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STUDIES ON THE TUNGESTEN MINERALS AND THEIR GENESIS FROM JAPAN AND KOREA

By

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(With 5 Tables and 4 Text-Figures)

Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 389

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I. Introduction

From 1942 afterwards the writer has been studied on the tungsten minerals and their deposits. This study was a part of the "Foundamental Studies on the Underground Natural Resources of Asia" at the Institute of the Natural Resources in Tokyo, and it is still going on under the guidance of Prof. Dr. Z. HARADA at Hokkaido University. Hitherto the mineralogical and geological researches of the tungsten minerals and deposits have been done not so many in Japan. Because it has been considered that the tungsten mineral was no more than a

warmineral, but also the mineral was devoid of mineralogical interests and also the deposits were rather minor and simple.

The scope of this study is to resolve the problems of genetical and paragenetical relations among the properties of the tungsten minerals and the other minerals which are accompanied with them, of the formation of mineral deposits and of the natur of ore forming solution in general.

For this purpose the writer has done his geological field works and laboratory investigations, espcially mineragraphical studies, with attending chiefly to the mineralogical characters of the minerals of tungsten and associated minerals as well as the composition, structur, and wall-rock alteration of the deposits. In this paper the writer summarizes some of the results of his investigations and touches merely on the chief points.

The writer wishes to express his indebtness to Prof. Dr. Z. HARADA carefull criticisms and valuable suggestions during the course of this study.

II. Tungsten minerals.

The known natural minerals of tungsten are classified into three groups according to their crystallographical and chemical properties.

Scheelite series

Scheelite	$CaWO_4$
Cuproscheelite	$(Ca,Cu)WO_4$
Cuprotungstite	$CuWO_4$
Stolzite	$PbWO_4$
Raspite	$PbWO_4$
Chillagite	$Pb(W,Mo)O_4$
Wolframocker	WO_3 (?) or WO_3H_2O
Meymacite	$WO_3 2H_2O$
Throtungstite	$2WO_3 H_2O \cdot (ThO_2, CeO_2, ZrO_2) H_2O$

Wolframite series

Wolframite	$(Fe,Mn)WO_4$
Hübnerite	$MnWO_4$
Ferberite	$FeWO_4$
Reinite	$FeWO_4$
Ferritungstite	$Fe_2O_3WO_3 6H_2O$

Sulfide of tungsten

Tungstenite	WS_2

In his original paper, the auther collected all data of crystallographical, physical and chemical properties of each tungsten mineral, which were reported by many authorities. In Japan, the optical properties of some scheelite were examined by Prof. Dr. Z. HARADA, and the phosphorescence of scheelite was tested by Dr. E. IWASE. But many other properties remain to be examined. Among these properties, here it would abstruct merely an investigation concerning to the crystal habit "Tracht" alone.

A. Crystallographic properties of tungsten minerals

The factors which effect on the form of growing crystals are too many and much complicated to be resolved. However from a mineral deposit, it has been frequently found the crystals which had a definit habit. It seems to be nothing but a evidence as a result that the many partial differences in physical and chemical conditions of a yielding mineral deposit were integrated by the geological time. Namely the habit of crystal is one of the most important features presented by the geological behaviors. So the writer has intended to examine the relation between the habit of minerals of tungsten and the geological factors dominating in the tungsten mineral deposits.

For this purpose it was selected two minerals, scheelite and wolframite, among the tungsten mineral species. Because these two minerals are very common hypogene minerals and the almost all tungsten in the earth crust concentrate into them.

Hitherto the minerals of tungsten have been reported from about 140 localities in Japan and same in Korea. But only from a few in those many localities the crystals have been found.

1. Scheelite

Crystals of scheelite from Japan and Korea have the pyramidal form, but there are two different types. One is represented by $e\langle 101\rangle$ as its groundform and the other by $p\langle 111\rangle$. Very rarely it is prismatic elongated parallel to the zone [101].

It is calculated that H-, F-, and P-values of the crystals of scheelite by the Niggli's method, and the results are shown in the following tables. The data account to calculation are that refered to the reports already published by other investigators and that of the writer's own examination. And it has been treated 64 crystals of scheelite from 41 localities.

If it compare the tables, it might be noticed that the order of the

numbers of p (111) and e (101) of scheelite from Japan to that of Korea are reverse.

TABLE. I. H-values (relativ Häufigkeitzahl) of the scheelite. 37 crystals from Japan and 27 crystals from Korea.

Crystal faces	H-values %		
	Japan	Korea	Both
p (111)	86.5	59.3	75.0
e (101)	78.4	88.9	82.8
β (113)	21.6	7.4	15.6
s (131)	21.6	11.1	17.2
c (001)	18.9	3.7	12.5
o (102)	13.5	7.4	11.0
h (133)	8.1	11.1	9.4
k (155)	2.7	3.7	3.1
g (122)	2.7	0	1.6
a (130)	2.7	0	1.6
m (110)	0	3.7	1.6

TABLE. II. F-values (Fundortpersistenzzahl) of the scheelite. 23 localities from Japan and 18 localities from Korea.

Crystal faces	F-values %		
	Japan	Korea	Both
p (111)	82.7	61.1	73.2
e (101)	78.3	94.5	85.4
β (113)	34.8	11.1	24.4
s (131)	21.7	11.1	17.1
c (001)	21.7	5.6	14.6
o (102)	21.7	11.1	17.1
h (133)	73.1	5.6	9.8
k (155)	4.4	5.6	4.9
g (122)	4.4	0	2.4
a (130)	4.4	0	2.4
m (110)	0	5.6	2.4

TABLE. III. P-values (Kombinationspersistenzzahl) of the scheelite. 14 groups from Japan and 11 groups from Korea.

Crystal faces	P-values %		
	Japan	Korea	Both
p (111)	92.9	81.9	88.9
e (101)	78.6	81.9	77.8
β (113)	35.7	18.2	33.3
s (131)	28.6	18.2	27.8
c (001)	28.6	9.1	27.8
o (102)	14.3	18.2	18.4
h (133)	21.4	27.3	27.8
k (155)	7.2	9.1	5.6
g (122)	7.2	0	5.6
a (130)	7.2	0	5.6
m (110)	0	9.1	5.6

From the values of H, F, and P, it is classified the degree of development of each crystal faces as follows and by this classification the crystal habit may be represented as a whole.

L-class (Charakteristische Leitformen>75%): p(111) e(101)
N-class (Charakteristische Nebenleitformen>50%): none
S-class (Charakteristische Spezialformen>25%): none
E-class (Charakteristische Erganzungsformen>10%): β(113) s(131) c(001) o(102) h(133)
I-class (Individuelle Formen<10%): k(155) g(122) α(130) m(110)

The triangular projection is shown Fig. I after the order of classes of each crystal face of scheelites from both Japan and Korea.

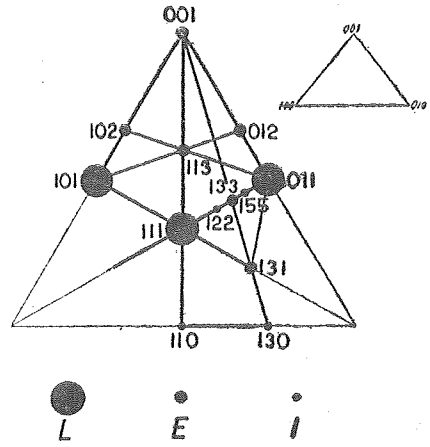


Fig. I. Triangural projection of scheelite from both Japan and Korea.

2. Wolframite

Crystals of wolframite from Japan and Korea are usually tabular parallel to the orthopinacoid but beening elongated parallel to the c-axis or rarely short columnar. The writer has treated 30 crystals of wolframite from 17 localities and the data calculated are that refered to the reports of many authorities and that of the writer's own examination.

It is caluculated that H-, F-, and P-values of the crystals of wolframite and the results are shown in the following Table IV.

From the Table IV the degree of development of each crystal face of wolframite are classified as follows.

L-class (>75%): a(100) m(110)
N-class (>50%): b(010) t(102)
S-class (>25%): f(011) ω(111) σ(121) o(111) c(001) x(101) y($\bar{1}$02)
E-class (>10%): h(310) l(210) s(121)
I-class (<10%): z(113) Δ(112) x(211) λ($\bar{1}$01) α($\bar{1}$32) (232) (230) (520) (720) (510) (1$\bar{2}$2) (211) (105)

The triangular projection of wolframite from both Japan and Korea is shown Fig. II after the order of classes of each crystal faces.

TABLE. IV. H-, F-, and P-values of the wolframite from both Japan and Korea.
30 crystals, 17 localities and 30 groups.

Crystal faces	H-values %	F-values %	P-values %
a (100)	100.0	100.0	100.0
h (310)	16.7	17.6	16.7
l (210)	20.0	17.6	20.0
m (110)	90.0	88.2	90.0
b (010)	63.3	70.6	63.3
f (011)	43.3	47.1	43.3
c (001)	33.3	23.0	33.3
t (102)	56.7	47.1	56.7
x (101)	30.0	17.7	30.0
λ ($\bar{1}$01)	6.7	11.8	6.7
y ($\bar{1}$02)	43.3	41.2	43.3
ω (111)	43.3	47.2	43.3
σ (121)	46.7	41.2	46.7
s ($\bar{1}$21)	23.3	17.7	23.3
o ($\bar{1}$11)	36.7	35.6	36.7
x ($\bar{2}$11)	6.7	11.8	6.7
a ($\bar{1}$32)	3.3	5.9	3.3
d (112)	6.7	5.9	6.7
z (113)	6.7	5.9	6.7

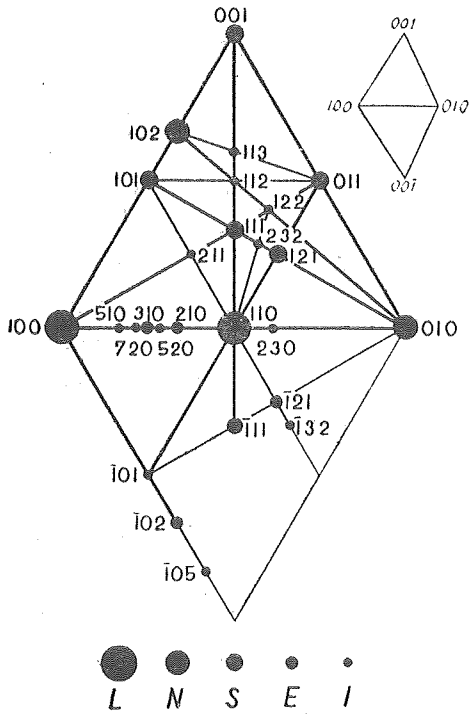


Fig. II. Triagngular projection of wolframite from both Japan and Korea.

3. Crystal habit and mode of occurrence.

The crystals of scheelite have two different types in habit ("Tracht"), and it has much account for their occurrences. In Japan many crystals of scheelite are found in pegmatites, pegmatitic quartz veins or skarn deposits of pegmatitic, and have prismatic habit as *p* ⟨111⟩ groundform. On the contrary in Korea they occur almost always in the hydrothermal veins or skarn deposits, and have prismatic as *e* ⟨101⟩ groundform.

The habit of scheelite may be controled by the amount of available calcium and their velocity of reaction with tungsten in a mineral forming solution. The arrengement of calcium (ion) on

the crystal face *e* (101) is more compact than on *p*, so *e*-face is more stable than *p* (111). If the concentration of calcium in a solution be sufficiently enough and the reaction also slow and complate, so the *e*-form might be developed. It has been thought that the concentration of calcium is low in a primary solution, then much of calcium must be brought into the solution from country rocks. Therefore stable and complate *e*-form may be difficult to form under a condition of rapid cooling such as pegmatitic.

The crystals of wolframite from Japan are found in pegmatites or pegmatitic quarz veins. They are tabular or platy and have well developed pyramidal faces which show sometimes sharp prismatic habit. The crystals from Korea are also tabular but some have orthodomas and base which show rather short columnar. They are found in pegmatitic or hydrothermal quartz veins.

It can not decisive what have effects on a habit of growing crystal of wolframite. But prismatic and thinner platy crystal may be formed under a pegmatitic or a rapid cooling condition, and short columnar wolframite may be formed under a hydrothermal or slow cooling condition. The crystal of wolframite rich in iron are more platy than that of poor.

B. Mutual relations between minerals of tungsten

Except scheelite and wolframite that are hypogene minerals almost all of the other minerals of tungsten are supergene minerals, and they have been found as the weathering products of the formers. Therefore sheelite and wolframite are the minerals which have geologically and genetically a important role in the tungsten mineral-deposits. So on the mutural relations between tungsten minerals it must be examined at first for these hypogene minerals that any genetical relation may exist among them.

Sheelite-wolframite

a. *Wolframite pseudomorph after Sheelite.* Sheelite is replaced by wolframite along the cleavage plane of (111) and (101), and then advancing replacement there is no referrence with the structur of scheelite. In this case wolframite deposits in scheelite with a few quartz.

The replacement is not interchange iron and calcium of scheelite, but scheelite dissolves in the solution and wolframite deposits in that place from the same solution. If the replacement is complate, the

mineral is called reinite. Still more reinite accompanies with thin platy wolframite in some cases. Mostly these wolframites are ferberitic or huebneritic in composition, and frequently associate with marcasite as a iron sulfide mineral. On the contrary primary scheelite or wolframite acompanies with pyrite. The facts may seem to suggest that the natur of solution has changed during the course of deposition.

b. *Scheelite pseudomorph after wolframite.* In most case wolframite is replaced by scheelite with carbonate minerals at the later stage in the same course of deposition. It does not occur any exchange of calcium for iron of wolframite. Wolframite dissolves in the hypogene solution of the later stage from which wolframite had crystallized out formerly. Differ from primary scheelite, secondary one usually is more deeply colored in gray or brownish. Because iron and manganese which has been made free from the dissolving wolframite have mixed into secondary scheelite as impurities. Colored scheelite accompanies some pyrite and much carbonate minerals, and in most cases the carbonate is ankeritic.

c. In many tungsten mineral deposits wolframite and scheelite have been found together, but there are no feature that they crystallized at same time, but in most cases wolframite has been veined brecciated or covered by scheelite. In other few cases wolframite have small inclusions of scheelite.

Wolframite-ferberite-huebnerite

Wolframite like plagioclase consists of a series of isomorphous mixed crystals, and the Mn rich endmember is called huebnerite and Fe richer one ferberite. Many wolframites are hypogene primary and some huebnerites and ferberites may be hypogene secondary. Wolframite occurs in pegmatitic or hypothermal, on the contrary huebnerite and ferberite occur in meso-, epi- or xenothermal deposits. This shows that the decreasing *p-t*-condition may lower the degree of miscibility of Fe and Mn in the wolframite. In most cases the wolframites from a certain deposit indicate about the same chemical composition. And in Korea as a whole, wolframite from the northern and southern parts of peninsula has more manganese content than the central part. But in a certain deposit the composition of wolframite is variable with respect to the *p-t*-gradients during its crystalization. Besides the physical factors it depends to the slight inhomogeneity in the original composition of mineral forming solution. At the Denso-heian mine, Heianhokudo, it has been found the following relation that wolframite

has richer in Fe or Mn seems to be indicated by the somewhat different assemblages of minerals in the cassiterite triplite wolframite sulfide quartz veins.

TABLE. V. MnO/FeO of wolframite of Denso-heian mine

Sample locality	FeO	MnO	MnO/FeO	Accompaning minerals
Heian vein	8.97	11.00	1.23	calcite
Furukawa vein	4.22	15.93	3.77	triplite calcite
Yamaguchi vein	3.95	13.96	3.53	triplite calcite
Renju vein	2.43	14.30	5.88	triplite rhodocerosite

The structure and the mode of occurrence of above each vein are almost the same. But wolframite poor in Mn associates with calcite or ankeritic calcite and does not with triplite, on the other hand wolframite rich in Mn associates with Mn-calcite or rhodochrosite and with triplite. Triplite has crystallized out earier and carbonate later than wolframite. Therefore these difference of properties of associated minerals poit out that wolframite has rich in Mn or not depends on the available amount of Mn in mineral forming original solution.

III. Character of tungsten mineral deposits

A. Geological and geographical distributions

The productive tungsten ore deposits distribute along the coastal region of ocean, especially the western circum-pacific region. Localities of the minerals of tungsten are also known in the same region, but some of them are found in the inner continent. The circum-pacific region is the strikingly folded zone and also the metallogenetic province of Mesoiden. Minerals of tungsten from this region are wolframite and scheelite, but it is remarkable that the mineral from inner land, stable schield, is only scheelite associated with gold in the quartz vein and does not wolframite. Tungsten ore and mineral deposits from both folded and stable areas are genetically connected with the granitic intrusives, and the lodes are always found in the granitic rocks and their adjecent rocks.

Emmons poited out that tungsten deposits were found around the summit or intermediate cupolas of batholith and in his hypothetical

ideal succession of hypogene zoning of metals the tungesten zone laid above next to the zone of tin, the deepest zone of metal. Such zonal distribution of metal, the lateral or downward change of facies, would be recognized in an area that had been in Niggli's hypo-abyssal condition. But if it was in other condition such as volcanic or subvolcanic condition, these zoning might hardly maintain and the mineralization of the deposits would become more and more complex resulted by telescoping of ore minerals. Often the transitional deposits which have temporal facies change in lode have been also found in tungsten deposits. Essencially minerals of tungsten have been found in the deeper zone accompanied with arsenopyrite, pyrrhotite, chalcopyrite, and frequently with cassiterite, bismuthinite, molybdenite, and tourmaline, but a mineral of tungsten has been rarely found in some shallower zone of mercury and antimony or of lead and silver. In such cases it is very important to determine that the mineral would be the primary hypogene mineral or rather the relict that had already crystallized at earier stage or in deeper zone.

In Japan main districts of tungsten deposits are as follows: 1. Kitakami mountains district, Iwate Pref. 2. Yamagata-Niigata Prefs. 3. Ena-Hirukawa district, Gifu Pref. 4. Kameyama district, Kyoto Pref. 5. Northern Kurashiki district, Okayama Pref. 6. Kuga district, Yamaguchi Pref. 7. Miyazaki-Kagoshima Prefs. The deposits have been found in the mesozoic granite and in the surrounding palaeozoic rocks. They are mostly pegmatites, or pegmatitic quartz veins with cassiterite or molybdenite, and some are skarn deposits with copper or lead-zinc sulfides. Several other deposits are hydrothermal quartz veins with tourmaline and copper, with siderite gold and copper, or with siderite gold and silver. These deposits are distributed from central to western of Japan and sometimes the telescoped deposits, as Ikuno-Akenobe mines, have been found among them. But the deposits from Kitakami, northwest of Japan, are the type of gold quartz vein with scheelite.

In Korea the deposits are rather resemble to that of south China and they related to the Bukkokuji granitic intrusives of mesozoic age and have been found in the granite or its adjacent metamorphic rocks of pre-cambrian, palaeozoic and rarely mesozoic of ages. almost all the deposits are hydrothermal some sulfides bearing quartz veins, but few skarn deposits are also found. In such later case the country rocks are not large limestone, as in the Great Limestone Series, but they are thin impure calc-chloritic lens in the slightly metamorphosed

pelitic or psamitic sedimentary series. There are three extensive and productive mining districts. The deposits of northern district of penninsula associate with cassiterite, that of central district associates with cassiterite, molybdenite, or beryl, and that of southern district of penninsula associate with molybdenite or rarely beryl, and sometimes much sulfides and toumaline.

B. The type of tungsten deposits

It was examined about 150 mines from both Japan and Korea refering to the reports of many investigators and the writer's observations. Chief ore minerals of tungsten are wolframite and scheelite. According to their mode of occurrence, their mineral species of tungsten and associated minerals of ore and gangue, the deposits are classified as of two kinds: fissure vein and skarn deposits.

Fissure vein type are divided into pegmatite and quartz vein deposits. Pegmatite deposits are found in the granitic intrusives and some extend into the metamophic rocks surrounding them. The essential minerals are the common rock forming minerals and other minerals often present are beryl, topaz, fluorite, or minerals of rare earth elements. The texture are coarse. The pegmatite deposits often pass into the quartz vein deposits, and they do not seem to be same one as solidified from the final magmatic residuum directly. Almost all the vein deposits of tungsten are included in the vein types which are consided as the deep seated veins except very few shallower types from 11 to 15 group. The skarn tungsten deposits are the pyrometsomatic scheelite deposits which are genetically connected with hypothermal deposits. They are characterized by their gangue minerals as skarn. The texture are massive, but often some parts of them pass into the quartz veins with wolframite.

A. Fissure vein type
  I. Pegmatite vein
    1. Beryl wolframite (or scheelite) pegmatite
    2. Cassiterite wolframite pegmatite
    3. Cassiterite scheelite pegmatite
    4. Wolframite pegmatite
    5. Scheelite pegmatite
  II. Quartz vein
    1. Beryl wolframite (or scheelite) quartz vein
    2. Phosphor mineral wolframite quartz vein
    3. Tourmaline cassiterite wolframite quartz vein

4. Tourmaline cassiterite scheelite quartz vein
5. Tourmaline wolframite quartz vein
6. Tourmaline scheelite quartz vein
7. Cassiterite wolframite quartz vein
8. Cassiterite scheelite quartz vein
9. Wolframite quartz vein
10. Scheelite quartz vein (sericitic calcitic gold quartz vein)
11. Copper tungsten quartz vein (sericitic gold copper quartz vein)
12. Silver tungsten quartz vein (sideritic gold quartz vein)
13. Antimony tungsten quartz vein
14. Kaolinite wolframite quartz vein
15. Telescoped lode

B. Skarn type

1. Skarn with cassiterite
2. Skarn without cassiterite

Above classification according to the morphological factors does not so important to consider the genesis of the deposits. But it gives some clues to find out the common and special relations of each deposit respectively and between the staffs of the deposits and that of altered wall rocks.

Generally, wolframite occurs restricted in the vein type, but scheelite occurs both the vein and the skarn types. The fact may show that calcium of scheelite has not been derived from the primary ore forming liquid.

C. Alteration of wall rocks

Kinds of alteration of wall rocks of the tungsten deposits have been known as follows: greisenization, tourmalinization, biotitization, amphibolitization, sericitization, silicification, carbonitization, chloritization, kaolnitization, and skarnization (silicatization).

It was examined that the mineralogical and chemical changes of these alterations. Though the kinds of alteration are so many, every one of such alteration may be noticed around the deposits of other metals and does not be restricted to the tungsten deposits. The fact seems to suggest that there are no necessary to consider that the tungsten may be carried by the specific medium in the primary ore forming liquid.

The difference among the kinds of alteration affected by the original composition and texture of wall rocks, and moreover by the

changes in conditions during the progression of the alteration. As many tungsten deposits were formed in the unsteady metamophosing aureoles. It was noticed that the alteration effected around the maximum metamorphic condition of country rocks were very complicated, but under a decreasing condition it was rather simple and regular.

Among the alterations some took placed before the deposition of staffs of a lode, and other were formed at same time or later. In many cases two or more alterations were superimposed. But kinds of alteration change corresponding to the succession of minerals in a lode. It was observed that sericitization and silicification of biotitic rocks and of amphibolitzed calcic rock and taken place closely connected with the stage of deposition of tungsten minerals in every lode. Without doubt these alteration had been caused by the process of the hydrothermal solution.

D. Paragenesis

There are various kinds of minerals in the tungsten deposits. It has been often selected such the minerals like cassterite, tourmaline, beryl, lithium mica or molybdenite as it gave a distinctive feature to the tungsten deposit. After the character of these typomorphous minerals, it has been determined that the deposits were formed during pneumatolytic or transitional stage from pneumatolytic to hydrothermal stage. But actually more common minerals always associate with minerals of tungsten: that are simple sulfides, carbonates, sericite and chlorite.

A paragenesis of one deposit may be rather easly

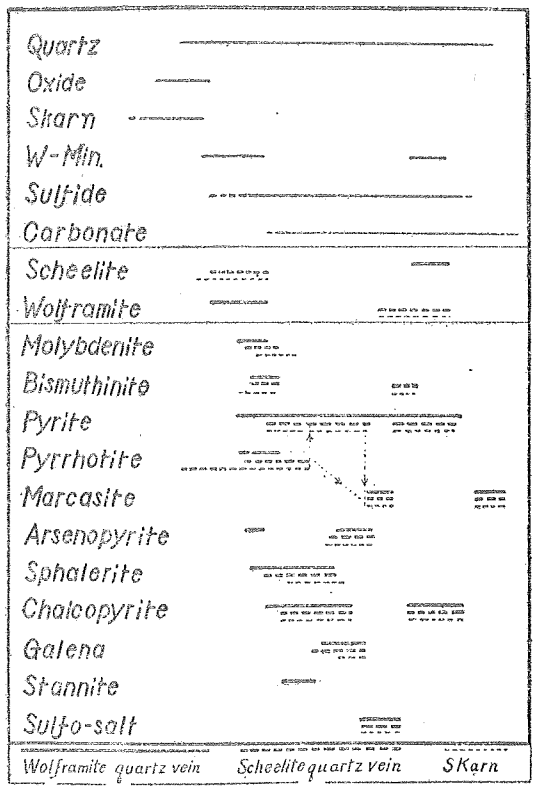


Fig. III. Schematic diagram of the mineral sequence in the tungsten mineral deposits.

determined, but it is difficult when it try to deal with the tungsten deposits as a whole. For there are various kind of minerals, poor in tungsten mineral species, no characteristic minerals accompanied with tungsten, and much differences of mineral composition in different types of deposits. Therefore now it has investigated the paragenetic relation in a deposit one after another, then made several sets of definit assemblage, and examined the mutual relations among each assemblage.

The results are that the existence of minerals of tungsten in a lode has little role about the course of crystalization of the other minerals, that the mineral of tungsten is not crystalized same time with so called pneumatolytic minerals, but often with common bydrothermal minerals. For a instance, scheelite has closely related with pyrrhotite or marcasite. Wolframite with much quartz exist in a scheelite skarn deposit, and reinite, ferberite or huebnerite formed with carbonates and sometimes with marcasite.

Generallized sequence of minerals in the tungsten deposits of both Japan and Korea is shown Fig. III.

IV. Genetical consideration of tungsten minerals and their deposits

It was investigated that the geological and geochemcal behaviours of the element of tungsten with reference to the chemical character of the element, and the distributions and the modes of occurrece of minerals of tungsten.

If the supposition may be admitted, it would be inferred that the element of tungsten distributed in a primary earth crust of silicate shell, and it circulated into the granitic magma which seemed to be the derivation from the migma in the shell according as its potential energy had transformed to kinematic one with the progress of geological cycles. In the magma tungsten had a tendency to from tungstic acid just like silicon to form silicic acid. It would be provable that the concentration of tungsten might become higher in the residual magma after the magma had rised and had been consolidated at near surface.

If the ore forming fluid would be derived from the residual magma, tungsten did not exist in the gas phase as unstable tungsten halogenide as formerly considered, but it might be transfered into the hydrothermal solution by the carriers of halogen. In the ore forming solution tungsten had a tendency to form tungstic acid salts. So the

minerals of tungsten do not pneumatolytic minerals, but hydrothermal one. This fact has been found in some skarn deposits, namely the eariest alteration caused in the calcareous rock is the silicatization, a sort of dry system alteration, and the followed alterations are the amphibolitization and sericitization, the wet system alteration, with depositing scheelite.

Natur of the hydrothermal solution is a very important problem, but many authoritis have not always the same conclusion. Natur of the solution is imposed on the lode minerals and wall rocks. From many evidences of tungsten mineral deposits, there were no necessary to consider a special natur of the solution. Here it was presumed the ore forming solution as the aqueous silisic hot colloidal solution, and for its chemical character it was also defined that an acid solution was considered as a solution containing one or more strong acids and an alkaline solution was defined as one containing alkali and no free strong acid, though it might contain one or more weak acids. The minerals of tungsten have been crystallized from the acidic solution.

Whether wolframite or scheelite may crystallize mostly depends on the concentration of the available calcium in a solution. There are two different stages of deposition of tungsten. The hypogene primary minerals of tungsten seem to be crystallized with some few pyrrhotite from the solution at early stage where the halogenic acids have dominant role, and the hypogene secondary one may be crystallized with much carbonate minerals or few marcasite from the same solution at later stage where the sulphuric and carbonic acids are active in the reaction system. At the intermediate stage many common sulfides of metals deposit form alkaline solution with an active hydrogen sulphide.

It must be taken up a method of analysis for the purpose of to deal with the many different characters of various kinds of tungsten deposits, to find out the common elements through them, and to get the genetical consideration based upon that elements. So if it assume the several definit set of mineral assemblage which have been maintained the same relations of the mineralogical and physico-chemical equilibriums among them, the set as the mineral facies could be regarded as a foundamental unit to consider the processes of formation of the tungsten deposits as a whole.

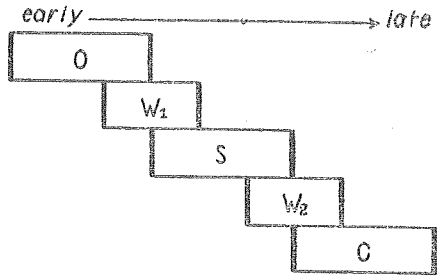
The definit assemblage of minerals is able to be determined actually by analysing the paragenetic relations of equal and different types of the deposits and by comparing with each other. So it may be

found that the common relation would exist in the different types of the deposits, and also that several alterations of wall rock superimposed in a deposit would be affected corresponing with a definit mineral facies respectively.

Generally the tungsten mineral deposits consist of the following four main mineral facieses:

1. Oxide mineral facies [O] : the subject is oxide mineral
2. Tungsten mineral facies [W] : the subject is tungsten mineral
3. Sulfide mineral facies [S] : the subject is sulfide mineral
4. Calbonate mineral facies [C] : the subject is carbonate mineral

The mineral facies changes with the definit sequence among each other as follows:



All the four facieses exist not always in every deposit, some deposits lack a O-facies and others do without W_2. Moreover if it be necessary, it could be settled several sub-facieses in a main facies, and they would make some distinctions among the different types of the deposits.

Under the ordinally conditions four facieses may be succesively formed from the ore solution. Therefore according with the mode of occurrence of the facies and mutual relation among the staffs of facies, it is possible to presume what geological or physico-chemical controlling factors enforced during the formation of the tungsten mineral deposits.