Distribution of Minor Elements in the Kieslager Copper-Pyrite Deposits of the Okuki Mine, Ehime Prefecture, Japan

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Distribution of Minor Elements in the Kieslager Copper-Pyrite Deposits of the Okuki Mine, Ehime Prefecture, Japan*

By

Hideyuki MATSUISHI

Abstract

The results of spectroscopic analysis of host green metamorphic rocks, cherts and ores of Cu pyrite deposits of the Kieslager type of the Okuki mine shows as follows:

1. The elements which are found in all host rocks and ores are Co, Ni, Mo, Ag, V, Be, Cr, Ga, As, Pd.
2. Each rock (bed) or ore has characteristic assemblage of minor elements in it.
3. Ores are classified into 4 types by the character of the assemblage of minor elements in them. These ores are zonally distributed along the border of ore body and the zonal arrangement is not symmetrical around the center of the ore body. Different types of ores are regularly arranged from the foot to the hanging wall of the deposit.

Introduction and Acknowledgement

Many Japanese geologists have recently been engaged in the study of cupriferous pyrite deposits of the Kieslager type in the outer zone of the southwestern Japan and we are gradually grasping its nature and genesis.

The writer has lately engaged in the study of the distribution of the minor elements in the ores and host rocks of the deposits of this type at the Okuki mine, Ehime Prefecture. The writer has examined the minor elements of 165 specimens of ores, host rocks, red cherts and vein minerals. The writer expresses his thanks to Prof. Toyofumi YOSHIMURA and Assistant Prof. Hiromu MUKAIYAMA of Kyushu University for their kind guidance to this researches and is also grateful to Prof. Toru TOMITA, Prof. Tatsuro MATSUMOTO, Assistant Prof. Kametoshi KANMERA and Mr. Yoshifumi KARAKIDA of Kyushu University for their many suggestions. The writer is much obliged to the staff of the Okuki mine for their kind assistance in the field work, especially Mr. Motomi MORI, mining geologist of Okuki mine, for his kind help to perform surveying and sampling of specimens. The writer is grateful to Mr. Kenjiro YANAGASE of Technological Institute of Kyushu Electronic Company and Mr. Keisuke TACHIBANA of Institute of Geo-chemistry, Kyushu University, for their kind instruction concerning spectroscopical analysis, also grateful to Mr. Hideyuki YAMADA of Department of Geology in Seinan Gakuin University for his kind assistance in the field and laboratory.

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Geology and Ore Deposits

Green metamorphic rocks, diabase, red cherts, gabbroic rocks, etc. which belong to the so-called Mikabu System, are distributed in the Okuki district and show an anticlinal structure.

Bedded cupriferous pyrite deposits are enclosed in these metamorphic rocks nearly parallel to their bedding plane and are concentrated mainly near the axis of anticline. Each ore body develops itself with red cherts as cap rocks along the boundary between a massive green rock of the hanging wall and a schistose green rock near the axis of minor foldings.

General stratigraphy in the district is as follows:

(a) Upper green metamorphic rocks
(b) Upper red cherts
(c) Lower green metamorphic rocks
(d) Massive green rocks
(e) Lower red cherts
(f) Cupriferous pyrite deposits
(g) Schistose green metamorphic rocks
(h) Meta-gabbroic rocks

(a) Upper green metamorphic rocks: Green to greenish grey metamorphic rocks with a highly developed schistosity consist of chlorite, epidote, plagioclase, quartz with some carbonate mineral, actinolite and hematite. They remain the texture of tuffaceous rock in the upper part and that of tuff breccia in the lower part. Moreover, in the lower part they often have thin layers of chert.

(b) Upper red cherts: Pale brownish red or dark red banded cherts are mainly composed of minor grain of quartz and often have a colloform texture, sometimes enclosing radiolaria. Small amounts of carbonate mineral, hematite and pyrite are also found. The cherts contain thin layers composed of simillar mineral composition to green metamorphic rocks. Those thin layers are rich in chlorite and epidote, and in some parts in clay minerals. Some of cherty rocks are rich in both iron and manganese, and in Fujikawa, oxidized part of these rocks were excavated as manganiferous iron ores.

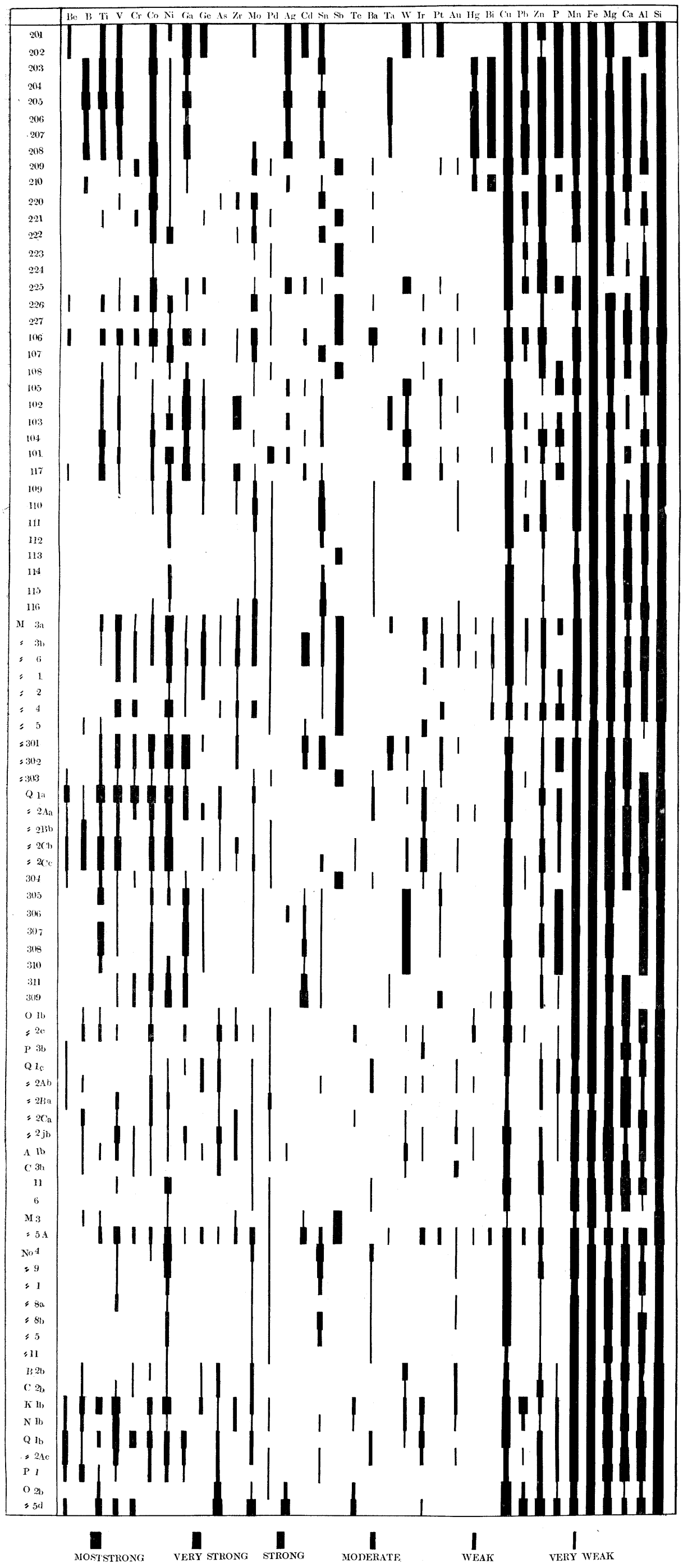
(c) Lower green metamorphic rocks: The rocks have almost the same appearance and mineral composition as upper green metamorphic rocks.

(d) Massive green rocks: Diabase is green to greenish grey in colour and massive. It generally has a porphyritic texture but sometimes shows a banded structure like lamination. They partly have thin layers of chert and iron-bearing quartz of irregular form. Main constituent minerals are chlorite, epidote, actinolite, plagioclase, small amount of hematite and magnetite.

(e) Lower red cherts: The rock has the same appearance and mineral composition as upper red chert. This chert bed is very thin, and sometimes absent in the neighbourhood of the ore deposits. Average thickness is ten centimeters. This chert is found on a hanging wall of the ore deposits.

(f) Cupriferous pyrite depsits: The deposit includes two types of ores: namely,

Fig. 1. Minor elements in random samples from the Showa and Jinnan Level, Okuki.



Explanation of Fig. 1.

201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 220, 221, 222, 223, 224: Massive ore, 223: Zincblende, 226, 227: Hematite (random samples, Showa and Jinnan level)

101, 102, 103, 105, 104, 117, 107, 112, 115, 111, 114, 110, 109, 116, 106, 113, 108: Red chert.

M1, M2, M3a, M4, M3b, M5, M6: Mn red chert, 306, 301, 311, 309, 302, 310, 308, 305, 307, 304, 303: Green rock.

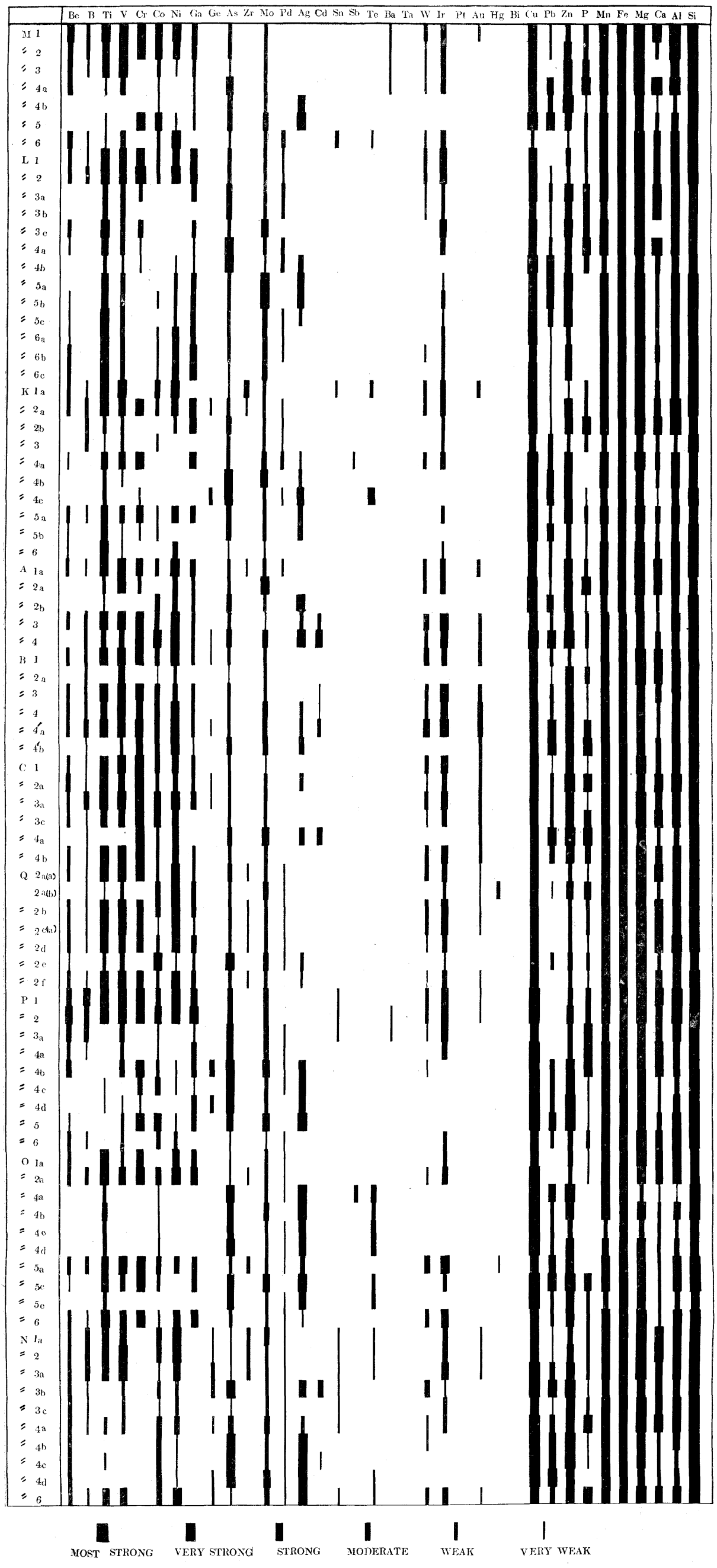
Q-1a, Q-2Bb, Q-2Aa, Q-2b, Q-2C(c): Green rock, Q-2C(a), Q-2B(a), Q-2A(b), Q-1c, A-1b, Q-2fb, O-1b, O-2b, C-3b, No. 11, No. 6, P-3b, M3, M5: Quartz vein.

C-2b, No. 11, No. 1, No. 8a, No. 9, No. 4, No. 5, B-2b: Pink vein.

N-1(b), Q-2(A)c, K-1(b), Q-1(b), P-1: Epidote vein.

O-2b, O-5d: Chalcopyrite vein.

Fig. 2. Minor elements in the set samples from the Showa and Jinnan Level, Okuki.



Explanation of Fig. 2.

M-1: Massive green rock, M-2: Massive green rock, M-3: Red chert, M-4a: Earthy red chert, M4b: Massive ore, M-5: Massive ore, M-6: Phyllitic green rock (M section, Showa)

L-1: Massive green rock, L-2: Massive green rock, L-3a: Red chert, L-3b: Red chert, L-3c: Red chert, L-4a: Massive ore, L-5a: Massive ore, L-5b: Massive ore, L-5c: Ore, L-6a, L-6b, L-6c: Phyllitic green rock (L section, Showa level)

K-1a, K-2a: Massive green rock, K-3: Red chert, K-4a: Thin layers of green rock in ores, K-4c: Massive ore, 4-5a: Impregnated ore, K-5b: Massive ore, K-6: Phyllitic green rock, (K section, Showa)

A-1a: Massive green rock, A-2a: Red chert, A-2b: Massive ore, A-3: Green rock, A-4: Impregnated ore, (A section, Showa)

B-1: Massive green rock, B-2a: Red chert, B-3: Phyllitic green rock, B-4: Phyllitic green rtck, B-4'a: Phyllitic green rock, B-4'b: Impregnated ore, (B section, Showa level)

C-1: Massive green rock, C-2a: Red chert, C-3a: Phyllithic green rock, C-3c: Green rock, C-4a: Impregnated ore, C-4b: Phyllitic green rock, (C section in Showa)

Q-2(a)a, Q-2(a)b, Q-2b, Q-2(c)a, Q-2d: Massive green rock, Q-2e: Impregnated ore, Q-2f: Phyllitic green reck (Q-2 section, Showa level)

P-1, P-2: Massive green rock, P-3a, P-4a: Red chert, P-4b, P-4c, P-4d, P-5: Massive ore, P-6: Phyllitic green rock (P section, Jinnan)

O-1a, O-2a: Massive green rock, O-4a, O-4c, O-4d, O-5a, O-5c, O-5e: Massiue ore, O-2: Phyllitic green rock, (O section, Jinnan)

N-1a, N-2: Massive green rock, N-3a, N-3c: Red chert, N-3b, N-4a, N-4b, N-4c, N-4d: Massive ore, N-6: Phyllitic green rock.

massive and impregnated ones. Massive ores consisting mainly of pyrite are compact. Gangue minerals are quartz, carbonates, chlorite and epidote. Small fragments and thin layers of green rocks are sometimes found in the ores which are distributed near the foot wall of the deposit. Small fragments and thin layers of red chert are also enclosed in ores which are siliceous and distributed near the hanging wall. The ore is generally massive but sometimes shows a banded structure and a colloform texture.

Impregnated ores are generally distributed in the foot wall or around the massive ore. They consist mainly of chlorite, epidote, quartz and pyrite. In general, the mineral composition of impregnated ores is similar to that of green metamorphic rocks which are somewhat siliceous and are impregnated by large amount of pyrite and some chalcopyrite. Hematite and magnetite are accompanied by some part of ores.

(g) Schistose green rocks: Greenish coloured, fine grained and highly schistose green rocks compose the foot wall. Main constituent minerals of this rock are chlorite, epidote, actinolite, quartz and plagioclase. Some parts are rich in hematite, magnetite and pyrite.

(h) Meta-gabbroic rocks: The rocks are mainly composed of epidote, chlorite, actinolite, plagioclase and small amounts of augite, and are generally coarse grained.

(i) Segregation veins: In host green rocks, red cherts and ores are present many veins of segregation in origin and so called " Hanekomi ". These veins are found only in a single bed.

Spectroscopic Analysis

(1) Samples: About 170 specimens were collected from the Syowa and Jinnan levels of this mine. 79 specimens are the set samples of ores and host rocks collected on section crossing ore body, and 88 specimens are random samples which are collected from the same ore body where the set samples could not be collected.

(2) Method and results: Shimazu QF-60 type Quartz spectrograph is used in this study. 7 seconds' exposure, Fuji Process Plate, FD 131 developing solution are used. Results of analysis are shown in Figs. 1 and 2. Since the analytical method used in this study could not make clear the presence of elements which have characteristic spectrographic lines of 3500~4500 Å, the elements having the lines of 2500~3500 Å were determined.

As shown in the figures and tables, the distributions of elements in the rocks and ore of the same occurrence or of similar mineral composition are quite similar. The distribution of the minor elements in the host rocks and ores is as follows:

(A) Common elements distributed throughout all host rocks are V, Mo, (Co), (Ni), (As), (Ga), (Pd).

(B) Each bed or ore encloses elements which characterize the bed, in addition to those generally found in all rocks.

(C) Common elements generally found in rocks and ore are

(a) Upper red cherts associated with manganese ores: Ni, Ga, Bi, Zr, Cd, Pd,

Table 1.

Frequency of distribution of minor elements in the ores							
	Common elements		Less common elements		Uncommon elements		Numbers of specimens
	100%	99-80%	79-60%	59-40%	39-20%	19% >	
Upper part of massive ores	Co, Ni	V, Ga, Sn, Ag	B, Hg, Ti	Mo, Bi, Ta	As, Pd, Be, Ir, W	Cr, Ba, Au, Ge, Cd, Pt	13
Middle part of massive ores		Mo	Co, Ag, As, Pd, Ti	Ni, Te	Ga, Cr	V, Be, B, Sn, Bi, Ba, W	20
Lower part of massive ores	Mo, Ag, As	V, Ga, Ti	Co, Be, Ni	Cr, Ir		Pd, Sb	7
Impregnated ores	Co, Mo, Ag, Ni		Ga, B, Au, V, As, Cr	Pd, W, Ir, Cd, Ti		Be	5
Average of massive ores		Co, Mo, Ag	Ni, As, Ti	Ga, Pd, V	Be, B, Sn, Bi, Hg, Ir, Cr	Te, Ba, W, Au, Ge, Ta, Cd, Pt, Sb	39

Sb, Cr, Sn.

(b) Massive green rocks of the hanging wall: V, Ni, Co, Mo, Ir, Be, B, Ti.

(c) Lower red cherts: Mo.

(d) Massive ores: Co, Mo, Ag.

(e) Impregnated ores: Co, Mo, Ag, Ni.

(f) Schistose green metamorphic rocks of the foot wall: V, Co, Mo, Ni, Be, As, Ir, Ti.

(g) Segregation veins:
Quartz veins: Pd, Co, As.
Epidote veins: Be, B, Co, Ni, As, Zr, Te, W.
Veins enclosing pink coloured minerals (quartz and Mn carbonates): Ni, Mo.

(D) Less common elements generally found in rocks and ore are

(a) Upper red cherts: Ge, Pt, V, Co, Au, As, Mo, Ir.

(b) Massive green rocks of the hanging wall: Cr, Ga, Pd, W, Au.

(c) Lower red cherts: V, Cr, Ga, Ni, As, Pd, Sn, Ba, Ir.

(d) Massive ores: Ni, As, Ga, Pd, V, Ti.

(e) Impregnated ores: V, Cr, B, Cd, W, Ir, Pd, Ga, Au, As.

(f) Schistose green rocks of the foot wall: As, B, W, Ir, Au, Pd, Cr.

Table 2.

Frequency of distribution of minor elements in the red cherts							
	Common elements		Less common elements		Uncommon elements		Numbers of specimens
	100%	99-80%	79-60%	59-40%	39-20%	19% >	
Red cherts associated with manganese ores	Sb, Zr, Pd, Ni	Ga, Bi, Cd, Sn, Cr	V, Ir, Ge, Ti	Co, Mo, Au, Pt, As	Hg	B, Ba, Ta	7
Red cherts associated with cupriferous pyrite deposits and enclosing clay materials	V	Mo	Co, Ga, Ir, Ti	Ni, W, Pd, As	Be, Zr, B, Sn, Cr, Ge, Pt	Cd, Ag, Ta, Sb, Au, Ba, Hg, Bi	22
Siliceous red cherts associated with cupriferous pyrite deposits	Ba	Ni, Mo, Pd	Sn	Au	Co, Ge, Zr	V, Sb, W	8
Average of red cherts associated with cupriferous pyrite deposits		Mo	V, Ni, Pd	Co, Ga, As, Sn, Ba, Ir, Ti, W	Be, Au, B, Ge, Pt, Zr	Cr, Cd, Sb, Ta, Hg, Bi	30

Table 3.

Frequency of distribution of the minor elements in the hanging and foot walls of the deposits							
	Common elements		Less common elements		Uncommon elements		Numbers of specimens
	100%	99-80%	79-60%	59-40%	39-20%	19% >	
Massive green rocks of the hanging wall	V, Ni, Co, Ti	Mo, Ir, Be, As, B	Cr, Ga, Pd, Au, W		Zr, Sn, Te, Ba	Cd, Sb, Ta, Pt	29
Schistose green rocks of the foot wall		Co, Be, Ni, Mo, V, Ga, Ti	W, As, B, Ir	Pd, Au, Cr	Ag, Cd, Sn, Ge, Zr, Pt	Sb, Te, Ba, Ta	25

(g) Segregation veins:
Quartz veins: B, Ni, Mo, V, Ba, W, Ir, Au.
Epidote veins: V, Ga, Sn, Au, Mo, Pd, Ti.
Veins enclosing pink coloured minerals: Pd, Ba, Au, V, Sn.

(E) Uncommon elements generally found in rocks and ores are
(a) Upper red cherts: Hg, B, Ba, Ta.
(b) Massive green rocks: Sn, Te, Ba, Zr, Ta, Pt, Cd, Sb.

Table 4.

Frequency of distribution of minor elements in segregation quartz vein, epidote vein and vein which encloses pink coloured mineral in the host rocks

	Common elements		Less common elements		Uncommon elements		Numbers of specimens
	100%	99-80%	79-60%	59-40%	39-20%	19% >	
Quartz vein	Pd	Co, As	B, Ni, Mo	V, Ba, Ir, Au	Be, Ga, Cr	Ag, Sn, Te, Ti	12
Epidote vein	Be, B, Co, Ni, As	Zr, W, Te	V, Ga, Sn, Au, Ti	Mo, Pd	Cr, Ba		5
Pink coloured mineral vein	Ni, Mo		Pd, Au, Ba	V, Sn	B, Cr, Co, As	W	9

(c) Lower red cherts: Be, Au, B, Ge, Cr, Pt, Cd, Sb, Ta, Hg, Zr, Bi.
(d) Massive ores: Be, B, Cr, Sn, Ir, Bi, Hg, Te, Ba, W, Ge, Cd, Ta, Pt, Sb.
(e) Impregnated ores: Be.
(f) Schistose green rocks of the foot wall: Ag, Sn, Cd, Ge, Zr, Te, Ta, Pt, Sb, Ba.
(g) Segregation veins:
Quartz veins: Be, Cr, Ga, Ag, Sn, Te, Ti.
Epidote veins: Cr, Ba.
Veins enclosing pink coloured minerals: B, Cr, Co, As, W.

(F) Zincblende and hematite: (The minerals are partly condenced as thin layers or small spots in some parts of ores.)
Common elements in zincblende are Co, Ga, Ag, W, V, Ge, Mo, Cd, while those in hematite are Co, Ni, Mo, Sb.

(G) Two or three minor elements adjoining each other in the atomic number often show the same distribution.

Distribution of Minor Elements in the Ore Deposits

(A) Distribution of the minor elements in the deposits of the Showa level.

As Figs. 3 and 4 show, the ore deposits are found between massive green rocks and schistose green rocks, associating with red cherts which occur as cap rocks. The distribution of the minor elements was examined in the set-samples collected on the sections of K, L, M and A, B, C at the Showa level. The sections A, B and C are to the west of the section M where the ore bodies are found to thin out. Results of the analysis are shown in Fig. 2. Geological map and the distribution of minor elements in massive green rocks (diabasic rocks) which are distributed on the hanging walls of the deposit are also shown in Figs. 2 and 3, respectively.

(B) Distribution of the minor elements in the deposits of the Jinnan level.

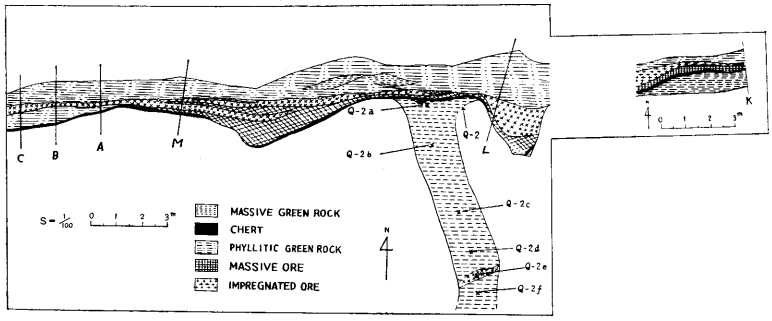


Fig. 3. Geological map of the Showa level.

As Fig. 4 shows, ore bodies are distributed between the massive green rocks and the schistose green rocks. Ore bodies intercalate thin beds of red cherts as a cap. The distribution of the minor elements in the sections P, O, N of the Jinnan level is shown in Fig. 2.

The ore bodies of the Showa and Jinnan levels are distributed in the same ore zone. Vertical distance between the Showa and Jinnan adits is 79 meters, their horizontal distance being 15 meters.

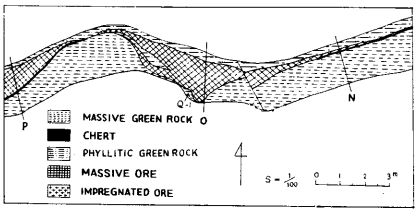


Fig. 4. Geological map of the Jinnan level.

Result of Examination

Assemblage of the minor elements in the ores is as follows:

(1) There is no notable difference in the assemblage of minor elements, common or less common elements at least, contained in host metamorphic rock, cherts and ores. But in general, ores and red cherts have less kinds of element compared with host rocks.

(2) The assemblages of minor elements contained in the green metamorphic rocks both on the hanging wall and on the foot wall are identical in character, and only little variation is seen even though they are situated far from the ore body.

(3) Kind of minor elements is few in the red chert compared with the argillaceous band which contains minerals consisting host green rccks.

(4) Ores are divided into three layers by the character of the assemblage of minor elements. Type A is a massive ore distributing in the upper part of the ore bodies and has a character of the assemblage which is between red-cherts and the ores of type B. Type B is a massive ore which is found in the center of the ore bodies and has few kinds of minor elements. Type C ore has a character between that of type B and green metamorphic rocks.

The ore includes massive and impregnated kinds and is distributed in the lower part of the ore bodies. As shown in the Fig. 6, characteristic elements which are found in the ores of these three types are:

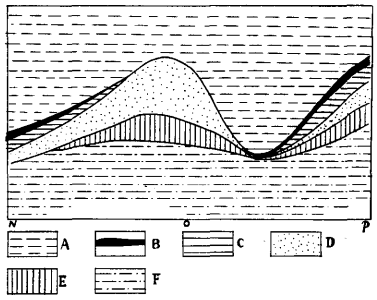


Fig. 5a. Schematic figure of ore deposit of the Jinnan level.

A: Massive green rock, B: Red chert, C: Type A ore, D: Type B ore, E: Type C-1 ore, F: Phyllitic green rock.

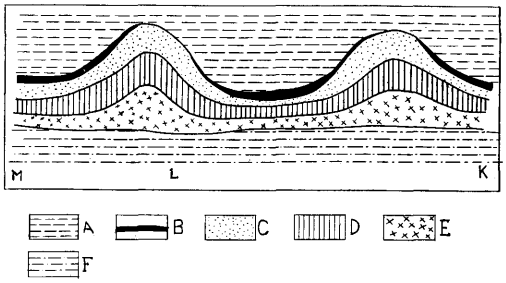


Fig. 5b. Schematic figure of ore deposit of the Showa level.

A: Massive green rock, B: Red chert, C: Type B ore, D: Type C-1 ore, E: Type C-2 ore, F: Phyllitic green rock.

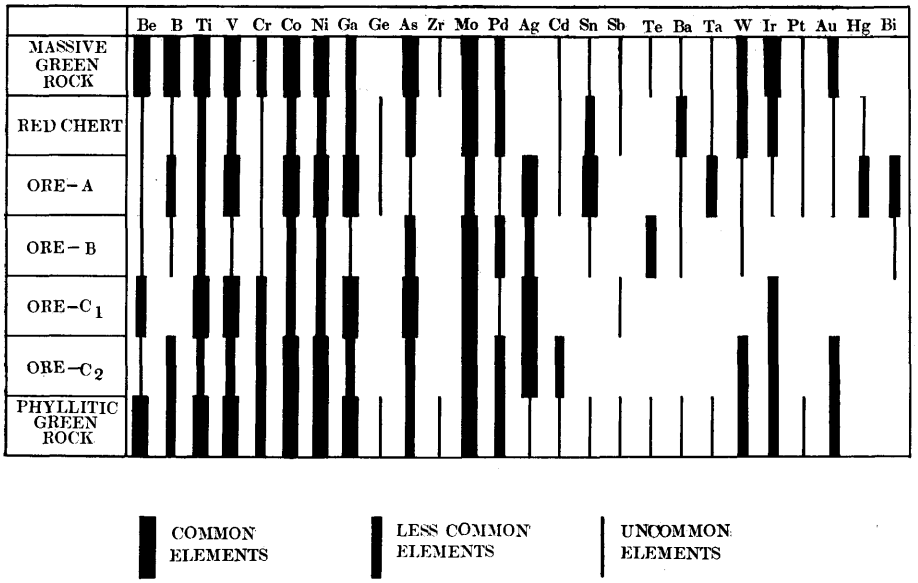


Fig. 6. Frequency of minor elements in massive green rock, phyllitic green rock, red chert, and 4 type ores.

Type A: Massive ores occurring in the upper part of the ore bodies. Common and less common elements: Co, Ni, Mo, Ag, Ga, V, B, Sn, Ta, Hg, Bi.
Uncommon elements: Be, Cr, Ge, As, Pd, Cd, Ba, W, Ir, Pt, Au.

Type B: Massive ores occurring in the center of the ore bodies. Common and less common elements: Co, Ni, Mo, Ag, As, Pd, Te.
Uncommon elements: Be, B, V, Cr, Ga, Sn, Ba, W, Bi.

Type C-1: Massive ores occurring in the lower part of the ore bodies. Common and less common elements: Co, Ni, Mo, Ag, V, Cr, Ga, As, Ir, Be.
Uncommon elements: Pd, Sb.

Type C-2: Impregnated ores. Common and less common elements: Co, Ni, Mo, Ag, Be, B, V, Cr, Ga, As, Pd, Cd, W, Ir, Au.
Uncommon elements: Be.

(5) (a) Elements which are generally found in all types of the ore are Co, Ni, Mo, Ag.

(b) The ores of type A are characterized by the presence of Sn, Ta, Hg, Bi, Ge, As, Ir, Pt, Au. Pt and Ge are found only in the ores.

(c) The ores of type B are characterized by Te, B, V, Ga, Sn, Bi. Te is seen only in this type of ore, while Au, Ir, Cd are not.

(d) The ores of type C-1 are characterized by V, Cr, Ga, As, Ir and Sb. Sb is found only in this type of ores, while B, Cd, Sn, Ba, W, Au, Bi are not. Be, B, V, Cr, Ga, As, Pd, Cd, W, Ir, Au are characterized in the impregnated ores. Be, Cd, W, Au are contained only in these ores. The ores of this type are characterized by Be, B, V, Cr, Gr, As, Pd, Cd, W, Ir, Au.

(6) The ores of types A, B and C are zonally distributed along the walls of ore bodies. The schematic occurrences of ores of these 3 types are shown in Fig. 3.

(7) Differences in the ores of types A, B and C can be seen well in their mineral compositions; that is, the ores of type A are generally siliceous as compared with types B and C, often containing small inclusions and thin layers of red cherts, which were taken off from the specimen analyzed. The siliceous parts often contain hematite. Type B is massive ore, consisting mainly of pyrite and chalcopyrite. Type C includes massive and impregnated ores which contain large amounts of chlorites and other minerals, which are the constituent minerals of schistose green rocks of the foot wall. The ores also contain thin layers of green rocks (the green rocks in the specimens are taken off before analysis).

Conclusions

The distribution of the minor elements in cupriferous pyrite deposits of the Okuki mine is as follows:

1. Elements which are found in all of the ores and host rocks of the mine are Co, Ni, Mo, Ag, V, Be, Cr, Ga, As, Pd.
2. Minor elements commonly contained in country rocks have something in common throughout metadiabase, schistose green rocks and metagabbros which are the host rocks of the deposit. The elements of high frequency of appearance are Co, Ni, Mo, Be, B, V, Cr, Ga, As, Pd, W, Ir. Assemblages of minor elements in red cherts are generally simple and few in kinds compared with those of green metamorphic rocks. Of banded cherts, more siliceous bands consisting mainly of quartz include less kinds of elements compared with argillaceous bands containing much clayey matter. Assemblage of minor elements in these argillaceous bands corresponds in character to that between the siliceous part and green rocks.
3. The elements which are generally found in cherty rocks are Co, Ni, Mo, V, Ga, As, Sn, Ir, B, Cr, Ge, Cd, Sb, Ba, Ta, Pt, Au, Hg.

4. The elements which are generally found in all types of ores are Co, Ni, Mo, Ag, (Ti).
5. Ores can be classified into four layers according to the character of assemblage of minor elements; that is, type A massive ores of the upper wall side of the deposits are characterized by B, V, Ga, Sn, Ta, Hg, Bi. Type B massive ores in the central part of ore deposits are characterized by As, Pd, Te. Type C-1 massive ores of the lower part of the deposits are characterized by V, Cr, Ga, As, Ir. Type C-2 impregnated ores which are distributed in the lower part of the deposits are characterized by Be, B, V, Cr, Ga, As, Pd, Cd, W, Ir, Au. A general character of the distribution of minor elements of type A is similar to that of type B plus character of red chert.
6. As to mineral compositions, the same relations are fairly seen; namely, type A is type B plus constituent minerals of the schistose green rocks. This similarity, however, can not be thought to owe only to the mineral composition, because the samples analyzed do not contain gangue minerals.
7. Differences in the character of assemblage of minor elements in the ores indicate a zonal arrangement of the ores in the deposits nearly parallel to the walls of the ore body. This zonal distribution is not symmetrical with regard to the center of the deposits. Regular variation in the character of the minor elements in the ore deposits can be noticed from foot wall to hanging wall.

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