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Metallogeny on Gold-Silver in South Korea*

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Abstract: This work is a metallogeny on gold-silver deposits in South Korea based on the close examination of the author's own data and a broad review of existing literature available.

The metallogenic epochs in Korea are temporarily connected with the history of tectonism and igneous activities, and are identified as the Precambrian, Paleozoic, Jurassic to early Cretaceous, late Cretaceous to early Tertiary, and Quaternary epochs, whereas the metallogenic provinces are spatially associated with some of the felsic to intermediate igneous rocks, lacking mineralization related to basic and ultrabasic rocks.

The metallogeny on the gold-silver deposits is mostly related to the granitic rocks intrusives.

Epigenetic gold-silver mineralization in South Korea ranges in metallogenic epochs from Precambrian through Triassic, Jurassic and Cretaceous to Eocene (?), in genetic types from hypothermal through mesothermal and epithermal quartz-sulfide veins to volcanogenic stockworks, with some disseminated types.

Reporting on metallic association from gold without silver, gold-silver, silver-gold, silver without gold, and gold or silver as a by-product from other metallic ores.

The most representative genetic types and metal associations of gold-silver deposits are hydrothermal quartz veins associated with the Daebo and Bulgugsa granitic magmatism.

The most closely associated paragenetic metallic minerals in gold-silver hydrothermal quartz-sulfide vein type deposits are: copper, lead, zinc, pyrite and arsenopyrite.

More than 560 gold-silver mines are plotted in the distribution map grouped within the 10 different metallogenic provinces of South Korea.

Specific mineralizations with related mineral association in both sulfides and gangues observed selected from 18 Korean and 8 Japanese Au-Ag deposits.

The 7 selected individual gold-silver mines representing specific mineralization types are described in this report.

INTRODUCTION

Before World War II, gold has been the main mineral products of Korea reaching up to 30 metric tons of annual output in 1939, although gold mining diminished during the war because most the gold mines were closed down in 1943 by the government's decree in order to divert the manpower and materials to the mining of other minerals more essential to the war effort. However, many gold mines were allowed to continue in operation because most of the Korean output of both lead and copper, which were in critically short supply, came as by-product of gold mining.

After World War II, gold mining in South Korea has long been less active than other mining, e.g. tungsten and anthracite coal, decreasing to 1 to 2 metric tons of its annual production (Fig. 1). The demand of gold,

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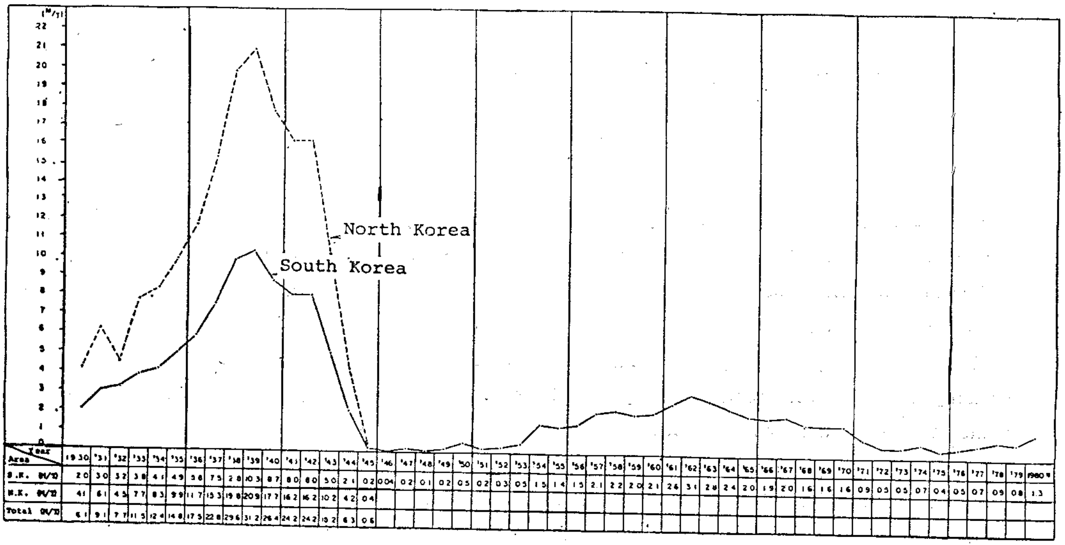

Fig. 1 Time-production relation of gold and silver in Korea.

however, has rapidly increased to about 5 metric tons or more in 1984 as her economy and industries including electronics have developed, resulting in its short domestic supply with 2.5 metric tons of annual output and 2.0 metric tons of imports from foreign sources in 1984 (Ministry of Energy and Resources, 1985). The figures for gold in official statistics, however, may be minimum or partial ones of the real amounts of total transactions.

Except for a few silver mines, silver has been produced mainly as co-product or by-product of gold mines, but by-product from lead-zinc and copper ores at smelters has steadily increased in quantity, as these base metal productions increase. Annual output of silver reached 120 metric tons in 1984 which was a surplus of domestic demand and made an export of 38 metric tons in that year.

DISTRIBUTION

Gold is so widely distributed throughout the country that the common assertion may well be true that gold can be found in every country. This concept of its abundance is a good introductory expression, but detailed examination reveals that the known gold occurrences can be grouped into fairly definite zones and trends, and these in turn reflect some clear relationships to the geological backgrounds.

Gold and silver deposits in South Korea consist of endogenic (lode) and exogenic (placer) formations. Originally, the bulk of gold and silver were extracted from placers and hydrothermal load deposits, and in recent years, the predominant amount of gold and silver has been concentrations obtained as a by-product in the treatment of base metal at smelters, as mentioned above.

Most of the endogenic deposits of gold and silver in Korea are closely related spatially to intrusive masses of the Jurassic and Cretaceous granites to which their genetic relationships are generally attributed. It is also postulated that some gold deposition may have been associated with the formation of the Precambrian granite, but this has not been proven except for a few cases.

Kim, O.J. (1970) presented a metallogenic zoning of gold and silver deposits in South Korea subdividing them into the following two groups. This was done by plotting of a total

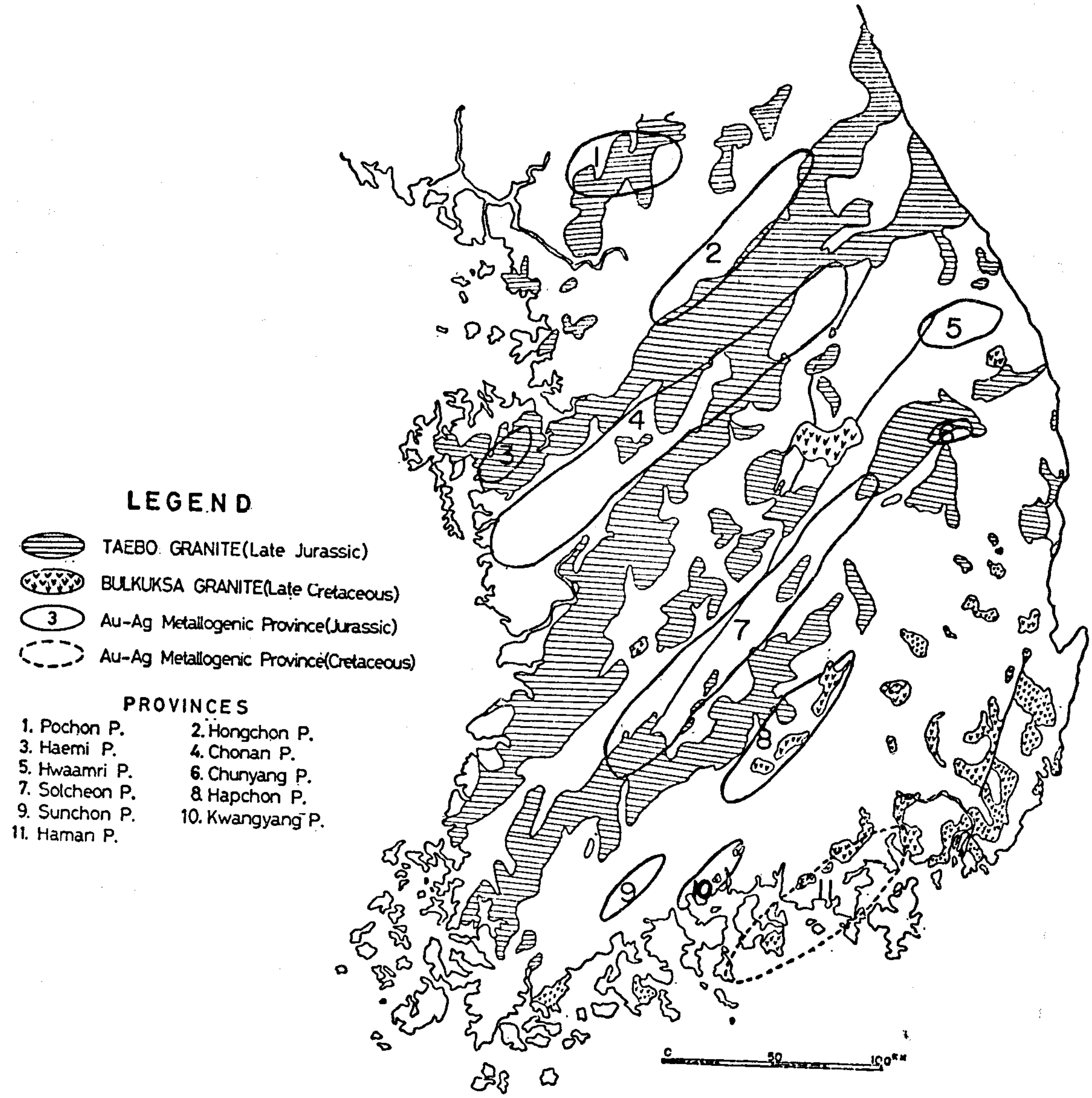

Fig. 2 Distribution of granites and gold-silver metallogenic provinces in South Korea (after Kim, O.J., 1970).

of 233 gold-silver mines data available on a map where the granites of Jurassic and Cretaceous in age are mapped (Fig. 2).

A. The late Jurassic gold-silver provinces

1. Pochon p.
2. Hongchon p.
3. Haemi p.
4. Chonan p.
5. Hwaamri p.
6. Chunyang p.
7. Solcheon p.
8. Hapchon p.
9. Sunchon p.
10. Kwangyang p.

B. The late Cretaceous gold-silver provinces

11. Haman p.

He emphasized in this grouping particularly on the northeast trending tendency for the individual deposits in their distribution, and the majority of gold and silver mineralization in South Korea appears to have related to the Jurassic granitic activity. The Cretaceous granitic intrusives, however, are increasingly found around or within the Jurassic granite terrains as the radiometric isotope age dates of granitic rocks are becoming more available so that some of the Jurassic gold-silver provinces of Kim, O.J. may be replaced by superimposing Cretaceous ones.

In this study, a total of 563 gold-silver mines, (see Fig. 3 for locations) which have some records on test pits, development and production was collected with data available and plotted on a map where two types of granites, the

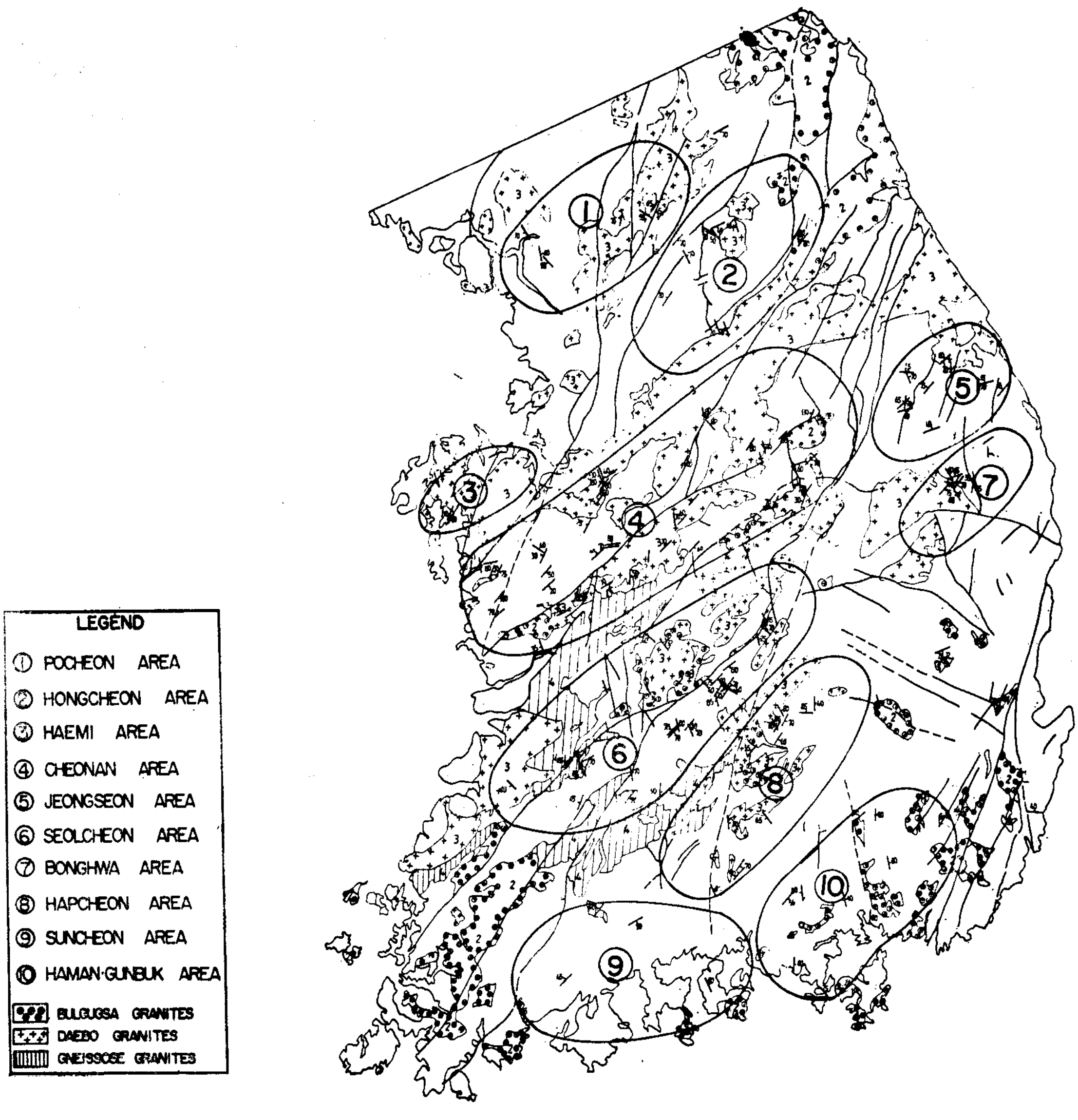

Fig. 4 Metallogenic zonation of gold and silver deposits in South Korea.

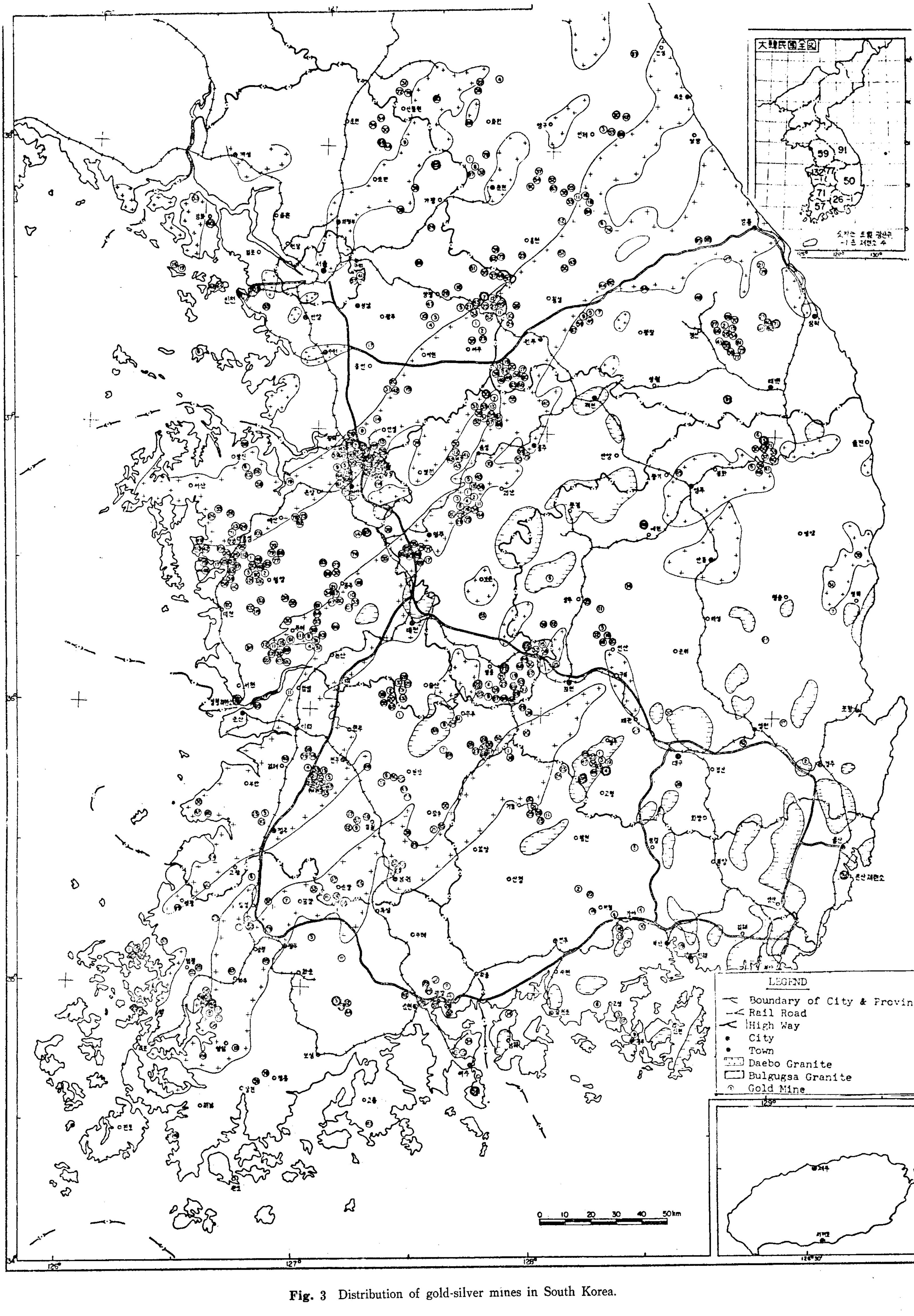

Fig. 3 Distribution of gold-silver mines in South Korea.

Jurassic and Cretaceous, are mapped in Fig. 3, and delineated a total of 10 mineralized zones in Fig. 4. Comparing thus map with the one by Kim, O.J. (1970), the several points to be made are as follows:

1) The distribution pattern of mine clusters appears to be roughly similar to the one by Kim, but several clusters are intermittently localized with in a northeast-trending belt rather than evenly throughout the belt.

2) Besides the northeast-trending mineral belts, some intermittent alignments of ore cluster trending northwest are also evident across the two or more north-east trending mineral belts delineated by Kim.

3) Several masses of Cretaceous granites are identified in my map, which can be checked on the map by Kim the area between the Chonan belt (4) and the Solcheon belt (6).

4) More Cretaceous gold-silver mineralization are identified in my map including the Kwangyang district and the Musan-Naju districts where the Kwangyang and Deogeum mines, respectively, are located.

GENERAL OCCURRENCES

The endogenic gold and silver deposits consist mostly of gold-bearing quartz veins which contain varying amounts of various metal sulfide minerals. As mentioned previously, the gold and silver deposits distribute with in or near the areas of Jurassic and Cretaceous granites. They are hosted in these granites and are also in Precambrian schists and gneisses, Paleozoic metasediments and carbonate rocks, as well as in Mesozoic sedimentary and volcanic rocks. The statistics of host rocks for a total of 190 gold-silver deposits in South Korea are as follows:

1) Jurassic and Cretaceous 73
2) Precambrian granite gneiss 43
3) Precambrian schist and gneiss complex 30
4) Paleozoic metasediments..................... 10
5) Paleozoic carbonate rocks 10
6) Mesozoic to Tertiary porphyries 9
7) Mesozoic sedimentary and volcanic rocks 8
8) Others... 7

Total 190

The above list is modified from Kim, W.J. et al (1982), and it suggests that most of the South Korean gold and silver mineralization belong to Pre-Tertiary metallogeny judging from the fact that gold-silver deposits are hardly found in Tertiary or more younger formations. Early literature dealing with the Korean gold-silver occurrences include many papers and reports, e.g. by Iijima (1916), Ishigaki (1922),

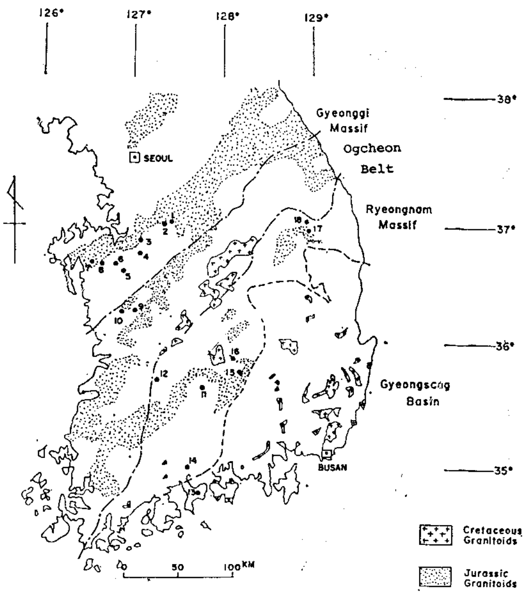

Fig. 5 Location of gold-silver mines in South Korea (after Kaneda et al., 1984).
1 : Mugug(無極) 2 : Geumwang(金旺) 3 : Cheonbo(天寶) 4 : Namchang(南倉) 5 : Samgwang(三光) 6 : Gubong(九峰) 7 : Gyeolseong(結成) 8 : Hwangbo(黃寶) 9 : Daedun(大屯) 10 : Jeonjuil(全州一) 11 : Beonam(蟠岩) 12 : Deukon(德溫) 13 : Sanggeum(上金) 14 : Gwangyang(光陽) 15 : Baekjin(白珍) 16 : Yanghang(梁項) 17 : Dadeuk(多德) 18 : Geumjeong(金井)

Table 1 Ore minerals observed from the Korean Au-Ag deposits.

Ore Deposits	Constituent ore minerals														Wall	rela.	Quartz vein	
	py	cp	apy	sp	gn	tet	po	el	ag	mo	wol	pyra	mya	Ag-sulf etc			strike	dip
1 Mugug	⧻	⧺	⧺	+				−	−	−					gr(J)	gr(J)	N S	90
2 Geumwang	⧻	+	⧻	⧺				−	+	−					gr(J)	gr(J)	N S	70~80W
3 Cheonbo	⧻	+	⧺	+	+			−	−	−					gn(P)	gr(J)		
4 Namchang	⧻	+	⧺	+	⧺			−	−						gn(P)		50~60 E	60~80 N, S
5 Samgwang	⧺	+	⧻	+	⧺			−							gn(P)		40 E	65 S
6 Gubong	⧺	−	+	+	+		⧺	−							gn(P)		50~60 E	30~40 S
7 Gyeolseong	⧺	⧺	⧺	⧺	⧻		+	−		−					gn(P)		N S	60W
8 Hwangbo	⧺		+	−	+			−							gn(P)		10~55 E	50~80 S
9 Daedun	⧺		×					−							sh(P)	Pr(C)		
10 Jeonjuil	⧻	+	×	⧺	⧺			−	−		−				gn(P)	Pr(C)	10~30 E	60~90W
11 Beonam	⧻	+	×							+					gn(P)			
12 Deukon	⧻	+	⧺	⧺	⧺			−	−						ss(C)	gr(C)		
13 Sanggeum	⧻	+	×	+						−					ss(C)	gr(C)		
14 Gwangyang	⧺	⧺	×	+	+			+	−						ss(C)	gr(C?)	network	
15 Baekjin	⧻	+	+	⧻		⧺		+	−	−					gn(P)		40 E	55N
16 Yanghang	⧻	+	×	⧺	+		+	−							gn(P)		40 E	50 S
17 Dadeuk	⧺	⧺	⧺	⧻	⧺		−		−									
18 Geumjeong	⧺	−	+	+	+		⧺	−	−						gn(P)		45W, 80 E	30~60N
Japanese Au-Ag Ore Deposits																		
Konomai	⧻			⧺	⧺	⧺		−	−			−		+	sed(T)	vol(T)		
Chitose	⧺	+		⧺	⧺	⧺		−	−			−	−	+	sed(T)	vol(T)		
Sado	⧺	+		+	+	+		−	−			−	−	+	sed(T)	vol(T)		
Takatama	⧺	−				+		−	−			−		+	sed(T)	rhy(T)		
Mochikoshi	+	+		−	+			−	−			−	−	+	sed(T)	sed(T)		
Kushikino	⧺	+		⧺	+	+		−	−			−	−	+	and(T)	and(T)		
Ooya	+	+	⧻	+	−		⧺	−	−	−					sed (Tr)	gr(J)		
Shimonomoto	+	−	⧺	+	+	−	−								sed(J)	gr(J)		

⧻abundant, ⧺moderate, +little, −rare

py: Pyrite, cp: Chalcopyrite, apy: Arsenopyrite, sp: Sphalerite, gn: Galena, tet: Tetrahedrite, po: Pyrrhotite, el: Electrum, Ag: Argentite, mo: Molybdenite, wol: Wolframite, Pyra: Pyrargyrite, mya: Myrargyrite, Ag-sulf: Ag bearing sulfosalt and etc.

gr(J) : granite (Jurassic age), gn(P) : gneiss (Precambrian age), sh(P) : shale (Precambrian age), Pr(C) : porphyry (Cretaceous age), ss(C) : sand stone (Cretaceous age), sed(T) : sedimentary rocks (Tertiary age), vol(T) : volcanic rocks (Tertiary age), rhy(T) : rhyolite (Tertiary age), and(T) : andesite (Tertiary age). Reproduced from Kaneda et al. (1984). rela.=related igneous rock

Szuki (1926; 1928), Oyama (1929), Otsubo (1934), Mogi (1936), Shiga (1937), and Welhaven (1939).

In most of the vein deposits, the gold and silver are present as free gold, free silver, or electrum, but in some they are hosted in associated metallic sulfide minerals. Yamaguch, (1942) records the interesting observation that the gold occurring in microscopic cracks in pyrite and arsenopyrite is especially common in massive or pyritohedral crystals of pyrite and less common in pyrite crystals of cubic form.

pyrite is present in nearly all the gold-silver-quartz veins, and it associated with varying

Table 2 Observed silicate minerals from the Korean Au-Ag deposits.

Ore Deposits	Constituent Silicate Minerals																		
	qz	Kfd	fd	cc	ank	sid	mus	bt	chl	apt	tour	adrl	koal	mo-nt	bart	pyro	Mn	chce	zeo
1 Mugug	+++			++			++		−							−			
2 Geumwang	+++	+	+	++			+												
3 Cheonbo	+++	++	++	++	++		++		+	−									
4 Namchang	+++	++		++			++		+										
5 Samgwang	+++			++	++	++			−										
6 Gubong	+++		++	++	++		+		−										
7 Gyeolseong	+++			++	++		+		−	−	−								
8 Hwangbo	+++			++	++		+												
9 Daedun	+++						−												
10 Jeonjuil	+++		++	++	++		+										+		
11 Beonam	+++	++					+		+										
12 Deukon	+++		++	++												−			
13 Sanggeum	+++		−	+			+		+										
14 Gwangyang	+++		+	++	++	++	++		+										
15 Baekjin	+++			++					+										
16 Yanghang	+++						++		−										
17 Dadeuk	+++			+			++		+								+		
18 Geumjeong	++	++	+				+++	+		−									
Japanese Au-Ag Ore Deposits																			
Konomai	+++			++			+		++			++	+	+				+++	
Chitose	+++		++	++			++					++	+		−				
Sado	+++		++	+			+		++			++	+	+	+		+	++	
Takatama	+++			+			++		++			++	+	+					
Mochikoshi	+++			++			++		++			++	+	+	+		+	+	+
Kushikino	+++			++			+		++			+	+				−	+	
Ooya	+++			++			+	+	+		−								
Shimonomoto	+++			++			+		++	−	−								

qz: quart, Kfd: K-feldspar, fd: feldspar(albite), cc: calcite, ank: ankerite, sid: siderite, mus: muscovite (or sericite), bt: biotite, chl: chlorite, apt: apatite, tour: tourmaline, adrl: adularia, kaol: kaolinite, mont: montmorillonite, bart: barite, pyro: pyprophyllite, Mn: manganese-bearing minerals, chce: chalcedony, zeo: zeolite, Reproduced from Kaneda et al. (184).

quantities of arsenopyrite, galena, sphalerite, chalcopyrite, and rarely pyrrhotite. In the veins, the gangue is almost entirely quartz, although some of them contain carbonate, fluorite, feldspar, or sericite. The quartz of the vein is generally massive and is milky white to dark in colour or gold-bearing rather than is colourless transparent.

According to the recent study by Kaneda et al. (1984), mineral associations in both sulfides and gangues of a total of 18 gold-silver mines in South Korea (Fig. 5), they examined, are as shown in Table 1 and 2. In Table 1, all of the mines contain pyrite. Most of the mines contain chalcopyrite (16 mines), sphalerite (16 mines), and electrum (15 mines) in addition to pyrite. Remainders contain galena (13 mines), arsenopyrite (12), argentite (9 mines), pyrrhotite (7 mines), molybdenite (6 mines) and wolframite (1 mines) in addition to pyrite and some of the already-mentioned ones. Lacking Au-bearing sulfosalt minerals from the South Korean gold-silver deposits differ from those of Japan.

In Table 2, all of the mines include quartz as a gangue. Most of the mines include muscovite (15 mines), calcite (14 mines), and chlorite (12 mines) in addition to quartz. Remaining mines include ankerite (8 mines), feldspar (albite, 7 mines), K-feldspar (5 mines), siderite (2 mines), apatite (2 mines), tourmaline (2 mines), pyrophyllite (2 mines), manganese minerals (2 mines) and biotite (1 mine) in addition to quartz and some of the already-mentioned ones. Comparing with those in Japan, K-feldspar and carbonate minerals are present while they are absent from those of Japan, and clay minerals such as kaolinite and montmorillonite, barite, chalcedony and adularia, which are very common in the gold-silver deposits of epithermal type in Japan, are notably lacking from those of Korea, except for the Bupyeong silver deposits where silver sulfosalts, adularia, and clay minerals occur (Seo, G.S. 1985).

This suggests that the formation conditions of most Korean gold-silver mineralization belong to mesothermal to hypothermal, except for a few volcanogenic silver deposits.

CLASSIFICATION

Several earlier classifications of Korean gold-silver deposits are found in the literatiures. Kawasaki (1918) offered a classification of the veins into four groups based on the character of the gangue and subdivided into six subgroups based on the dominant sulfide minerals. Shiraki (1933) recognized six types simple on the basis of the contaminant sulfides. Otsubo's classification (1934) set up six types, named after mines that typified them, and based upon tenor in relation to kinds of associated minerals. Shiga, Y. (1937) had a somewhat similar idea, and Nakajima (1937) attempted a distinction of types based upon mineral paragenesis. Tsuchida, S. (1944) classified the Korean gold-silver veins into the following six types on the basis of dominant sulfides:

1) Arsenopyrite type
   Examples: Chungang mine, Chungchungnamdo and Kwangyang mine, Cheolanamdo
2) Galena type: Daeneung mine, Chungcheongbuk-do
3) Pyrite type: Jojam mine, Kangwon-do
4) Sphalerite type: Hanheong mine, Hamgyeongnam-do
5) Chalcopyrite type: Daejeon mine, Hamgyeongbuk-do
6) Bismuthinite type: Iltong mine, Kyeonggi-do

As to the formation temperatures of gold-silver deposits in South Korea, Kaneda et al (1984) recently presented their results (Fig. 6) deduced from pyrite-arsenopyrite-wall rock geothermometry and arsenopyrite geothermometry by Kretshmar and Scott (1976). According to this approximation in Fig. 6, the formation temperatures of 18 mines are grouped as follows:

1) 500°—400°C: Mugug 2) 500°—350°C: Cheonbo, Gubong 3) 500°—300°C: Gyeolseong 4) 400°—300°C: Yanghang, Geumjeong	Hypothermal
5) 500°—400°C, 300°—200°C: Geumwang 6) 500°—350°C, 300°—200°C: Namchang	Hypothermal Mesothermal
7) 430°—250°C: Dukon 8) 400°—250°C: Dadeuk, Baekjin 9) 350°—250°C: Jeonjuil 10) 350°—200°C: Gwangyang	Hypothermal to Mesothermal
11) 300°—200°C: Samgwang, Hwangbo, Sanggeum	Epithermal

It may be worthy of note that two phases of formation temperature found in the Geumwang and Namchang deposits are of significance because most endogenic gold-silver deposits are formed by multiphase mineralization rather than by a single phase as shown, e.g., by Smirnov, et al. (1983). More variable ranges of formation temperature of individual deposits are expected to be identi- fied when more data on geothermometry including fluid inclusion studies of these deposits become available.

Most of the deposits, examined by Kaneda et al (1984) in Fig. 6, are of quartz-sulfide veins except for the Geumjeong deposits which has been classified as an alaskite vein type (Kato, T., 1963) or pegmatite-alaskite vein type (Lee, H.Y., 1980). The formation temperature of the Geumjeong, 400°—300°C, which is determined by a sulfide association can be lower than that of pegmatite phase, which was followed by later alaskite-sulfide phase in its composite vein.

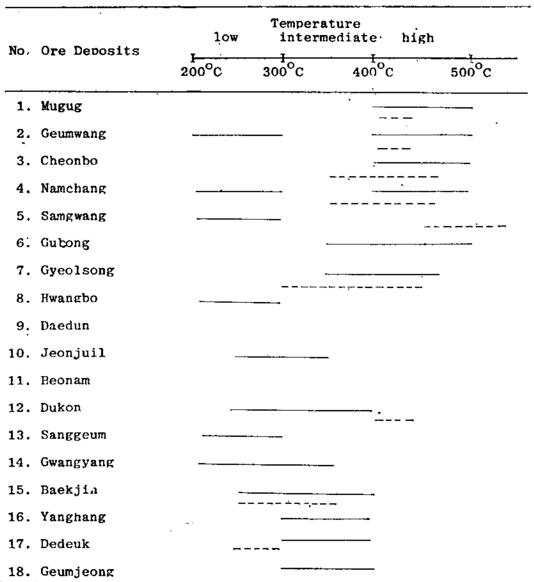

Fig. 6 Presumed formation temperatures of the Korean Au-Ag deposits in this study. Solid lines are represented by the pyrite-arsenopyrite-wall rock geothermometer, while dotted lines are estimated through arsenopyrite geothermometer by Kretschmar and Scott. Reproduced from Kaneda et al. (1984).

Table 3 Production trends of gold and silver from major mines in South Korea.

Metal	Mine	Location	Production in kg					
			'80	'81	'82	'83	'84	Total
Gold	Geumjeong	Bonghwa-gun, Chunyang-myeon	9	18	32	64	67	
	Geumwang	Eumseong-gun, Geumwang-myeon	—	7	4	47	78	
	Jeonjuil	Wanju-gun, Unju-myeon	—	44	31	36	75	186
	Cheonbo	Cheonwon-gun, Ibbjang-myeon	51	53	33	27	4	
	Sangdong	Yeongweol-gun, Sangdong-myeon	33	30	25	22	23	
	Deukum	Naju-gun, Gongsan-myeon	—	5	31	8	8	52
Silver	Bupyeong	Incheon Si, Nam ku	31, 377	41, 096	34, 158	32, 509	35, 516	
	Jeonjuil		1, 682	8, 406	11, 071	9, 079	6, 261	
	Yeonhwa	Bonghwa-gun, Socheon-myeon	—	7, 035	10, 027	6, 655	—	15, 805
	Janggun	Bonghwa-gun, Socheon-myeon	—	4, 765	4, 821	3, 276	2, 943	36, 499
	Sambong	Koseong-gun, Samsan-myeon	1, 064	1, 088	1, 106	2, 334	—	
	Deukon		957	941	1, 231	2, 012	1, 527	6, 668
	Komyeong	Koseong-gun, Hyeonnae-myeon	—	—	2, 259	1, 828	2, 210	
	Ulchin	Ulchin-gun, Buk-myeon	—	1, 911	1, 549	1, 069	—	
Ag/Au	Jeonjuil	36, 499/186=196						
	Deukum	6, 668/ 52=128						

Data from Ministry of Energy and Resources, Korea, 1985.

Table 4 Major types of gold-silver deposits in South Korea.

Age	Genetic Type	Metal	Sulfide and/or Ore Mineral	Type Mine
	A. Hypogene Gold-Silver Deposits Proper			
Precamprian	Pegmatite-Alaskite	Au	Pyrite, Pyrrhotite	Geumjeong(1)
Jurassic	Hypothermal quartz-sulfide vein	Au, Ag	Pyrite, Arsenopyrite, Sphalerite, Galena	Gubong(2)
		Au, Ag	Pyrite, Sphalerite	Yanghang
		Au, Ag, (Pb)	Galena, Sphalerite Arsenopyrite	Gyeolseong
	Hypothermal to mesothermal quartz-sulfide vein	Au, Ag	Pyrite, Arsenopyrite, Galena	Namchang
		Au, Ag	Pyrite, Sphalerite, Galena	Deukon
		Au, Ag	Pyrrhotite, Pyrite, Sphalerite, Galena	Taechang-Boryeon(3)
		Ag, Au	Pyrite, Sphalerite, Fluorite	Jeonjuil(4)
	Epithermal volcanogenic stockwork	Ag	Native Silver, Argentite, Galena	Bupyeong(5)
Cretaceous	Hypothermal quartz-sulfide vein, Hypothermal to mesothermal quartz-sulfide vein	Au, Ag	Pyrite, Arsenopyrite, Sphalerite	Geumwang(6)
		Au, Ag	Sphalerite, Galena, Pyrite	Goryeong
		Au, Ag	Pyrite, Chalcopyrite	Gwangyang
	Epithermal quartz-sulfide vein	Au, Ag	Pyrite, Chalcopyrite, Sphalerite	Sanggeum
Eocene(?)	Epithermal quartz-sulfide vein	Ag, Au	Rhodochrosite, Pyrite, Argentite	Tongyeong(7)
	B. Gold or Silver as a By-Product from Other Metallic Ores (8)			
Cretaceous	Contact metasomatic scheelite deposits	W, Mo, Bi, (Au)	Scheelite, Molybdenite, Bismuthinite	Sangdong
	Contact metasomatic lead-zinc deposits	Zn, Pb(Ag)	Sphalerite, Galena, Pyrrhotite	Yeonhwa I, II, Ulchin
	C. Placer Deposits (Desribed in a Separater)			

(1), (2), (3) ect. are described in the following section.

It is interesting to find several low-temperature epithermal gold-silver deposits from Fig. 6. They are the Samgwang, Hwangbo, and Sanggeum, among which the former two (5 and 8) are located in northwest of the area studied (Fig. 5), and the latter (13) is in the southern edge of the peninsula. It should be noted here that there is an other big silver deposits of epithermal volcanogenic origin (Seo, G.S., 1985), the Bupyeong mine, near Incheon to the west of Seoul, although this was not included in the work by Kaneda et al. (1984). As to classifying the gold-silver deposits based on the main metal component, there has been loose usage in defining "Au mine", "Au-Ag mine" etc. For instance, Ministry of Energy and Resources, Korea divides into "Au mine" and "Ag mine" in their mineral statistics as shown in Table 3, in which some of the mines producing both gold and silver appear in both categories of "Au mine" and "Ag mine".

The Jeonjuil and Deukum mines produced siver 196 and 128 times of gold in weight, respectively, during the last several years so that they have to be refferred to as "silver-gold mines" rather than as "gold-silver mines", most people say so. If this kind of calculations were made for the other so-called gold-silver mines, there would be many more silver-gold mines, instead of gold-silver, that could be identified.

Making allowances for all the data available, most of which already mentioned, it possible to summarize the various types of gold-silver deposits in South Korea as shown in Table 4. They are grouped into three categories based on the sources of metal: A. Hypogene gold-silver deposits, which are mostly of hydrothermal quartz-sulfide veins, B. Gold or silver extracted as a by-product from other metallic ores, mainly of contact metasomatic deposits of tungsten for gold, and of zinc-lead for silver, C. Placer deposits, mainly of alluvial and beach placers.

The former two categories are subdivided into a number of genetic types of endogenic deposits to hypothermal, hypothermal to mesothermal and epithermal quartz-sulfide veins and volcanogenic stockworks, ranging from Precambrian through Jurassic-Cretaceous to Eocene in their ages of mineralization. Then, each of these genetic types are further subdivided into several classes of mineral associations with economic metals and mine examples.

DESCRIPTION OF INDIVIDUAL ORE DEPOSITS

Seven gold-silver mines proper of various genetic types are chosen as type mines and described in some detail concerning mainly with the location, production history, geologic setting, or and size of the deposits, mineralogy of ore and quangue, and genetic interpretation of mineralization. Other metallic ore deposits, from which gold or silver is extracted as by-product, are also briefly mentioned.

Geumjeong Mine

The Geumjeong mine is at Geumjeong in Choonyang-myeon, Bonghwa-gun, Gyengsang-buk-do, about 25Km by road north northwest of Chunyang. The south portal of the main haulage tunnel is at 37°04′04 "N. and 128°49′ 16" E. An incomplete record of production from 1923 until 1943, when gold mining operation was suspended for the war, indicates a total of about 7 metric tons of gold. After long-continued cessation of operations, recent production has been gradually increased and amounted to 67Kg of gold in 1984.

The mine area is underlain by the Precambrian biotite hornfels, cordierite hornfels, and quartz-biotite-cordierite schist which were intruded by stocks or dikes of two-mica granite, biotite granite, granite porphyry, pegmatite and alaskite (Lee, D.W. and Kim, S.W., 1965). The largest stock is Nongeori two-mica granite from which a number of pegmatite dikes branch out. The K-Ar ages of the Nongeori granite were determined to be 1,530 Ma by Ueda (1969) and 1,761± to 1,802±18 Ma by Yun (1985), and of the pegmatite to be 1,880 Ma by Ueda (1969), and 1,792± to 1,805±18 Ma by Yun (1985). Interpreting that the Geumjeong pegmatite-alaskite veins were developed during the identical event of the Nongeori granite and related pegmatite formations, the age of the Geumjeong gold deposits can be considered Precambrian in its age of mineralization. The Geumjeong deposits is a composite vein composed of earlier pegmatite, intermediate alaskite, and later quartz veins, among which the alaskite veins contain gold.

There are several veins including the Cham-

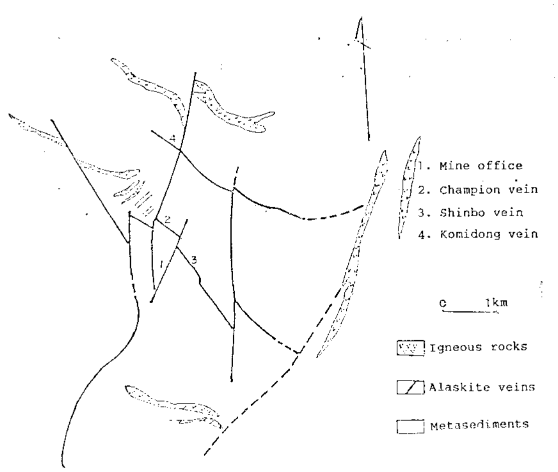

Fig. 7 Vein pattern of Geumjeong mine area (after John, 1973).

pion, Shinbo, and Komidong veins all of which strike NW and dip NE (Fig. 7). These veins are cut by NS-trending faults. The Champion vein has been mostly profitable. It has been explored for 1,000m along the strike and to a depth of 350m. Thickness of the vein varies up to 4m averaging about 1m. According to Kato (1936), pegmatite, the oldest, pinches and swells very irregularly, whereas the succeeding alaskite is continuous and less variable in thickness, attaining a width of 1m in some places and pinching out in other places. Alaskite is characterized by a medium-grained granulated aggregate of predominant quartz and subordinate microcline with small but variable amounts of muscovite, biotite, tourmaline, sulfides and gold.

Sulfides include pyrite, sphalerite, pyrrhotite and galena. A small amount of arsenopyrite cocur in association with pyrite. Native gold occurs in association with sulfide minerals and in grain boundaries of quartz or cracks of toumaline crystals in alaskite veins.

At least 90% of the total gold produced from the Geumjeong mine has been obtained from one ore shoot. This was approximatley 570m long in the upper level of the mine, but gradually tapered downward to a length of less than 100m on the deepest level.

The Shinbo vein, a northwest-trending vein, has been explored for a length of 800m and to a depth of 125m. Two small stopes of ore containing 5 or 6 gr/T were mined. The Komidong vein strikes N60°W, and dips 70°NE with thickness of 0.2~1.5m. Some exploratory work on the Geumjeong property has been done at three other prospects: They are the Galgol, Cheonpyeong, and No.6 workings.

It is interpreted that following the pegmatite phase, the alaskitic residual fluid was introduced through the reopened fissures along the preexisting pegmatite dike. From the alaskitic residual fluid, quartz crystallized first as anhedral crystals followed by alkali-feldspars which filled the interspaces of quartz grains. After the crystallization of quartz and feldspar, the residual fluid become enriched in boron mineralizers, alkalies, sulfides, and gold. Crystallization of tourmaline, sericitization of the feldspars, and precipitation of sulfides and native gold took place in this stage. Lastly a barren quartz vein was introduced to the pegmatite-alaskite composite dike.

Gubong Mine

The Gubong mine was discovered in 1908 and was one of the principal producers of gold in this country before it was closed in 1971; until that time total output of gold and silver amounted to about 13.3 metric tons and 4.6 metric tons, respectively. The mine is located in Kuryeong-ri, Sayang-myeon, Chungyang-gun, Choongcheongnam-do at 36°24′14″N and 126°45′30″E.

The geology of the area consists of granitic

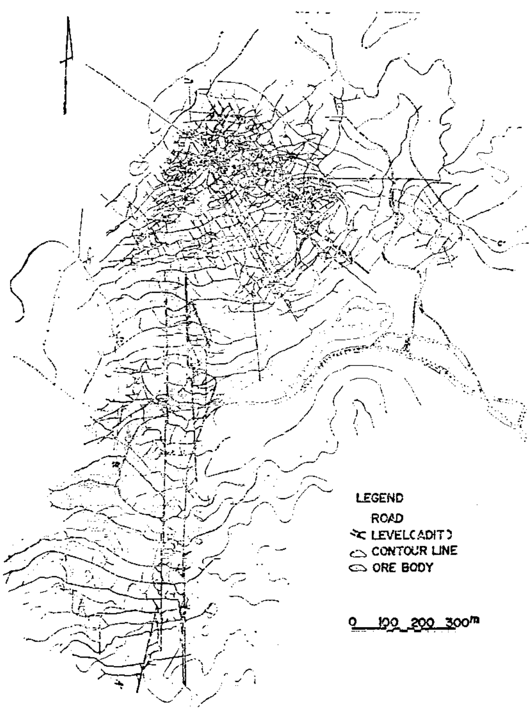

Fig. 8 Underground map of Gubong mine showing trend of ore shoot (after Cheon and Oh, 1970).

gneiss, augen-gneiss, sedimentary rocks including sandstone and conglomerate of Mesozoic Daedong series. Basic dikes intrude these formations. The meta-sedimentary formations strike N10°-40°E, and dip N5°-40°W in general. They were deformed in a gentle anticline, of which axis plunges southward.

Gold and silver were obtained from three main and several subsidiary quartz-(sulfide) veins filled fissures devloped in the anticlinal zone strike about N50-60E, and dip 30°-40°SE as seen in Fig. 8. They range in width from 40cm to 150cm and in length from 120m to 650m. The average grades range from 6 to 8 gr/t Au, and 5-6 gr/t Ag. The veins contains small amounts of pyrite, pyrrhotite, arsenopyrite, galena, sphalerite and very few amount of chalcoplyrite. Relatively abundant pyrrhotite occurs. Electrum is contained in the pyrite grain as inclusions (Kaneda et al., 1984).

There is a single large ore shoot in the main vein. It dips 20°-25° southeast and then south (Fig. 9), and is long about 400m on -1,760 ML but 200m on -1,440 ML indicating a gradual decrease with depth (Cheon and Oh, 1970).

Brecciation and shear fractures occur abundantly in wall rocks suggesting that hydrothermal ore fluids were introduced accompanied by a forceful fissuring of the wall rocks.

Minor fractures later than the vein quartz

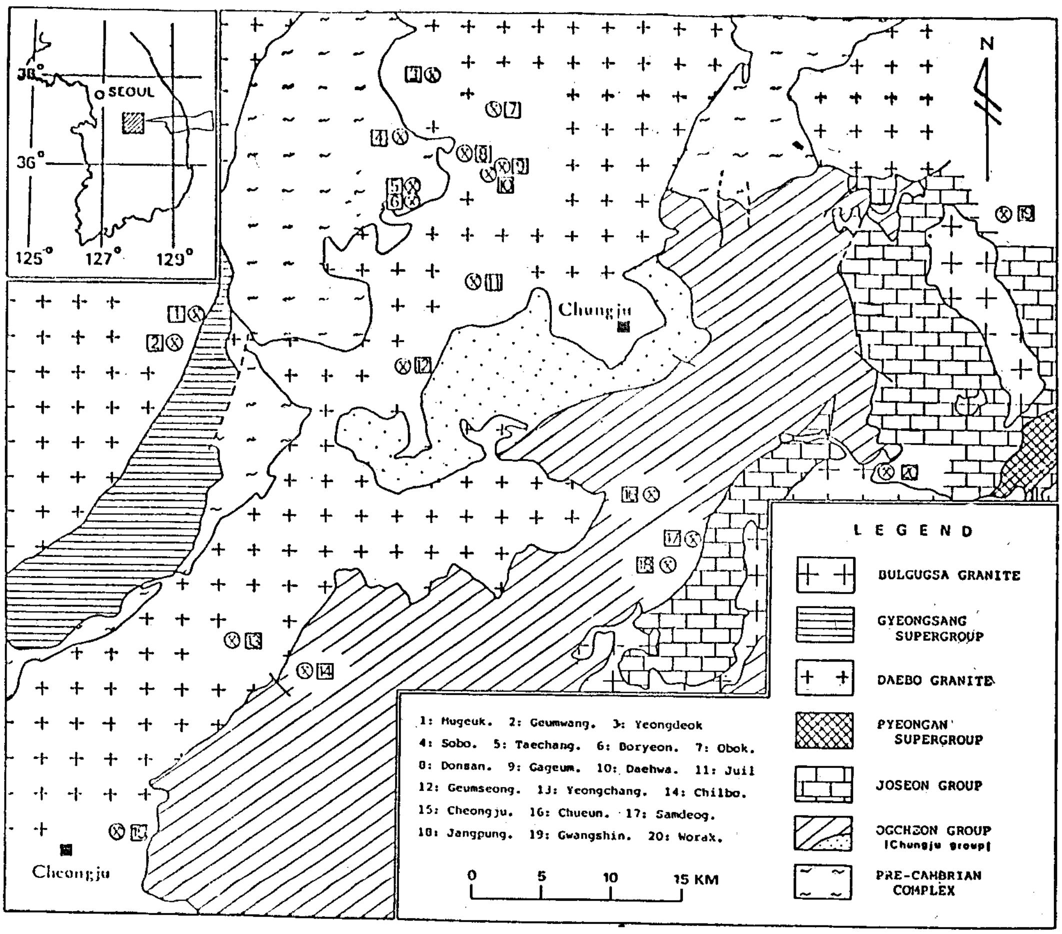

Fig. 9 Geology and location of major mines in Jungwon district, Choongcheongbuk-do (after Park et al., 1985).

containing sulfide minerals and calcite veins indicate that gold and silver were precipitated during the later stage of vein formation. The formation temperatures of these veins by Kaneda et al. (1984) range from 350°C to 500°C indicating that these were mineralized under a hypothermal condition.

Taechang and Boryeon Mines

A number of gold-siver, tungsten-molybdenum, and lead-zinc deposits are distributed in the Jungwon district, Choongcheongbuk-do, northwest and west from Chungju (Fig. 9). The Taechang and Boryeon mines together with the Mugug and Geumwang mines are the most important gold-silver producers in this area.

The Taechang mine is located at 37°04′46″N and 127°46′34″E. Only a few records of production before World War II are available. The mine was opened in 1930. In 1942 it produced 52Kg of gold and 7.5Kg of silver. After for long cessation of operation, it was reopened in the early 1970's with annual output of several Kg of gold and recently increasing to the amount to 120Kg of gold in 1980. Records for silver production are not available but the figures might have been less than those of gold judging from the gold/silver ratio of older records mentioned above.

Geology of the mine area consists of the Precambrian granitic gneiss, schistose gneiss and banded biotite gneiss which were intruded by granite and dike rocks. The gold-silver were mineralized as a fissure filling quartz(sulfide) vein in the Precambrian metamorphic rocks metioned above.

Three paralled veins, which are concordant with foliation of the metamorphic rocks, have been recognized.

K-Ar ages of muscovite from a vein and of biotite from the granite were determined by Park et al. (1985) to be 156±2 Ma and 147±13 Ma, respectively, so that the gold-silver mineralization can be considered to be of Jurassic in age.

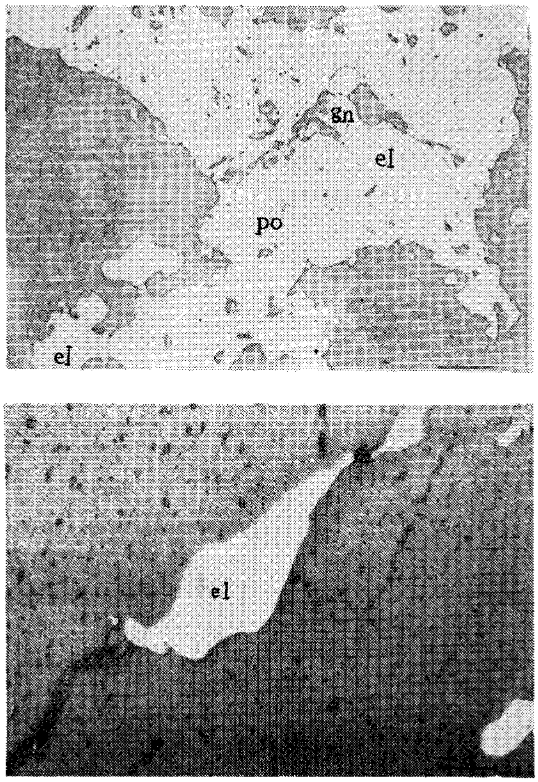

Fig. 10 Photomicrograph showing electrum associated with galena and sphalerite (above), or developed aong cracks of quartz (bellow). The black bar scale represents 0.1mm (after Park et al., 1985).
el: electrum gn: galena po: pyrrhotite

The Boryeon adit vein, which is currently in operation, strikes NS-N15°E, and dips 15°-30° NW consists mainly of quartz with minor amounts of pyrrhotite, pyrite, sphalerite, galena and electrum. Gold-silver concentration has a tendency to increase along the contact between quartz vein and dike rocks or between vein quartz and wall-rock xenolith in the vein. Electrum occurs in association with galena and pyrrhotite (Fig. 10 above), or along the cracks of quartz grains (Fig. 10 below). The Ag/Au ratios of electrum range from 0.32 to 0.33 in atomic percent (Park et al., 1985).

The Boryeon mine is located in south of the

Taechang mines in both of which gold-silver mineralization can be considered to be of similar geologic setting. The main vein strikes NS-N15°E, dips 20°-30°SE, and is 400m long with 0. 1-1. 2m width. The Boryeon deposits is analogous to that of the Taechang in vein materials including sulfide minerals and associated electrum. The Ag/Au ratios of electrum range from 0. 27 to 0. 31, which is wider than that of the Taechang electrum.

Homogenization temperatures of fluid inclusions in quartz from the Boryeon vein indicate that quartz was precipitated within a temperature range from 390°-238°C, so that this vein can be considered as an hypothermal to mesothermal mineralization.

Jeonjuil Mine

The Jeonjuil mine, formerly Jeonju mine, is located 0. 5Km south of Changseon-ri, Unju-myeon in northernmost Wanju-gun. The southernmost working face is at 36°04′25″N and 127°17′25″E.

The area consists of slate, and phyllite and interbedded limestone of the Ogcheon Group striking N20°E and dipping 50°-70°NE. Two parallel fissure veins, were hosted in these metamorphic rocks, run with an interval of 10 to 30m trending N10°E. The veins are exposed in three separate areas along this trend: the vein is 0. 6-2. 5m wide and 500-700m long.

The vein consists of quartz and minor sulfides with fluorite occurring sporadically. The quartz is dark in color due to contamination with pervasive carbonaceous matter. Pyrite predominates in sulfide minerals occurring as large corroded crystals in association with sphalerite and magnetite. Avery little amount of galena and chalcopyrite occur disseminated in the wall rocks. Argentite is present in close association with galena. No Arsenopyrite is observed.

The Jeonjuil mine is characteristic in that it produces more silver than gold in price so that it should be referred to as silver-gold mine.

Bupyeong Mine

The Bupyeong silver deposits is one of the rarely found volcanogenic epithermal deposits in South Korea. It began to produce silver 1969, and has been rapidly increased output to reach to 35. 5 metric tons of silver in 1984.

The Bupyeong mine is located in Mansu-dong, Nam-ku, Inchon City, or at 37°28′~37°39′N and 126°42′10. 4″~43′10. 4″E. In district geology, Mesozoic pyroclastic rocks, intrusive breccias, granite and other acidic intrusives are distributed around the Bupyeong mine show a close relationship with the topographic circular structure (Fig. 11).

According to Seo (1985), K-Ar ages of two granite bodies, 162 and 148±7 Ma, indicate that the pyroclastic rocks, which were intruded in these granites, were effused in the Jurassic period. From the evidence of field occurrences, mineral composition, texture, and chemical composition of igneous rocks in addition to the circular structure, Seo (1985) considers that

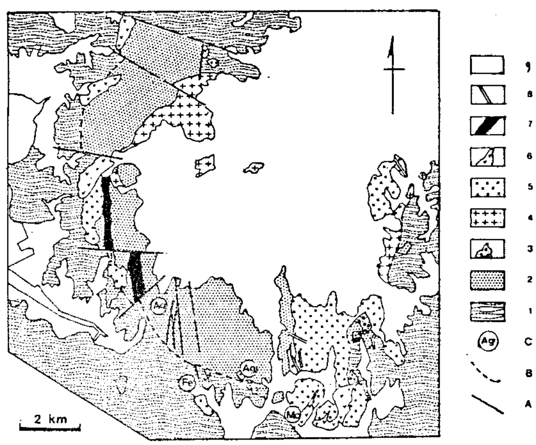

Fig. 11 Structural map around the Bupyeong mine (1. Gyeonggi gneiss complex, 2. Pyroclastic rocks, 3. Intrusive breccia, 4. Central pluton, 5. Ring granite complex, 6. Felsitic porphyries, 7. Intrusive rhyolite, 8. Acidic dykes, 9. Alluvium, A. Fault, B. Postulated caldera margin, C. Ore deposits) (after Seo, G.S., 1985).

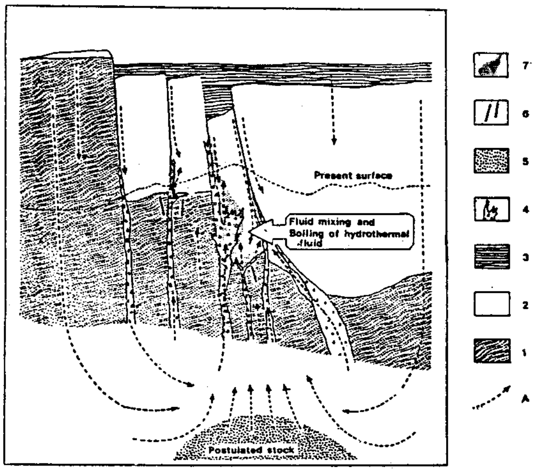

Fig. 12 Proposed genetic model of the Bupyeong silver deposits.
(1. Gyeonggi gneiss complex, 2. Pyroclastic rock, 3. Caldera-fill sediments, 4. Intrusive breccia, 5. Plutonic rock, 6. Vein-type deposits, 7. stockwork deposits, A. Migration path of fluides). (after Seo, G.S', 1985).

these igneous rock were formed during a resurgent caldera evolution.

Mineralization took place at the caldera margin (Fig. 12) after the caldera subsidence and the intrusion of granities. Silver ore occurs as the stcokworks hosted in the Jurassic pyroclastic rocks and intrusive breccias, filling the minor fractures developed along the main fault zone with the unconformity placed between the Precambrian metamorphic rocks and overlying pyroclastic rock (Fig. 12).

Silver occurs mainly as native silver. Other silver minerals, very minor in quantity, are tetrahedrite-freibergite, pyrargyrite, polybasite, dyscrasite, canfieldite and argentite. Four stages of mineralization are recognized (Fig. 13): Stage 1 is the main oxide and sulfide mineralization. At stage 2, Ag-Sn-S, Cu-Sn-Fe-Zn-S, and Cu-Ag-Fe-Zn-Sb-S minerals were formed. Stage 3 is the main stage of native silver mineralization. At stage 4, minor amount of pyrite was precipitated along siderite veinlets.

Extensive silicification and adularization pre-

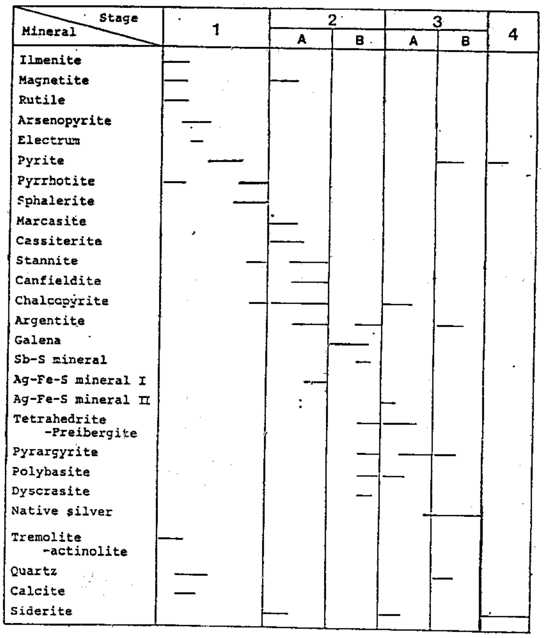

Fig. 13 Paragenesis of ore and gangue minerals in the Bupyeong silver deposits (after Seo, G.S., 1985).

ceded the main ore deposition. During stages 1 and 2, vein-related garnet-chlorite alteration occured widely. During stage 3, relatively weak argillic alteration took place accompanied with native silver precipitation. During stage 4, pervasive sericitization occurred.

The filling temperatures of fluid inclusions in the quartz veinlets (Seo, 1985) of the stage 1 range from 260 to 335°C, and those of the stage 3 from 115° to 140°C, indicating that the main stage of silver mineralization (stage 3) corresponds to an epithermal range, although the earlier quartz stage (stage 1) belongs to a hypothermal to mesothermal range. Judging from the shallow environment of these vein formations, the early high-temperature stage can be considered as a xenothermal condition started from the volcanogenic resurgent activity.

Geumwang Mine

The Geumwang gold-silver mine is located in Bonggok-ri, Geumwang-myeon, Eumseong-gun, Choongcheongbuk-do, 2Km south of the Mugug

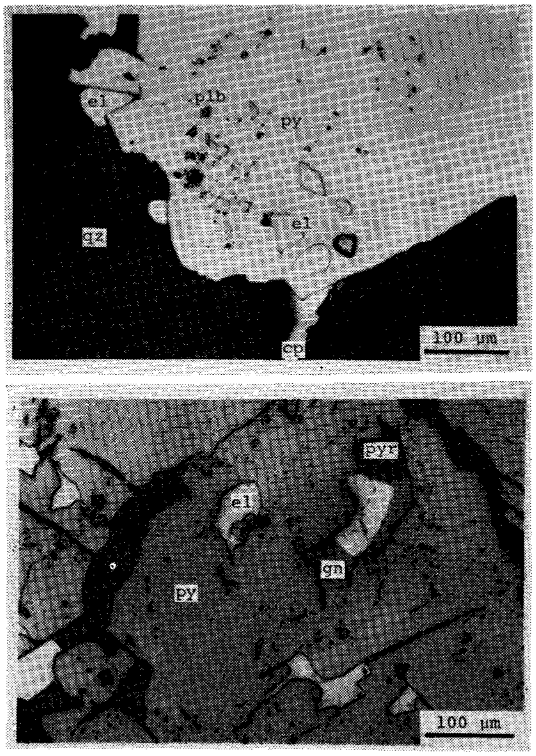

Fig. 14 Photomicrograph showing electrum contained in pyrite.
el: electrum, pyr: pyrargyrite, plb: polybasite, gn: galena, cp: chalcopyrite, py: pyrite, qz: quartz

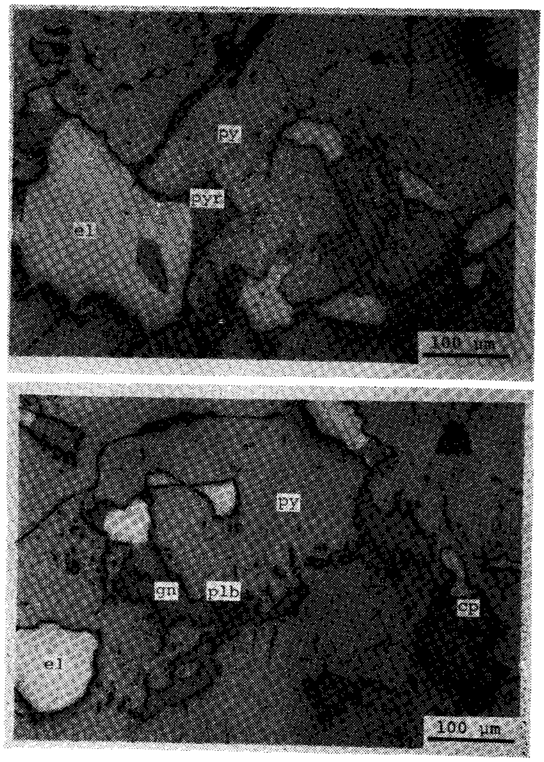

Fig. 15 Photomicrograph showing electrum fiilled in the interstices of pyrargyrite, galena and polybasite (after Sugaki, 1982).
el: electrum, pyr: pyrargyrite, plb: polybasite, gn: galena, cp: chalcopyrite, py: pyrite

mine, which is located at 36°57′-37°01′N and 127°34′-37′E. Their old history of production are not available, but the Geumwang and Eumseong mines have rapidly increased their annual production of gold and silver amounting to 78Kg of gold and 1,610Kg of silver, respectively, in 1984.

The mine area consists of coarse biotite granite in the west and Mesozoic sedimentary rocks in the east (Fig. 9). The K-Ar age of biotite from the granite in the Mugug mine is 112 Ma and field evidences from the intrusions in the Geumwang mine indicates the Au-Ag mineralization occurred during the Cretaceous igneous activity (Park, et al., 1985).

The gold and silver are contained in quartz-(sulfide) veins developed along fissures in leucocratic granite which intrude the coarse biotite granite. A total of 8 veins have been recognized in the Geumwang mine, in which the No. 1, No. 2, No. 4 and No. 8 veins are more important. The No. 1 and No. 2 veins strike N10°E and dip 85°SE, and are 300~400m long and 30~100cm wide. The No. 4 and No. 8 veins strike N50°W-N70°W, and dip 30°SW, and are 100~200m long and 10~80cm wide.

Sulfide minerals are pyrie, arsenopyrite, tetrahedrite, sphalerite, chalcopyrite, pyrrhotite, pyrargyrite and electrum Sugaki (1982) further identified (Park, et al., 1985). In addition, polybasite, pyrargyrite, stephanite, diaphorite, miargyrite, freibergite, and native silver (Fig. 14 and 15).

The Ag/Au ratios in atomic percent range from 1.00 to 1.99 indicating higher proportion of Ag than that of the Taechang-Boryeon mines (Park, et al., 1985). This means that the Jurassic Taechang-Boryeon mineralization was higher in gold content in electrum than in the Cretaceous Geumwang mineralization.

Tongyeong Mine

The Tongyeong mine is located in Jeongyang-dong, Choongmu City, Gyeongsangnam-do, or at 34°50.2′N and 128°26.1′E. It was one of the principal producers of gold and silver in Gyeongsangnam-do. The records of production are not available except for some figures form before World War II, e.g., its annaul production of gold and silver were 72Kg Au and 793Kg Ag in 1943, 75Kg Au and 825Kg Ag in 1944, and 39Kg Au and 453Kg Ag in 1945, respectively (Gallagher, 1963).

The deposit is a quartz vein along a sheared and brecciated zone in propylite tuff and agglomerate of the Cretaceous Silla group. The vein strikes N40°~60°W, and ranges in dip from 75°NE to 75°SW. It has been explored for a length of 750m and to a depth of 180m below the highest outcrop, which was situated 30m above sea level. Thickness of the vein zone ranges up to 3.75m and averages 1.5m.

The vein is in part a simple quartz-filled fissure with some rhodochrosite and minor sulfides, and is in part a breccia zone cemented by the vein minerals. Auriferous pyrite, argentite, chalcopyrite, sphalerite, galena,and psilomelane are reported (Hoshina, 1921).

In the mined and oxidized portion of the vein, native gold was associated with limonite, but below sea level in the unoxidized portion of the vein, all of the gold is contained in pyrite.

According to Kato (1923) the vein of the Tongyeong mine is a conspicuous example of a geologically young vein formed at shallow depth, a type of ore deposit that can be said, is rare in Korea. He says it is closely related to the quartz-porphyry dikes which intrude the late Mesozoic propylite and tuff breccia, and that these dikes are strongly altered by hydrothermal reaction, whereas the diabase dikes of the district remain unaltered.

He believes that the mineralization followed the intrusion of the quartz-porphyry dikes and was prior to the intrusion of the diabase dikes, and concludes that the Tongyeong vein was therefore formed in early Teriary time.

Gold and Silver Ore as By-product From Other Metallic Ores

Gold as a by-product mainly from Sangdong tungsten ore and silver from the Yeonhwa-Ulchin lead-zinc ores share a large part of total production of these metals in South Korea. Annual output of gold from the Sangdong ore amounted to 23Kg in 1984 recording the 4th place among the leading producers of gold in that year.

Annual production of silver from lead-zinc ores were much greater amounting to about 10 metric tons from the Yeonhwa I, II, and Ulchin ores in 1984. They were extracted from base-metal ores at Janghang refinery. Annual output of gold from Janghang refinery in 1980 was 570Kg sharing 23% of the national total of 1,282Kg, and of silver was 32,060Kg sharing 22% of the national total of 71,301Kg.

This is the reason for author to consider gold and silver production as by-product from other metallic ores.

The geology and ore genesis of the Sangdong tungsten deposit will be discussed in a separate chapter. The lead-zinc deposits of the Yeonhwa I, Yeonhwa II, and Uichin mines were formed as a contact metasomatic skarn type, hosted in the Cambro-Ordovician carbonate sequence in genetic relations with the Cretaceous granitic rocks at Yeonhwa I and Yeonhwa II, and with the Eocene rhyodacite at Ulchin (Yun, 1985).

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南韓의 金·銀鑛化作用에 對한 考察

金 元 祚

요약 : 본 논문은 남한의 금은 광상의 금속광화작용(광상생성)에 대해서 필자 자신의 조사연구 자료와 아울러서 금은 광상에 관한 가능한 기존 자료를 광범위하게 참고해서 작성한 것이다.

한국의 광상 생성기는 구조지질적 활동내용과 화성활동 시기들에 관련되여지고 있는 바 선캠브리아기, 고생대, 쥬라기-백악기초, 후백아기-제 3 기초 그리고 제 4 기로 구분되어지며, 이에 대한 광상 생성구로는 지역적으로 규장암질 내지 중성질 화성암류와 관련지어지고 있으며 반면에 염기성암과 초염기성암류와의 광화작용은 거의 없는 것이 특징적이라고 하겠다.

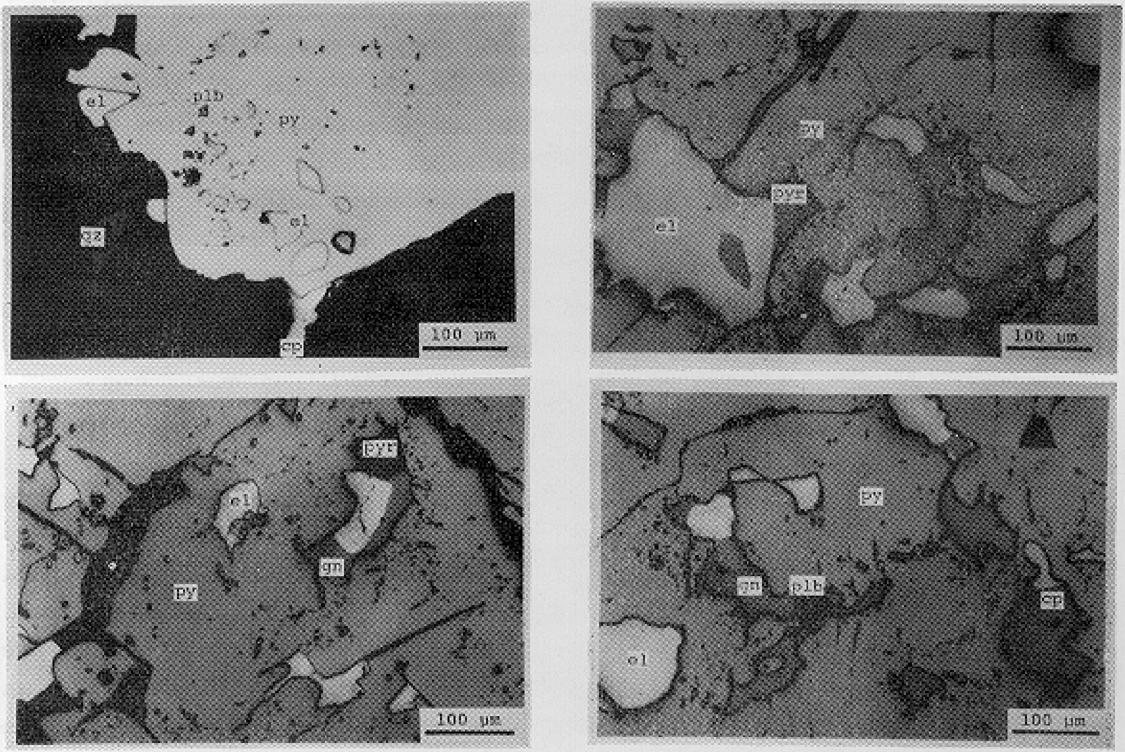
금·은광에 있어서의 광상 생성작용은 거의 모두가 화강암류들의 관입과 관련되어져 있다. 남한에 있어서의 금·은광의 후생 광화작용의 시기적 범위는 선캠브리아에서 부터 삼첩기, 쥬라기와 백악기에서부터 시신세(?)까지로 보아지며, 광상 생성(작용)형은 심열수광상에서 부터 중열수광상과 천열수광상인 석영-유화광맥형과 화산암관입 생성 망상 광상형과 그리고 광염 광상형들로 구분된다.

금속 광물들의 광화작용 관련형으로서는 은광을 수반치 않는 금광 단일형과 금·은 혼합형, 은-금 혼합형, 금광을 수반치 않는 은광 단일형 그리고 금광 혹은 은광을 부산물로 하는 다른 금속광형들이다.

가장 대표적인 광상 생성 타입의 금-은 광상으로서는 열수광상형 석영맥인 바, 대보 화강암과 불국사 화강암질 암류의 화성활동에 관련된 것이다.

석영-유화물 열수광상형의 금-은 광상에 있어서 가장 밀접하게 관련된 공생광물들은 동, 연, 아연, 유화철 그리고 유비철광이다.

560개 이상의 금-은광산을 광산 분포도에 기재하여 남한에서의 대표적인 10개 지역의 금-은 광화지구를 구획지워 보았다. 그리고 남한에서 8개 금-은 광상을 선별하고 일본에서 8개 금-은 광상을 선정하여 금속 광물들이 각각 유화광물과 맥석광물에 관련된 특유한 광화작용을 비교 고찰하여 보았다. 끝으로 7개의 대표적인 금-은광상을 선정하여 각 개별 광상에 대한 특성적인 광화작용에 대해서 기술하였다.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