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Ore Deposits of Central Hyogo Prefecture and the Ore Forming Processes —Study on the Mineralization of Late Cretaceous to Early Tertiary in the Inner Zone of Southwest Japan (2)—

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Abstract: In the metallic province of central Hyogo Prefecture which is divisible into the west and east zones, there occur magnetite skarn, porphyry copper, tin-tungsten bearing polymetallic vein and gold-silver bearing quartz vein deposits. Mineralization could be closely related to late Cretaceous plutonic rocks.

A peculiar mineralization process is recognized in these deposits, and these occur attending characteristic ore phases. Especially, horizontal and vertical zoning of ore phases best demonstrated by Sn–W, Cu–Zn, Au–Ag and Pb, Zn, Cu, Sn–W are found through the Ikuno, Akenobe, Akagane and Omidani ore deposits.

The ore constituents can be classified by their textures and mineral assemblages as follows: i) Al, Mg limesilicates-iron oxides and ii) Al, Mg hydrosilicates-iron oxides-Cu, Zn and Pb sulphides in the skarn deposits, i) K, Al silicate-Cu sulphides (potassic phase), ii) K, Al hydrosilicate-iron, titanium oxides-Cu, Pb, Zn, Mo and As sulphides (phyllic phase) and iii) Na, Al silicate-Mg, Al hydrosilicate-iron oxide (propylitic phase) in porphyry copper deposits, i) Mg, Al hydrosilicate-Cu, Zn sulphides and ii) Sn–W oxides in tin-tungsten bearing polymetallic deposits, i) K, Al silicate-Ag sulphides and ii) Mg, Al hydrosilicate-Ag, Cu, Zn, Pb and Sn sulphides in gold-silver deposits and i) Mg, Al hydrosilicate-Cu, Pb, Zn and As sulphides in pyrrhotite-bearing polymetallic deposits.

Individual ore phases occur together, especially polymetallic type veins in the Ikuno and Akenobe. Polyascendent model was proposed for this type of mineralization by previous works. However, monoascendent model combined with evolution of ore solution, and tectonic movement, and osmotic and fractional precipitation processes could produce such composite ores.

1. Introduction

In the central Hyogo Prefecture, many ore deposits bearing various kinds of metal elements as iron, base metals, gold, silver, tin and tungsten are known. The mineralized district is divided into two zones, west and east. The west mineralized zone is characterized by zonal arrangement of ore deposits as follows: Zone-I) iron oxide and sulphide skarns, porphyry copper, arsenic bearing polymetallic vein, Zone-II) tin-tungsten bearing polymetallic vein, gold-silver bearing quartz vein and Zone-III) pyrrhotite bearing polymetallic vein types around the plutonic mass. The ore deposits in the east zone do not form zonal arrangement. In this zone, plutonic rock is small in size, but ore deposits of skarn type, tin-bearing gold-silver vein and polymetallic vein types are known. Some different ore phases are recognized in all these ore deposits.

The previous study described geologic structure of the mineralized district (NARITA, MIMURA and KOMURA, 1979). In this paper, the ore forming process of the ore deposits as

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deduced from the mineral assemblage is considered.

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2. Localization of Fracture Pattern

The studied area can be characterized by fracture swarms represented mainly by NW direction which may be resulted from up-heaved movement of plutonic intrusions (NARITA, MIMURA and KOMURA, 1979). Some minor fractures in each block bordered by faults occasionally exhibit different pattern. The mineralization occurs regularly arranged around the plutonic mass and the main ore deposits are controlled by NW fracture. The blocks occluded by faults are called (1) Chigusa, (2) Asahi, (3) Akenobe west, (4) Akenobe east, (5) Motoyama, (6) Ikuno west, (7) Ikuno east, (8) Tomisu, (9) Mikata and (10) Dainichi (Fig. 1). Fracture systems in above-stated blocks are composed of the following sets:

Block	Fracture system	Type of ore
(1) Chigusa	ENE	Skarn, porphyry copper
(2) Asahi	NE, subordinate NW, N–S	Skarn, porphyry copper, As bg. polymetallic vein
(3) Akenobe west	E–W and NW, subordinate N–S	Sn–W bg. polymetallic vein and Au–Ag vein
(4) Akenobe east	NW cutting across NE	Sn–W bg. polymetallic vein, and Au–Ag vein
(5) Motoyama	E–W and ENE	Sn–W bg. polymetallic vein, polymetallic vein and Au–Ag vein
(6) Ikuno west	NW	Sn–W bg. polymetallic vein, polymetallic vein and Au–Ag vein
(7) Ikuno east	N–S and NW	Sn–W bg. polymetallic vein, polymetallic vein and Au–Ag vein
(8) Tomisu	E–W	Au–Ag vein
(9) Mikata	NW, E–W and ENE	Pyrrhotite bg. polymetallic vein
(10) Dainichi	NE, E–W and NW	*ditto*

These fracture should be formed by a differential movement of each block (Fig. 1). The ore deposits of many types from high temperature type to low temperature one occur in the whole area of the mineralized zones, while the individual ore forming processes are locally performed in the different fracture systems.

3. Outline of Ore Deposits

Ores from the western area of the mining district are arranged zonally around the plutonic mass without any relation to the arrangement of the block presented in Figure 1, though the fracture patterns restricting the mineralization are characterized in each block. The regional zonal arrangement of ore deposits is realized by the presence of (I) skarn, porphyry copper, arsenic bearing polymetallic vein, (II) tin-tungsten bearing polymetallic vein, gold-silver bearing quartz vein and (III) pyrrhotite-bearing polymetallic vein from inner to outer sides of the plutonic mass as above-mentioned. In relation with the ore deposits of each type, a round number of production and ore reserves are shown in Figure 2 and Table 1. So the ore deposits of each zone are briefly described in this chapter.

Zone I

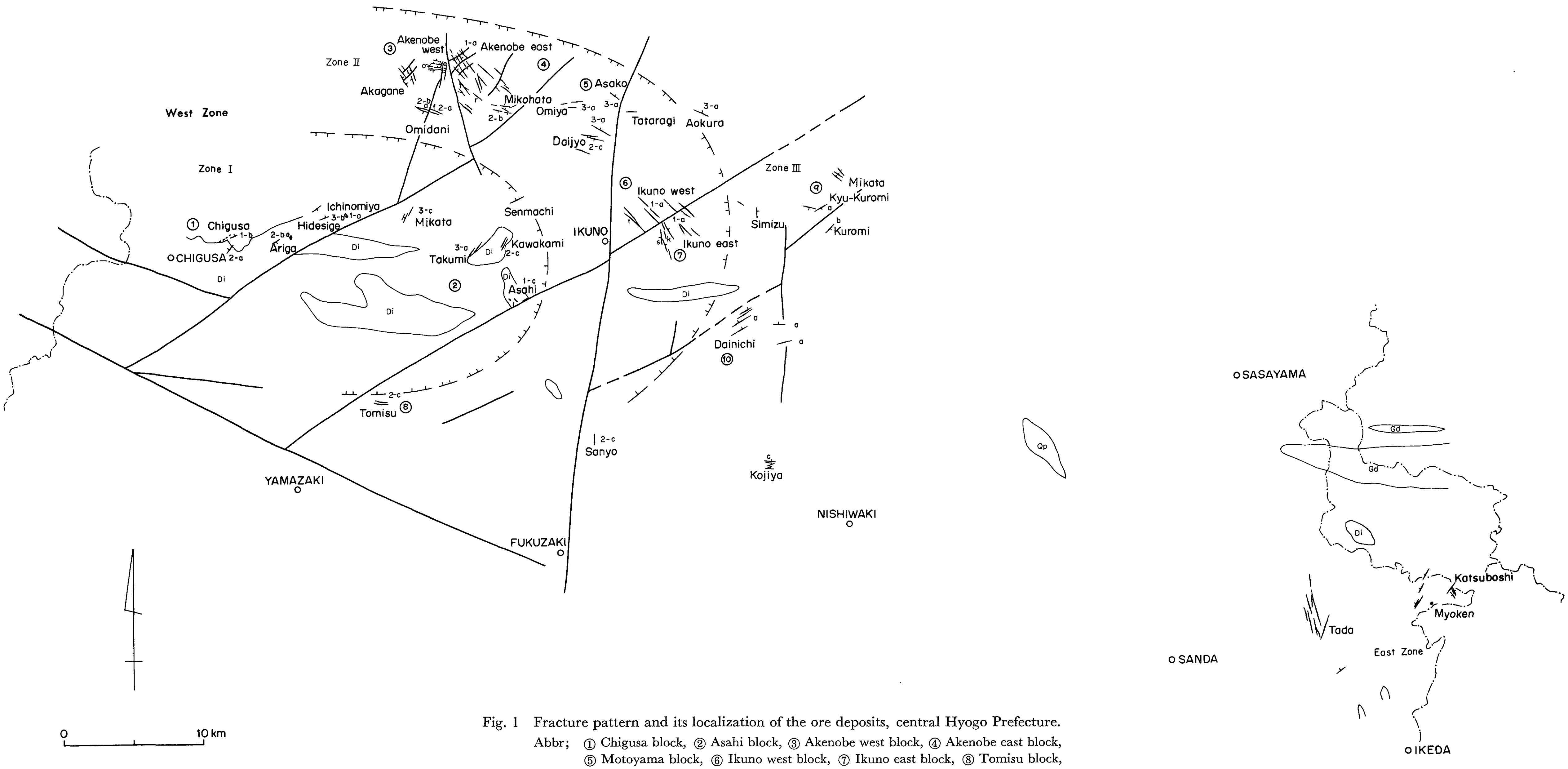

Fig. 1 Fracture pattern and its localization of the ore deposits, central Hyogo Prefecture.
Abbr; ① Chigusa block, ② Asahi block, ③ Akenobe west block, ④ Akenobe east block, ⑤ Motoyama block, ⑥ Ikuno west block, ⑦ Ikuno east block, ⑧ Tomisu block, ⑨ Mikata block, ⑩ Dainichi block, o: Otohime-hi, e; Eisei-hi, y; Yonmyaku-hi, r; Ryusei-hi, f; Fusei-hi, a; Awatachi-hi, t; Tasei-hi, s; Senjuhon-pi, k; Kinsei-hi

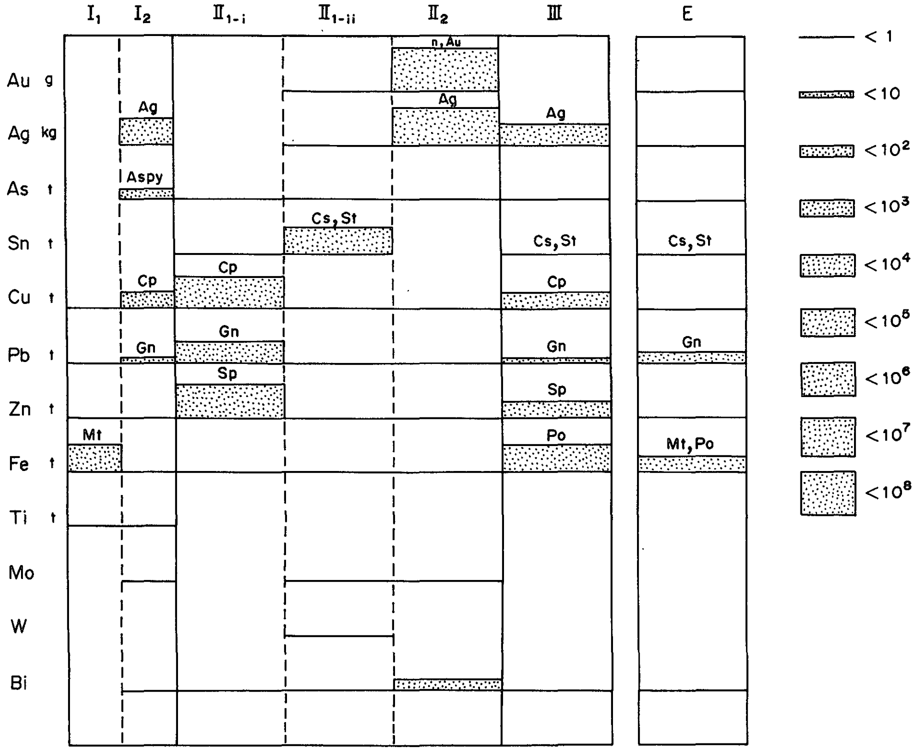

Fig. 2 Metal abundances of each phase of the ore deposits of central Hyogo Prefecture.

Abbr; I_1; skarn deposits of zone I, I_2; disseminated copper deposits of zone I, II_{1-i}; Cu–Pb–Zn phase in Sn–W bg. polymetallic vein of zone II, II_{1-ii}; Sn–W phase in Sn–W bg. polymetallic vein of zone II, II_2; gold-silver vein of zone II, III; pyrrhotite bg. polymetallic vein of zone III, E; ore deposits of east zone. Main ore forming minerals: n. Au; native gold, Ag; argentite, Cp; chalcopyrite, Sp; sphalerite, Gn; galena, Asp; arsenopyrite, Po; pyrrhotite, St; stannite, Mt; magnetite, Cs; cassiterite.

1) Skarn type

The skarn type deposits are known in three mines along the northern borders of Chigusa quartz diorite and the southern border of Asahi quartz diorite stock. Two magnetite deposits are known as Ichinomiya and Chigusa mines, and one sulphide deposit is Asahi mine.

The Chigusa magnetite deposit is located in the northwesternend of the Chigusa block. This consists of five ore bodies: i.e., Chigusa, Suyadani, Ichinotani, Murodani and Takadani. The main ore body of Chigusa mine occurs in shear zone of andesite showing lens-form with N70°W strike and 50°NW dip. The Chigusa main body has typical skarn association consisting of garnet, amphibole, epidote, chlorite, magnetite, minor sphalerite and pyrite. The Chigusa magnetite deposit had been worked by the Kobe Seiko Co. since 1937 and the ore reserves of 40,000 tons (Fe 40–50%) were estimated. The Suyadani deposit is clay-pyrite vein trending N60°E. The Ichinodani deposit consists of irregular form magnetite-pyrite mass. The Murodani deposit is composed of magnetite-pyrite-quartz vein trending N75°E and the Takadani deposit aligns along a fault trending N60°E. These four ore bodies are low grade, the main ore body in them was only developed.

The Ichinomiya deposits lies about 8 km east from the Chigusa mine. This mine produced the crude ore of 63,000 tons from 1948 until 1958. The deposit is pyrometasomatic type that replaced limestone in the Maizuru Group, and the magnetite bodies associated with garnet

Table 1 Ore deposits of

	Mine	Ore body	Strike	Dip	Length	Width	Depth	Ore
West, Zone I								
	Ore deposits of skarn type				(m)	(m)	(m)	
1	Chigusa	Chigusa	N70°E	50°NE	140	1.	75	mt–ep–amp–grn
		Suyadani	N60°E	85°NW		0. 05		clay–py
		Ichinotani	N60°E	80°NW	15	0. 75		mt–py
		Murodani	N75°E	50°NW	40	5.		mt–py–q
		Takadani	N60°E			1.		
2	Ichinomiya		N20°W	45°SW	140	10.	60	mt–grn–s–ep–dol–cal–q
6	Asahi	No. 1	N40°W	70°NE		0. 5		sr–q–py
		No. 2	N45°E	70°SE	46	0. 5	15	sp–gn–ht–py–grn–ep–cl–cal
		No. 3	N40°E	80°SE		0. 15		py–k
			N30°W	80°NE		2.		py–k
		Kinko	N40°W	60°NE		0. 5		py–k
	Ore deposits of porphyry copper type							
3	Arao	No. 1	N45°E	80°NW	40	0. 25		potassic, phyllic diss. ore
4	Ariga	No. 1	N–S	70°E	18	12	18	phyllic diss. cp–mo–sr–q
		No. 2	N–S	80°E	28	10	40	〃
9	Kawakami	Kamewaka	N43°E	NW				phyllic diss. cp–sp–py–asp–mo–sr–q
		Yoshiwaka	N30°E	80°SE				〃
		Seichi	N28°E	75°SE	300	0. 1		〃
		Daikoku	N40°E	70°SE				〃
		Hon-pi	N40°E	80°SE				
	Ore Deposits of polymetallic vein type							
7	Takumi		N50°E	75°NW	80	0. 8	150	cp–sp–asp–py–cc–cl–q
5	Hideshige		N70°E	80°NW	40	0. 8		cp–sp–gn–asp–py–cl
8	Mikata	Kyuko	N30°E	55°SE	140		40	
		Kamashita	N30°E	55°NW	50	0. 3	50	sp–gn–py–sr–cl–q
		No. 1	N35°E	70°NW	160	0. 3	50	
West, Zone II								
	Ore deposits of tin-wolfram bearing polymetallic vein							
12	Ikuno	Table 3						i cl–cp–sp ii q–sn–w
10	Akenobe	Table 2						i cl–cp–sp ii q–sn–w
11	Akagane	Honko	N35°W	50°SW		0. 6		cl–q–cp–sp–gn–cs–tt–f–q
		Taisen	N20°W	60°SW	27	1.	40	cl–cp
		Kawamukai	N50°W	80°NE		0. 2		cl–cp
	Ore deposits of gold-silver bearing quartz vein type							
14	Omidani	Fusei	N70°W	80°SW	700	0. 3	150	i cl–q–cp–cf ii q–cp–cf
		Daisen	N50°W	75°SW	460	0. 5		q–ad–nAu–cf
		Awatachi	N60°W	80°SW	520	0. 7		q–cp–sp–gn–cf

central Hyogo Prefecture.

Form	Production (ore reserve)	Country rock	Block	Plate	References
lens	(40,000 t, Fe 40–50%)	Ikuno G. and.	1	4–1	7, 20
vein		〃 rtf.	〃		
vein	(1,000 t, Fe 50%)	〃 〃	〃		
vein		〃 〃	〃		
vein		〃 〃	〃		
lens	63,000 t dur. 1948–'58 (10,000 t, Fe 53.16 %)	Tamba G. ls.	1	1–1	7, 20
vein		Ikuno G. and.	2		7, 21, 29
lens	(1,526 t, Cu 0.13%, Ag 283.5g/t, S 40.18 %)	〃 〃	〃	4–2	
vein		〃 〃	〃		
vein		〃 〃	〃		
vein	(Fe 15%)	〃 〃	〃		
diss	(Cu 0.2–0.6%)	q. diorite	1	4–3, –4, –5, –6	7, 20, 28
diss	750 t, Cu 4.28%, dur. 1941–'43 (6,000 t, Cu 1.5%)	〃	〃		7, 20, 28
diss					
diss	27,000 t, Cu 0.81% until 1956	〃	2	1–2	6, 7, 21, 28, 29
vl	6,000 t, Cu 1.25%	〃	〃		
diss		〃	〃		
diss	2,430 t, Cu 1.25%	〃	〃		
		〃	〃		
vein	11,200 t, As 13%, 1956 (Cu 3.79%, As 15.69%, S 40.15%)	q. diorite	2		7, 21, 29
vein	(Cu 1%, Zn 6.5%)	〃	1	2–1	7, 20, 28
vein	(1,439 t, Pb 0.9%, Zn 2.4%)	Ikuno G. rtf.	2		7, 20, 28, 29
vein		〃 〃	〃		
vein		〃 〃	〃		
vein	15 million t, Cu 1.68%, Pb 0.14%, Zn 0.80%, Sn 0.12%	Ikuno G.	6, 7	4–7, –8, 5–1, –2, –3, –4, –5	7, 9, 10, 11, 13, 17, 18, 27, 28, 29, 30, 31
vein	16 million t, Cu 1.26%, Pb 1.09%, Zn 2.20%, Sn 0.27%	Maizuru G.	3, 4	2–2, 3, 5–6, –7, –8, 6–1, –2	1, 2, 4, 7, 8, 9, 10, 12, 13, 14, 15, 16, 19, 20, 21, 22, 23, 25, 28, 29
vein	240 t, Cu 10% until 1936 (5,500 t, Cu 5%, 6 t, Cu 22%, Cu 10%, prob. ore 2,030 t, Ag 128 g/t, Cu 13.95%)	〃	3		7, 20, 21, 28
vein		〃	〃		
vein		〃	〃		
vein	40,000 t, Au 2.1 g/t, Ag 400 g/t, dur. 1971–'73	〃	〃		7, 20, 21, 26, 28, 29
vein		〃	〃		
vein	(Au 0.5 g/t, Ag 100 g/t)	〃	〃		

Table 1 (*Continued*)

	Mine	Ore body	Strike	Dip	Length (m)	Width (m)	Depth (m)	Ore
	Mikohata	Kasei	N65°W	65°NE	2,200	6.		nAu–ag–cp–sp–gn–py–q–rc–sd
		Shusei						
16	Daijo	Takarazawa	N85°W	75°SW	1,000	1.7	270	nAu–ag–cp–sp–q
		Noza	N77°W	70°SW	1,500	6		
15	Tomisu	No. 1	N80°W	85°NE	130	0.7	80	nAu–ag–py–q–ad
		No. 2	N85°E	85°NW	80	0.4	80	
		No. 3	E–W	75°N	180	0.6	80	
	Ore deposits of polymetallic vein type							
19	Nii	Yamamoto	N60°W	80°SW	170	0.6		cp–sp–gn–ag
		Yashiro	N65°W	70°SW	50	0.3	25	sp–gn–ag
18	Asako		N45°W	80°NE	100	0.3		cp–gn–bn–ag–sp–q
17	Omiya	No. 1	N75°E	70°SE		0.6		cp–gn–sp–ag–py–q
		No. 2	E–W	60°N	35	0.8		
		No. 3	N75°W	80°SW	20	0.8		
20	Tataragi	Kameya	E–W	85°N		0.3		cp–gn–sp–bn–py–f–q
		Sennin	E–W	85°N		0.3		cp–gn–sp–bn–py–q
		Eisei	E–W	85°N		0.3		cp–gn–sp–bn–py–q
	Tatara		E–W	55°N	145	0.7		cp–gn–sp–bn–ag–py–q
21	Aokura	Honko	N72°W	65°NE	550	0.7		cp–gn–sp–bn–q
		No. 2	N55°W	75°NE	100	0.6		cp–sp–gn–py–asp–q
22	Sanyo		N–S	80°E	150			cp–sp–gn–py–ag–cl–q
West, Zone III								
	Ore deposits of polymetallic vein type							
26	Mikata	No. 1	N30°W	55°SW	9			
		No. 2	N20°W	55°SW	26	0.03	8	
		No. 3	N–S	80°E	34	0.15	12	
		No. 4	N35°W	70°NE	60	0.2	15	cp–sp–po
28	Kyukuromi	3-ko	N70°E	70°SE	70	0.2	30	cp–gn–sp–po–py–asp
29	Shinkuromi		E–W	70°S	130	0.4	35	cp–gn–sp–po–mo
27	Kuromi		N40°E	70°SE	230	0.05	30	po–gn–cp–sp–py–asp
31	Torima		N80°W	70°SW	140	0.25	5	cp–sp–gn–bn–f–q
			E–W	60°S		0.25		cp–sp–gn–f–q
30	Kiyomizu		N10°E	60°SE	30	0.3		sp–gn–py–cl–q
36	Dainichi (Kanekura)	No. 4	N50°E	50°NW	280	0.35	120	po–cp–asp–sp–py–cl–q
		No. 6	N45°E	60°NW	360	0.2	100	po–cp–asp–sp–py–cl–q
		No. 8	N40°E	60°NW	250	0.22	100	po–cp–asp–sp–py–cl–q
35	Kabasaka		E–W	70°N	1,400	0.15	110	po–cp–asp–sp–gn–m–cb
32	Omisaka		N40°W	75°NE	300	0.2	100	cp–gn–sp–asp–mo–cl–sr–q
33	Kojiya	No. 1	N75°W	80°NE	110	0.8	22	cp–tt–sp–cup

Form	Production (ore reserve)	Country rock	Block	Plate	References
vein	430,000 t, Au 10 g/t, Ag 650 g/t	Ikuno G.	4		21
vein		〃	〃		
vein	(Au 5.0 g/t, Ag 500 g/t, Cu 0.8%)	Maizuru G. gb	5		7, 21, 29
vein	100 t/m, Au 12 g/t, in 1960, 250 t/m, Au 8–16 g/t since 1961 (15,050 t, Au4 g/t, Ag 350 g/t)	〃	〃		
vein		Ikuno G.	8		7
vein		〃	〃		
vein		〃	〃		
vein	40,000 t, Cu 3–8%, Ag 200–700 t (27,000 t, Cu 1.2%)	Maizuru G.	5		7, 21, 28, 29
vein		〃	〃		
vein	(Cu 4%, Ag 400 g/t)	〃	〃		7, 21, 28, 29
vein	(Cu 1–2%, Pb 8–14%, Zn 4–5%, Ag 100–200 g/t)	〃	〃		7, 21, 28, 29
		〃	〃		
		〃	〃		
vein	(Cu 0.5–2%, Pb 2%, Zn 1%)	Tamba G.	6		28, 29
vein		〃	〃		
vein		〃	〃		
vein	(Cu 0.3–1.2%, Pb 1–6%, Zn 1–2%, Ag 30–50 g/t)	〃	〃		7, 28, 29
vein	(32,000 t, Cu 0.3–1.2%, 1–6%, Zn 1–2%, Ag 30–500 g/t)	Ikuno G.	〃		
vein		〃	〃		3, 7, 28, 29
vein		〃	10		
vein		Tamba G. sl.	9		
vein	(100 t, Cu 15.47%, Zn 0.75%, Pb 0.01%, Fe 15.7%, S 10%)	〃 ch. ss.	〃		7, 28
vein	〃	Ikuno G. rtf	〃		
vein	〃	Tamba G. sl.	〃		
vein	(70 t, Cu 0.56%, Zn 15.41%, Pb 0.46%, Fe 31.32%, S 19.9%)	〃 〃	〃		7, 28
vein		Ikuno G.	〃	6–3	7
vein	(3,750 t, Cu 0.30%, Zn 2.88%, Pb 0.37%, Fe 53.43%, S 34.04%)	〃	〃		5, 7
vein	(Cu 3%, Pb+Zn 40 %)	〃	〃		5, 28, 29
vein		〃	〃		
vein	(Cu 2–3%, Zn 15%, Pb 1%, 400 g/t)	〃	7		7
vein	Cu metal 1,141 t (Zn 6.7%)	Tamba G. sl.	10	6–4	5, 7, 28, 29
vein	(Zn 7.7%)	〃	〃		
vein		〃	〃		
vein	1,361 t, Cu 3.3%, Zn 15%, Pb 1%, Ag 210 g/t in 1943, 61 t in 1954 (86,000 t, FeS)	〃	〃		5, 7, 28, 29
vein	(Cu 1–3%, Zn 3.16%, Au 0.2 g/t, Ag 171 g/t)	Ikuno G.	〃		7, 28
vein	(Cu 2–3%)	〃	〃		

Table 1 (*Continued*)

Mine	Ore body	Strike	Dip	Length	Width	Depth	Ore
				(m)	(m)	(m)	
Kojiya	No. 2	N75°E	65°SE	50	0.6		cp–tt–sp–cup
	No. 3	N50°E	65°SE	30	0.3		cp–tt–sp–cup
	No. 4	N45°E	55°SE	35	0.2		〃
	No. 5	E–W	70°S				〃
Nyukaku	Kita	N60°W	60°NE		0.3		cp–py–ag–gn–cs–cl–q
	Minami	N80°E			0.3		
East zone							
Ore deposits of skarn type							
37 Myoken							po–mt–cp–py–grn–s–ep–cl–q
Ore deposits of polymetallic vein type							
38 Katsuboshi		N30°W	55°NE	1,000	1	200	cp–py–m–bn
40 Akamatsu	Ebisu	N50°E	75°NW	62	0.3		cp–po–py–sp–gn–asp
	Nunoya	N50°E	75°SE	50	0.5	60	cp–po–py–sp–po–cp–q
Unoto		N40°E	70°NW				
39 Tada	Ogane	N40°E	70°NW	700	0.4	150	
	Hyotan	N25°W	70°NE	800	0.4	250	cp–sp–gn–cs–st–std–mw–nAg–q
	Gochaku	N25°W	60°NE	450	0.4	120	cp–sp–gn–asp–cs–st–mw–bn–cc–q
	Ishigane	N25°W	60°NE	1,500	0.6	150	
	Eboshi	N25°W	70°SW	80	0.4	10	
	Byobuiwa	N–S	55°E	300	0.5	50	

Abbr; nAu–native gold, nAg–native silver, nCu– native copper, mt–magnetite, ht–hematite, rt–rutile, sn–tin oxide and sulphides, w–wolframite, sc–scheelite, cp–chalcopyrite, sp–sphalerite, gn–galena, mo–molybdenite, po–pyrrhotite, asp–arsenopyrite, py–pyrite, ag–argentite, cf–canfieldite, cs–cassiterite, cup–cuprite, m–malachite, bn–bornite, cc–chalcocite, st–stannite, std–stannoidite, mw–mawsonite, grn–garnete, s–salite, amp–amphibole, ep–epidote, cl–chlorite, sr–sericite, q–quartz, cb–carbonate, dol–dolomite, rh–rhodochrosite, f–fluorite, ss–sand stone, sl–slate, ch–chert, ls–limestone, hf–hornfels, and–andesite, rtf–rhyolitic tuff, gb–gabbro

(Pl. 1–1) are formed extending about 140 meters. The ore reserves of the mine was estimated about 10,000 tons as crude ore.

The Asahi deposit is situated at about 13 km southeast from the Ichinomiya mine. The deposits are constructed from skarn and vein types, the ore body of No. 2 adit is lens-form along the northeast fault. It shows about 2 meters wide and 46 meters long. Stockwork ores near No. 2 adit show an association of garnet-epidote skarn with sphalerite, galena, hematite and pyrite. Ore reserves were estimated by the internal material of M.I.T.I.[1)] to be about 920 tons of 40.18 percent sulphur and 283.5 gr/t silver.

1) Ministry of International Trade and Industry

2) Porphyry copper type

The ore deposits of Arao, Ariga and Kawakami mines are known in the innermost side of zone I. These deposits are characterized by the presence of sulphide minerals controlled by intricate fractures taking network within a block bounded by faults. Sulphide minerals scatter in potassic and phyllic altered rocks and reveal mineral assemblage of orthoclase-sericite-quartz and sericite-quartz. Chalcopyrite and pyrite are common, and magnetite, rutil, molybdenite, arsenopyrite and sphalerite are ob-

Form	Production (ore reserve)	Country rock	Block	Plate	References
vein		Ikuno G.	10		7, 28
vein		〃	〃		
vein		〃	〃		
vein		〃	〃		
vein	(Cu 13%, Ag 450 g/t)	〃	〃		
					7, 28, 29
lens	(Cu 0.24%, Fe 51.75%, S 34.35%)	Tamba G. sl. ls.	E		7
vein	(12,000 t, Cu 11, 13%, Au 1.359 g/t, Ag 334.8 g/t)	〃	〃		7, 28
vein	6,850 t, Cu 1–2%	〃 sl. hf.	〃	6–8	7, 28
vein	(Cu 2.3%, Zn 27.04%)	〃 〃	〃		
vein		〃 〃	〃	14–1	
vein	Au 11,930 t dur. 1575–1598, Cu 3 t, Au 59.6 kg in 1905, 970 t,Cu 1.2%, Ag 2,000 g/t in 1967, Au 27,113 t, Ag 11.2 t, Cu 702 t until 1969, 36,000 t, Cu 2.5%, Ag 350 g/t	Ikuno G.	〃		
vein		〃	〃	6–6, –7	7, 10, 13, 24, 28, 32
vein		〃	〃	6–5	
vein		〃	〃		
vein		〃	〃		
vein		〃	〃		

Ref; 1, Abe (1963), 2, Abe & Sekine (1963), 3, Bessho, Hukui & Ozaki(1948), 4, Haraguchi, Ozaki & Takeichi(1952), 5, Haraguchi (1957), 6, Hirabayashi & Hukuchi (1904), 7, Ikebe et al. (1961), 8, Ikeda (1970), 9, Imai et al. (1957), 10, Imai (1978), 11, Kato (1959), 12, Kato & Shinohara (1968), 13, Kato & Hujiki (1969), 14, Kato (1917), 15, Kato (1920), 16, Kojima & Asada (1973), 17, Kondo & Kawasaki (1943), 18, Maruyama (1957), 19, Muraoka & Ikeda (1968), 20, Nakamura et al. (1973), 21, Nakamura et al. (1974), 22, Saigusa (1958), 23, Sato, Asada & Kasamatsu (1977), 24, Sawamura (1937), 25, Sekine (1959), 26, Sumita (1969), 27, Taguchi & Kizawa (1973), 28, Takimoto (1968), 29, Takimoto et al. (1968), 30, Tanaka, Mori & Sasaki (1971), 31, Yamaguchi (1939a, b), 32, Yamashita (1894).

served as subordinate minerals in some deposits. The ore texture and mineral assemblage are somewhat similar to those of porphyry copper deposits. Thus these deposits are callded porphyry copper type, although their size is small and no concentric zoning is observed.

The Arao mineralized area located at the south side of Chigusa mine was explored by Mitsubishi Metal Mining Co. in 1960 and 1966. The Arao deposit is found in the northern margin of the Chigusa quartz diorite and is composed of ore consisting of orthoclase-sericite-quartz-chalcopyrite-pyrite, quartz-sericite-chalcopyrite-pyrite and secondary bornite-azurite-cuprite-chalcocite association. The vein prospected at No. 1 adit is about 40 m long and 0.2 to 0.3 m wide. It strikes N45°E and dips about 80°NW. Ore of phyllic association is low grade of 0.2 to 0.6 percents copper.

The Ariga deposit on the east side of Arao mine is located within the Chigusa block and is pipe-like, steeply dipping about 80° to the south. It lies in the Chigusa quartz diorite and consists of two ore bodies called No. 1 and No.

2. The No. 1 body is 18 m long, 12 m wide and 18 m deep. The No. 2 body located at the northwest side of the No. 1 body is 28 m long, 10 m wide and 40 m deep. The former consists of network vein of quartz-sericite with sulphide minerals as chalcopyrite, pyrite and molybdenite. The crude ore of 750 tons of 4.28 percent copper were produced between 1941 and 1943.

The Kawakami deposit is located at about 14 km east from Ariga mine and at the northeast side of the Asahi block. It is said that Kawakami mine was exploited during the Tokugawa shogunate. The deposit consists of vein-form ones and disseminated ones in the Asahi quartz diorite (Pl. 1–2). Five veins, Kamewaka-hi striking N43°E and dipping to NW, Yoshiwaka-hi striking N30°E, Seichi-hi striking N28°E and dipping to 75°SE, Daikoku-hi striking N40°E and dipping to 70°SE and Hon-pi (Mae-hi and Oku-hi) striking N40°E and dipping to 80°SE are known. Hon-pi, Seichi-hi and Kamewaka-hi are of the three champion veins. As main ore minerals of the veins, arsenopyrite, pyrite, chalcopyrite and sphalerite are observed. Disseminated ore appears near the vein, and arsenopyrite, pyrite and chalcopyrite are seen in quartz-sericite phyllic altered rock of quartz diorite (Pl. 1–2). Production of ore from the mine had been reported to be about 27,000 tons of 0.81 percent copper until 1956 in the internal material of M.I.T.I.

3) Polymetallic vein type

Some deposits of Takumi, Hideshige, Mikata and other mines belong to this vein type. The Takumi deposit is situated at about 2 km from the Kawakami mine, which lies on the western margin of the Kawakami quartz diorite. The deposit is a chlorite-quartz vein containing sulphide minerals of arsenopyrite, chalcopyrite, sphalerite, galena and pyrite. It strikes N50°E and dips steeply to north, and it is about 80 m long horizontally and about 150 m long vertically. The Hideshige deposit is located between Ariga and Ichinomiya mines and its geologic portion is the northern margin of the Chigusa quartz diorite. This deposit is vein type consisting of arsenopyrite, chalcopyrite, sphalerite and it strikes N70°E and dips steeply to 80°NW, attaining to about 40 m long and 0.85 m wide. Metal grade of the ore from the vein is 1 percent copper and 6.5 percent zinc (HARAGUCHI, 1933).

The Mikata deposit consisting of three parallel lead-zinc-quartz veins is found between the Takumi and Ichinomiya mines. These parallel veins strike NNW and dip to either SE or NW, and the length of vein is about 160 m at a maximum.

Zone II

The ore deposits of zone II appear along the main fracture zone running at the distances of about 25 km from the middle area between zone I and zone III as shown in Figure 1. The direction of vein swarm in each block shows different from one to another. This difference may be caused by individual movement of each block. The vein swarm is composed of the veins of three types as tin-tungsten bearing polymetallic, polymetallic and gold-silver veins. The zone II in question is at least 6 km wide. These veins are zonally arranged from center to outer side in the following order.

1) Tin-tungsten bearing polymetallic vein type

The tin-tungsten bearing polymetallic vein is the main ore deposit in the western mineralized zone. Akenobe, Ikuno and Omidani mines are well known for the preceding ones. Akenobe and Ikuno ore deposits are peculiar in size and mineral assemblage.

The Akenobe deposit is situated at about 50 km north from Himeji City, and it is believed that the mine was discovered more than 1,000 years ago and exploited since the Daido era. At the end of 18th century, the Mitsubishi Metal Co. got possession of mine. The production of metallic ores from the mine in 1967 is given as follows:

Copper ore 140,953 tons
(Cu 1.55%, Zn 1.84%,

		SnO_2 0.43%)
Zinc ore	207,457 tons	
		(Cu 1.06%, Zn 2.08%, SnO_2 0.19%)
Zinc-lead ore	15,511 tons	
		(Cu 0.46%, Pb 1.09%, Zn 4.31%)
Tin ore	62,729 tons	
		(Sn 0.75%)

The Akenobe mineralized area is divided into two blocks called the west and east areas bordered by Akenobe fault trending N–S. These are composed of about sixty veins controlled by many diverse fracture patterns as shown in Table 2. Vein swarm in the west area consists of veins trending E–W represented by Ebisu-hi or Otohime-hi, whereas that in the east area is composed of veins running to NW represented by Gochaku-hi, Higashiyama-hi, Sekiei-hi, Shakken-hi, Nihonmatsu-hi, Daisen-hi, Ryusei-hi or Kusagane-hi. N–S and NE veins are subordinate among the above-stated veins. On the other hand, NE veins occurs in the NE faults and E–W vein are subordinate in the east area. These veins are composed of sulphide and oxide minerals containing Cu, Pb, Zn, Sn and W. The distribution of each metal element has been examined vertically and horizontally by SAIGUSA (1958), ABE (1963) and IKEDA (1970), it has been clarified that these metallic elements, as well as many sulphide and sulphosalt minerals as Mo, Bi and Ag show zonal arrangement. Akagane mine was established about three hundred years ago and gold ores from Kosoku adit were mined and refined as "Yama-

Table 2 Main veins of Akenobe mine

Vein	Strike	Dip	Length Horizontal	Length vertical
Honjiki	N70°E	50°N	250 m	150 m
Hansei	N70°E	50°N	250 m	110 m
Fujiishinmyaku	E–W	40°N	160 m	95 m
Fujii	N40°E	40°N	200 m	40 m
Fujigane	E–W	45°N	300 m	200 m
Eiko	N50°E	45°N	330 m	120 m
Karigane	N70°W	50°N	600 m	200 m
Ebisu	E–W	45°N	800 m	400 m
Fudono	N60°W	45°S	170 m	64 m
Nansei	N65°W	60°N	390 m	214 m
Nanamyaku	N50°W	70°N	400 m	350 m
Yonmyaku	N50°W	75°N	600 m	450 m
Benten	E–W	60°N	200 m	100 m
Urashima	N50°W	50°N	150 m	
Hotei	E–W	60°N	400 m	150 m
Eisei	N60°W	75°N	250 m	200 m
Nimyaku	N50°W	80°N	150 m	60 m
Ichimyaku	N40°W	70°S	100 m	30 m
Higashiyama no. 1	N50°W	60°N	150 m	50 m
Myoken no. 1	N60°W	60°S	150 m	120 m
Higashiyama	N40°W	70°S	650 m	250 m
Seiei	N40°E	40°N	600 m	200 m
Komori	N50°W	65°S	600 m	250 m
Daisen	N–S	70°W	400 m	150 m
Hokusei	N5°W	70°W	350 m	150 m
Yuzurio	N40°W	65°N	150 m	
Gosetsu	N50°W	60°N	450 m	150 m
Kamagatani	N40°W	70°N	900 m	450 m
Shotoku	N45°W	65°N	1200 m	350 m
Hyakken hanging wall	N85°W	55°N	370 m	250 m
Hyakken	N35°W	75°N	1000 m	600 m
Sekiei	N40°W	75°N	1500 m	600 m
Fukuei	N75°W	65°N	500 m	400 m
Nihonmatsu	N40°W	75°N	1400 m	450 m
Daisen	N35°W	75°N	1000 m	450 m
Ryuei	N40°W	75°S	350 m	250 m
Kusagane	N40°W	60°N	600 m	200 m
Daido	N10°W	70°E	350 m	250 m
Rokusei	N35°W	80°W	650 m	200 m
Ryusei	N35°W	35°S	750 m	220 m
Tairei	N40°W	60°S	450 m	300 m
Shiraiwa	N50°W	70°N	350 m	270 m
Shiraiwa -hyakken	N40°W	65°N	300 m	250 m
Mansei	N80°W	60°N	100 m	150 m
Suehiro	N50°W	50°N	200 m	150 m
Ginsei	N55°W	55°N	300 m	110 m
Nanei	E–W	60°N	270 m	50 m
Shirogane	N40°W	50°S	300 m	150 m
Chosei	N55°W	60°S	420 m	70 m
Kasei	N70°W	55°N	1100 m	90 m
Kanayama	N70°W	55°N	300 m	170 m
Shusei	N65°W	80°S	220 m	70 m
Kinsei	N70°W	60°N	220 m	40 m
Chiemon	N60°E	50°N	150 m	240 m

(Akenobe mine)

buki". The Akagane deposit consisting of eight veins trending NE which include three main ore bodies, Daisen-hi, Honko-hi and Kawamukai-hi, is situated at about 3 km southwest of Akenobe mine, and the deposit is composed of ore minerals of chalcopyrite and galena, subordinate bornite, hematite, cassiterite and pyrite.

Ikuno mine is located at about 18 km southeast side of Akenobe mine. It is said that the Ikuno deposit was discovered in 809 and the mine produced about 15 million tons of crude ore until 1973. The production of metallic ores from the mine on April, 1971 is given as follows:

Copper-lead-zinc ore 15,000 tons
(Au 0.13 gr/t, Ag 0.57 gr/t, Cu 1.69%, Pb 0.14%, Zn 0.73%)

"Keiko" (siliceous ore) 250 tons
(Au 4.0 gr/t, Ag 150 gr/t)

Ikuno mining area is divided into two blocks called the west and the east. These two blocks are bordered by Nendo fault trending NE. The Ikuno deposit consists of more than fourty five veins as shown it Table 3. In the west block, there are some main veins trending NW as represented by Tenju-hi and Taseioku-hi, and as subordinate one of Osei-hi and Tenjuhon-pi trending E–W, and Oju-hi and Urushidani-hi trending N–S. In the east block, there are some veins striking N–S as represented by Kinsei-hi, Senjuhon-pi and Senjumae-hi. As subordinate veins Koei-hi and Sakura-hi trending NW are observed. This vein swarm extends in an area of about 54 km^2 (Fig. 1 and Table 3). Ore of the Ikuno deposit is mainly composed of Cu, Pb and Zn sulphides, and Sn, W, Bi and As minerals are accessory.

2) Gold-silver bearing quartz vein type

Some gold-silver deposits are known at Omidani and Mikohata, in surrounding the tin-tungsten bearing polymetallic subzone. This occurrence implies that the gold-silver deposits may have been resulted from successive ore forming process continued from tin-tungsten bearing polymetallic mineralization stage.

The Omidani deposit is located at about 2 km in the south side of Akenobe mine and it mainly consists of three parallel gold-silver bearing quartz veins striking WNW. This area is divided into two blocks of the east and the west bounded by Fusei NE fault branching out from the Akenobe fault. The east block is called "Fusei. area" and also the west one "Otate area". The Fusei deposit is a gold-silver bearing quartz vein containing minor amounts of Cu, Zn, Pb, As, Ag and Sn sulphides (SUMITA, 1969). The Otate deposit is characterized by

Table 3 Main veins of Ikuno mine

Vein	Strike	Dip	Length Horizontal	Length vertical
Tenju	N50°W	60°N	1410 m	500 m
Seiju	N35°W	65°N	230 m	310 m
Shoeihon	N65°W	80°N	350 m	150 m
Taseioku	N40°W	80°N	500 m	170 m
Nishirokugo	N40°W	70°N	200 m	200 m
Nanten	N55°W	70°N	230 m	270 m
Kokurin	N35°W	65°N	170 m	170 m
Tamaru	N35°W	70°N	540 m	260 m
Kisei	N80°W	65°N	300 m	100 m
Taseihon	E–W	65°N	300 m	320 m
Ryokuju	N20°W	60°S	730 m	440 m
Urushidanihon	N20°W	70°S	920 m	350 m
Urushidaninaka	N25°W	80°S	220 m	200 m
Urushidanimae	N25°W	80°S	370 m	250 m
Sengan	N15°W	80°S	500 m	260 m
Kuho	N–S	85°W	460 m	110 m
Momiji	N–S	60°W	200 m	150 m
Oju	N15°E	80°N	230 m	260 m
Seiei	N20°W	75°S	250 m	180 m
Hokuto	N10°W	80°N	300 m	500 m
Keiju	N10°W	70°N	540 m	960 m
Kinsho	N40°W	75°N	240 m	210 m
Koei	N40°W	80°N	1000 m	420 m
Hoju	N30°W	75°N	400 m	210 m
Sensan	N15°E	85°S	270 m	200 m
Kinsei	N–S	80°E	1170 m	1070 m
Kinseiuwaban	N–S	80°E	190 m	210 m
Kinseishitaban	N20°E	85°S	110 m	80 m
Senjuhon	N–S	80°E	1600 m	1070 m
Senjumae	N–S	80°E	1300 m	1010 m
Kanidani	N15°W	80°N	760 m	640 m
Ogiyama (Senzan)	N15°E	85°S	270 m	200 m
Sakura	N30°W	75°S	600 m	370 m
Hyotan	N80°W	70°S	450 m	320 m

(Ikuno mine)

banded quartz vein with black streak rich in Ag minerals, which is known as "Ginguro" (HARAGUCHI, OZAKI and TAKEICHI, 1952). Adularia is present in this vein. Two adularia-quartz veins are also known in Daisen-hi and Awadachi-hi trending N60°W in the west area.

The Daijo deposit is about 12 km east of Omidani mine and it was explored by Ueda mine in 1905, and then it was exploited in cooperation with Mr. OKADA and Rasa Mining Co. in 1936. The mine was closed down in 1941 because of the governmental reajustment of gold mine. The Daijo deposit consists of two veins of Takarazawa-hi trending N85°W and Noza-hi trending N77°W. The former is a gold-silver bearing banded quartz vein, about 1 m wide, containing minor amounts of Cu, Zn, Pb sulphides. The latter is a gold-silver bearing banded quartz vein extending about 1,600 m long and 6 m wide at a maximum.

Two gold mines are located at Tomisu and Sanyo in the southern part of the west mineralized zone. The Tomisu deposit consists of three parallel gold-silver bearing banded quartz veins trending E–W as No. 1-hi, No. 2-hi and No. 3-hi. The mine is, however, working today not as metallic mine, but as "Keiseki" mine for quartz. The Sanyo deposit is composed of three veins trending N–S and NW. The veins contain minor amounts of sulphide minerals. It is said that only silver ore was mined in ancient times.

3) Polymetallic vein type

Some polymetallic veins called Nii, Aokura are known at the northernmost area in the zone II. The Nii deposit is located at the area between Akenobe and Ikuno mines. This deposit is composed of three similar veins of Yashiro-hi trending WNW, Yamamoto-hi trending WNW and Etsuzan-hi. Ores from these veins are composed of simple Cu, Zn, Pb and Ag sulphides. The Aokura deposit trending WNW in the Ikuno west block is similar to the above-mentioned Pb–Zn veins, and it contains minor amounts of bornite, arsenopyrite, cassiterite and secondary malachite (BESSHO, HUKUI and OZAKI, 1948). Other some mines as Omiya, Tatara, Tataragi and so on are known in the Asako block. All of these mines, however, are small in scale.

Zone III

The ore deposits of zone III are located at the outermost part of the Chigusa quartz diorite. These are polymetallic deposits including an abundant pyrrhotite. Mikata, Kyukuromi, Kuromi, Dainichi, Kabasaka and Nyukaku mines are known in this zone. On the other hand, some deposits of Shimizu, Torima and Kojiya mines are free of pyrrhotite.

Pyrrhotite bearing polymetallic vein type

The Dainichi deposit is located at about 10 km southeast of Ikuno mine. It consists of eight parallel veins trending NE in slate of the Tamba Group. Main three veins of No. 4-hi, No. 6-hi and No. 8-hi are composed generally of pyrrhotite, arsenopyrite, chalcopyrite, sphalerite, galena and pyrite. The No. 4-hi strikes N40°–50°E and dips to the north, and it extends about 280 m along the strike side and about 120 m along the dip side. The No. 6-hi is about 360 m long and about 100 m deep, and No. 8-hi is about 250 m long and about 100 m deep.

The Kabasaka deposit is located about 1.5 km at the eastern side of the Dainichi mine. This is a polymetallic vein striking E–W and has the length of about 1.4 km along the strike. Vein is made up with chlorite, quartz and Cu, Pb, Zn and As sulphides, with subordinate amounts of cassiterite, manganese carbonate and secondary malachite (HARAGUCHI, 1957). The Omisaka deposit is about 1.5 km south of Kabasaka mine and it is a polymetallic vein striking NW, about 300 m long. This vein is composed of sericite, quartz and Cu, Zn, Pb, As and Mo sulphide minerals. The Kojiya deposit lies at about 9 km south from the Kabasaka mine and consists of five veins called No. 1-hi, No. 2-hi, No. 3-hi, No. 4-hi and No. 5-hi. The No.1-hi is major vein being exploited about 110 m long along the strike. The width is about 0.8 m. It strikes

N75°W and dips 80°NE. The No. 2-hi is about 50 m long and 0.6 m wide, and it strikes N75°E and dips about 65°SE. The other veins, No. 3-hi, No. 4-hi are both running in NE and No. 5-hi has E–W strike. These three are small in scale, less than 30 m along strike. Ore from these veins are mainly composed of chalcopyrite. Tetrahedrite, sphalerite and secondary cuprite may be present.

The Mikata deposit is located at the northeasternmost part of the west zone and it constitutes a vein swarm crowding together with the veins called Torima, Mikata, Kyukuromi, Kuromi and Sinkuromi. The deposit consists of four veins of No. 1-hi, No. 2-hi, No. 3-hi and No. 4-hi. No. 4-hi strikes N35°W and dips 70°NE, and exploited about 60 m and 15 m along the strike and dip, respectively. Some veins of Kuromi and Kyukuromi mines are composed mainly of pyrrhotite, Cu, Zn, Pb and As sulphide minerals. The Shinkuromi deposit strikes E–W and dips 70°S and has been exploited about 130 m along the strike. The composition of the vein is similar to that of Kyukuromi mine. Molybdenite-sericite veinlet is found in Shinkuromi granodiorite. This molybdenite is coarser than that of Ariga and Akenobe mines (Pl. 6–3). The Kuromi deposit is made up by the pyrrhotite bearing polymetallic vein which is similar to the above-stated ones in the compositions. It strikes N40°E and dips 70°SE, being 230 m explored and mined.

East zone

The east zone is situated at the easternend portion of Hyogo Prefecture. There are a few ore deposits but many types as skarn, tin bearing gold-silver vein and simple polymetallic vein. Myoken, Katsuboshi, Akamatsu and Tada mines are known in this zone.

The Myoken deposit is located near the peak of the Mt. Takatoriyama being about 10 km north from Ikeda City and occurs in sandy slate of the Tamba Group near quartz diorite. It consists of skarn type ore containing garnet, salite, epidote, chlorite and quartz associated with pyrrhotite, chalcopyrite and pyrite. The Katsuboshi deposit lies about 1.5 km at the northeast side of Myoken mine, and it is chlorite-copper vein. The major copper minerals are chalcopyrite and bornite, pyrrhotite and secondary malachite are attended in the vein and along the bedding of hornfelsed sandy slate. It strikes N30°W and dips about 55°NE. It is about 1 km long. Ore reserves were estimated in 1955 to be about 12,000 tons of mean values 1.539 gr/t gold, 334.8 gr/t silver and 11.13 percent copper. The Akamatsu deposit is located at about 9 km northwest from Ikeda City. This deposit is vein type consisting of such minerals as chlorite, chalcopyrite, sphalerite, bornite and secondary malachite.

Tada mine is located at about 4 km northwest from Akamatsu mine. Tada mine is exploiting tin bearing gold-silver vein, whereas all the other mines in the east zone have been closed. It is said that the Tada ore deposit was exploited for construction of "Daibutsu" during Nara era. The production of the mine in 1967 was around 970 tons per month by crude ore containing 1.3% copper and 2,000 gr/t silver. The Tada deposit consists of six veins of Hyotan-hi (N25°W, 70°NE), Gochaku-hi (N25°W, 60°NE), Ishigane-hi (N25°W, 60°NE), Eboshi-hi (N25°E, 70°SW), Byobu-iwa-hi (N–S, 55°NE) and Ogane-hi (N40°E, 70°NW). Hyotan-hi and Ogane-hi are both champion veins of the mine, while Ogane-hi was already closed. The champion veins attain to about 800 meters long. The type of the deposit is tin bearing gold-silver quartz vein which contains chalcopyrite, bornite with minor amounts of sphalerite, galena, native silver and tin minerals as cassiterite, stannoidite and mawsonite.

Although the zonal arrangement as found in the west zone is not observed in the east zone, the similar types of ore deposit as skarn, tin bearing gold-silver vein and pyrrhotite bearing polymetallic vein are also found in the east zone.

4. Ore Phases in Each Zone

Regional consideration of the mineralization in this district has been described in the recent report (NARITA, MIMURA and KOMURA, 1979). In detailed observation on individual ore deposits, different mineral assemblages and stages of the mineralization are recognized in the ores of all deposits. These may illustrate various ore forming processes and are called ore phase in this paper.

Zone I

1) Skarn type

Skarn type deposits of this district are formed in Cretaceous andesite and in Paleozoic limestone occupying the outer side of quartz diorite. Three mines a) Ichinomiya, b) Chigusa and c) Asahi are known as skarn type and these ore deposits contain the following ore phases:

a) (i) magnetite-garnet, (ii) dolomite-calcite-quartz, (iii) jasperoid-chalcedonic quartz

b) (i) garnet-salite, (ii) amphibole-epidote-chlorite-quartz-magnetite-sphalerite-pyrite

c) (i) garnet-salite, (ii) epidote-chlorite-quartz - hematite - sphalerite - galena-pyrite

Magnetite from Ichinomiya and Chigusa mines are different one another on its habit, forming stage and associated mineral assemblage. The magnetite of Ichinomiya mine occurs with an euhedral cubic dodecahedron andradite (phase i). The magnetite from the Chigusa mine shows a platy habit presenting hematite pseudomorph (phase ii), (Pl. 4–1). Garnet in the phase i from Ichinomiya mine grows surrounding the mass of euhedral magnetite (Pl. 1–1). Ores of the phase ii from above three mines are frequently associated with

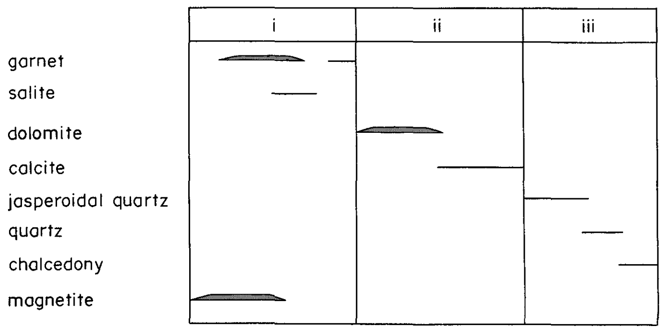

Table 4 Paragenetic table showing the mineral sequence in the Ichinomiya deposit.

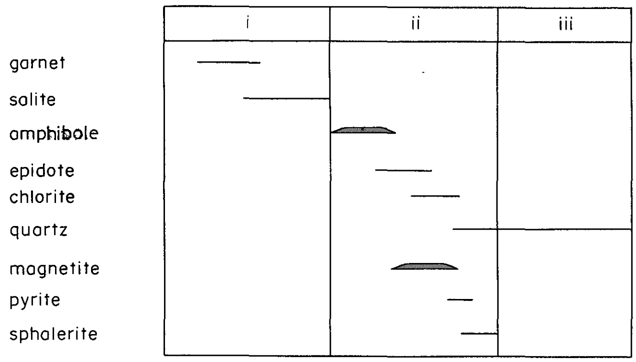

Table 5 Paragenetic table showing the mineral sequence in the Chigusa deposit.

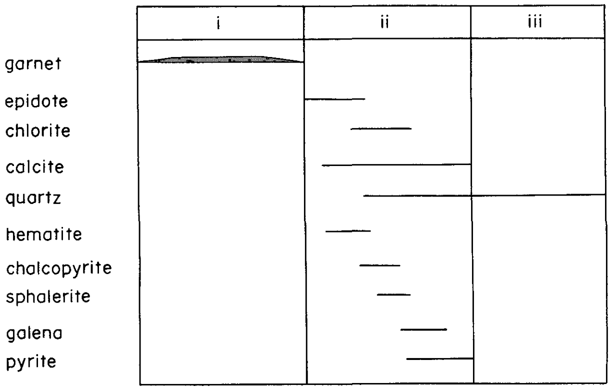

Table 6 Paragenetic table showing the mineral sequence in the Asahi deposit.

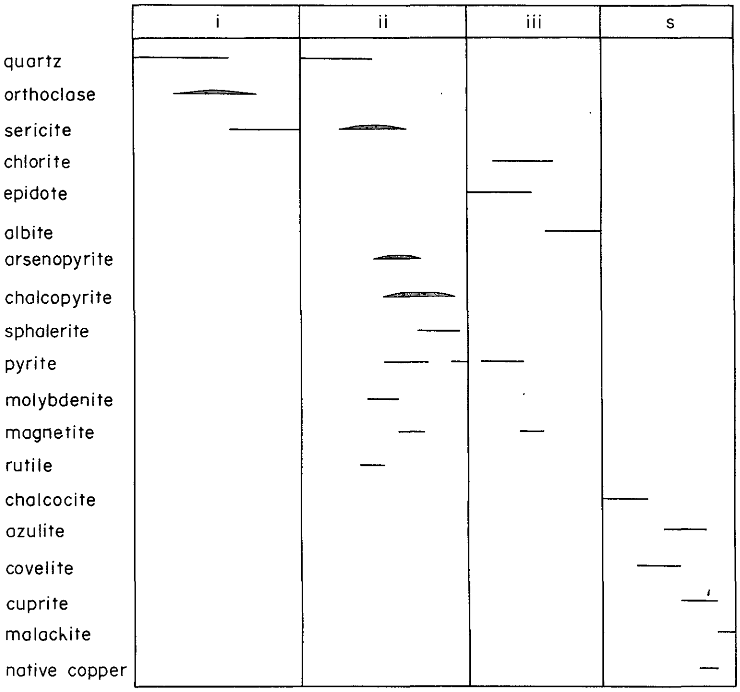

Table 7 Paragenetic table showing the mineral sequence in the ore deposits of porphyry copper type.

copper, zinc and lead sulphide minerals (Pl. 4–2). Dolomite-quartz association of the phase ii of Ichinomiya mine cuts through and replaces the earlier stages garnet-magnetite skarn ore and it encloses brecciated garnet and magnetite of the phase i. Ore from Ichinomiya mine also is accompanied with chalcedonic quartz indicating low temperature in the latest stage, phase iii (Table 4, 5, 6).

2) Porphyry copper type

Ores of porphyry copper type from a) Arao, b) Ariga and c) Kawakami mines show three phases as follows:

a) (i) orthoclase-sericite-quartz-chalcopyrite, (ii) sericite-quartz-chalcopyrite-pyrite-rutile, (iii) chlorite-albite-magnetite-pyrite

b) (ii) sericite-quartz-chalcopyrite-pyrite-pyrrhotite-molybdenite, (iii) chlorite-albite-magnetite-pyrite

c) (ii) sericite-quartz-magnetite-bornite-arsenopyrite-chalcopyrite-sphalerite-pyrite, (iii) epidote-chlorite-albite-magnetite-pyrite

The phase i is only found at Arao mine (Pl. 4–3). Chalcopyrite disseminates in altered quartz diorite and fills under the microscop interstices of secondary perthitic orthoclase and quartz. The phase ii represented by sericite-quartz-chalcopyrite is found in all of the above stated three mines, and chalcopyrite is main ore mineral. Tiny flakes of molybdenite are attended disseminating in the ore of the phase ii from Ariga mine, and minor amounts of magnetite, bornite, arsenopyrite and sphalerite are present in the ore of phase ii from Arao and Kawakami mines. Arsenopyrite is especially abundant in the ore from Kawakami mine (Pl. 1–2, Table 7). The phase i and ii form a low grade ore of about 0.5 percent in copper. Mineral associations of orthoclase-sericite-quartz, sericite-quartz and epidote-chlorite are called "potassic", "phyllic" and "propylitic", respectively, following LOWELL and GULLBERT (1970).

3) Arsenic bearing polymetallic vein type

Ores from a) Takumi, b) Hideshige and c) Mikata mines are constituted by ore phases as follows:

a) (i) chlorite-arsenopyrite-chalcopyrite-pyrite-sphalerite-galena

b) (i) sericite-arsenopyrite-pyrite, (ii) sericite-quartz-pyrite-sphalerite-galena, (iii) barren quartz

c) (ii) sericite-quartz-pyrite-sphalerite-galena, (iii) barren quartz

The phase i from Takumi mine is mainly constituted with chlorite and arsenopyrite, accompanied by minor amounts of chalcopyrite, sphalerite and galena. It is said that only arsenic mineral was mined in this mine. Two phases i and ii are observed in the Hideshige vein. The former occurs in replacing country rock near the fracture, and is overlapped by the phase ii, and the secondary replacement bleached out chlorite. Vein and stringer represented by the phase ii is realized by gray quartz, chalcopyrite, sphalerite and galena in quartz-sericitized country rock and in the breccia of the phase i ore (Pl. 2–1). Main phase in the Mikata vein belongs to phase ii consisting of quartz, sphalerite, galena, pyrite; thus this vein is a simple Pb–Zn ore. Barren quartz vein of phase iii cuts through the ores of phase ii of Hideshige and Mikata veins.

Zone II

1) Tin-tungsten bearing polymetallic vein type

Tin-tungsten bearing polymetallic veins of the Ikuno and Akenobe types spreads over along the main tensional NW fracture. Zonal arrangement of Sn–W, Cu–Zn and Au–Ag ores is observable from center to outer parts in the Ikuno and Akenobe mineralized area, as mentioned previously. The mineralization of the Ikuno and Akenobe mines were described in detail by SAIGUSA (1958), ABE (1963), MURAOKA and IKEDA (1968), IKEDA (1970), TANAKA, MORI and SASAKI (1971), NAKAMURA (1976), SATO, ASADA and KASAMATSU (1977) and the zonal arrangement of these deposits based on the metal grade of Sn, W, Cu, Zn, Pb, Au and Ag has been defined horizontally and vertically. Megascopical and distinctive zonal arrangement of ore phases are also found in these deposits. Based on the metal grade, the Akenobe vein system can be horizontally divided into the Sn–W zone of Sekiei-hi, Nihonmatsu-hi, Daisen-hi; the Cu–Sn zone of Gomyaku-hi, Higashiyama-hi, Shakken-hi, Nihonmatsu-hi, Daisen-hi, Kasei-hi, Eisei-hi and Yonmyaku-hi; the Pb–Zn zone of Eiko-hi, Sirogane-hi and Kosoku-hi (Akagane mine); the Au–Ag zone of Kinsei-hi (Mikohata mine), Kasei-hi, Otate-hi (Omidani mine), Awadachi-hi, Yakisugi-hi, Hidemori-hi (Mikohata mine), Kawato-hi (Akagane mine) and Fusei-hi (Omidani mine) at the outermost side. Vertical subzonal arrangement of ore phases distinguished by metal grade is also clear. These subzonally arranged mineralization might have been performed itself making the different ore phases in the same way as described on the ores of skarn and porphyry copper types.

Feature recognized based on the sketches for many Cu–Zn and Sn–W type veins can be summarized as the following three main ore phases:

(i) chlorite-chalcopyrite-sphalerite-galena-pyrite- (arsenopyrite) - (pyrrhotite) - (cassiterite)-(stannite)-(kesterite)-(roquesite)

(ii) huebnerite-ferberite-scheelite-cassiterite-stannoidite - mawsonite - (molybdenite)-(bismuthinite)-native bismuth-magnetite-bornite-chalcopyrite-pyrite-argentite-gray quartz-fluorite-calcite

(iii) barren white quartz-(chalcopyrite)-(sphalerite)-(pyrite)

In the Akenobe and Ikuno mines (Fig. 3, 4, 5, 6, Pl. 2–2, 3, Table 8), the Cu–Zn phase is mainly composed of chlorite-chalcopyrite-sphalerite in association with minor amounts of arsenopyrite, pyrrhotite, galena, cassiterite, and tin-indium sulphides. Veinlet or network vein containing a lot of chlorite remains chloritized

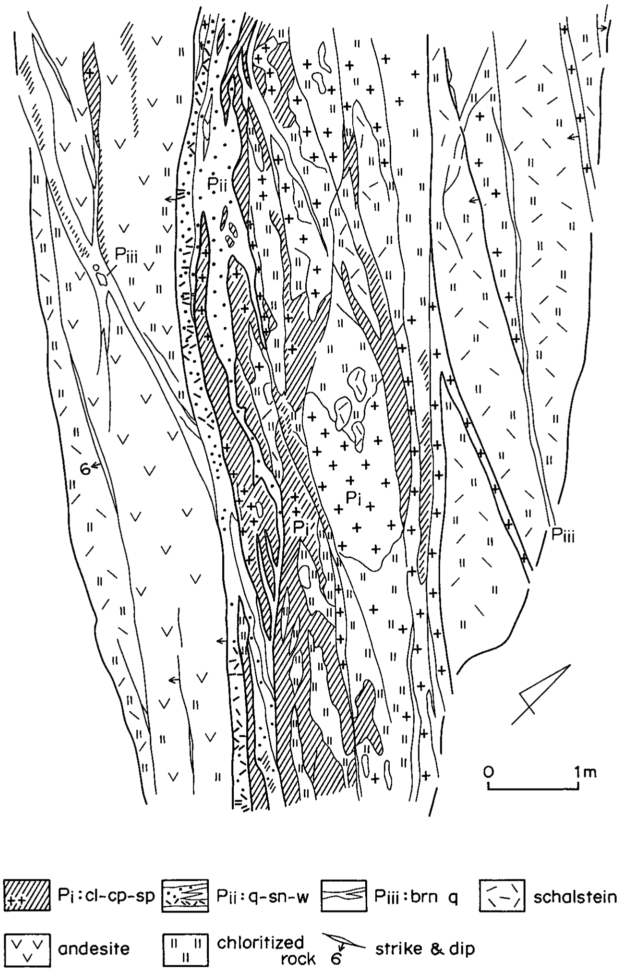

Fig. 3 Sketch of the Eisei-hi, 10th level, Akenobe mine.

Abbr; Pi: cl–cp–sp; phase i ore associated with chlorite-chalcopyrite-sphalerite, Pii: q–sn–w; phase ii ore associated with quartz-tin-tungsten oxide minerals, Piii: brn q: phase iii barren quartz.

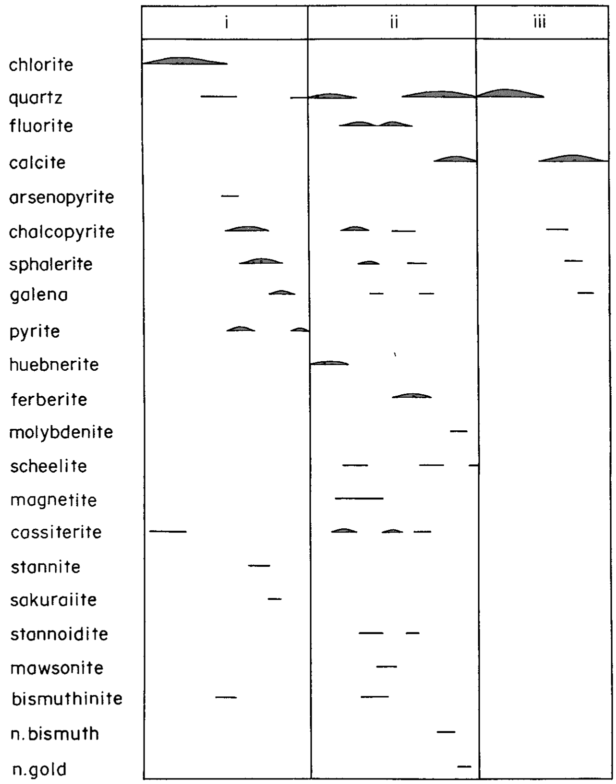

Table 8 Paragenetic table showing the mineral sequence in the ore deposits of the tin-tungsten bearing polymetallic vein type.

country rock of that phase. Two subphases of Cu rich and Zn rich ores are found in the phase i of Yonmyaku-hi, Eisei-hi and Ryusei-hi at Akenobe mine and Senjuhon-pi and Kinsei-hi at Ikuno mine. Cu subphase i-1 is massive ore mainly composed of chalcopyrite and is regarded to be precipitated in the earlier stage than that of Zn subphase i-2 (Pl. 2–2), and the former is more abundant on the lower levels than the upper levels. Cassiterite in subphase i-1 is replaced and generally cross-cut by chalcopyrite of the same phase (Pl. 4–7) in Kinsei-hi, 35 level, Ikuno mine, and tin-indium sulphide mineral associates with sphalerite of subphase i-2, in Senjuhon-pi, 0 m level, Ikuno mine.

Ore of the phase ii generally occupies innerside of the vein and it mainly consists of quartz-tin-tungsten minerals. It is subdivided into some subphases as shown in the sketch and photograph of Eisei-hi (Fig. 4, Pl. 2–2). The subphases show banded texture made up by ii-1 huebnerite-cassiterite (Pl. 2–2, 3), ii-2 fluorite (Pl. 2–2, 3), ii-3 quartz-chalcopyrite-magnetite-cassiterite-stannoidite, ii-4 quartz-cassiterite-ferberite-chalcopyrite-bornite and ii-5 fluorite-calcite-quartz of Eisei-hi (Fig. 4) and of Yonmyaku-hi, Akenobe mine. In the case of the Eisei-hi, Akenobe mine and of some veins, Ikuno mine, the ore of phases i and ii sometimes lacks some subphases and in such a case, it contains Bi, Sb, As and Ag sulphide minerals as observed in Tenju-hi, Ryokuju-hi and Oju-hi, Ikuno mine. In some cases, phase ii contaminates the ore of phase i and copper-tin ore containing a lot of chlorite appears here. Phase iii prevails in the innermost side or center part of the vein and frequently it distributes as network crossing the ores of phases i and ii. Phase iii consists of white banded quartz and calcite, sometimes a minor amounts of chalcopyrite, sphalerite and pyrite are attended.

These different relation of each phase were explained by SAIGUSA (1958), ABE (1963), MURAOKA and IKEDA (1968), TANAKA, MORI and SASAKI (1971) and NAKAMURA and MIYAHISA (1976), and these appearances of phases were interpreted as polyascending action of ore solution by them. Although the distinctive zonal arrangement, both vertically and horizontally, is observed on the metal grade and textures of the ores (Fig. 5, 7), the metal contents in each vein do not always show the zoning. These metals tend to be enriched together at site of "bonanza" (Fig. 5, 8). At Ryusei-hi of Akenobe mine, for example maximum metal contents of Cu, Zn, Sn and W are seen together in the only 3rd level, and concentration of the metals is about 52 percent among the sketched vein. Total metal content

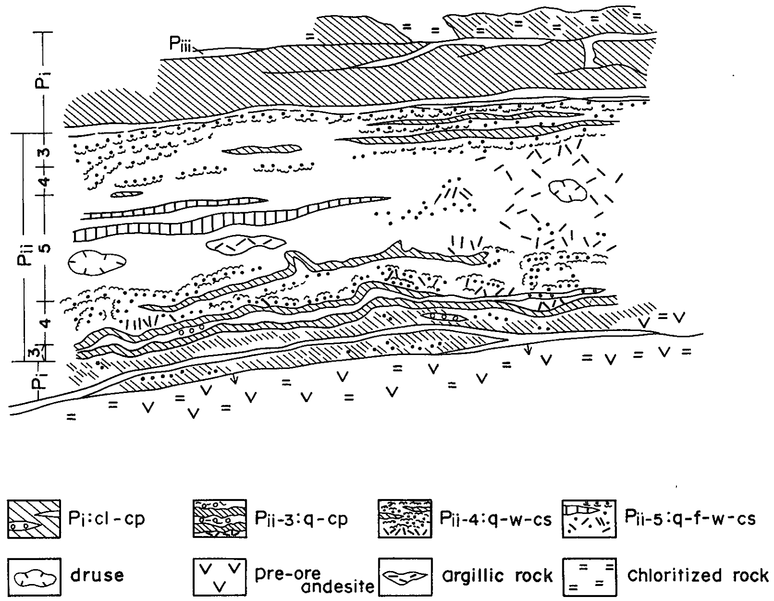

Fig. 4 Sketch of the Eisei-hi, no. 20, 10th sublevel, Akenobe mine.

Abbr; Pi: cl–cp; phase i ore of chlorite-chalcopyrite, Pii–3: q–cp; subphase ii–3 ore of quartz-chalcopyrite, Pii–4: q–w–cs; subphase ii–4 of quartz-wolframite-cassiterite, Pii–5: q–f–w–cs; subphase ii–5 of quartz-fluorite-wolframite-cassiterite.

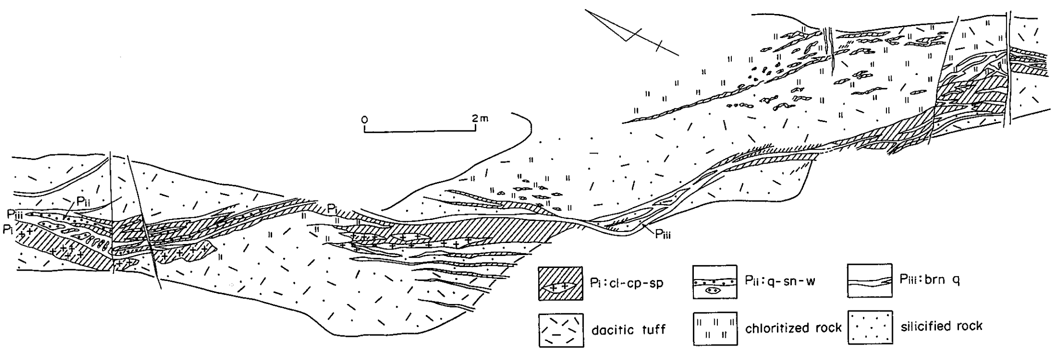

Fig. 6 Sketch of the Kinsei-hi, 33rd level, Ikuno mine.

Abbr; Pi: cl–cp–sp; phase i ore of chlorite-chalcopyrite-sphalerite, Pii: q–sn–w; phase ii ore of quartz-cassiterite-wolframite, Piii: brn q; phase iii of barren quartz

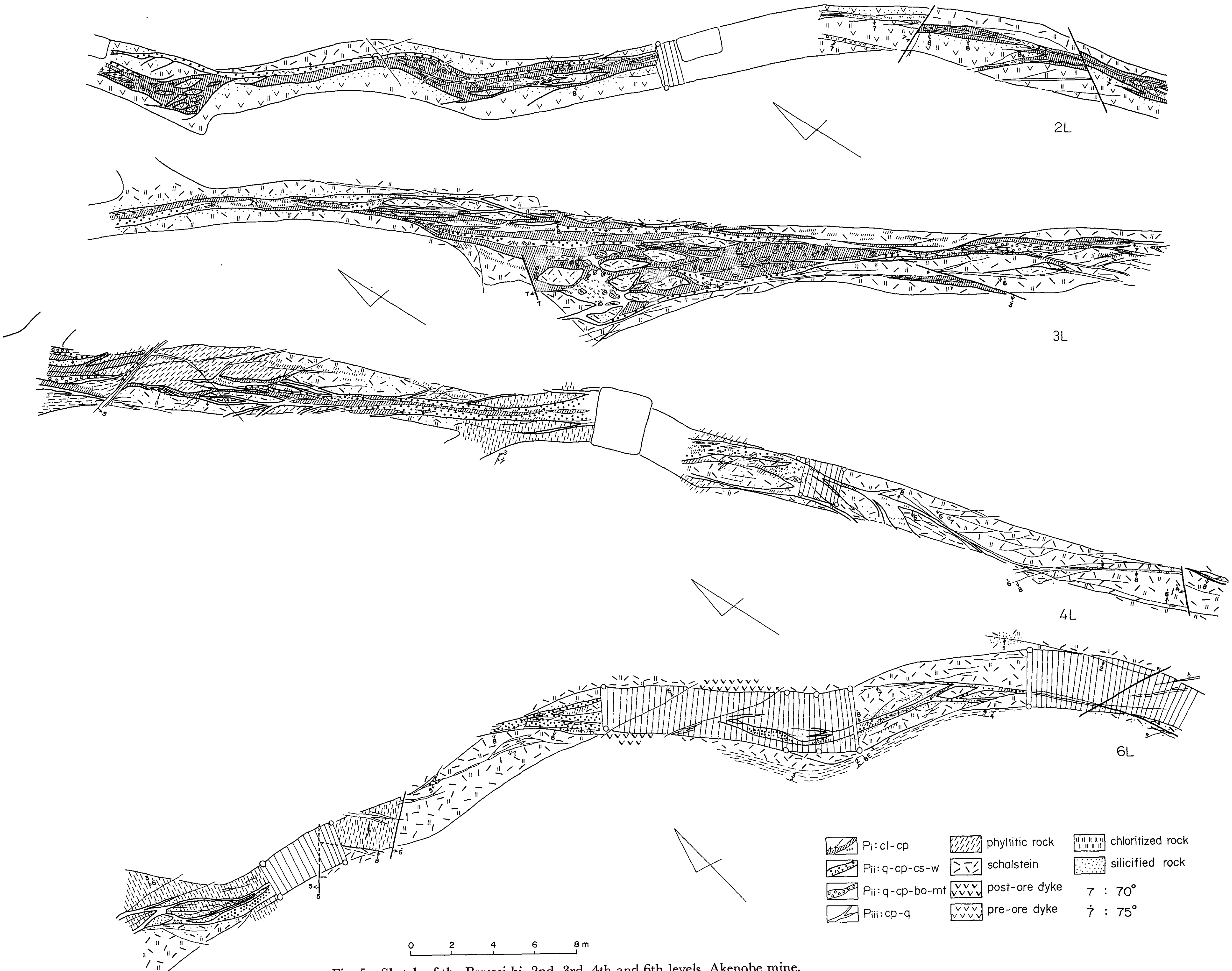

Fig. 5 Sketch of the Ryusei-hi, 2nd, 3rd, 4th and 6th levels, Akenobe mine.

Abbr; Pi: cl–cp; phase i ore of chlorite-chalcopyrite, Pii: q–cp–cs–w; phase ii ore of quartz-chalcopyrite-cassiterite-wolframite, Pii: q–cp–bn–mt; phase ii ore of quartz-chalcopyrite-bornite-magnetite, Piii: cp–q; phase iii of chalcopyrite

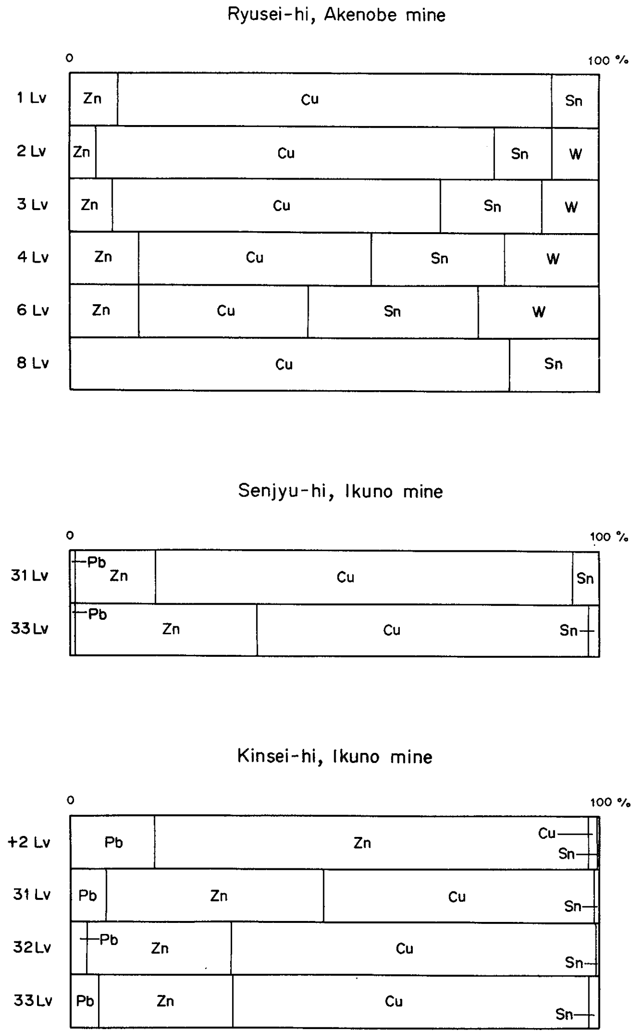

Fig. 7 Vertical zonal-arrangement represented by metal grade in the tin-tungsten bearing polymetallic vein type.

from 2nd to 4th level attains to about 96%. This feature is also observed in Senju-hi and Kinsei-hi of Ikuno mine (Fig. 8). Here, the metal contents of vein radially decrease from the bonanza of 31st level of Senjuhon-pi, and that of 31st and 33rd levels of Kinsei-hi to ascending and descending levels.

2) Gold-silver bearing quartz vein

The gold-silver quartz veins of Omidani, Mikohata and Daijo mines occur to surround tin-tungsten bearing or free polymetallic veins. These deposits consist of banded quartz vein which accumulates precious gold and silver metals and accompanies minor amounts of base metal sulphides. Veins of a) Fusei-hi, b) Awa-tachi-hi and Daisen-hi of Omidani and c) Ta-karazawahi of Daijo mines contain minor amounts of sulphide minerals as chalcopyrite, sphalerite, galena, argentite and canfieldite in phase of early stage, and ore phase in the veins is divided into three or four phases as follows:

a) (i) chlorite - banded quartz - argentite-canfieldite, (ii) gray quartz-argentite-canfieldite-bornite-chalcopyrite-sphale-

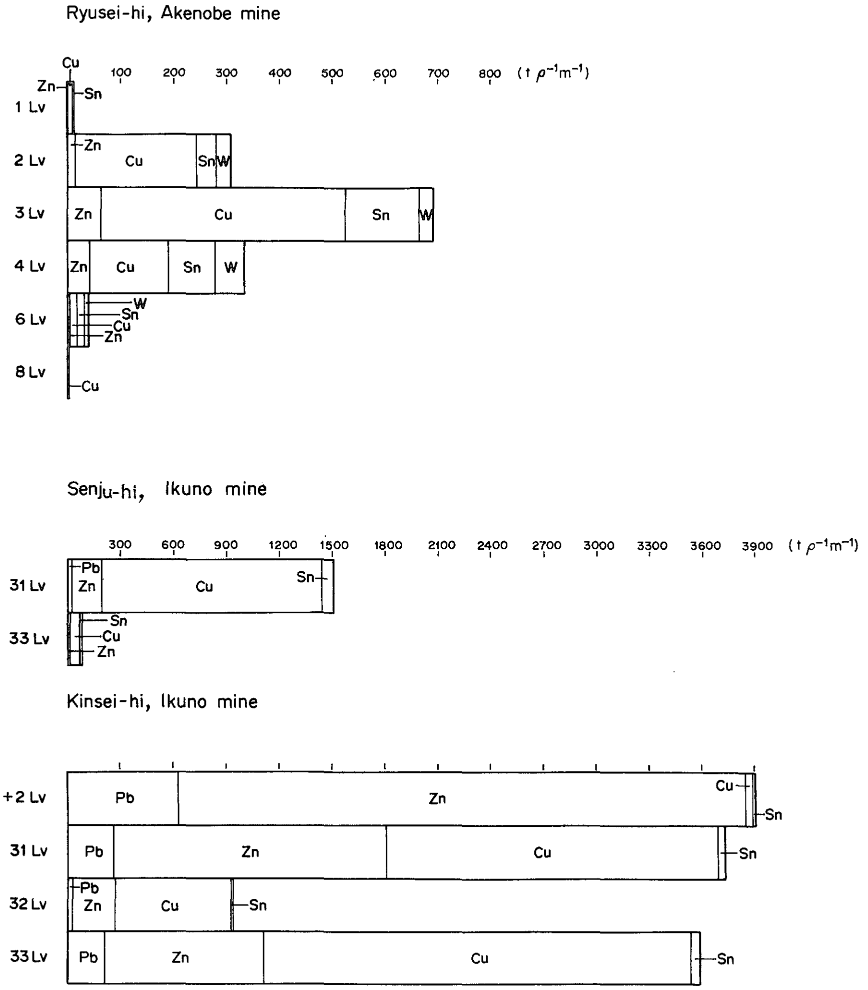

Fig. 8 Vertical metal abundances in some ore deposits of the tin-tungsten bearing polymetallic vein type.

rite-galena, (iii) banded quartz, (iv) pinkish quartz-amethyst

b) (i) adularia-banded quartz-argentite, (ii) gray quartz-argentite-native gold, (iii) pinkish quartz

c) (i) banded quartz-argentite, (ii) gray quartz(chalcopyrite-sphalerite-galena-pyrite)

As mentioned above, the Fusei-hi is composed of four phases and it contains minor amounts of sulphide minerals of argentite and canfieldite in the phase i and of argentite, canfieldite, bornite, chalcopyrite, sphalerite and galena in the phase ii. Gold and silver are enriched in the phase i consisting of chlorite-banded gray quartz and in the phase ii composed of gray quartz. Phase iv consisting of aggregation of fine grain pinkish quartz accompanies and contaminates a block like xenolith of the precious metal phases i and ii, and it cuts or replaces the above-mentioned phases i, ii and iii (Table 9). It occupies about half parts of the vein. Daisen-hi and Awadachi-hi of Omidani mine form a banded quartz-adularia vein, and these are composed of the above-mentioned three phases. The Mikohata and Daijo gold-silver deposits are similar to gold-silver vein of Omidani mine. Although the Tomisu and Sanyo de-

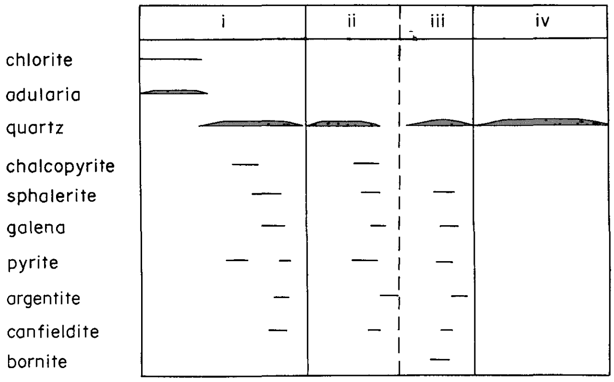

Table 9 Paragenetic table showing the mineral sequence in the ore deposits of the gold-silver vein type.

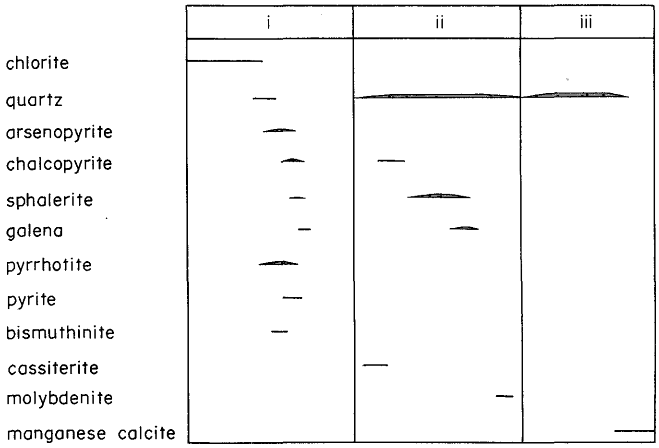

Table 10 Paragenetic table showing the mineral sequence in the ore deposits of the pyrrhotite polymetallic vein type.

posits are far from the Omidani and Daijo, these are also similar to the gold-silver vein. The Sanyo silver deposit contains some sulphide minerals as chalcopyrite, sphalerite and galena.

3) Polymetallic vein type

a) Tatara, Tataragi and b) Aokura deposits are located to the northeast of the Ikuno mine, and the ore deposits of these mines consist of the similar polymetallic vein containing some sulphide minerals as chalcopyrite, sphalerite, galena and argentite. Three ore phases are found as follows:

a) (i) chlorite-chalcopyrite-sphalerite, (ii) quartz-fluorite-sphalerite-galena-argentite, (iii) barren quartz

b) (ii) quartz - fluorite - chalcopyrite-sphalerite-galena-(argentite)-pyrite-(cassiterite), (iii) barren quartz

These are very similar to the ore phase of Cu–Zn subzone of the Ikuno and Akenobe mines, and the ore of the Aokura deposit contains minor amounts of cassiterite.

Zone III

Pyrrhotite bearing polymetallic vein type

The deposit of this type is different from that of zone II, because of the presence of abundant pyrrhotite, though it is similar to the vein of Ikuno and Akenobe mines. These ore phase (Table 10) are found as follows:

a) (i) chlorite-pyrrhotite-arsenopyrite-chalcopyrite-sphalerite-galena, (ii) quartz-chalcopyrite-sphalerite-galena-argentite-(cassiterite)-(molybdenite), (iii) quartz-manganese calcite
b) (ii) quartz-chalcopyrite-sphalerite-galena, (iii) quartz

Phase i ores from a) Dainichi and Kabasaka include abundant pyrrhotite and chalcopyrite associating with minor sphalerite skerton star, pyrite, sphalerite and galena replacing pyrrhotite. Phase ii ore of Nyukaku mine accompanies cassiterite and that from Omisaka and Ueda mines, molybdenite.

East zone

Ore deposits of east zone do not show the distinctive zonal arrangement as found in the west zone. The ore phases are shown as follows:

a) garnet-pyrrhotite-magnetite-chalcopyrite pyrite
b) chlorite-chalcopyrite
c) quartz-chalcopyrite-sphalerite-galena-arsenopyrite-pyrrhotite
d) quartz-chalcopyrite-sphalerite-galena-bornite-pyrite-mawsonite-stannoidite-cassiterite - argentite - native silver-fluorite-calcite

The a) Myoken deposit is sulphide skarn type contaning pyrrhotite and minor magnetite and chalcopyrite. The b) Katsuboshi, Aode and Naomori deposits are chlorite copper vein including minor sphalerite, galena and pyrrhotite, which is similar to the phase i ore of Ikuno, Akenobe and Dainichi mines. The c) Akamatsu deposit is pyrrhotite bearing polymetallic vein, and it also looks like one of Dainichi mine. The d) Tada deposit is composed of vein containing quartz-chalcopyrite-sphalerite-cassiterite-stannoidite-mawsonite-tennantite-bornite which resembles to the phase ii ore of Ikuno and Akenobe mines.

5. Ore Forming Minerals

Many ore and gangue minerals are known in this mineralized zone and a variety of mineral has been described in particular at the Ikuno mine. Major minerals will be described here.

Garnet occurs in magnetite skarn ores from Ichinomiya and Chigusa mines and in sulphide skarn ores of Asahi and Myoken mines. Garnet from Ichinomiya mine growing with granular magnetite of the phase i is brownish, euhedral dodecahedron to anhedral andradite (Pl. 1–1). Garnet in the ore from Asahi mine is pale yellowish brown,andradite. Ones from Chigusa (Pl. 4–1), Asahi (Pl. 4–2) and Myoken mines are replaced by epidote, amphibole, chlorite, quartz, calcite, pyrite, sphalerite and hematite of the phase ii.

Salite replaced by amphibole-epidote skarn is found in the phase ii of Ichinomiya mine. It shows emerald green megascopically and colourless in thin section. $c \wedge Z = 45°$.

Amphibole associated with platy magnetite in green skarn ore from Chigusa mine is green in colour and it shows a week pleochroism. $c \wedge Z = 20°$. So it is actinolitic (Pl. 4–1).

Epidote is found in green skarn of the phase ii ore from Chigusa and Asahi mines and it grows as an aggregation of pool-like or as euhedral prismatic or as radial crystal in a part between amphibole- and orthoclase-enriched portions.

Chlorite is found in the Pb–Zn phase ii replacing garnet skarn of the phase i (Pl. 4–2) and in the Cu–Zn phase i ore of vein type. The former is dark green and it shows moderate pleochroism. The latter is common in the chlorite-chalcopyrite-sphalerite phase i, and is dark green megascopically. Its pleochroism changes from pale green, yellow to colourless in the thin section, but it does not show a strong pleochroism in comparision with the former. Chlorite of contamination phase i is also found associating with cassiterite, huebnerite and scheelite of the phase ii (Pl. 4–8).

Orthoclase which is pinkish and mosaic, is found in potassic phase of Arao mine (Pl. 4–3). Orthoclase from Chigusa mine is regarded to be replaced by green skarn and it appears closely related to albite. This orthoclase is perthitic.

Albite is found in the phase ii ore showing the association of quartz-cassiterite-huebnerite at Akenobe and Ikuno mines, and it has a well developing albite twin.

Adularia is well recognized in an early phase of Daisen-hi of Omidani mine, and it is pinkish growing up to about 2 centimeters. This mineral has been rarely found in the ore of vein type deposits from Ikuno, Akenobe and other mines.

Quartz associates with the ores of all type. In the case of skarn type ore at Ichinomiya it occurs in vugh of the latest stage, as hexagonal prism, metacolloidal band and chalcedonic quartz (Pl. 1–1). In veins of Ikuno, Akenobe and other mines, it is euhedral prismatic and coarse grain quartz of the phase i, prismatic gray quartz and metacolloidal or lineage quartz associating with cassiterite of the phase ii, white semitransparent quartz of the phase iii and banded quartz of Omidani gold-silver vein.

Topaz was described by KATO (1917) and YAMAGUCHI (1939) from the quartz vein, 21st level of Kanten galarey, Ikuno mine.

Fluorite occurs to alternate with banded quartz and calcite of the phase ii ore from Ikuno, Akenobe and other mines (Pl. 2–2, 3). Rarely, it associates with sphalerite of the phase i ore of Senjuhon-pi, 2nd level, Ikuno mine. It is generally pale green, but can be pale pink, pale violet or colourless.

Dolomite occurs in skarn ore of the phase ii at Ichinomiya mine (Pl. 1–1). According to the information from Ikuno mine's staff it occurs in Sakura-hi, 2nd level, Ikuno mine.

Siderite is found in each vein at Akenobe mine, associating with quartz, cassiterite and magnetite of Ryusei-hi, Eisei-hi and Yonmyaku-hi. This mineral could be genetically related to magnetite at Akenobe mine (SEKINE, 1959; ABE and SEKINE, 1963). Although siderite shows a similar occurrence to that of phase ii at Ikuno mine, its amount is very small.

Rhodochrosite is found in ore of the latest stage at the main cross adit of Ikuno mine and is also found in the ore from Kabasaka mine.

Calcite is present in all of the veins of later stage of the phase ii. Calcite associates with white quartz which is main gangue mineral of phase iii. High strontium is recognized in calcite from Yonmyaku-hi at Akenobe mine and Nanten-hi, Kinsei-hi and Tenju-hi at Ikuno mine.

Sericite mostly occurs within potassic phase i (Pl. 4–3) and phyllic phase ii of Arao, Ariga and Kawakami mines, which is comparatively coarse grain as about 2 mm. It is $2M_1$ poly-type (Table 11), and is associated with molybdenite, chalcopyrite, pyrite, bismuthinite, magnetite and rutile of the phase ii at Ariga mine. Although it is concomitant with chlorite of the phase i and quartz of the phase ii in all the vein type ores, sericite is finer in size and smaller in

Table 11 X ray powder diffraction data of sericite

1		2		3	
d	I/I_0	d	I/I_0	d	I/I_0
10.0	5	10.0	7	10.1	35
5.01	2	5.02	3	5.05	22
4.48	1/2	4.48	1/2	4.50	12
4.28	2	4.25	1	4.31	3
3.71	1/2	3.78	1/2	4.12	2
				3.98	5
				3.89	5
3.71	1/2	3.78	1/2	3.74	6
3.48	1/2	3.47	1/2	3.50	10
3.34	10	3.34	10	3.35	48
3.25	1	3.24	1	3.21	11
		3.11	1/3	3.13	5
3.04	1				
3.00	1	2.99	1	3.01	12
2.88	1/2	2.89	1/2	2.88	8
2.80	1/2	2.86	1/2	2.81	6
		2.56	1	2.57	13
2.49	1	2.49	1	2.51	5
2.46	1/2	2.45	1/2	2.46	4
2.38	1/2	2.38	1/3	2.38	5
2.21	1/3	2.23	1/2	2.20	3b
2.13	1	2.16	1/2	2.136	5
1.956	2	1.995	3	2.006	20
1.819	1	1.817	1		

1. sericite, Kawakami mine.
2. sericite, Arao mine.
3. sericite, SUDO (1974).

amount than chlorite.

Chalcopyrite is widely found in ore from skarn type of Ichinomiya and Chigusa mines, porphyry copper type of Arao (Pl. 4–4, –5), Ariga and Kawakami mines and vein type of Ikuno, Akenobe, Omidani and other mines. Chalcopyrite from all of these types contains sphalerite star and sometimes bismuthinite and native bismuth. Inclusion of other minerals is generally little in these chalcopyrite except for the phase ii ore of Ikuno, Akenobe and Tada mines. Chalcopyrite from these mines is sometimes associated with cassiterite, mawsonite, stannoidite, huebnerite, ferberite, scheelite, galena, sphalerite, bismuthinite and native bismuth. It forms a micrographic texture with stannite, indium stannite and sphalerite (Pl. 5–4). Chalcopyrite from Tada mine shows zonal growth with cassiterite, stannoidite, mawsonite, bornite (Pl. 6–6). Sometimes, it is accompanied by argentite, canfieldite and cassiterite.

Sphalerite is found in all but a few ore deposits in this district. It is, however, small amounts in ores of skarn, of porphyry copper and of gold-silver vein types. On the other hand, it is abundant in ores of tin-tungsten bearing or free polymetallic and pyrrhotite bearing polymetallic vein types. Sphalerite is commonly dark brown in colour like marmatite. Some sphalerite in ore from gold-silver vein type is much more faint, rather brown. Dark brown sphalerite of skarn type is considered to be a later stage product of the phase ii, but similar sphalerite of vein type deposit is regarded to be early stage product of the phase i. Sphalerite of the phase i of Senju-honko, Ikuno mine is associated with kesterite and sakuraiite taking micrographic and polysynthetic textures. Sphalerite dot and skerton star are common, especially in chalcopyrite of polymetallic vein type ore and porphyry copper type ore.

Galena is scant in comparision with sphalerite. It appears in later stage of the phase i ore and is frequently associated with Bi and Ag minerals at Nanten-hi, Ikuno mine and at Gochaku-hi, Tada mine.

Arsenopyrite occurs in early stage in all the ore deposits, especially it is abundant in ores of porphyry copper, arsenic bearing polymetallic vein and pyrrhotite bearing polymetallic vein types. Arsenopyrite from Dainichi and Akenobe mine is generally replaced by chalcopyrite (Pl. 5–1). Arsenopyrite from Kawakami mine is euhedral prismatic and it attains to about 5 mm at a maximum and about 2 mm in a mean size (Pl. 1–2). Cobalt bearing arsenopyrite was observed in the phase ii ore from Ikuno mine.

Pyrite is common in all the deposits and it shows such forms and habits as euhedral cubic, octahedron, pentagonal dodecahedron and subhedral, and the modes of occurrence are dissemination and massive aggregation.

Pyrrhotite occurs in most deposits of skarn type of the Myoken, and in the polymetallic veins of Ikuno, Akenobe, Dainichi, Kabasaka, Kuromi, Unoto and Akamatsu mines. Occurrence of pyrrhotite in these mines is very similar to each other, which is associated with fine-grained pyrite, arsenopyrite, chalcopyrite and sphalerite in the chlorite-copper phase i. Pyrrhotite from zone II of Ikuno and Akenobe mines can be distinguished to hexagonal and monoclinic poly-types, and that from zone III of Dainichi, Kabasaka and from zone E of Unoto mine is only monoclinic poly-type.

Tetrahedrite is anhedral, and its occurrence is very little. This is found in ores from Senju-hon-pi, Senjumae-hi of Ikuno mine and from some veins of Akenobe mine.

Tennantite occurs in the phase i ore from Hideshige mine and in the phases i and ii ores from the fourth level, Senjumae-hi, Ikuno mine.

Bismuthinite and native bismuth are frequently found in all the ore deposits of the district, especially in the phase ii ore from Tenju-hi and Nanten-hi (Pl. 5–5). It forms a big crystal, about 5 mm in maximum size and it occurs associating with cassiterite in the phase ii ore.

Ikunolite is found associating with huebnerite and cassiterite of the phase ii ore from Yonmyaku-hi, Akenobe mine (Pl. 5–6) and from Senjumae-hi of Ikuno mine. It is creamy white and it shows moderate to strong anisotropism. Ikunolite from Senjumae-hi was described by KATO (1959).

Argentite is generally associated with sulphide minerals in ores from polymetallic vein and gold-silver vein types and it is found in ores from Nanten-hi, Ikuno mine and Koei-hi, Akenobe mine and from Aokura, Omidani and Tada mines.

Matildite was described as silver mineral in ores of vein type and it is found associating with tin sulphides, chalcopyrite and sphalerite in ore from Nanten-hi, Tenju-hi and Kinsei-hi, Ikuno mine (TANAKA, MORI and SASAKI, 1971).

Pyrargyrite, proustite and stephanite described by TANAKA, MORI and SASAKI (1971) belong to the phase ii which is found in ore from Sakura-hi, Hokuto-hi, Koei-hi, Nishirokugo-hi and other veins.

Cobaltite is found associating with chalcopyrite from amphibole skarn phase ii of Chigusa mine and it is also known in ore from Tenju-hi, Ikuno mine.

Molybdenite is recognized in disseminated copper ore from Ariga mine and in quartz gangue of the phase ii ore associating with cassiterite and ferberite at Eisei-hi of Akenobe mine as a clot aggregation and in granophyre of Ueda mine as molybdenite veinlet (Pl. 6–3).

Tin sulphide minerals have been described by YAMAGUCHI (1939) that the tin sulphide minerals distributed in wide area from 9th level to 22nd level of Kanagase area of Ikuno mine. Association of tin minerals has been well known in the ores from the wide area, e.g. from tin-tungsten bearing polymetallic vein of Ikuno and Akenobe mines, from gold-silver vein of Omidani, Aokura and Tada mines and from pyrrhotite bearing polymetallic vein of Kabasaka mine (KATO and SHINOHARA, 1968; KATO and HUJIKI, 1969; KATO, 1974; LEE, TAKENOUCHI and IMAI, 1974). Tin sulphide minerals were observed at Senjuhonko level to 35th level of Ikuno mine and also in areas of Otohime-hi, Yonmyaku-hi, Eisei-hi and Ryusei-hi of Akenobe mine through this investigation. Tin minerals are subordinate in general, but these concentrate in the phase ii ore from Ikuno and Akenobe tin-tungsten bearing polymetallic vein. Isostannite, Hexastannite, normal stannite, stannoidite, mawsonite, kesterite and indium stannite are well recognized in association with cassiterite, huebnerite and other sulphide minerals. Although tin sulphide minerals as well as cassiterite mainly concentrate in the phase ii ores from Ikuno, Akenobe, Kabasaka and Tada mines, some tin minerals as stannite and sakuraiite of Senjuhon-pi and cassiterite of Kinsei-hi of Ikuno mine are also recognized in association with chalcopyrite and sphalerite of the phase i ore. Tin sulphide minerals show characteristic assemblages in each mineralized area as follows: bornite-stannoidite-stannite-chalcopyrite, mawsonite-stannoidite-chalcopyrite-pyrite and bornite-stannoidite-mawsonite-pyrite at Akenobe mine; rouquesite - sakuraiite - stannite, bornite - stannoidite-stannite-chalcopyrite and stannoidite-stannite-chalcopyrite at Ikuno mine; bornite-mawsonite-stannoidite, mawsonite-stannoidite-chalcopyrite-pyrite and bornite-stannoidite-pyrite at Tada mine.

Isostannite is associated with indium stannite forming polysynthetic twin and micrographic texture in the phase i ore of Senjuhon-pi on Tsudo level, Ikuno mine. It is yellowish olive green and isotropic and is similar to stannite II described by IGARASHI (1963) and RAMDOHR (1958). It was estimated to be α–stannite by MOH (1975).

Normal stannite which is called β–stannite by MOH (1975) is similar to isostannite in colour, whereas it shows weak anisotropism, and it may be tetrastannite. It associates with isostannite and indium stannite in the phase i ore from Senjuhon-pi on Tsudo level, Ikuno mine.

Hexastannite is brownish, distinctively anisotropic and it is found in the phase ii ore from Otohime-hi (Pl. 5–8), Eisei-hi of Akenobe, Nanten-hi (Pl. 5–5), Kinsei-hi, Senjuhon-pi of Ikuno and Gochaku-hi of Tada mines. It is said that the hexastannite mineralogically coincides with stannoidite by RAMDOHR (1975) and LEE, TAKENOUCHI and IMAI (1974).

Stannoidite is violet to brownish in pleochroism, distinctively anisotropic and it occurs zonally in association with cassiterite-bornite, stannoidite-mawsonite-chalcopyrite in phase ii ores from Otohime-hi, Kosei-hi, Eisei-hi Yonmyaku-hi, Ryusei-hi, Hakugin-hi, Nihonmatsu-hi of Akenobe mine, Senju-hi, Nanten-hi (Pl. 5–5), Oju-hi, Ryokuju-hi, Senjuhon-pi, Kinsei-hi of Ikuno mine and Gochaku-hi (Pl. 6–5, –6) of Tada mine.

Mawsonite is brownish violet, strong pleochroic and anisotropic, forming mozaic aggregation (Pl. 6–7) and it zonally arranges outer side of cassiterite and stannoidite (Pl. 6–6). That is recognized in the phase ii ore from Gochaku-hi of Tada mine, whereas other mowsonite has been found in the ores from Otohime-hi, Kosei-hi, Ryusei-hi of Akenobe mine and Senjuhon-pi, Kinsei-hi from 29th to 35th levels at Kanagase area of Ikuno mine. This mineral was already described by KATO and FUJIKI (1969).

Sakuraiite occurring in Senjuhon-pi, No. 19 Honko level, Ikuno mine is light gray, and it associates showing a micrographic texture with zincian stannite-sakuraiite in sphalerite of the phase i ore.

Rouquesite is light gray and it forms a mylmekitic texture in chalcopyrite and it occurs in association with cassiterite-huebnerite-wurtzite - chalcopyrite - sphalerite - magnetite-native bismuth in the phase ii ore from Eisei-hi, 8th level, Akenobe mine (KATO and SHINOHARA, 1968).

Cassiterite is common tin mineral in ore from tin bearing vein. From the mode of occurrence, cassiterite is distinguished into two stages. One is of the phase i and it is associated with tiny chlorite, which is inserted by chalcopyrite stringer of the phase i. This feature is observed in Kinsei-hi, 35th level, Ikuno mine (Pl. 4–7). Others commonly occur in association with ferberite-scheelite of the phase ii ore at Ikunomine (Pl. 4–8), Akenobe (Pl. 2–2, 3, 5–6, –7, Table 12) and Tada mines, and these take euhedral granular (Pl. 5–6, –7) and metacolloidal (Pl. 6–1, KATO, 1917) forms. Cassiterite from Gochaku-hi of Tada mine is prismatic, about 2 mm (Pl. 6–7), and it forms reaction rim of tin sulphides such as stannite, stannoidite and mawsonite between chalcopyrite and cassiterite (Pl. 6–7).

Table 12 X ray powder diffraction data of cassiterite

1		2		3	
d	I/I_0	d	I/I_0	d	I/I_0
3.70	3	3.70	3		
3.34	10	3.34	10	3.36	8
2.92	2	2.92	2		
2.64	7	2.63	5	2.64	7
2.36	1/2	2.36	2	2.37	3
2.30	1	2.30	1/5	2.30	1/2
1.95	2	1.95	1		
1.852	1	1.850	1/2		
1.761	6	1.760	4	1.762	10
1.673	2	1.671	2	1.672	4
1.590	1	1.590	1/2	1.590	2
1.564	1/2	1.564	1/2		
1.496	2	1.495	1	1.497	4
1.437	2	1.436	1	1.437	3
1.414	2	1.412	1	1.412	5

1. Cassiterite, Ryusei-hi 4 level, Akenobe mine.
2. Cassiterite, 30 level, no. 4, Kaneuchi mine.
3. Cassiterite, 226, BERRY and THOMPSON (1962).

Huebnerite is found at shallow level of tin-tungsten bearing polymetallic vein, and the crystal from Yonmyaku-hi, Akenobe mine is big, attaining to about 7 cm in size (Table 13). It is steel brown, semitransparent, dark red in internal colour and platy in form. Sometimes hubnerite and ferberite are replaced by scheelite remaining it pseudomorph (Pl. 4–8, 5–6).

Ferberite is found in the phase ii ore of tin-tungsten bearing polymetallic vein of Ikuno and Akenobe mines. It is steel black, untransparent and thin platy in form (Pl. 5–7).

Scheelite is from pale yellowish brown to colourless in colour and it occurs taking sub-

Table 13 X ray powder diffraction data of huebnerite and cassiterite

1		2		3		4		5	
d	I/I_0	d	I/I_0	d	I/I_0	d	I/I_0	d	I/I_0
3.67	w	3.68	4						
3.34	vs							3.36	8
3.08	m	2.99	10	2.96	10	2.94	2		
2.91	w	2.95	9	2.94	10	2.91	10		
2.78	w	2.87	3	2.85	3	2.83	2		
2.63	vs							2.64	7
2.49	w	2.49	7	2.48	7	2.45	5		
2.45	m	2.41	2	2.39	2	2.41	1/2		
2.36	s						2	2.37	3
2.30	w	2.23	1	2.22	1	2.35	2	2.30	1/2
		2.20	4	2.19	3	2.18	4		
2.05	s	2.05	1	2.05	1/2	2.04	2		
1.990	m	2.02	1	2.03	1/2				
		1.917	1	1.911	1/2	1.922	2		
1.818	w	1.843	2	1.835	2	1.813	3		
1.760	s	1.779	6	1.771	4	1.757	3	1.762	10
		1.741	4	1.737	1	1.730	1		

1. huebnerite and cassiterite, Yon-myaku 6th level, Akenobe mine.
2. huebnerite, 287, Berry and Thompson (1962).
3. wolframite, 288, Berry and Thompson (1962).
4. ferberite, 289, Berry and Thompson (1962).
5. cassiterite, 226, Berry and Thompson (1962).

hedral form between quartz and cassiterite grains (Pl. 4–8, 5–6), euhedral fine crystal in vugh or pseudomorph of huebnerite and ferberite in the phase ii ore.

Hematite, which is micaceous, platy and red powder, occurs in skarn ore of Asahi and Chigusa mines, in disseminated ore of Arao mine and in the phase ii ore of vein type. Hematite from Chigusa, Arao, Ikuno and Akenobe mines have been changed to magnetite, but remained its pseudomorph (Pl. 4–1, –4).

Magnetite is found in the most of ore deposits. Only one from Ichinomiya mine associating with garnet skarn is euhedral dodecahedron form (Pl. 1–1), whereas the most of magnetite occurs with pseudomorph taking on platy habit after hematite. Platy magnetite associates with amphibole, epidote, chlorite and quartz in skarn phase ii ore from Chigusa mine (Pl. 4–1), and with sericite, quartz and sulphide minerals in the phase ii ores of porphyry copper and in vein type of Arao (Pl. 4–4) and Akenobe mines, and frequently it has been replaced by chalcopyrite.

Rutile is dark gray in colour and is rounded in shape. Twinning is observed. It is restrictedly found in ore of porphyry copper type.

Barite is comparatively rare, and it occurs in Kinsei-hi of Ikuno mine (Noma, 1952).

Native gold is frequently found in sulphide ore from Ikuno and Akenobe mines, especially in silver black ore, in fluorite and quartz of the phase ii ores. Some tiny grains of native gold are found in the phase ii cassiterite-ferberite-native bismuth ore of Nanten-hi, 9th level, Ikuno mine. Today, it is able to see the native gold at the outcrop of Taiju-hi quartz vein.

Native bismuth is conspicuous in the phase ii ore of polymetallic vein, especially in Tenju-hi, Nanten-hi (Pl. 5–5) and Ryokuju-hi of Ikuno mine. In sphalerite of the phase ii ore of Senjuhon-pi, Honko level, euhedral prismatic native bismuth associates with cassiterite. Besides, it is also found in Kanitani-hi, Akenobe mine, in Senjuhon-pi 21st level, Ikuno mine and in ore of Kawakami and Takumi mines.

Secondary minerals as native silver, native copper, native arsenic, azurite, bornite, chalcocite and malachite are found in supergene zone of mineralized area. Azurite, chalcocite, bornite and cuprite grows in the secondary oxidized zone of porphyry copper type of Arao mine (Pl. 4–5, –6). In the tin-tungsten bearing polymetallic vein type at Akenobe mine, in Senjuhon-pi, Hokuto-hi of Ikuno mine and in Hyotan-hi of Tada mine, native silver, native copper, native arsenic, azurite and chalcocite are also found.

6. Concentration Processes of Metallic Components

As mentioned previously, the metal content of ore deposits are differently concentrated in each mineralized zone. The concentration is shown quantitively in Figure 2. I_1 skarn subzone mainly includes iron metal as Fe_3O_4, accompanying minor $CuFeS_2$, ZnS and PbS. Metal components of porphyry copper subzone are $CuFeS_2$ and FeS_2, accompanied by minor Ag_2S, ZnS, PbS, $AsFeS_2$, Bi_2S_3, MoS_2, Fe_2O_3 and TiO_2. II_{1-i} is the phase i subzone of tin-tungsten bearing polymetallic vein type and its main components are $CuFeS_2$, ZnS and PbS, accompanied by minor Sn, W, Bi, As and In oxide or sulphide minerals. II_{1-ii} is the Sn–W phase ii subzone of the same vein type and it is mainly composed of SnO_2, $FeMnWO_4$ and accompanies minor Ag, As, Cu, Zn, Pb, Mo and Bi sulphide minerals. II_2 is the phase ii and iii subzones of the same vein and gold-silver vein types, and it is mainly composed of Ag minerals accompanied by minor Cu, Zn, Pb, Bi and Sn sulphide minerals. III is pyrrhotite bearing polymetallic vein and its main component is FeS, $CuFeS_2$, ZnS and PbS, and it is associated with minor amounts of SnO_2 and MoS_2. The deposits of the east zone show a mixed characteristic of skarn deposit, polymetallic vein and tin bearing gold-silver vein, but its metal content is low in comparision to that in the west zone.

Metal contents and mineral assemblages of I, II, III and E zones appear to be related to distance and position from the central plutonic mass. Local characteristics on individual deposits might have been controlled by the tectonic fractures in each block and by the thermal gradients from plutonics. Subzonal arrangements of Cu–Zn, Sn–W and Au–Ag mineralization of Akenobe, Akagane, Omidani and Ikuno mines, in particular, prove relation of each ore phase clear. Besides, vertical zonation is also recognized in Ryusei-hi as model, and Figure 7 well illustrates the zonal distribution of Cu, Zn, Sn and W by metal grade about Ryusei-hi, Senjuhon-pi and Kinsei-hi.

Discontineous boundary between the phase i Cu–Zn and phase ii Sn–W ores is found not only in the vein of Ikuno and Akenobe mines but in all the other deposits including skarn and gold-silver vein types. This observation led most of the previous works (Saigusa, 1958; Abe, 1963; Muraoka and Ikeda, 1968; Ikeda, 1970; Tanaka, Mori and Sasaki, 1971; Nakamura *et al.*, 1976) to interprete the Ikuno-Akenobe type mineralization performed through polyascending processes of the ore solution.

Figure 7 is the metal grade of the polymetallic vein converted to percentage, the metal ratio are vertically changed as best shown on the Ryusei-hi example. The original assay value considered with physical dimension $t \cdot \rho^{-1} \cdot m^{-1}$ means tons/specific gravity/meter quotient. The number of $\rho \cdot m$ product will be constant, if $\rho = 3.5$ and one space between levels is assumed about 30 m. Numerical values computed by the above-described physical dimension are able to compare with the metal contents on each level. Regular vertical variation of metal contents is not found on the diagram of Figure 8. Most of the metals concentrate on restricted level at so-called bonanza and remarkably decrease toward the upper and lower sides from the bonanza. Further, the horizontal and vertical variations of metal grade among Cu, Zn, Pb and Sn-W zoning in the tin-tungsten bearing ore deposits do not imply paradoxically the characters made up by uncontineous polyascendant ore solution, because these are wholly rather gradual and contineous as shown on the variation diagram of Ryusei-hi, Akenobe mine (Fig. 7). These facts indicate that the elements as Cu–Zn and Sn–W of the phases i and ii were derived from the same solution, and it is conceivable that concentration of element is realized in a similar site during the transportation of the same ore solution. So it is more reasonable that the transportation of metal elements was rather monoascendant and that ore of the phase ii fractionally precipitated from the original solution which formed ore of the phase i during osmotic action. The discontinuity between the phases i and ii can be considered to have formed related to osmotic and fractional precipitation from original ore solution and to tectonic break during precipitation process of ore solution.

This tectonic movement has an important bearing on the discontinuity. The phase ii Sn, Au and Ag metals are often recognized to be concentrated at the crossing part of NE fault over vein swarm trending NW; i.e., Setani fault and Yonmyaku-hi vein swarm of Akenobe mine (Muraoka and Ikeda, 1968; Takimoto, 1968; Nakamura *et al.*, 1976); Tenju fault and Tasei-hi; Sanjugo fault and Senjuhon-pi; Nendo fault and Koei-hi, Sakura-hi of Ikuno mine. Some cassiterite are found in early stage of the phase i mineralization. Sakuraiite and stannite association in later stage of the same phase indicates that tin mineralization began from early stage of the phase i mineralization. Thus ore solution of the phase ii mineralization could have been remnant of the phase i Cu–Pb–Zn sulphide mineralization concentrating tin, bismuth, gold and silver during the evolution of the ore solution; then the host rocks were block-faulted. This kind of tectonic setting would give rise to the discontinuity observed between the ores of phases i and ii.

Geochemical consideration of these mineralizations will be discussed in the following report from the view point of solubility-temperature relation of hydrothermal Cu, Zn, Pb, Sn chloride and fluoride complexes model.

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兵庫県中央地域の鉱床と鉱石形成過程
—西南日本内帯白亜紀末-第三紀初期の鉱化作用(2)—

成田英吉・山田敬一

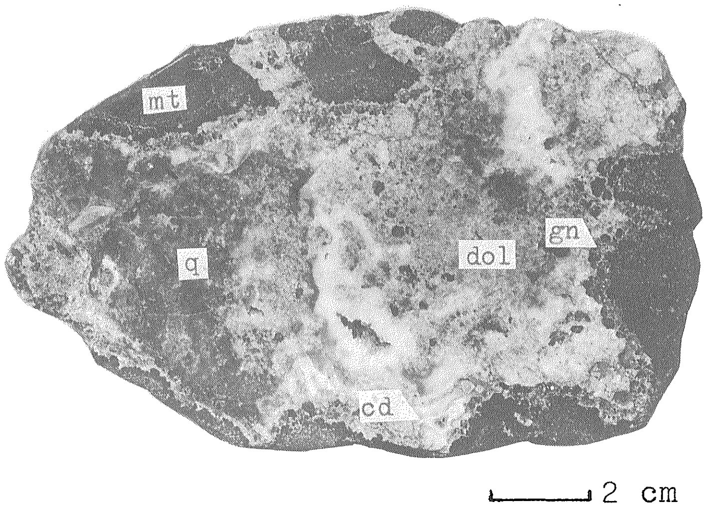
要　旨

兵庫県中央地域の鉱化作用は白亜紀の深成岩を中心としてゼノサーマル型の鉱床を形成するが，西部地区の鉱床は内側から斑岩銅鉱床型・スカルン型・含錫－タングステン多金属鉱脈型・金銀鉱脈型・含磁硫鉄鉱多金属鉱脈型鉱床の帯状配列を形成する．これらの鉱床は，また，それぞれ異なった鉱物組合せの鉱石相を作っており，地域的な鉱石の帯状配列を形成する．

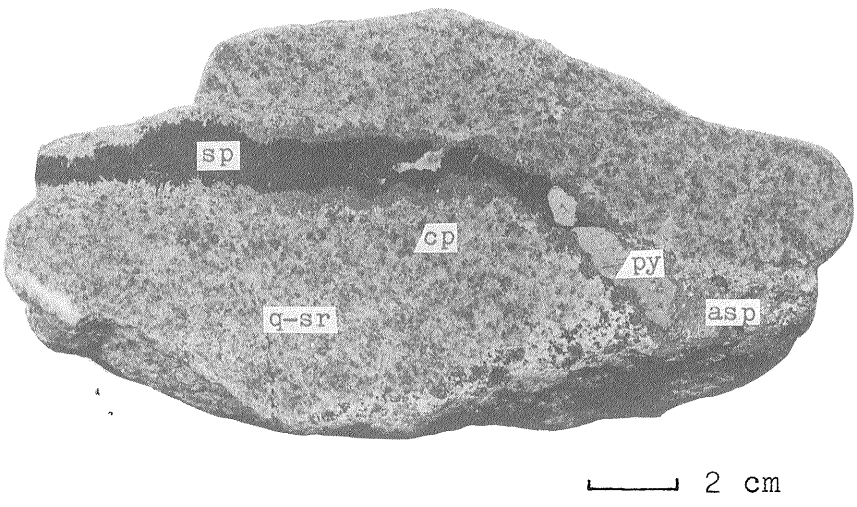
鉱石相による地域的な帯状配列の代表的な例は生野・明延鉱山の含錫－タングステン多金属鉱脈型鉱床で，これまでは鉱石相間の不調和性から polyascendent な鉱化作用と考えられてきた．しかし，鉱石相間の不調和性にも拘らず各金属元素の濃集過程の上・下の変化は同一の傾向性をしめし，異なった鉱石相の形成期の違いは同一鉱液中の各元素の浸透係数に依存して分別的に形成されたものである．また，鉱石相間の不調和性は，鉱石形成期をとおして作用したブロック運動によるものと説明した．

これらの鉱化作用の地化学的考察は次の報告で検討する．

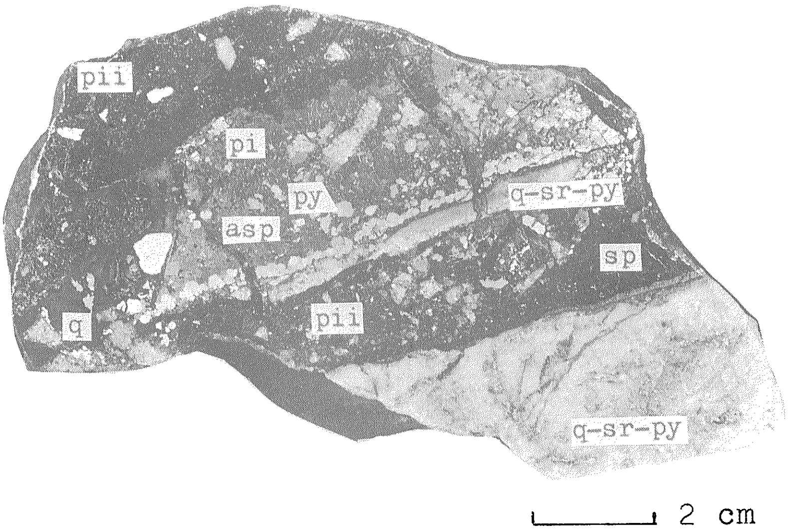
(受付：1979年12月3日；受理：1980年7月11日)



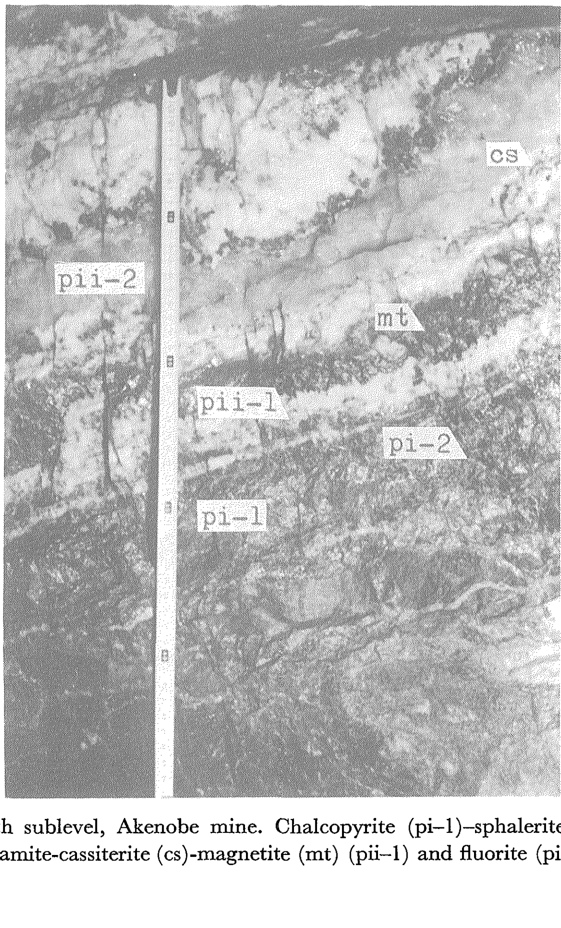
1. Magnetite skarn ore, Ichinomiya mine. Magnetite (mt)–garnet (gn) phase i crossed by dolomite (dol)–quartz (q). Chalcedonic quartz (cd) is in vugh of the latest stage.



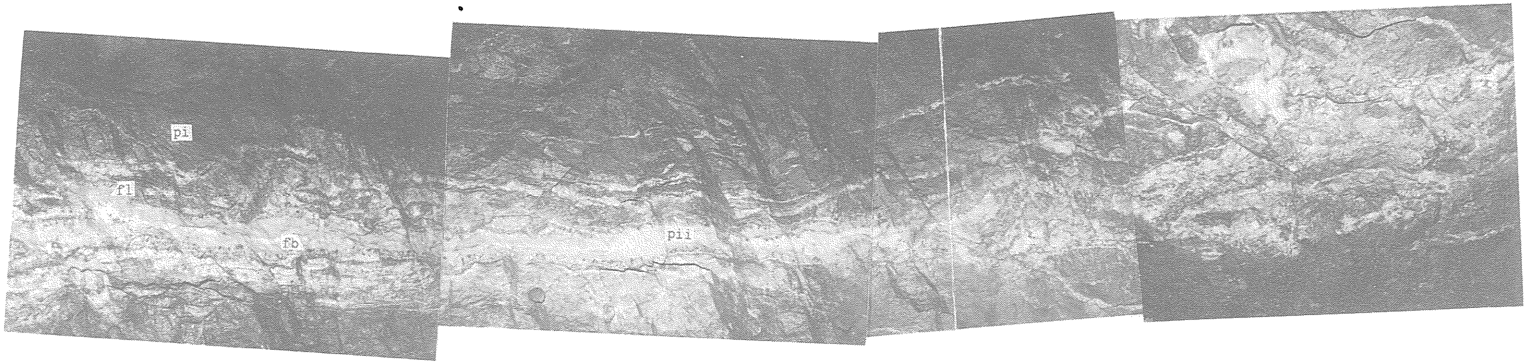
2. Disseminated copper ore, Kawakami mine. Arsenopyrite (asp)–sphalerite (sp)–pyrite (py) veinlet in phyllic rock (q–sr) disseminated by chalcopyrite (cp).



1. As–Zn ore, Hideshige mine. Quartz-sericite-pyrite rock (q–sr–py) and arsenopyrite (asp)–pyrite (py) phase i (pi) brecciated by sphalerite (sp)–pyrite (py)–quartz (q) phase ii (pii).



2. Eisei-hi, 10th sublevel, Akenobe mine. Chalcopyrite (pi–1)–sphalerite (pi–2) and quartz-wolframite-cassiterite (cs)-magnetite (mt) (pii–1) and fluorite (pii–2) of phase ii.

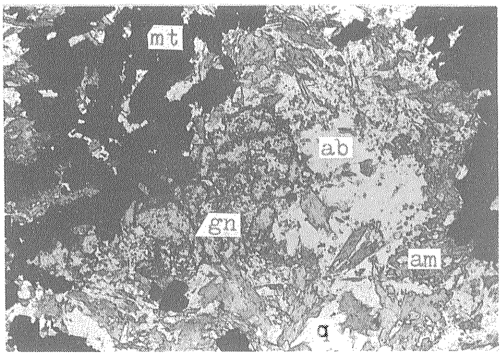


Eisei-hi, 10th sublevel, Akenobe mine. Chalcopyrite phase i (pi), quartz-ferberite (fb)-cassiterite, fluorite (fl) and quartz-ferberite-cassiterite phase ii (pii).

Plate 4

1. Magnetite skarn ore, Chigusa mine. ×65, -nicol, thin section. Magnetite (mt) after hematite-green amphibole (am)-albite (ab)-quartz (q) phase ii ore replacing garnet (gn) phase i.
2. Garnet skarn, Asahi mine. ×65, -nicol, thin section. Hematite (ht)-chlorite (cl)-calcite (c)-sphalerite (sp)-quartz (q) phase ii ore replacing euhedral garnet (gn) phase i.
3. Dissemination copper ore, Arao mine. ×65. -nicol, thin section. Potassic phase i rock associating with orthoclase (or)-sericite (sr)-quartz (q)-chalcopyrite (cp)-pyrite (op).
4. Dissemination copper ore, Arao mine. ×65, -nicol, polished section. Magnetite (mt) after hematite-chalcopyrite (cp) phase ii ore.
5. Oxidation copper ore, Arao mine. ×65, -nicol, polished section. Chalcopyrite (cp) replaced by azurite (az).
6. Oxidation copper ore, Arao mine. ×80, -nicol, polished section. Colloform malachite (m) and cubic cuprite (cpr).
7. Copper phase i ore, Kinsei-hi, 35th level, Ikuno mine. ×50, -nicol, thin section. Cassiterite (cs) of early stage replaced and penetrated by chalcopyrite (cp), and associating with chlorite (cl).
8. Sn–W contamination ore, Kinsei-hi, 31st level, Ikuno mine. ×100, -nicol, thin section. Quartz (q)-cassiterite (cs)-scheelite (sc)-quartz phase ii ore contaminating chlorite(cl) phase i.

1


mt
ab
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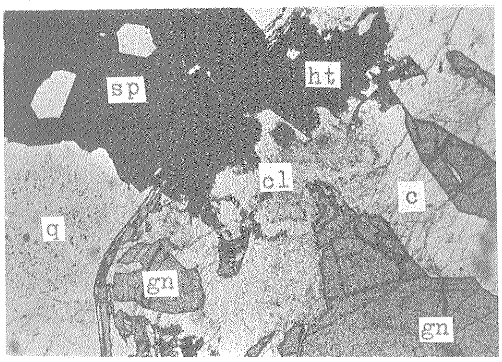
am
q

2


sp
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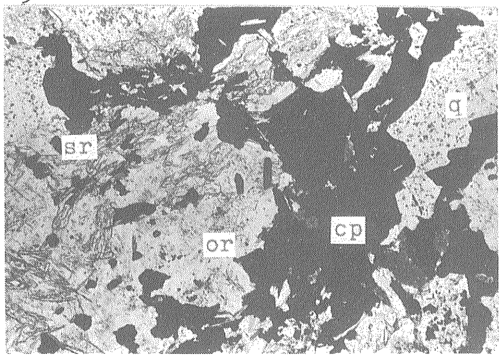
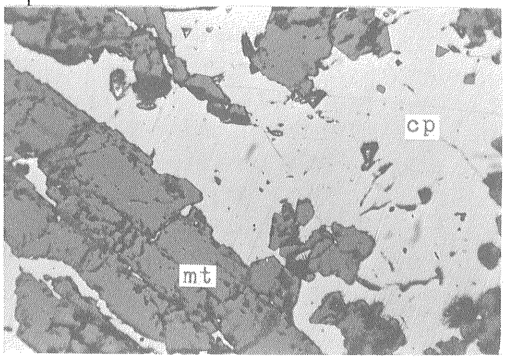
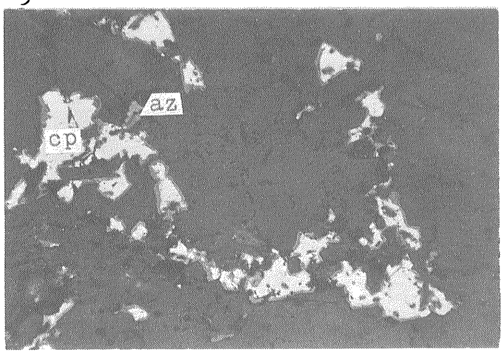
3


q
sr
or
cp

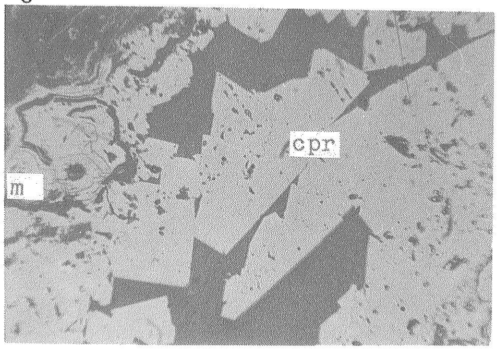
4


cp
mt

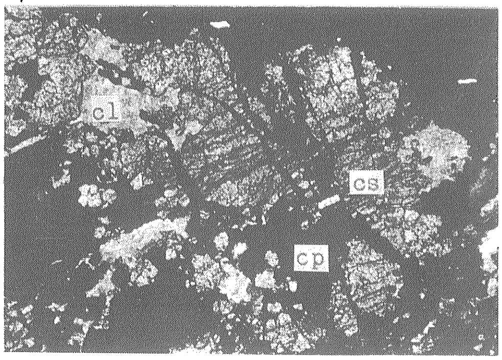
5


az
cp

6


cpr
m

7


cl
cs
cp

8

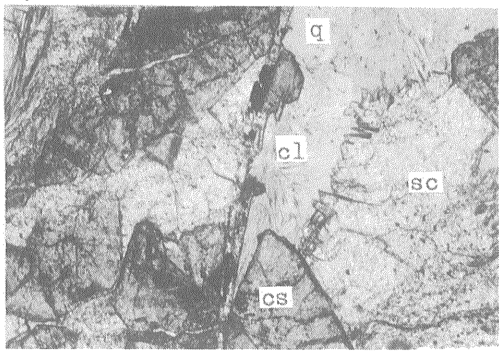
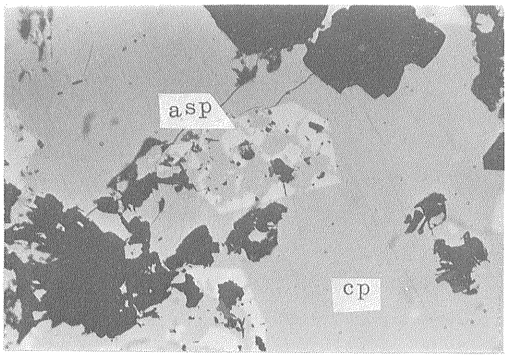

q
cl
sc
cs

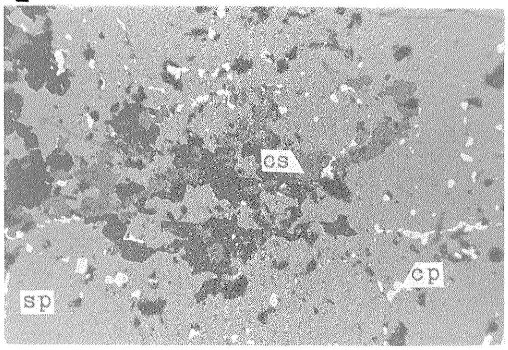
Plate 5

1. Copper phase i ore, Kinsei-hi, 32nd level, Ikuno mine. ×65, -nicol, polished section. Arsenopyrite (asp) replaced by chalcopyrite (cp) phase i.
2. Zinc phase i ore, Kinsei-hi, 35th level, Ikuno mine. ×65, -nicol, polished section. Cassiterite (cs)-sphalerite (sp)-chalcopyrite (cp) phase i.
3. Cu–Zn phase i ore, Kinsei-hi, 34th level, Ikuno mine. ×65, -nicol, polished section. Skeletal sphalerite (sp) associating with chalcopyrite (cp) replaced by galena (gn).
4. Sphalerite (sp), stannite (stn) and chalcopyrite (cp) in phase ii ore, Kinsei-hi, out-crop, Ikuno mine. ×65, -nicol, polished section.
5. Sn–Bi phase ii ore, Nanten-hi, 9th level, Ikuno mine. ×65, -nicol, polished section. Cassiterite (cs), native bismuth (bi) and stannoidite (std).
6. Sn–W phase ii ore, Yonmyaku-hi, 6th level, Akenobe mine. ×65, -nicol, polished section. Huebnerite (hb) replaced by scheelite (sc), cassiterite (cs) and Ikunolite (ik).
7. Sn–W phase ii ore, Eisei-hi, 10th level, Akenobe mine. ×65, -nicol, polished section. Platy ferberite (fb) and grannular cassiterite (cs).
8. Cu–Sn phase ii ore, Eisei-hi, 10th level, Akenobe mine. ×65, -nicol, polished section. Hexastannite (sth) in chalcopyrite (cp).

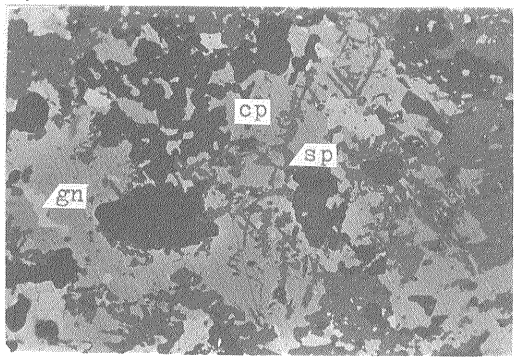
1


asp
cp

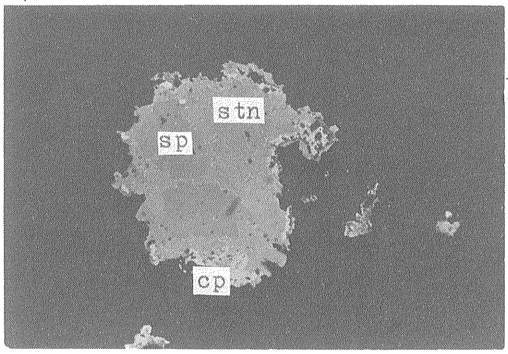
2


cs
cp
sp

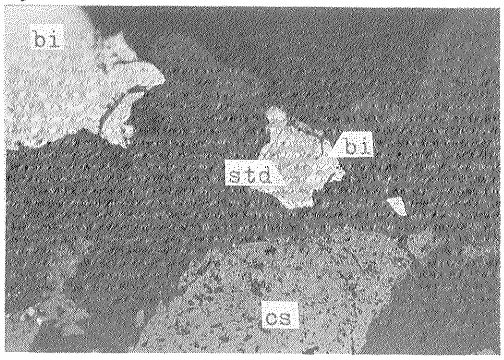
3


cp
sp
gn

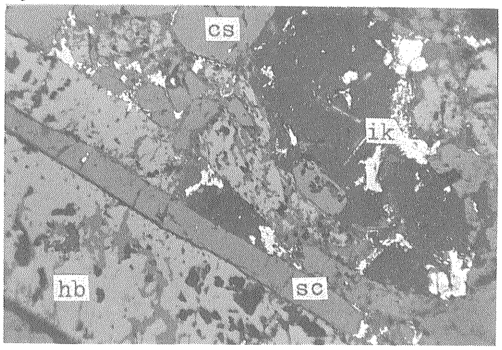
4


stn
sp
cp

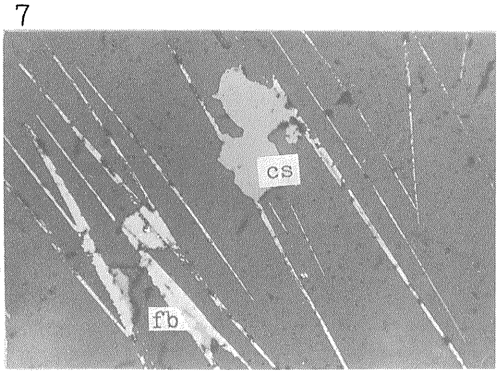
5


bi
bi
std
cs

6


cs
ik
hb
sc

7


cs
fb

8

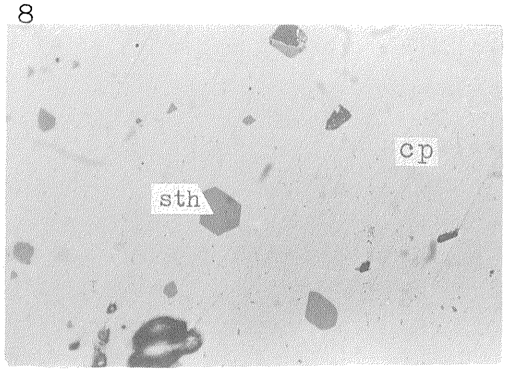
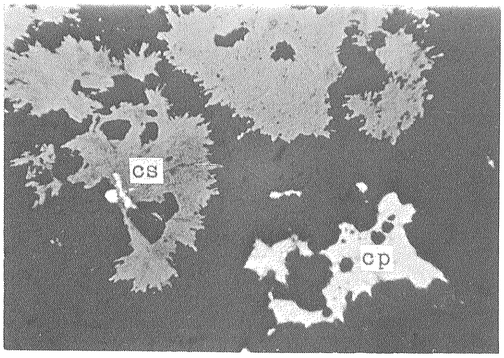

cp
sth

Plate 6

1. Sn phase ii ore, Ryusei-hi, 2nd level, Akenobe mine. ×65, -nicol, polished section. Metacolloidal cassiterite (cs) and chalcopyrite (cp).
2. Zn–Sn phase ii ore, Nihonmatsu-hi, 6th level, Akenobe mine. ×65, -nicol, polished section. Euhedral cassiterite (cs) and dotting chalcopyrite (cp) in sphalerite (sp).
3. Molybdenite in granophyre, Ueda mine. ×65, -nicol, polished section.
4. Pyrrhotite-copper ore, Dainichi mine. ×120, -nicol, polished section. Pyrrhotite (po), chalcopyrite (cp) and arsenopyrite (asp).
5. Cu–Sn phase ore, Gochaku-hi, 120 m. level, Tada mine. ×65, -nicol, polished section. Galena (gn), chalcopyrite (cp), spharelite (sp) and stannoidite (std).
6. Cu–Sn phase ore, Hyotan-hi, 180 m. level, Tada mine. ×65, -nicol, polished section. Chalcopyrite (cp), bornite (bn), mawsonite (mw) and stannoidite (std).
7. Cu–Sn phase ii ore, Hyotan-hi, 240 m. level, Tada mine. ×65, -nicol, polished section. Mawsonite (mw) and stannoidite (std) replacing cassiterite (cs).
8. Zn phase i ore, Akamatsu mine. ×65, -nicol, polished section. Pyrrhotite (po) and chalcopyrite (cp) taking on exsolution texture in sphalerite (sp).

1



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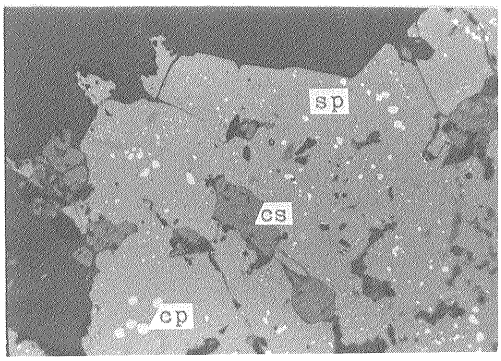

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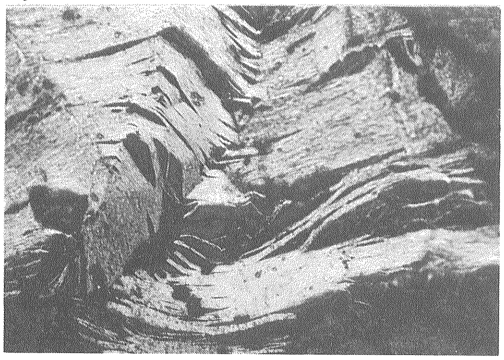

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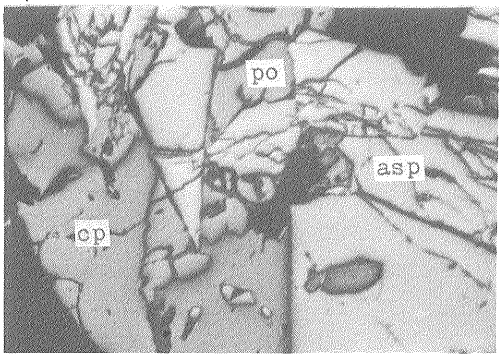

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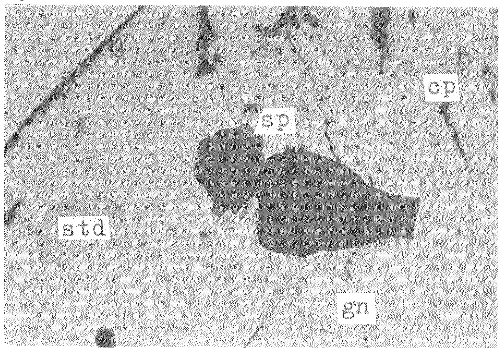

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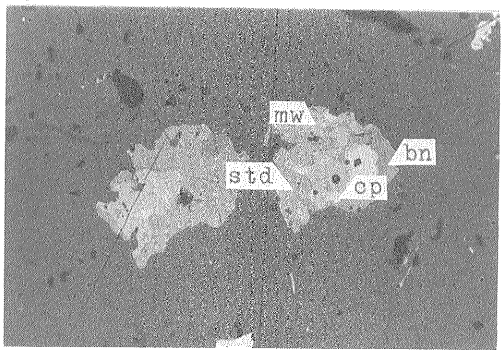

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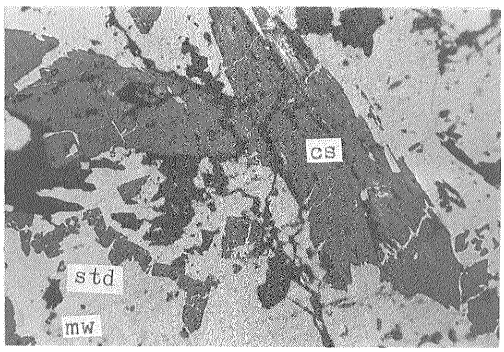

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