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Geochemistry of Ogbang Tungsten Deposits, Southern Korea

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Abstract: Detailed studies of regional geology and geochemistry of the tungsten mineralisation of Ogbang mine were carried out; in particular geochemical trends of major and trace elements of different lithological units, in comparison with those of the Sangdong area, together with igneous plutons in the area.

The Ogbang deposit is in a pegmatitic association localised only in amphibolites whilst pegmatites in adjacent schists and gneisses are barren. The tungsten is geochemically accompanied by increase of K_2O, Na_2O and Rb, and depletion of Sr. The trend of Rb/Sr ratio to the type of mineralisation, in commonly seen in the mineralised granites of the world, suggests that the tungsten in the Ogbang pegmatites was supplied by hydrothermal processes which at the same time caused Rb enrichment and Sr depletion. These trend could be of use in the search for new ore bodies in common with those of mineralised granitic or pegmatitic host rocks.

There is no evidence that the granites in the area have any genetic influence spacially and temporarily on the initial scheelite formation.

INTRODUCTION

The Ogbang mine (lat. 36°55′10″N and long. 128° 18′ 20″ E) is situated in the vicinity of Ogbangchon, Gwanghoe-ri on the northeastern border of Bongwha-gun and Uljin-gun, Gyeongsangpuk-do, about 40 kilometres to the southeast from the Sangdong mine (Fig. 1).

Tungsten minerals have been mined for over a half century in Korea. The Sangdong tungsten mine has been one of the worlds largest tungsten producers since 1950's and the Ogbang mine, which is the second largest tungsten deposit in the country, has been economically operated, with an output of about 200~300 tons of scheelite concentrates annually.

However the geology and mode of occurrence of the Sangdong and Ogbang ore deposits differ. The Sangdog deposit, consisting mainly of scheelite and gangue minerals, are embedded in the Myobong Slate of Lower Cambrian age and occur in flat or stratiform bodies, lying parallel to the layering of the Myobong Slate (Kim, S. Y., 1976). Whilst the Ogbang area consists mainly of Precambrian schists and gneisses which were intruded by basic igneous rocks, now present as amphibolites. The ore bodies are scheelite-bearing pegmatites which are closely associated with the amphibolites (Lee, S.M., 1967; Kim, O.J., 1969 and Ahn, S.C., 1969).

The ore bodies in the area have not been genetically studied in detail. Most of the previous studies have concentrated on the main ore bodies themselves and have been concerned with the mineralogy and structure of the ore bodies.

No systematic attempt has been made to study the geochemistry of the ore deposits. Therefore an attempt has been made to study the geochemistry of the Ogbang scheelite deposit, the host pegmatites/amphibolites and its adjacent Precambrian rocks together with various igneous stocks in the Sangdong-Ogbang area, in order to determine whether there are any consistent geological and geochemical trends of tungsten

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mineralisation in common with those of the Sangdong.

Laboratory studies were undertaken during the period of the writer's Ph. D. course in the early of 1970's, when a large number of rocks and ores from different geological environments were analysed to determine the distribution and variation of elements and the source of tungsten in the area. This work was carried out by X-ray Fluorescence Spectrometer and Electron Microprobe in the Department of Earth Sciences, University of Leeds, under supervision of Dr. George Hornung, to whom the writer is especially indebted for his advice and guidance on geochemical analyses, geological discussions together with his encouragement in the research project culminating in a critical appraisal of the text.

GEOLOGIC SETTING

Rocks of Precambrian and Lower Palaeozoic age are extensively exposed in the Sangdong-Ogbang area. The area were studied as part of a regional geological mapping project during the 1960's. Subsequently geological maps at a scale of 1:50,000 and 1:250,000, covering the whole studied area were published by the Geological Survey (Kim, O.J., et al., 1963; Lee, D.S., 1966; Lee, D.U., et al., 1965; Son, C.M., et al., 1968 and Yun, S.K., 1963).

The area straddles the bounday of the north-eastern part of the Ogcheon Basin and the Ryeongnam Massif. The Ogcheon Basin is dominantly a calcareous sequence of marine sediments, known as the Joseon Supergroup of Cambro-Ordovician age. The Ryeongnam Massif comprises Precambrian basement rocks bounded by the Ogcheon Fold Belt on its north-western side and overlapped by a thick Cretaceous sedimentary-volcanic assemblage deposited in the Gyeongsang Basin to the south-east (Ogbang mine area) (Reedman and Um, 1976).

A brief description of the various formations and igneous plutons believed to be genetically related to the tungsten mineralisation in the area is given below. The Chunyang and Hongjesa granites, which are considered not to have any relevance to the mineralisation, have not been discussed here. Detailed geologic map with location of the mine is shown in Fig. 1.

Precambrian Rocks

Three main metasedimentary rock groups of Precambrian age are the Pyeonghae, Weonnam and Yulri Groups.

The Pyeonghae Group, which is assumed to be the oldest, consists of banded biotite gneiss and augen gneiss with thin beds or lenses of quartz-sericite schist, phyllite and marble, and is exposed to the south-west of the Ogbang mine as a small isolated patch. In the mine area the relationship between the Pyeonghae and Weonnam Groups is obscure but to the east of the studied area, Kim, O.J. et al., (1963) concluded that the Weonnam Group was younger than the Pyeonghae Group.

The Weonnam Group consisting largely of gneisses, similar to those of the Pyeonghae Group, with lenses of mica-sillimanite schist, graphite schist and hornblende schist, is mainly exposed in the mine area as enclaves surrounded by the Buncheon Granitic Gneiss. The biotite-garnet gneiss, originally argillaceous, is common in gneisses and is generally medium-grained, grey to purple grey in colour, displaying well developed augen and gneissic structures. The augens range from two to four millimetres in diameter. Porphyroblastic textures are common with large porphyroblasts of garnets, ranging from a few millimetre to a maximum of two centimetres in diameter. The rock is generally composed of orthoclase and plagioclase as augen and small tabular flakes of biotite, interlayered within mosaics of quartz and plagioclase in the matrix surrounding the augen.

The Yulri Group consists dominantly of

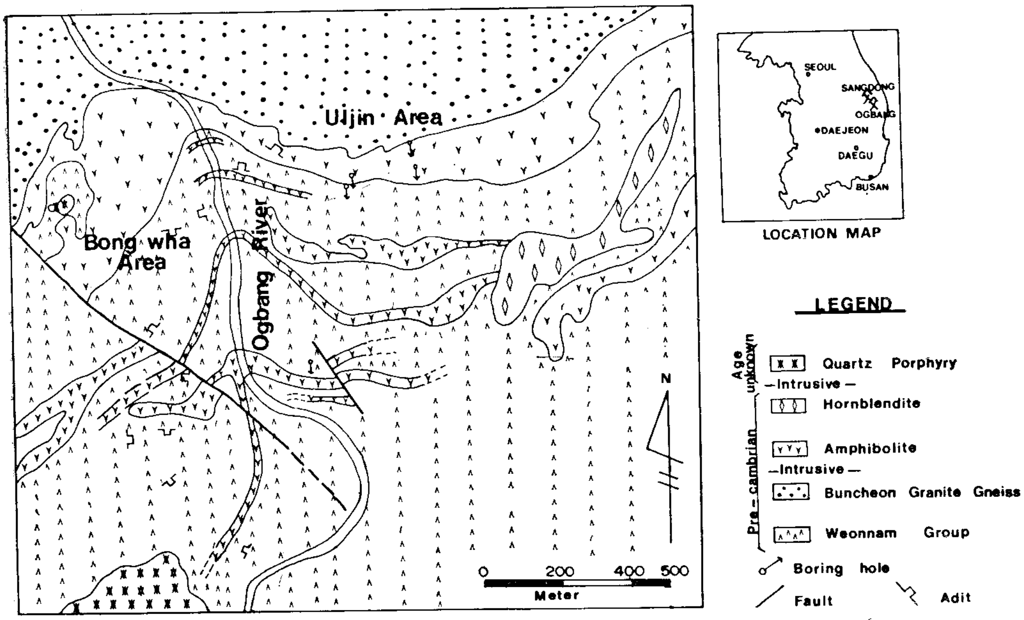

Fig. 1 Geological map of Ogbang mine area.

chlorite-biotite schists and phyllitic rocks. The rocks have a wide crescentic outcrop around the northern half of the Chunyang granite batholith, with a strike length of at least 50 kilometres.

The Yulri Group can be subdivided into three groups on lithology: pelitic schists, psammitic gneisses and migmatitic gneisses. Northwards the pelitic schists, locally known as the Taebaegsan Schists of the Sangdong mine area, are well exposed and unconformably overlain by Cambrian formations. Whilst southwards, on the Samgunri quadrangle near the Ogbang mine area, psammitic paragneisses are exposed, and rest unconformably upon gneisses of the Weonnam Group. Eastwards, on the Ogdong quadrangle the metasedimentary rocks of the former two subgroups grade into migmatic paragneisses. The three subgroups represent a sedimentary sequence in which cross-bedding and slump structures are sometimes preserved which have been metamorphosed under low P/T condition and in place, migmatised.

The Buncheon Granitic Gneiss forms a crescentic outcrop surrounding the belt of amphibolites in the Ogbang mine area and is well exposed in the northern part of the mine, around Buncheon town. It is intruded by the Hongjesa granite in the north of the Jangseong quadrangle and intrudes the Yulri Group in the west and the Weonnam Group in the south. The rock is medium-to coarse-grained and has a well developed foliation. In the Ogbang mine area, where the granitic gneiss is in contact with amphibolite, the foliation has a general east-west strike with an average dip of 50° to the north. This foliation is broadly concordant with the amphibolite layers.

Amphibolites and Pegmatites

Amphibolites: Within the gneisses near the contact zone between the Weonnam Group and the Buncheon Granitic Gneiss, several belts of amphibolite are exposed in the Ogbang mine area. These amphibolites invariably form the wall rocks of the tungsten-bearing pegmatites. The amphibolites vary from 30 to 120 metres in thickness and the strike length of the amphibolites extends almost 3 kilometres (Fig. 1). The strike and dip of the foliation are generally concordant with those of the gneisses, with a general strike of N 30°∼60°E and dip of 30° to 50° to northwest.

Though a large amphibolite belt lies in contact with the granitic gneiss and the Weonnam Group, other amphibolites are interlayered within the metasediments of the Weonnam Group. In general these amphibolites lie parallel to the compositional layering of the metasediments. But in many localities, particularly in the present working area of the Ogbang mine, amphibolite apophyses clearly cut the enclosing metasediments of the Weonnam Group and gneisses. A small spherical outcrop of hornblendite is exposed in the southwestern area of the mine and is bounded with the amphibolites showing rather gradational contact between them. The quartz porphyries, as a small dykes scattered in the mine area, cut the gneisses and amphibolites (Fig. 1).

The amphibolites are dark green to black and vary from fine-to coarse-grained, though they are most commonly medium-grained. There appears to be no palimpsest structure, probably due to the foliation which affects most of the amphibolites. They commonly display gneissic structure and in many localities ptygmatic folding of aplitic material is also seen.

The hornblendite shows somewhat different lithologic characteristics from the amphibolites. The rock is fine-to medium-grained, black, dense and compact. In thin section it is seen to consist predominantly of colourless or slightly greenish actinolite-tremolite, in addition to common hornblende and biotite. The rock also has a high magnetite content of about 3 percent.

The origin of the amphibolites is rather ambiguous. They would be derived from basic or semi-basic igneous rocks or from impure calcareous and dolomitic sediments. Kim, O.J., et al., (1963) and Kim, O.J. (1969) considered the amphibolites to represent a basic front, the material having been derived from the adjacent Buncheon Granitic Gneiss during granitisation, whilst Lee, S.M. (1968) has argued that the amphibolites have an intrusive origin. Despite this he states that the contact between the amphibolite and the gneiss is 'gradational features' and contamination and metasomatic replacement are seen in thin sections, which seems to imply some granitisation or remobilisation.

Though a large amphibolite belt lies in contact with the granitic gneiss and the Weonnam Group, other amphibolites are interlayered within the metasediments of the Weonnam Group. It is true that in general these amphibolites lie parallel to the compositional layering of the gneisses, but in many localities amphibolite apophyses clearly cut the enclosing gneisses. Relics of impure limestone, dolomitic or pure limestone rocks have not been observed in the amphibolites of Ogbang mine area and calcite has not been seen in thin sections.

Field evidence and petrographical evidence suggest that the amphibolites probably have an intrusive origin, of basic igneous rocks, modified by regional metamorphism, to the assemblage hornblende-plagioclase-epidote (-quartz-biotite) (Turner and Verhoogen, 1960, p. 546).

Pegmatites: Several pegmatitic bodies are surrounded by amphibolite in the Ogbang mine, prominent amongst which is the third one from the contact with the Buncheon Granitic Greiss (see Fig. 1). The pegmatites are essentially vein-like, with lenticular pipe, and 'teardrop' shapes indicated by evidence from underground. There are wide variations in thickness ranging from a several tens centimetres up to a maximum of three metres, and pegmatites can be seen to die out along the strike as well as downwards. The contacts with the country rock amphibolite appear to be irregular, the strike lies within a range of N30°∼60°E and there is an average dip of 40° to the northwest.

Almost the whole of any particular pegmatite is coarse-grained, occasionally gradidng into aplitic veins and with a coarser massive texture inwards, becoming finer and gneissose towards the amphibolite. The pegmatite is composed of a pure milky white albite with some oligoclase biotite, hornblende and subhedral to anhedral quartz, with only local appearance of orthoclase and tourmaline. There is no significant sign of zonal arrangement of minerals, and this places it in the category of unzoned, exterior graphic pegmatite (Hornung, 1961).

Albite is the most abundant plagioclase. It is predominant in the upper levels of Ogbang mine where albite twins and graphic intergrowths with plagioclase, milky white in colour, is predominant. It contains commonly small inclusions of quartz grains and alters to quartz, biotite and muscovite, showing corroded graphic intergrowth aggregate. It also appears to have slightly curved twin lammellae in the unaltered grains, probably caused by deformation. Modal analysis of the plagioclase shows 75 per cent in the lower levels.

Biotite occurs as clusters in the pegmatites, in many places porphyritic, dark brown to reddish brown in colour. Particularly where the scheelite forms an ellipsoidal-shaped lens as concentrated aggregates, the biotite occurs as bleached yellowish brown, large flakes, selvage bands surrounded by pegmatite alter to biotite clusters. Generally the amount of biotite varies from 5 to 10 per cent.

The pegmatite hornblende is green, blue and bluish green. It amounts to less than 5 per cent of pegmatite. The amount of hornblende increases outwards to the contact of the amphibolite, as well as downwards to the lower level. It is not certain whether there is any primary hornblende present in the pegmatite. However the relics of hornblende, altered to or replaced by biotite, may indicate that the hornblende scattered through the pegmatite is derived from the amphibolite.

Quartz is transparent white to opaque milky white; the transparent variety appears to be predominant in the upper level, whilst the opaque type is dominant in the lower levels. Orthoclase and tourmaline are seen only in few localities, in the upper levels, where vein quartz invades the pegmatite.

To summarise, the irregular boundaries between the pegmatite and the amphibolite, the mode of occurrence of the pegmatites, the replacement features of some minerals and the modal changes occurring towards the contact suggest that the pegmatite cropping out in the mine area may be regarded as intrusive, and that assimilation of the amphibolite had taken place, with metasomatic replacement.

The age of the amphibolites and pegmatites intrusion is uncertain. The amphibolites are assumed to be of late Precambrian age between the post-Buncheon Granitic Gneiss and the Precambrian sedimentation, since the amphibolites intrude the contact of the Buncheon Granitic Gneiss and the Weonnam metasediments and their apophyses clearly cut the enclosing gneisses or metasediments. The pegmatites in the Ogbang area are assumed to be almost identical in age to those of the tin-bearing pegmatites which intrude the Yulri Group in the Sangdong area. The latter is clearly younger than the Buncheon Granitic Gneiss as this has a demonstrable intrusive relationship.

Igneous Intrusions

Several batholithic and stock-like intrusions are scattered around the Sangdong-Ogbang area and include Precambrian, Jurassic (Daebo) and Cretaceous (Bulgugsa) intrusions. South of Sangdong mine, the Chunyang granite batholith, which consists mainly of foliated and porphyritic coarse-grained biotite granite, crops out, and intrudes Precambrian metasediments of the Yulri and Weonnam Groups (except its southern side, where it is in contact with a hornblende granodiorite). South-eastwards, in Jangseong quadrangle, the Hongjesa granite consisting mainly of medium-to coarse-grained biotite-muscovite granite, frequently with porphyritic texture, crops out. It contains xenoliths of Palaeozoic sedimentary rocks together with Precambrian metasedimentary rocks. These plutonic intrusions represent the Daebo Granite Series of Jurassic age.

In the neighbourhood of Sangdong mine, only three plutons crop out and they are of relatively small dimensions. Their rock types vary from granodiorite to granite and adamellite. Westwards, the Imog granite intrudes the lower Palaeozoic sedimentary sequence, except at its southwestern side, where it is in contact with the Precambrian metasedimentary rocks. The rock type is a porphyritic, fine-to medium-grained biotite granodiorite or locally adamellite. The Nonggeori granite in the south is a particularly fine-to medium-grained equigranular grey granite and is unusual in that it contains abundant muscovite and almost no mafic minerals. Northeastwards, the Eopyeong granite is mainly granodiorite, with dominant hornblende.

Due to the probable significance of these two latter granite stocks as a focus of tin-bearing pegmatite and their possible relationship with tungsten deposits, together with other polymetallic deposits in the studied area, situated less than 4 kilometres from the granites, they are geochemically studied more fully than the other granites.

GEOCHEMISTRY OF THE OGBANG MINE AREA

The geochemistry of the pegmatites, amphibolites and metasedimentary rocks in Ogbang mine was studied by analysing whole rocks and a few separated samples of biotite, hornblende and feldspars. Whole rock samples from the Buncheon Granitic Gneiss, through amphibolite to the Weonnam Group were taken from the Gangweon level and the Upper 11 level cross-cuts, (traverses 7~5 and 7~6, respectively). Pegmatites and amphibolite wall-rocks were taken from the two sections in the Gangweon upper sub-level where the tungsten ore shoot has recently been found (traverse 7~8).

The mode of occurrence of the tungsten in the Ogbang mine is rather peculiar as it is concentrated in the pegmatite, as pure scheelite lenses or pockets (Details are described in Kim, S.Y., 1976).

Geochemical Variations of the Amphibolites

Geochemical data for the amphibolites are presented in Tables 1 and 2, and the chemical compositions are plotted on an ACF diagram (Fig. 2). Elemental variations are also represented diagrammatically Figs. 3 (7~5) and 4 (7~6). Geochemical data for pegmatites within the traverses are not shown in the tables and figures but are presented separately in Table 3 and 4.

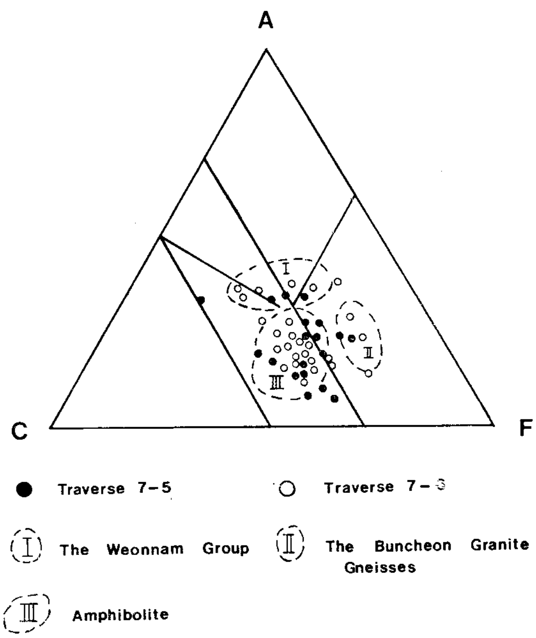

Fig. 2 The chemical composition of the traverse 7~5 and 7~6 in the Ogbang mine, plotted on ACF diagram, showing the approximate compositional field (After Winkler, 1965 and Hutchison, 1974).

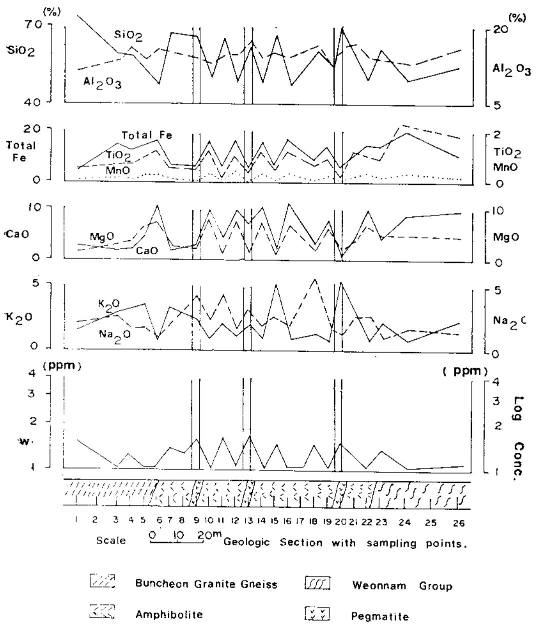

Fig. 3 Major element and tungsten variations of the traverse 7∼5 in the Ogbang mine area.

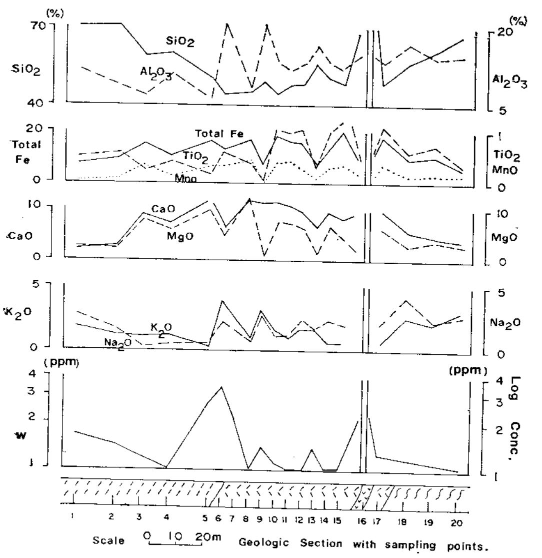

Fig. 4 Major element and tungsten variations of the traverse 7∼6 in the Ogbang mine area.

Geochemical Variations in Major Elements: The amphibolite falls into the compositional field of basic rocks of the ACF diagram with a small spread, while the Buncheon Granitic Gneiss fall into the magnesian field and the Weonnam Group falls into the pelitic to feldspathic fields with a wide spread.

Variations of major elements are distinctive. The silica content of the amphibolites decreases towards the contact whilst the remaining elements increase in the same direction. Major elements in the amphibolites show a noticeable enrichment and depletion of certain elements at 5∼10 metres intervals. As K_2O and Na_2O increase, total Fe, TiO_2, CaO and MgO decrease. The distributions of silica and alumina from the two traverses are contradictory as alumina remains constant and silica is variable in traverse 7-5, whilst in traverse 7-6 their behaviour is reversed.

Tungsten and Trace Elements: Tungsten contents of the Buncheon Granitic Gneiss are 20∼50ppm, increasing towards the contact with the amphibolite, whilst most of the Weonnam Group analysed are below the detection limit of 10ppm. The tungsten values for the amphibolite are similar to those of the Buncheon Granitic Gneiss adjacent to the contact. Exceptionally high concentrations of tungsten are obtained from both Buncheon rocks and amphibolites, 5 metres from their contact (470 ppm and 2, 090 ppm respectively) where the former has high CaO-MgO but low K_2O-Na_2O-SiO_2-Al_2O_3 and the latter has high K_2O-Na_2O-SiO_2-Al_2O_3 but moderate CaO-MgO. The tungsten concentration in both the Yulri Group and Myobong Slate in Sangdong exhibit a close relationship with increasing CaO and decreasing K_2O (Kim, S.Y., 1976), whilst the Buncheon rocks and amphibolite in Ogbang indicate the reverse. This suggests that tungsten in Ogbang is present partly in feldspars (50∼120 ppm) and partly in hornblende and biotite. It also suggests that tungsten is extremely enriched in the alumina-silica rich rock, probably due to the absorption into clay minerals, as suggested by Jeffery (1959).

Other trace elements also show a contrasting

Table 1 Analytical results of traverse 7~5. (major in wt. % and trace in ppm)

Sample	75001	75002	75003	75004	75005	75006	75007	75008	75010	75011	75012	75014	75015	75016	75017	75018	75019	75020	75021	75022	75023	75024	75025	75026
SiO_2	73.97		59.26	58.25	54.00	47.65	67.44		49.28	66.43	47.92	48.38	67.27	47.34		60.01	54.27	68.82	58.07	49.24	61.28	48.47		54.31
TiO_2	0.48		0.69	0.66	0.83	1.25	0.57		1.18	0.18	0.96	1.12	0.42	1.15		0.63	0.85	0.19	1.16	1.02	0.82	2.71		1.71
Al_2O_3	11.23		13.86	15.33	13.50	15.16	14.44		12.32	14.38	14.40	13.63	14.69	13.61		15.95	11.39	15.49	16.03	13.95	11.86	12.35		15.60
Fe_2O_3	4.34		14.73	12.45	13.88	16.00	6.76		16.24	5.45	16.58	16.38	6.21	16.57		8.70	12.49	5.13	9.24	13.95	13.04	18.88		9.98
MnO	0.03		0.11	0.10	0.22	0.27	0.14		0.29	0.04	0.37	0.28	0.06	0.24		0.04	0.20	0.07	0.13	0.24	0.16	0.30		0.14
MgO	1.54		2.76	3.98	6.59	7.41	2.29		7.70	0.75	7.10	6.89	1.09	6.89		1.94	6.17	1.70	3.86	6.48	4.56	4.96		4.49
CaO	2.56		1.82	2.05	4.44	10.29	1.78		9.57	4.21	9.86	9.61	1.81	10.91		3.02	7.57	0.82	4.09	9.79	4.06	8.47		9.36
K_2O	1.58		2.97	3.23	3.55	0.68	3.34		0.74	2.07	1.09	0.90	4.94	0.78		1.24	0.67	5.16	2.52	0.58	2.11	0.78		2.09
Na_2O	3.18		2.76	1.62	1.70	0.80	1.93		2.28	4.37	1.68	1.94	2.52	1.92		6.83	1.96	1.23	2.54	2.52	0.98	1.65		0.94
P_2O_5	0.06		0.16	0.18	0.14	0.17	0.12		0.18	0.67	0.17	0.15	0.09	0.19		0.14	0.08	0.13	0.22	0.19	0.14	0.23		0.35
H_2O+	1.43		0.89	1.43	2.14	1.79	2.08		1.61	1.79	1.25	1.29	1.07	1.07		1.25	1.79	2.14	2.16	2.07	1.08	1.68		1.58
Total	99.40		100.01	99.01	100.99	101.46	100.86		101.39	100.34	101.28	100.67	100.17	100.67		99.75	99.44	100.93	100.02	100.03	100.09	100.38		100.55
Nb	13	15	13	—	—	—	13	15	—	—	—	—	15	—	—	17	—	—	14	—	—	—	—	—
Y	31	15	60	59	65	32	62	55	32	58	28	30	37	25	28	62	24	56	43	26	43	30	44	63
Sr	81	59	11	72	53	32	85	84	75	193	77	85	113	71	99	108	87	56	287	131	86	73	96	108
Rb	108	78	199	163	210	35	146	194	47	283	55	50	206	19	23	153	29	173	101	19	116	27	102	157
Zr	399	174	133	116	80	59	232	155	60	11	59	61	298	71	63	236	58	108	239	54	181	76	68	114
W	33	16	—	18	—	—	24	19	—	48	—	—	31	—	—	35	—	40	15	—	23	—	10	11
Bi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sn	—	10	10	15	22	148	12	13	21	13	175	45	14	53	32	13	14	16	13	57	12	103	71	20
Sb	—	—	—	—	—	—	—	—	—	4	2	4	—	—	—	—	6	—	—	—	—	—	—	—
As	—	46	10	69	204	27	42	34	67	—	265	117	—	10	17	—	10	—	4	230	—	232	40	14
Cu	36	18	65	41	96	92	61	81	144	41	19	267	35	208	33	30	—	50	32	357	47	301	29	128
Zn	119	78	52	119	128	115	145	72	173	35	126	90	99	69	60	43	77	32	71	89	60	117	127	52
Pb	206	135	52	48	25	17	57	58	15	84	21	12	77	15	27	68	23	142	34	15	36	16	24	21

Note: —indicates under detection limits.
Samples 75001~75005 : Buncheon Granitic Gneisses.
Samples 75006~75022 : Amphibolites.
Samples 75023~75026 : Weonnam Group.

Table 2 Analytical results of traverse 7~6. (major in wt. % and trace in ppm)

Samples	7601	7602	7603	7604	7605	7606	7607	7608	7609	7610	7611	7612	7613	7614	7615	7617	7618	7619	7620
SiO_2	70.53	71.25	59.25	60.26	50.56	44.66		45.77	49.91	44.83	47.99	48.11	56.00	50.81	48.93	48.41	56.63	61.13	66.28
TiO_2	0.50	0.57	0.26	0.41	0.16	0.62		0.38	0.09	1.12	0.98	1.04	0.31	1.00	2.18	1.39	0.57	0.73	0.32
Al_2O_3	10.16	8.92	6.81	11.17	6.44	20.79		8.10	21.06	13.54	11.85	13.16	16.68	13.34	12.08	13.40	17.05	14.15	14.82
Fe_2O_3	7.19	9.87	15.08	10.99	16.39	13.09		17.13	7.95	18.40	16.29	15.81	7.05	15.80	20.10	17.91	8.92	10.90	6.24
MnO	0.04	0.07	0.32	0.15	0.31	0.32		0.41	0.06	0.37	0.44	0.26	0.08	0.28	0.33	0.34	0.13	0.15	0.15
MgO	2.36	2.17	2.80	6.07	9.72	4.88		12.29	0.91	7.31	7.23	6.28	1.66	6.62	4.54	6.19	2.52	3.65	2.68
CaO	2.01	2.20	8.95	7.27	1.50	6.25		11.85	11.31	11.45	10.69	9.43	6.99	9.47	8.15	9.65	5.48	4.34	3.45
K_2O	1.82	1.26	1.04	1.37	0.45	3.93		0.99	3.01	1.59	1.12	1.70	1.67	0.63	0.61	0.65	2.57	2.07	3.12
Na_2O	2.82	1.74	0.39	0.51	0.51	2.37		0.95	2.24	1.18	1.18	2.50	5.83	2.40	2.15	2.21	4.10	2.21	1.21
P_2O_5	0.09	0.09	0.11	0.21	0.12	0.32		0.16	0.07	0.18	0.26	0.15	1.47	0.17	0.25	0.21	1.00	0.35	0.46
H_2O+	2.86	2.76	0.93	1.27	1.75	2.32		1.61	2.64	0.58	2.14	1.54	2.18	0.86	1.02	0.54	1.61	1.23	1.48
Total	100.38	100.90	100.94	99.68	99.91	99.55		99.64	99.75	100.55	100.17	99.98	99.92	101.38	100.34	100.90	100.58	100.91	100.21
Nb	11	24	10	12	—	13	13	—	—	—	—	—	18	—	—	—	20	11	14
Y	45	31	33	48	20	113	60	42	84	73	42	27	67	31	33	30	30	92	62
Sr	179	75	38	43	19	106	135	11	147	35	55	110	172	106	88	90	154	102	121
Rb	256	115	83	153	112	493	265	69	178	128	105	37	148	29	24	25	226	146	185
Zr	360	245	91	217	113	148	108	25	6	60	48	43	15	51	68	69	166	106	317
W	48	31	—	—	477	2095	134	—	26	14	—	—	26	—	—	—	28	16	25
Bi	—	—	—	—	68	—	—	20	—	35	—	—	—	—	—	—	—	—	—
Mo	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—	—
Sn	18	14	78	34	32	30	23	323	17	194	113	38	11	39	69	130	13	21	17
Sb	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
As	—	—	—	28	38	—	12	16	86	264	218	64	45	68	12	181	10	23	—
Cu	25	221	116	38	286	—	16	—	49	664	14	152	124	29	228	—	83	847	24
Zn	29	67	146	79	82	190	130	1202	32	171	175	75	101	100	98	131	102	80	33
Pb	36	36	—	13	17	32	40	20	48	16	21	20	100	15	17	19	66	29	25

Note: Samples 7601~7605 : Buncheon Granitic Gneisses.
Samples 7606~7617 : Amphibolites.
Samples 7618~7620 : Weonnam Group.

pattern. Cu, Zn and Pb are relatively constant in the Buncheon rocks (40～60ppm) whilst in the Weonnam Group they are much higher (200 ～300 ppm), and are slightly lower in the amphibolite though extremely enriched adjacent to the contact of the pegmatite. As contents in general correspond with Cu and Zn, suggesting that all are probably accommodated in sulphides, and As and Pb appear to be more enriched than in Sangdong area. Sn is enriched markedly in the amphibolite, particularly adjacent to the pegmatite where CaO predominates over K_2O–Na_2O, reflecting a negative correlation with tungsten. Bi, Mo, Sb and Nb are almost undetectable, rarely exceeding 20 ppm. In general, there is no significant geochemical trend to be found in these ore metal elements which can be related to tungsten.

In contrast, the lithophile elements such as Sr and Rb tend to be either enriched or depleted with changing tungsten levels. Sr is extremely depleted in the amphibolite at a level of 50～80 ppm, though the CaO rises to 6～10%; Rb is high in the amphibolite, though the K_2O decreases to 1%. There is a good correlation between tungsten enrichment and Rb/Sr ratios, as tungsten increases with increasing Rb/Sr as it does in the mineralised igneous rocks in Hwanggangri area (see Table 7). If one relates the trend of Rb/Sr to the type of mineralisation, seen in the mineralised granites, then this suggests that the tungsten in Ogbang area was supplied by hydrothermal processes which at the same time caused Rb enrichment and Sr depletion.

Geochemical Variations in Tungsten and Trace Elements of the Pegmatites

The trace element geochemistry of the two unmineralised pegmatites and the three mineralised pegmatites is presented in Table 3 and 4.

The tungsten content of the unmineralised pegmatites is similar to the wall rock amphibolite and it increases slightly at the contact, or in

Table 3 Analytical results of the unmineralised pegmatites (in ppm).

Samples / Elements	Unmineralised Pegmatites								Mineralised Pegmatites				
	750091 PQ	750092 A	750093 A	750094 A	750131 PQ	750132 PF	750133 PB	750134 C	750135 A	76161 PF	76162 PB	76163 C	76174 A
Nb	—	11	—	—	—	13	15	13	—	13	—	—	—
Y	10	45	35	30	28	142	113	32	18	136	71	2	63
Sr	—	23	86	90	96	227	144	111	93	34	10	15	160
Rb	111	173	161	—	23	253	107	177	19	151	123	117	186
Zr	276	48	99	70	7	143	340	51	16	—	—	—	10
W	40	25	—	—	43	15	30	—	40	142	69	69	32
Bi	—	—	—	—	—	—	—	—	—	—	—	—	—
Mo	—	—	—	—	—	—	—	—	—	—	—	—	—
Sn	14	12	11	18	98	12	13	15	12	22	15	10	17
Sb	—	—	—	—	3	2	—	—	—	—	—	—	—
As	10	12	23	—	24	—	—	—	—	62	327	—	—
Cu	58	39	39	218	429	51	160	40	173	165	141	251	93
Zn	—	—	49	72	104	60	71	55	46	82	—	—	80
Pb	—	22	13	16	20	75	55	60	17	35	—	20	63

Note: A: Amphibolite, C: Contact between A and P, PQ: Quartz rich pegmatite,
PB: Biotite rich pegmatite, PF: Feldspar rich pegmatite.
Samples 750091～750095 and 750131～750135: from traverse 7～5.
Samples 79161～76164: from traverse 7～6.

Table 4 Analytical results of the mineralised pegmatite and wall rock amphibolite (in ppm).

Samples / Elements	At 20m from Cross-cut										At 50m from Cross-cut									
	7801 A	7802 C	7803 P B	7804 P F	7805 P Q	7806 P F	7807 P B	7808 C	7809 A	7810 A	7811 A	7812 A	7813 C	7814 PBF	7815 P F	7816 P Q	7817 P F	7818 PBF	7819 C	7820 A
Nb	—	16	31	31	—	—	—	—	—	—	—	—	—	22	—	—	—	—	—	—
Y	96	252	64	97	45	64	36	56	29	78	54	216	52	83	37	34	33	44	38	41
Sr	148	227	31	176	34	62	88	184	68	214	54	197	43	123	84	252	90	221	105	113
Rb	251	161	325	417	89	321	164	273	26	167	82	288	297	373	319	55	24	10	82	105
Zr	100	7	44	173	61	88	55	31	69	14	83	11	85	10	116	—	104	—	91	90
W	25	32	558	19	—	205	26	22	—	24	—	44	49	129	46	30	—	29	—	10
Bi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sn	90	21	60	38	669	64	217	75	304	26	288	30	212	57	79	24	186	23	20	—
Sb	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
As	121	37	872	219	562	290	369	269	695	—	466	128	355	679	—	162	342	140	383	—
Cu	85	17	469	—	256	22	140	64	126	94	463	19	537	74	—	36	412	236	131	—
Zn	204	97	288	188	172	146	151	141	166	29	167	39	166	180	105	—	142	45	64	—
Pb	27	66	37	45	52	46	36	55	26	75	27	63	18	35	—	99	25	83	17	24

Note: All samples from the upper sub-level of Gangweon main level, about 50m below the upper 11 level.
All abbreviations: see Table 3.

biotite-rich pegmatite and decreases a little on the hanging-wall. Similarly tungsten in the mineralised pegmatites is enriched either in the contact or in the biotite-rich pegmatites and it decreases towards the hanging-wall amphibolite. The mineralised pegmatites have higher values of tungsten (140～550 ppm) than the unmineralised pegmatite (40 ppm), whilst the wall rocks of both pegmatites remain constant (20～30 ppm).

Rubidium, tin, arsenic, copper and zinc show a significant increase in the mineralised pegmatites and hence distinguish the mineralised pegmatites from the unmineralised ones. There is a remarkable rise in the Rb/Sr ratio where the tungsten is concentrated in the pegmatite to more than 150 ppm. The rise in rubidium content is probably related to potassic alteration of feldspars and is accompanied by a rise in tin levels, whilst a rise in arsenic is reflected in the occurrence of arsenopyrite (which is virtually negligible in the unmineralised pegmatite) associated with copper and zinc-sulphides.

Many of the other trace elements show small variations between mineralised and unmineralised pegmatites though this cannot be related to tungsten contents.

GEOCHEMISTRY OF IGNEOUS ROCKS IN SANGDONG-OGBANG

The Nonggeori, Eopyeong and Imog granite stocks and the pegmatites in Sungyeong and Kakhi mines are the main igneous intrusions in the Sangdong mine area and it is important to know the geochemical composition of these intrusives to determine whether any are genetically related to the tungsten mineralisation of Sangdong-Ogbang or not. For this purpose, a comparative study was made with granites from the Hwanggangri area where they are intensely altered and accompanied by a visible W-Mo mineralisation (Reedman, et al., 1974).

The geochemical work was carried out on 9 granite samples and 2 pegmatites from Sangdong and 11 samples from the various stocks in Hwanggangri.

Geochemical data for Sangdong are presented

Table 5 Analytical results of igneous rocks in Sangdong-Ogbang. (major in wt. % and trace in ppm)

	Eopyeong Granite			Nonggeori Granite			Imog Granite			Pegmatite	
	3011	3012	3013	3021	3022	3023	3031	3032	3033	3081	3091
SiO_2	70.95	69.26	70.68	67.88	67.29	67.77	71.36	71.67	70.55	67.49	64.81
TiO_2	0.56	0.85	0.35	0.13	0.04	0.09	0.35	0.50	0.46	0.02	0.01
Al_2O_3	14.16	14.58	14.23	17.38	17.18	17.25	14.46	14.99	14.98	18.01	16.45
Fe_2O_3	3.26	4.98	3.40	2.09	2.45	2.49	1.74	2.02	1.89	0.90	0.38
MnO	0.04	0.11	0.15	0.02	0.02	0.02	0.07	0.08	0.05	0.02	0.02
MgO	0.65	0.48	0.78	0.82	0.79	0.94	1.21	0.88	1.14	0.20	0.14
CaO	1.68	1.71	2.89	1.53	1.71	1.64	2.94	2.46	2.07	1.72	1.47
K_2O	3.82	3.68	3.24	6.43	6.29	6.66	3.39	3.41	3.92	1.04	4.95
Na_2O	4.38	4.64	4.42	3.12	3.57	3.29	3.55	3.75	3.78	8.17	6.69
P_2O_5	0.32	0.44	0.41	0.34	0.27	0.19	0.13	0.20	0.32	0.99	0.95
H_2O^+	0.35	0.38	0.49	0.46	0.86	0.66	0.57	0.76	0.92	0.71	1.07
Total	100.17	101.11	100.94	100.20	100.87	101.30	99.98	99.72	100.08	98.55	94.88
W	—	18	—	—	—	—	—	—	—	10	10
Bi	—	—	—	—	—	—	—	—	—	—	—
Mo	10	—	—	—	—	—	—	10	—	20	16
Sn	12	10	—	36	42	38	10	15	10	86	64
Cu	77	14	66	26	—	31	24	52	48	61	54
Zn	15	26	32	17	24	28	29	26	31	26	32
Pb	22	20	28	19	23	21	33	30	41	—	—
As	—	—	—	—	—	—	—	—	—	—	—
Sb	—	—	—	—	—	—	—	—	—	—	—
Nb	13	13	10	22	28	25	16	20	18	93	38
Y	50	49	57	63	71	66	59	61	54	154	144
Sr	577	505	542	32	68	71	339	352	385	156	276
Rb	110	126	132	310	421	398	143	158	176	815	753
Zr	281	214	268	111	98	121	255	241	236	35	13

Note: a) 3011, 3021 and 3031 taken at 50m from the contact.
b) 3012, 3022 and 3032 taken at 100m from the contact.
c) 3013, 3023 and 3033 taken at 200m from the contact.
d) 3081 taken from old adit of Sunkyeong mine, about 4km west of Sangdong mine.
e) 3091 taken from old adit of Kakhi mine, about 6km southwest of Sangdong mine.

in Table 5 and comparisons of the composition of the granites from tungsten mineralised areas over the world are presented in Table 6, whilst trace element contents of the Hwanggangri granites are presented in Table 7.

Geochemistry of the Sangdong-Ogbang Intrusives

The compositions of the three granite stocks in the area vary slightly. The Eopyeong and Imog granites have Na_2O predominant over K_2O and CaO, whilst in the Nonggeori granite K_2O is higher than Na_2O and Ca_2O. The Nonggeori granite has much higher Al_2O_3 and K_2O and lower SiO_2, CaO and Na_2O than those of the other two granites.

The ratios K_2O/Na_2O, K_2O/CaO and K_2O+Na_2O/CaO of the Sangdong granites, together with the granites associated with tungsten mineralisation elsewhere in the world are shown in Table 7. These ratios are considered an

Table 6 Comparison of chemical composition in Sangdong-Ogbang granites with those in other areas.

	Sangdong(1)			Japan(2)		China(3)		Shap(4)		K.I.(5)	Average (6)
	I	II	III	I	II	I	II	I	II		
SiO_2	67.29	70.30	71.67	68.45	74.37	74.83	74.92	70.71	70.51	66.46	73.86
TiO_2	0.04	0.35	0.50	0.54	0.22	0.08	0.15	0.71	0.66	0.24	0.20
Al_2O_3	17.18	14.32	14.99	15.26	13.22	12.58	14.08	13.79	14.21	16.35	13.75
Fe_2O_3	2.45	3.88	2.02	0.23	0.08	0.68	0.71	2.88	2.51	0.98	0.78
FeO	—	—	—	3.09	0.79	1.31	0.40	—	—	2.48	1.13
MnO	0.02	0.11	0.08	0.09	0.04	0.07	0.14	0.05	0.03	0.24	0.05
MgO	0.79	0.63	0.88	1.27	0.12	0.41	0.48	0.46	0.41	1.45	0.26
CaO	1.71	2.09	2.46	2.87	1.26	0.78	0.97	2.61	2.17	3.37	0.72
Na_2O	3.57	4.48	3.75	3.40	3.12	3.81	3.37	2.61	3.14	4.31	3.51
K_2O	6.29	3.58	3.41	3.16	4.59	4.48	4.50	4.73	5.80	2.78	5.13
P_2O_5	0.27	0.39	0.20	0.29	0.05	0.01	—	0.56	0.49	0.14	0.47
Ig. Loss	0.86	0.41	0.76	1.08	1.86	0.61	0.01	—	—	1.24	0.14
Total	100.87	100.54	99.72	99.73	99.72	99.65	99.74	100.00	100.00	100.04	100.00
K_2O/Na_2O	1.76	0.80	0.91	0.93	1.47	1.17	1.32	1.36	1.59	0.65	0.80
K_2O/CaO	3.67	1.71	1.39	1.10	3.64	5.74	4.63	1.81	2.67	0.82	0.86
K_2O+Na_2O/CaO	5.76	3.85	2.91	2.29	6.12	10.63	8.11	3.16	4.12	2.10	1.94

Note: All Fe is as Fe_2O_3 in analyses of Sangdong and Shap. Ig. Loss include water and volatiles.
(1) The present study from Table 5 (I: Nonggeori, II: Eopyeong, III: Imog)
(2) Ishihara (1971), Table 2.
I: Muscovite bearing biotite granite, unaltered, II: Altered aplitic granite.
(3) I: Kiangsi granite, Dept. of Geology, Nanking Univ. (1974), Table 3.
II: Hunan granite, Wung (1969, p. 622), Table 2.
(4) Kim, S.Y. (1973, p. 92); I: unaltered, II: altered
(5) Edwards, et al. (1955, p. 59), Granite, Table 1.
(6) Krauskopf (1967, p. 390), Average Granite, Table 14-1.

adequate indicator for delineating rock type, and also are favourable with mineralisation (Kim, S.Y., 1973).

The ratios for the Nonggeori granite are similar to those of granite and particularly altered tungsten-bearing granites of the world, whilst the Eopyeong and Imog granites are closer to unaltered granodiorite.

The normative composition of the granites in Sangdong are plotted on the ternary diagram plagioclase-potassic feldspar plus quartz-mafic minerals which is used by Lee, D.S. (1971) and Ishihara (1971), and data for the igneous stocks from the Ogcheon Belt (Lee, D.S., 1971) are added to the diagram for comparison (see Fig. 5).

The contrast is seen clearly in Fig. 5 where the Cretaceous granites and the Jurassic granites fall into distinct fields with little overlap. Reedman et al., (1973) concluded that the granites of Worak, Samduk, Sujung and Jesamuk in the Hwanggangri area which are associated with the W-Mo mineralisation are late Cretaceous adamellitic granites.

The normative composition of the Eopyeong and Imog granites falls into the Cretaceous granite field, whilst the Nonggeori granite falls into the Jurassic granite field. The former two granites are of Cretaceous age, but the Nonggeori granite is late Precambrian (Kim, S.Y., 1976).

Distribution of Tungsten in Igneous Rocks

There has been no previous description of

Table 7 Trace elements of igneous rocks in Hwanggangri area (in ppm).

	Worak			Samduk			Sujung		Jesamuk		
	3041	3042	3043	3051	3052	3053	3062	3063	3071	3072	3073
W	17	48	113	23	67	1255	18	58	29	63	71
Bi	—	—	—	13	—	64	—	—	15	18	71
Mo	35	88	186	10	48	362	76	176	—	10	50
Sn	10	15	40	15	26	43	20	30	15	15	20
Cu	—	—	79	43	58	290	119	111	108	42	114
Zn	41	21	330	56	62	254	37	51	15	35	60
Pb	65	66	384	38	80	174	75	80	73	80	86
As	—	—	69	—	—	—	20	48	73	40	51
Sb	—	—	20	—	—	—	—	—	—	—	—
Nb	42	51	78	48	68	448	87	155	45	67	83
Y	271	201	119	391	243	186	294	234	256	345	212
Sr	66	15	17	40	10	—	24	—	10	34	10
Rb	234	371	667	339	443	805	462	523	460	621	874
Zr	193	142	108	299	166	107	150	103	326	157	42

Note: 3041, 3051 and 3071: Fresh granites, 50 metres from vein lode.
3042, 3052, 3062 and 3072: Altered granites, 5 metres from vein lode.
3043, 3053, 3063 and 3073: Wall rocks adjacent to vein lode, intensively altered.

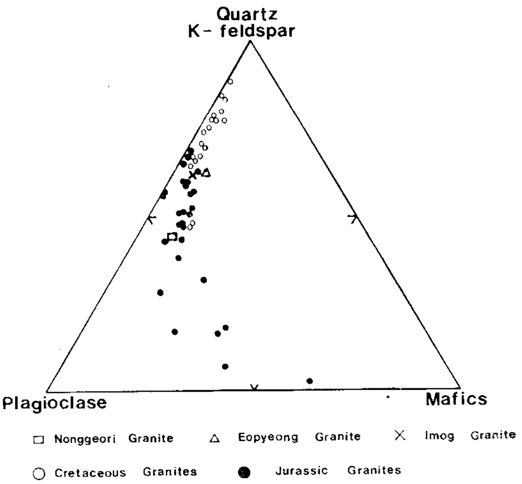

Fig. 5 Triangular diagram of the modal compositions of the granites in Sangdong-Ogbang area (After Lee, D.S., 1971).

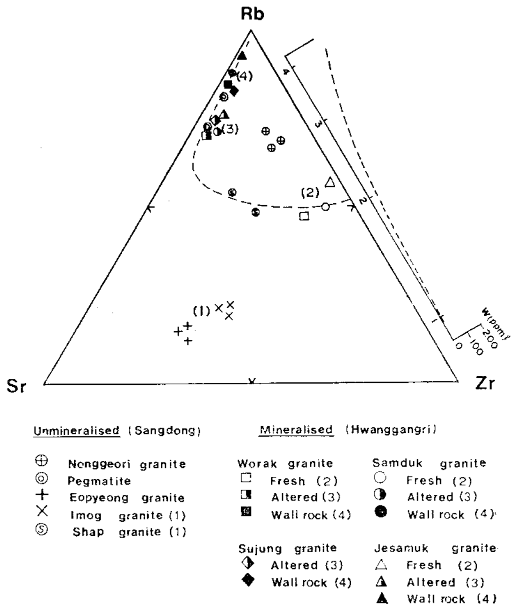

Fig. 6 Triangular plots of selected trace elments of the unmineralised granites in Sangdong-Ogbang area and the mineralised granites in Hwanggangri area.

tungsten distribution in the Sangdong granites and therefore it is described in some detail here. Tungsten is relatively scare and is mostly below the detection limit of 5ppm in igneous intrusions in Sangdong. Only one sample, of Eopyeong granite which contains high total Fe and TiO_2, has been detectable tungsten, probably associated with iron minerals such as magnetite and ilmenite, and the two pegmatites have 10ppm W, probably associated with muscovite. In contrast, all the granites from Hwanggangri have a considerable amount of tungsten, ranging from 17~29ppm in the fresh granites, 48~63ppm in the altered granites and 71~113 ppm (except a sample, from Samduk which is anomalously high at 1,255ppm) in wall rocks. These suggest that the igneous rocks of Sangdong may contain a general average tungsten content of as low as 2ppm, whilst high values in the Hwanggangri granites reflect abnormal concentrations directly associated with tungsten deposits. Reedman et al (1973) considered from study of the Hwanggangri area that these four granites are related both spatially and genetically to the tungsten mineralisation. A similar conclusion is reached regarding granites associated with tungsten deposits elsewhere in the world.

Ivanova (1963 and 1969) and the Department of Geology, Nanking University (1972) pointed out that the granites which were responsible for the tungsten mineralisation have been altered (muscovitised), presumably by the ore-forming solutions, and they reveal anomalous tungsten concentrations. In this aspect, the Nonggeori granite seems the most favourable, since it has been altered (highly muscovitised) and exhibits a high index of K_2O/CaO (see Table 6). However, there is no evidence to be seen of percolation of the ore-forming solutions into the granite as neither veins nor veinlets are found, nor is tungsten apparent in the whole rocks or separated muscovite.

Geochemical data for the granites in Sangdong suggests that none of the intrusions are associated genetically with the tungsten mineralisation.

Trace Elements in Igneous Rocks

Bismuth, Molybdenum and Tin: These three elements are considered together as they are commonly associated with tungsten in vein deposits within granite. Bismuth is below the detection limit of 10ppm in all the granites and pegmatites of Sangdong which were analysed. Most of the molybdenum levels are also below the detection limit of 10ppm and only two granite samples and the pegmatites contain detectable molybdenum (less than 20ppm), whilst tin appears in most of samples analysed, and the contents rarely exceed 40ppm in the granites. Pegmatites show a range of 60~90ppm or about twice the level of the granites.

In contrast, the molybdenum levels in the mineralised granites in Hwanggangri have a wide range of 10~76ppm in the fresh rocks, 10~88 ppm where altered and 40~6,360ppm in wall rocks. Bismuth appears in the Samduk and Jesamuk granites, having a range of 13~64ppm with an increase towards the wall rock whilst the Worak and Sujung granites are below detection limit. Tin is seen in all the granites at levels comparable to those of Sangdong with a slight increase towards the wall rock from 20 to 40ppm. In general, the mineralised granites are more highly enriched in Mo and Bi than the granites in Sangdong.

Copper, Zinc and Lead: These elements are constant of all the intrusions in Sangdong, with ranges of 20~70ppm Cu, 20~30ppm Zn and 20~40ppm Pb. The Nonggeori granite has a slightly lower content of Cu, Whilst the pegmatites are below detection limit for Pb. The mineralised granites have much higher contents than those of Sangdong, ranging from 40~380 ppm Pb, with a general increase towards the wall rocks.

Arsenic and Antimony: These two elements are below detection limits in all the Sangdong intrusions. Antimony is generally below the detection limits in the Hwanggangri samples analysed, whilst arsenic is present in the mineralised granites, having a range of 20~70ppm, with an increase towards the wall rocks.

Niobium: The niobium contents in the granites of Sangdong remain constant, with a small range of 10~20ppm, with slight enrichment in the

Nonggeori granite and pegmatite, to 20~30ppm and 40~90ppm, respectively. In contrast, the mineralised granites in Hwanggangri exhibit a considerable concentration with 40~80ppm in the fresh rocks, 50~150ppm where altered and 70~450ppm in the wall rocks, a good positive correlation with tungsten and molybdenum.

Zirconium: Zirconium remains fairly constant in the granites of Sangdong with a small range of 220~280ppm and is depleted in the Nonggeori granite and pegmatites which have 100~120ppm and 10~35ppm, respectively. Zirconium in the mineralised granites decreases towards the wall rocks, from 200~300ppm down to 100ppm.

Yttrium: Yttrium shows a constant value in the granites of Sangdong with small variations (50~70ppm) but it is slightly enriched in the pegmatites to 140~150ppm. In contrast, the mineralised granites in Hwanggangri have higher concentrations (250~390ppm) than the granites in Sangdong and this decreases markedly towards the wall rocks to a level of 110~210ppm. This may suggest that yttrium is probably present in feldspars and is leached out by the alteration processes.

Strontium: The strontium generally exhibits a similar trend to yttrium as it decreases towards the wall rocks. It remains constant in the unmineralised biotite-hornblende granite with a range of 340~580ppm, but muscovite granite and pegmatite have low contents of 60~70ppm and 140~150ppm, respectively. However, the mineralised granites in Hwanggangri show a considerable depletion in some muscovite granite, and it decreases in wall rocks adjacent to the quartz veins to the detection limit of 10ppm. Strontium is probably present within the feldspars, and the depletion in the mineralised granites, particularly in wall rock is due mainly to the removal and replacement of plagioclase feldspar.

Rubidium: The rubidium contents of the unaltered granites are 110~130ppm and 140~170 ppm and these contents increase in the muscovite granite and pegmatites to 300~420ppm and 750 ~810ppm, closely following the potassium values. A high rubidium content is also exhibited by the mineralised granites (200~500ppm) and it increases markedly towards the wall rocks, where it is especially concentrated in the wall rocks adjacent to the mineralised quartz veins, with a 3~5 fold enrichment. The high concent of the mineralised granites and the enrichment in the wall rocks provides a strong negative correlation with strontium, and this is one of striking features of the granites related to the mineralisation.

A triangular plot of Rb-Sr-Zr (see Fig. 6) shows several distinct fields for unmineralised and mineralised granites, and these can be related to the tungsten contents. The unmineralised Eopyeong and Imog granites fall close together with high Sr, intermediate Zr and low Rb, whislt the mineralised granites in Hwanggangri fall in the high Rb and intermediate Zr and Sr field, and move towards the Rb corner as the alteration and mineralisation increases towards the wall rocks. The Shap granite which has zones of moderate alteration (Kim, S.Y., 1973) shows a similar trend, as the Rb increases towards the altered selvage adjacent to veins. The Nonggeori granite and pegmatites have initial high Rb contents accommodated by muscovite, and no trends are apparent.

DISCUSSION AND CONCLUDING SUMMARY

The scheelite concentration of Ogbang is confined to pegmatites which have been developed within the amphibolite and no scheelite-bearing pegmatites has been found in the gneisses or schists surrounding the amphibolites. Here, it occurs as lenses, 'barrels' or oval masses, consisting of almost pure massive scheelite surrounded by rims about one centimetre thick of aggregates of large brown biotite flakes.

In contrast, the tungsten mineralisation in Sangdong is closely related to three well-defined and specific lithologic units of the Myobong Slates, comprising calcareous shales and biotite-hornblende sandy shales. Here, the scheelite in the mineralised ore beds is concentrated heavily in the hornblende-biotite-quartz rich zone which comprise competent, dense layers of stratified alternations of thin bands of hornblende-bearing rocks, exhibiting excellently preserved sedimentary fabrics, as uniformly disseminations of fine grains of scheelite throughout the ore beds.

In fact, tungsten is present in varying contents in all the rock types of the Sangdong-Ogbang area (except the Jangsan Quartzite and the Great Limestones). From many traverses of both the mineralised and unmineralised Myobong Slate, it is clear that the concentration of tungsten exceeds normal crustal abundances often by several hundred times and this is confined to the specific rock types, such as biotite-hornblende rich calcareous shales and sandy shales associated with thin bands of skarn rocks (Kim, S.Y., 1976). Similarly, the amphibolites around Ogbang mine area also contain amounts of tungsten several hundred times greater than the normal crustal abundance.

The distinct differences in geochemical compositions and distribution of the two tungsten deposits are significant. The tungsten concentration is correlated with the increase of CaO, MgO and total Fe in Sangdong, whilst in Ogbang area the tungsten concentration is correlated with an increase of K_2O and Na_2O, together with a remarkable increase of Rb and decrease of Sr.

The trend of increasing tungsten, accompanied by increasing of CaO, MgO and total Fe, and decrease of certain mobile trace elements, such as Rb and Sr, from older to younger sediments (from the Weonnam Group through the Yulri Group to the youngest Myobong Slate) suggest that the primary concentration of tungsten in specific rock units of the Myobong Slate is probably related to transport of basic rock materials by volcanic activity, as seen in Ogbang amphibolites, followed by cycles of erosion.

Therefore, important primary concentration of tungsten occurred at a very early stage, in basic volcanic rocks (now amphibolites) and subsequent pegmatite intrusions around Ogbang which owe their abnormal content of 100~200ppm tungsten to accommodation in hornblende.

The granites around Sangdong-Ogbang are unaltered and exhibit a normal concentration of tungsten and trace elements whilst the granite around Hwanggangri which has tungsten and molybdenum mineralisation associated, has considerable enrichment of tungsten and rubidium accompanying an intense wall rock alteration. It is clear that the granites in the area have no direct influence on the initial scheelite formation.

Trace elements, particularly Rb and Sr, associated with the mineralisation in the granites show distinct trends from the fresh to the wall rocks, so these could be of use in the search for new ore bodies, though the extent of the dispersion patterns produced is restricted to visible zones of alteration. Rb and Sr in the wall rocks vary due to the addition or removal of feldspars by the alteration which accompanies with the mineralisation.

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玉房重石鑛床의 地球化學

金　相　燁

要約 : 玉房重石鑛床에서의 鑛化作用의 特性을 糾明하기 爲하여 廣域的인 地質調査와 여러 岩層들에 對한 主成分元素, 微量元素의 地化學的 傾向을 檢討하였으며, 上東地域과 相互 比較를 해보았다.

이 鑛床에서의 重石鑛化作用은 角閃石內에 發達된 페그마타이트에서만 있었고, 片岩이나 片麻岩 附近에 發達된 페그마타이트에는 鑛化作用의 痕跡이 보이지 않는다. 重石의 濃集은 地化學的으로 K_2O, Na_2O, Rb이 增加하고 Sr이 減少할 때 나타나며, Rb/Sr 比의 傾向으로 볼 때 페그마타이트內 重石의 流入은 Rb濃集과 Sr 減少를 隨伴한 熱水作用에 起因되었음을 알 수 있다. 이러한 樣相은 花崗岩 혹은 페그마타이트를 母岩으로하는 鑛床들에 對하여 探鑛의 指針이 될 수 있다.

이 地域에 있는 花崗岩이 灰重石의 成因에 對하여 空間的으로나 時間的으로 影響을 미친 證據는 觀察되지 않았다.