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Structural Constraints on Gold-Silver-Bearing Quartz Mineralization in Strike-slip Fault System, Samkwang Mine, Korea

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ABSTRACT: The Samkwang mine is Cretaceous gold-silver-bearing deposits located in the western part of the Ogcheon belt. The ore deposits have been emplaced within granite gneiss of the Precambrian age. The Au-Ag deposits are hydrothermal-vein type, characterized by arsenic-, gold- and silver-bearing sulphides, in addition to the principal ore-forming sulphides arsenopyrite, galena, sphalerite, chalcopyrite, pyrite and pyrrhotite. Their proven reserves are 355,000 MT, and grades are 8.4 g Au/t and 13.6 g Ag/t. On the basis of their structural characters, the Au-Ag-bearing quartz veins are classified into three types of ore veins; (1) The Main vein shows N40°-80°E strike and 55°-90°SE dip, (2) the Sangban vein shows E-W strike and 30°-40°S dip, and (3) the Gukseong vein has N25°-40°W strike and 65°-80°SW dip. The emplacements of the ore veins are closely related to the minimum stress axis (σ_3) during the strike-slip movement of the study area. The ore-bearing veins filled with extension fractures during strike-slip movements were sequentially emplaced as follows: 1) When σ_1 operates obliquely to NE-series discontinous surface, the Main fault zone (F_1) developes. 2) During the same time, extension fractures (T_1, Gukseong veins) take place. 3) When the fault progress continuously, the existing T_1 may be high angle and T_2 (Daehung vein) developes continuously. 4) When σ_1 changes to sinistral sense, T_3 (basic dyke) occurs. 5) When a reverse fault becomes active, the Sangban vein is branched from the Guksabong vein.

INTRODUCTION

The Samkwang mine is located about 8 km northeast of Cheongyang in the Ungog-Myeon, Cheongyang-Gun of Chungcheongnam-Do, Korea, at latitude 36°31′ and longitude 126°54′. Their proven reserves are 355,000 MT, and grades are 8.4 g Au/t and 13.6 g Ag/t. Hydrothermal fluid along the fractures and faults is significantly important for the formation of epigenetic ore deposits (Henley, 1985). The gold-silver deposits are of hydrothermal fissure-filling type characterized by the marked hydrothermal alteration of wallrocks such as silicification, chloritization, sericitization and argillic alteration. The ore deposits have been emplaced within granite gneiss of the Precambrian age structually controlled by the strike-slip fault.

Um *et al.* (1963) studied the general geology of the Samkwang mine area. Studies on the ore deposits have been carried out by Moon (1986) and So *et al.* (1988).

In spite of the previous studies, the relationship between geologic structures and ore genesis is ambiguous. The aim of this paper is to explain the structural constraints on the ore genesis, based on structural interpretation of the underground, surface geology and distributions of the veins in the Samkwang mine.

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GEOLOGIC SETTING

The gold-silver-bearing ore veins in the Samkwang mine are hosted by the granite gneiss which is chracterized by the banded and augen structures, and unconformably overlain by the Jurassic Ungogri Formation (Fig. 1). Granite gneiss that strikes N50°-80°E and dips 45°-70°SE consists mainly of quartz, feldspar, biotite, muscovite, sericite and chlorite with minor amounts of hornblende and garnet. The Ungogri Formation consists of conglomerate, sandstone, dark gray sandstone, siliceous shale and black shale intercalated with coal seam. The strike is N30°-50°E and the dipping is different in each locality. Dykes which are composed of felsite, andesite and quartz vein intruded both basement and sedimentary rocks. These are considered to represent the youngest rocks in the mapped area and intruded reversly. These dykes show N60°-80°E strike and 45°-75°SE dip and are parallrel or subparallel to the F_1 fault, foliation of granite gneiss and sedimentary bedding. Acidic dykes with N15°-30°E strike and 40°-60°SE dip are also developed in the fault zones. Throughout the study area, basic dykes irregularly intruded the granite gneiss. Basic dykes contain needle-like and anhedral-shaped feldspar, quartz and calcite as phenocrysts.

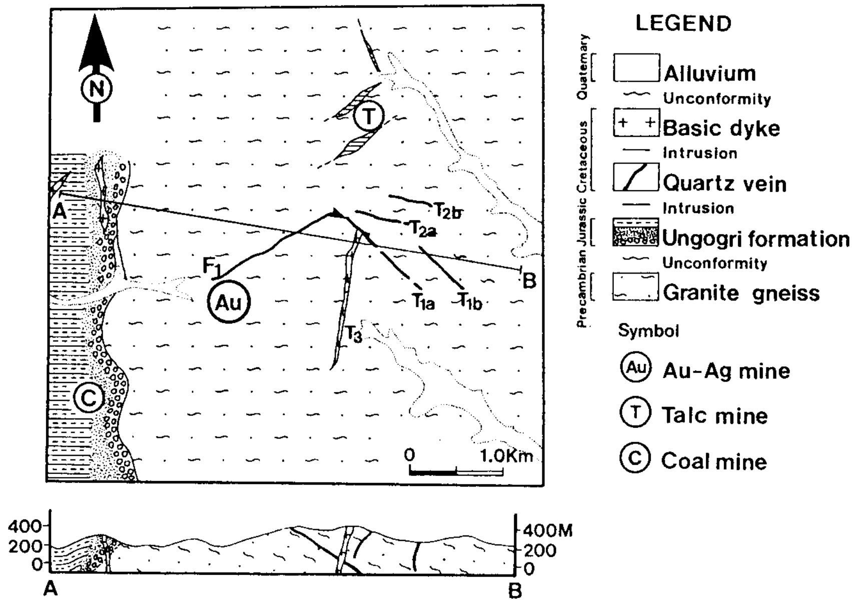

Fig. 1. Geologic map of the Samkwang gold-silver deposits.

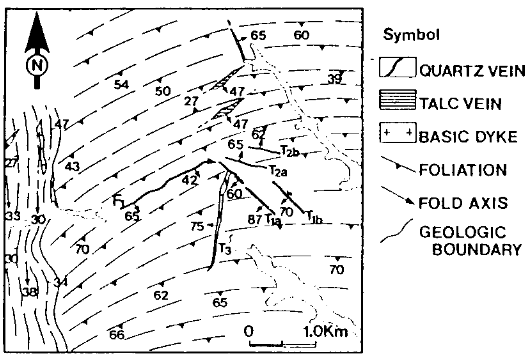

Fig. 2. Structural map of the Samkwang gold-silver deposits.

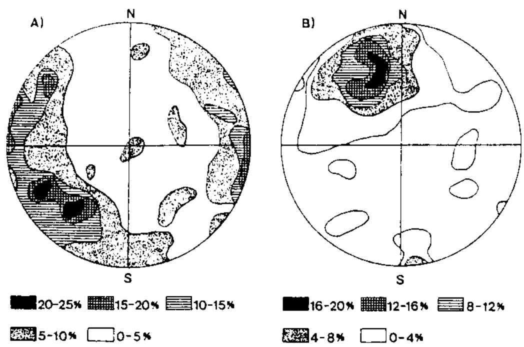

Fig. 3. Stereographic projection of joint surfaces (A) and foliation (B) from the Samkwang mine area. Total number of measured elements: joint (580), foliation (1300).

Based on the boundary of the veins and regional foliation of granite gneiss, quartz veins are produced as a concordant and disconcordant types in underground.

GEOLOGICAL STRUCTURES

Ore-bearing veins, faults and folds structures characterize the geologic structures of the Samkwang mine area (Fig. 2). Especially, most of quartz veins and dykes are associated with the fault systems showing N60°-80°E/40-75SE. The horizontal striation of the slikensides of these veins and en echelon extension fractures are often recognized on their walls indicating that the original fissure is stike-slip fault.

Joints obliqued to the beddings and foliations in the sedimentary rocks and the granite gneiss. Fig. 3A shows 240°/18°, 219°/28° equal to N30°W/72°NE, N51°W/62°NE, respectively. These are consistent with extension fractures (T_1) originated from the strike-slip fault zone (F_1). The general strike and dip of foliation of granite gneiss are N72°E and 63°SE (Fig. 3B). Mesoscopic open gentle plunging folds are developed in the Jurassic Ungogri Formation. Minor ptygmatic folds and pinch and swell structures are shown in the polyphase deformed granite gneiss.

Table 1. Au, Ag grade and sulfide mineral composition for each vein in the Samkwang mine.

Vein (deposits)		Location		Grade (g/t)		Sulfide minerals (%)							Remark
		Level	Sea lv.	Au	Ag	Asp	Py	Cp	Gn	Sp	Po	Other	Number
Main	Tongdong	1-2	193-145 m	33.9	41.7	41	11	6	23	14	2	3	53
		2-3	145-123 m	20.3	28.7	49	10	5	18	13	1.5	3.5	
		at 6	16 m	4.5	9.3	59	17	3	11	7	–	2	
		Average		24.5	32.0	46.7	11.7	5.2	19.3	12.5	2.0	2.6	
	Bonhang	3-4	125-99 m	11.7	14.5	48	13	5	21	11	1	1	63
		4-5	99-74 m	6.8	11.7	53	16	4	17	9	0.5	0.5	
		5-6	74-16 m	17.5	24.6	42	13	7	22	12	1	3	
		Average		11.3	16.2	48.4	14.3	5.1	19.6	10.4	0.8	1.4	
	Guksabong 1	3+	127+ m	43.5	45.5	32	11	12	24	18	1	2	148
		3-5	127-79 m	19.4	19.2	38	11	9	21	16	3	3	
	2	0+	213+ m	16.3	19.6	45	7	10	19	14	3	2	118
		2-3	152-126 m	13.6	24.6	45	9	13	16	13	2	2	
		3-5	126-84 m	9.4	16.3	53	13	9	14	10	–	1	
	3	0+	214+ m	14.2	23.2	48	9	5	20	14	1	3	133
		2-3	151-126 m	8.7	16.2	50	4	2	24	19	–	1	
		3-5	126-85 m	7.9	16.7	49	7	6	20	17	–	1	
	4	2+	149+ m	5.3	9.0	61	14	6	10	8	–	1	20
		2-3	149-125 m	11.3	18.7	43	90	11	18	13	3	3	
		Average		12.8	17.2	45.1	10.2	8.7	19	11.9	2.3	2.8	
	Sangban	3+	126+ m	21.4	23.3	28	10	11	27	19	2	3	
		3-5	126-86 m	8.8	15.6	36	10	12	23	15	1	3	
		5-6	86-55 m	8.4	14.7	44	10	11	19	14	–	2	
		Average		9.0	15.9	34.8	10	11.6	23.2	15.8	1.7	2.9	
	Gukseong	0+	215+ m	4.5	8.3	72	9	3	9	6	–	1	88

Abbreviation: Asp; Arsenopyrite, Po; Pyrrhotite, Py; Pyrite, Sp; Sphalerite, Cp; Chalcopyrite, Gn; Galena.

Table 2. Characteristics of each vein in the Samkwang mine.

Vein (deposits)		Ore minerals	Au-bearing minerals	Ag minerals	Fluid inclusion	Au content	Electrum occurrence	Textures
Main	Tongdong	Asp, Gn, Sp, Cp, Py, At, El	Asp, Cp, Py	El, At	202-370℃	Au=64% Ag=36%	Subhedral, Irregular, Tabular	Fissure-filling texture within the Asp, Cp and Py
	Bonhang	Asp, Gn, Sp, Py, Cp,Ma,Pr,At		El, Pr, At	296-386℃			
	Guksabong	Asp, Gn, Sp, Cp, Py, Po, El	Asp, Gn, Py, Cp, Qtz		203-370℃	Au=64% Ag=36%	Euhedral, Tabular	Fissure-filling texture within the Asp, Replacement texture within Py and Gn
Sangban		Asp, Gn, Py, Cp, Sp, Po, El	Py,				Irregular, Tabular	Fissure-filling texture within the Py
Gukseong		Asp, Py, Gn, Sp	Py		212-337℃	Au=78% Ag=22%		Intergrowh within the Py

Abbreviation: Asp; Arsenopyrite, Py; Pyrite, Po; Pyrrhotite, Sp; Sphalerite, Cp; Chalcopyrite, Gn; Galena, Ma; Macasite, At; Argentite, Pr; Pyragyrite, El; Electrum, Qtz; Quartz.

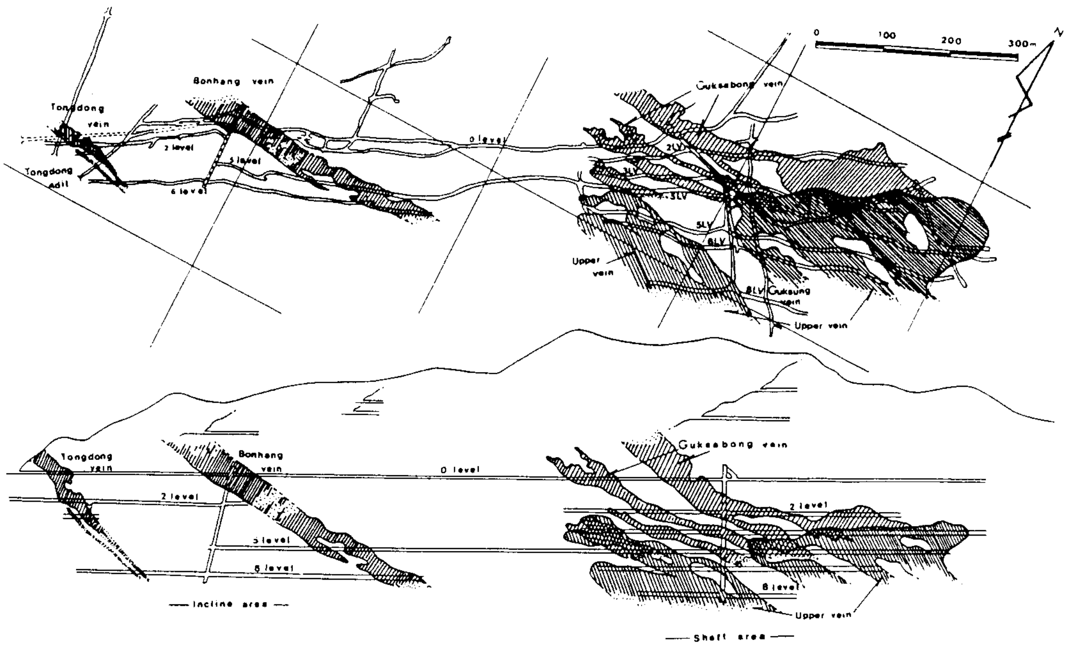

Fig. 4. Underground geologic map of the Samkwang gold-silver deposits. Upper part is the horizontal projection map, and lower part is the vertical section map.

OUTLINE OF ORE DEPOSITS

The ore veins of the Samkwang mine may be classified into three types, i.e., the Main vein, Sangban vein and Gukseong vein (Fig. 4, Table 1 and 2). The charateristics of the veins are as follows.

Main Vein

The Main vein showing strike N60°-80°E and dip to 40°-75°E occurs along the fault zone (F_1). This has a strike length about 1.4 km, and extends for over 400 m downdip, with an average width of 1 m. The Tongdong, Bonhang and Guksabong orebodies have been mined along the Main vein. The blanket-shaped Tongdong orebody intruded by acidic dikes has 0.4 m in width and 50 m in length, with an oreshoot toward 118°/72°. The Tongdong orebody was later overprinted by the strike-slip movement. Orientations of sickenside lineation on the ore veins are 090°/56°. The vein ores consist principally of arsenopyrite, sphalerite, galena, chalcopyrite, pyrite, with minor or trace amounts of marcasite, pyrrhotite, argentite and electrum. The average grades of ore veins are 22.8 g Au/t and 31.7 g Ag/t.

The Bonhang orebody is about 0.3-1.2 m in width and 220 m in length. The ore vein is pinched out

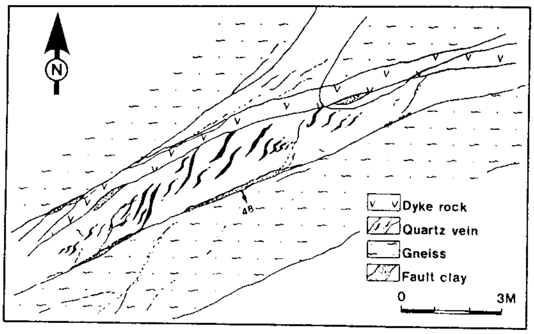

Fig. 5. Sketch showing en echelon structure originated from the strike-slip movement.

or branched into two or three veins due to several small faults. Where the quartz vein is pinched out, several veins with en echelon structure were formed (Fig. 5). Along the ore veins the small faults or the fault zone (F_1) abundantly developed. These are partly fractured by the later strike-slip fault. Orientations of sickenside lineation on the ore veins are 100°/38°. The vein ores consist of pricipally arsenopyrite and small amounts of sphalerite, galena, pyrite, chalcopyrite and marcacite. Chalcopyrite increases toward ore mineral rich zone. Total Au and Ag grades of the ore vein are lower than those of the other veins. The average grades of ore veins are 11.7 g Au/t and 15.3

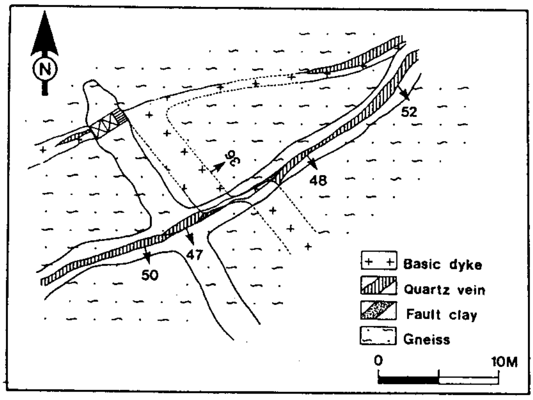

Fig. 6. Sketch showing the relationship between quartz vein and basic dyke that are deformed by continuous strike-slip movement.

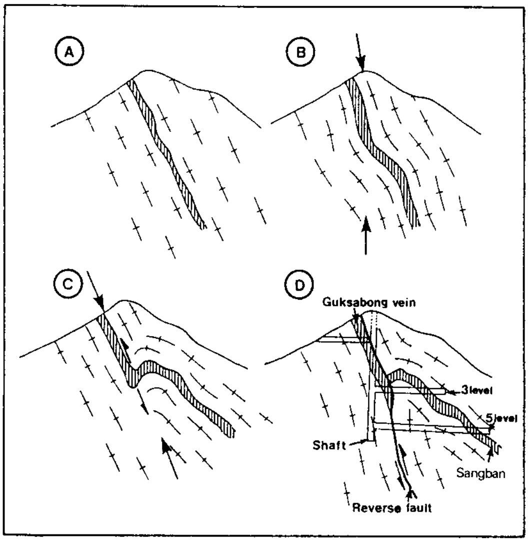

Fig. 7. Sketch showing the Sangban vein origined from reverse fault.

g Ag/t.

The Guksabong orebody is about 0.5-1.5 m in width and 320 m length, with an oreshoot toward 112°/31°. Orientations of slickenside lineation on the fault plane are 100-120°/30-40°. These are concordant with those of Tongdong and Bonhang orebodies. Four basic or intermediate dykes that have of N5-35°E and N30°W with the dip of 65-75°SE and 45°NE respectively change into sill-shapes and crosscut to the ore veins where contact with the fault zone (F_1) (Fig. 6). The vein ores consist pricipally galena, sphalerite, arsenopyrite, pyrite, chalcopyrite and pyrrhotite. Most minerals except the pyrrhotite contain electrum, and the average grades of ore vein are 9.0 g Au/t and

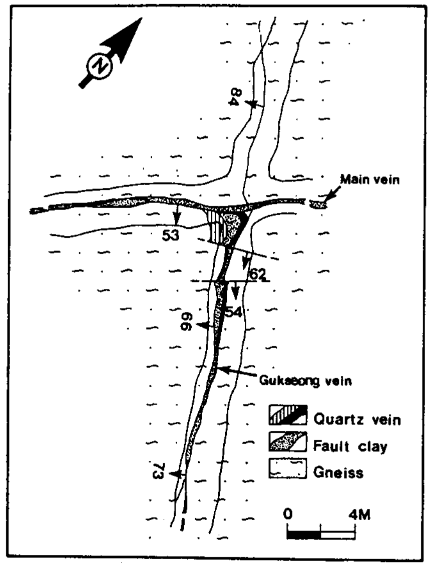

Fig. 8. Sketch showing the relationship between the Main and Gukseong veins.

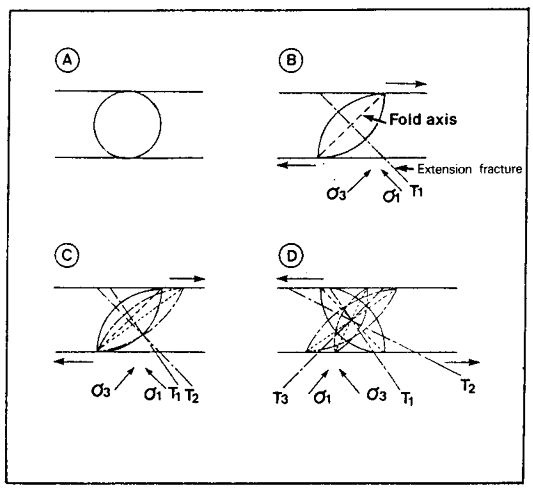

Fig. 9. Idealized model of the evolution pattern for strike-slip fault system (modified from Wilcox *et al.*, 1973).

12.7 g Ag/t.

Sangban Vein

Sangban vein is separated from the Main vein by the reverse fault. The Sangban vein is 0.3-12.0 m in width and 320 m in length. This strikes EW with the dip of 30°-40°S. The ore vein is drag-folded by the reverse fault (Fig. 7). The vein ores consist pricipally sphalerite, chalcopyrite, galena, pyrite, arsenopyrite, pyrrhotite and trace amounts of argentite. Ge-

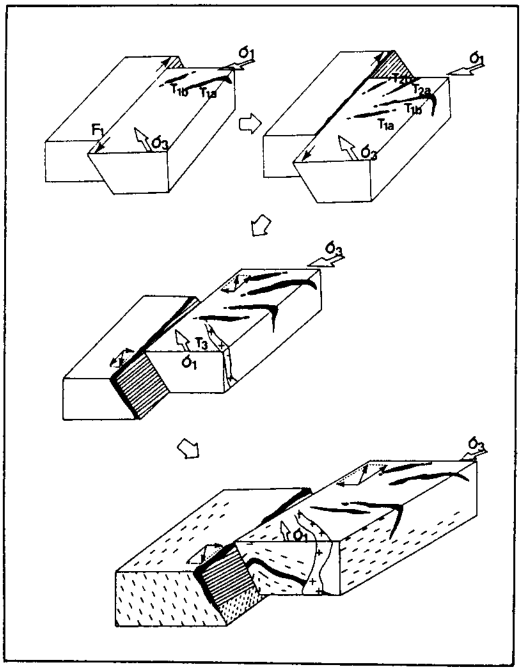

Fig. 10. Schematic diagram for development of the veins in the strike-slip fault system.

nerally the amounts of arsenopyrites are lower than those of the other ore veins and increase at a barren zone of the Sangban vein. Electrum mainly occurs in arsenopyrite, sphalerite, galena and chalcopyrite, with minor pyrite. Average grade of the ore vein is 27.5 g Au/ton and 16.3 g Ag/ton.

Gukseong Vein

Gukseong vein is 0.5-1.5 m in width and 320 m in length. This vein strikes N30°W with the dip of 65°-70°SW. Ore vein does not occur at the lower No. 2 adit level because extention fractures (T_{1a} and T_{1b}) weakened below the No. 2 adit level. The ore vein is dragged out and crosscut at the fault zone (F_1) by the strike-slip fault (Fig. 8). The mineralization of this vein is similar to that of the Guksabong vein but considerably different in the mineral assemblages. The vein ores consist pricipally arsenopyrite with galena and sphalerite. The average grades of ore vein are 4.5 g Au/t and 5.7 g Ag/t.

Other Veins

Other ore veins are exposed in the mine field. These are Daehung 1, 2 veins, Bonggabri vein and Sinri vein. The Daehung vein is 200 m in length and strikes N55°-65°W with the dip of 60°-75°NE at the western part of the Guksabong summit. The length of Bonggabri vein is about 1 km around the Bonggabri and that of Sinri vein is 700 m in length at 600 m east from the Gukseong vein. Relationship between these veins and ore veins of the Samkwang mine may be explained by the ore veins which filled extension fractures originated from strike-slip fault.

DISCUSSION AND CONCLUSION

Formation of the epigenetic ore deposit is related to hydrothermal fluids associated with the various structures. Quartz veins and dykes are also closely related to the structural features. Several patterns of the dykes and quartz veins are found around the Samkwang mine distirct. These are associated with general geological structures including faults, folds and lineations. Quartz veins and dykes can be divided into three types from T_1 to T_3 in a strike-slip fault system. Based on the orientations of slikenside lineations, quartz veins and dyke rocks, the structural constraints of the Samkwang mine is explained by the Wilcox's model (Wilcox *et al.*, 1973). Circles on the surface of the clay cake are distorted into ellipsed by the progressive development of shear strains (Wilcox *et al.*, 1973); (Fig. 9). The long axis of the strain ellipse is consistent with a fold axis as the development of the strike-slip fault. Extension fractures occur along with the short axis of the strain ellipse. In the three dimensional view, the extension fractures occur parallel to σ_1, σ_2 planes. Therefore, the directions of stresses can be estimated by the directions of the extension fractures. A possiable history of the structural constraints and ore genesis for the Samkwang mine is explained follows (Fig. 10): 1) When σ_1 operates obliquely to NE-series discontinous surface, the Main fault (F_1) developes. 2) During the same time, extension fractures (T_1, Gukseong veins) take place. 3) When the fault progress continuously, the existing T_1 may be high angle and T_2 (Daehung vein) developes. 4) When σ_1 changes, T_3 (basic dyke) occurs. 5) When a reverse fault becomes active, the Sangban vein is branched from the Guksabong vein.

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삼광광산에서의 주향이동단층에 의한 함금-은 석영맥에 대한 구조규제

이현구 · 유봉철 · 홍동표 · 김경웅

요 약: 삼광광산은 옥천대의 서부에 위치하는 백악기의 금-은 광상으로서 선캠브리아기의 화강편마암내에 배태되어 있다. 광산의 금과 은의 품위는 각각 8.4 g/t, 13.6 g/t으로서 가채 매장장은 335.000 MT으로 추정된다. 이 광상은 Au-Ag광물 이외에 유비철석, 방연석, 섬아연석, 황동석, 황철석, 자류철석을 함유하는 열수성 석영맥상광상이다. 광상을 이루는 맥들의 구조를 근거로 할 때 광화작용의 구조규제는 N40°-80°E 주향과 55°SE-수직의 경사를 보이는 본맥의 생성, EW주향과 30°-80°S의 경사를 보이는 상반맥의 발달 그리고 N25°-40°W 주향과 65°-80°SW 경사를 갖는 국성맥의 생성 등 3가지로 나눌 수 있다. 광상배태의 구조운동은 이 지역에 발달하는 주향이동단층의 최소응력축(σ_3)과 관련이 있으며 광맥은 이때에 발생한 열극을 충진한 것으로서 다음과 같이 5단계로 해석된다. (1) NS계의 불연속면에 예각으로 작용한 주응력(σ_1)에 의한 주단층(F_1)의 생성, (2) 이와 동시에 발달한 인장파쇄대(T_1)를 충진한 국성맥의 생성, (3) 단층의 계속적인 성장과 T_1의 경사가 커짐에 따른 T_2(대홍맥)의 계속적 발달, (4) σ_1이 우수향을 보일 때 발달하는 T_3(염기성 암맥)의 관입, (5) 역단층의 활동에 의한 국사봉맥으로부터 상반맥의 생성이 있었던 것으로 보인다.