center for hydrothermal invasions could be high in the ratio Rb/K_2O. The author estimates that the higher Rb/K_2O in the Sangdong area reflects the higher intensity of hydrothermal activity which give rise to scheelite mineralization.

The following suggestions are presented.

a. A further study on the trend surface model of the ratio Rb (x 1000)/K_2O in strike direction; this would need additional profiles in between profile 2-8 and the mineralized area

b. The ratios Rb (x 1000)/K_2O of profiles in mineralized and background areas are estimated at around 55 and 40 respectively.

c. The optimum distance between profiles in a exploration program is estimated at 8km. The optimum distance between samples in proyles is estimated at 50m ($210/6 \fallingdotseq 35$). An exploration program using the proposed sampling procedure for the rocks of Chosun Supergroup with som 150km lateral extension is suggested. It needs about 650 rock sampling and 2000 chemical analysis (Rb, K_2O, W),

d. Extremely fresh rock samples are needed in hard rock geochemical survey. For this reason, blasting is proposed. Mercury from blasting does not effect contamination in our case.

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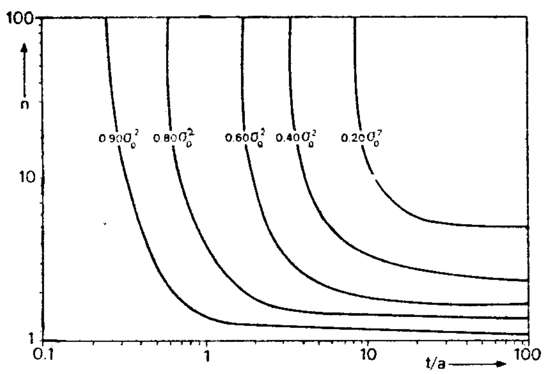
Appendix



Botman, Dijkstra. Kubik, Singh

Fig 1. Dependence of var[Mi(t)] on section site t/a and number of points for discrete random fuctions