Sulfur Isotope Composition and Isotopic Temperatures of the Shinyemi Lead and Zinc Ore Deposits, Western Taebaegsan Metallogenic Belt, Korea.

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Abstract: Sulfur isotope compositions (δ^{34}S) of seventy one sulfide minerals from the Shinyemi ore deposits were determined to range from -10.1 to $+5.0‰$ with a mean value of $+2.1‰$.

These values are roughly comparable to those of various hydrothermal ore deposits in Korea, about $+2.0$ to $+7.0‰$ in δ^{34}S, suggesting that they are to be same in source of sulfur.

The Shinyemi deposits are grouped into two types; the western bedded skarn orebodies and the eastern small pipes and veins. The δ^{34}S values of sulfide minerals from the bedded orebodies (early mineralization) are ranging from -10.1 to $+2.5‰$, which is relatively wide in range, whereas those of the pipes and veins (later mineralization) have a narrow range of δ^{34}S values, $+2.7$ to $+5.0‰$, regardless of the kind of sulfide minerals.

Isotopic temperature obtained from the sphalerite-galena mineral pairs of the New B orebody appeared to be about 400 to 540°C are reasonably good agreement with the comparable data of skarn mineral assemblages. It is concluded that the west orebodies were formed in earlier stage at higher temperatures than the east orebodies formed later at lower temperatures.

Judging from the various data from the present study, the Shinyemi deposits can be defined as a typical contact metasomatic deposit. The source of sulfur in the hydrothermal solutions is considered to be comagmatic with the Shinyemi granodiorite.

Introduction

Sulfur isotopic study of sulfide ore deposits is generally used as a useful tool to seek the genesis of sulfide ores. The origin of sulfur and physicochemical conditions of ore deposition were discussed on the basis of the sulfur isotopic, geological, mineralogical and geochemical data (Kajiwara 1971, Ohmoto, 1974, Robinson and Ohmoto, 1973, Ohmoto and Rye, 1979, Corsin et al., 1980).

The Shinyemi deposits is occur in contact aureole of the Cambro–Ordovician Maggol limestone and Shinyemi granodiorite of Paleocene age. The deposits consist of the bedded skarn orebodies in the west orefield and the small pipes and veins in the east ore field. The bedded orebody of lead–zinc skarn is rarely known in this country and attracted many geologist's interests.

In this paper, sulfur isotopic characteristics of the above two different types of orebodies in the Shinyemi mine was examined, and isotopic temperature and source of sulfur were discussed, on the sulfur isotopic composition of 71 sulfide minerals from the mine. The isotopic analysis was carried out at Nagoya University, Japan.

Geologic setting and ore deposits

The Shinyemi mine area consists geologically of the Cambro–Ordovician Maggol Formation, tuffaceous sandstone of unknown age, the Carboniferous Hongjom Formation, and the Paleocene granodiorite and dike rocks (Fig 1).

Details of the geology and ore deposits of the Shinyemi mine were described by Kim, S.U. et al. (1965) and Kim and Kim (1978).

The following is a brief summary of geologic setting and ore deposits of the mine.

The Maggol Formation, the uppermost unit of the Great Limestone Series, is widely distributed

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in the mine area. This Formation consists of gray crystalline limestone which is intercalated by thin layers of dark shale. Attitude of this formation is rather gentle showing N20–30°E strike and 20–25°NW dip. This formation is intruded by the Shinyemi granodiorite (60 m.y. by K–Ar method: Kim and Kim, 1978) and dikes of rhyolite, felsite, and quartz porphyry. The Shinyemi skarn deposits are hosted in the Maggol formation along or near the contact with the granodiorite and the felsic dikes. Near the contact zone, the limestone was partially brecciated and the intercalated shale, dark gray to chocolate–colored, has transformed to hornfels as seen in the west orefield.

Dike rocks of rhyolite, quartz porphyry and felsite are abundant particularly in the vicinity of the ore deposits. Trends of these dikes are nearly north–south. The felsite seems to be related to the late stage of mineralization.

The Shinyemi deposits are emplaced in and near the contact zone between the Maggol limestone and the Shinyemi granodiorite cupola. The principal ore minerals are sphalerite, galena, chalcopyrite and molybdenite, and sulfide gangues are pyrrhotite pyrite and arsenopyrite. Magnetite also occurs in the west ore field. Skarn silicates consist mostly of garnet with clinopyroxene, tremolite and epidote.

The Shinyemi deposists can be divided into the west and east orebodies according to the mode of occurrence and location.

The west orebodies: The western orebodies are embedded in the upper part of the Maggol limestone in which black to purplish red shale beds are intercalated (Fig. 1). The limestone beds were selectively replaced by skarn and ore mininerals whereas the shale layers were altered to hornfels. The hornfels grade into unaltered black or purplish shales along or across the beds. Irregular blebs and veinlets of pyrrhotite are found in the hornfels. The ore minerals of the west orebodies are sphalerite, chalcopyrite and molybdenite which

are accompanied with minor amounts of galena, pyrite and pyrrhotite. Scheelite is also found occasionally at the lower levels of the orebodies.

Skarn minerals consist mainly of grandite garnet (Andradite 12–60 mole%, Kim, et al., 1981), clinopyroxene, tremolite and calcite. The ore beds have a few centimeter to 15m in thickness and extend up to 200m in length. The chemical composition of sphalerite determined by electron microprobe analysis is characterized with 10.74–11.75 mole percent of FeS, 0.17–0.26 mole percent of CdS and 1.8–2.3 mole % of MnS (Kim, et al. 1981). Garnet from the west orebody exhibits anisotropic zoned structure. According to Miyazawa (1977), it is explained that anisotropic garnet was formed at a later stage and isotropic one at an early stage of mineralization.

The east orebodies: The east orebodies occur in and near the contact zone of lower part of the Maggol limestone and the Shinyemi granodiorite,in the form of veins and small pipes along the fissures (Fig. 1). Most of the veins strike mostly N30–45W, dip 60–80NE and strike N–S, dip 60–80NE. Ore minerals, almost sphalerite, also disseminate in the granodiorite as well as in the limestone.

The east orebodies are generally lacking skarn minerals except for a few places, and this is a significant difference from the west orebodies. Skarns are dominated by garnet and epidote. Ore minerals in the east orebodies are sphalerite and minor galena, chalcopyrite and molybdenite, in association with gangue minerals: pyrite, pyrrhotite, marcasite, calcite. Composition of garnet is Andradite 22–56 mole %. FeS content of the sphalerite ranges from 13.8 to 22.9 in mole percent. CdS and MnS contents are 0.17–0. 26 and 1.0–1.7 mole %, respectively.

Sampling and analytical procedures

The sampling program was designed firstly to determine the isotopic compositions of sulfide minerals from the Shinyemi deposits which were
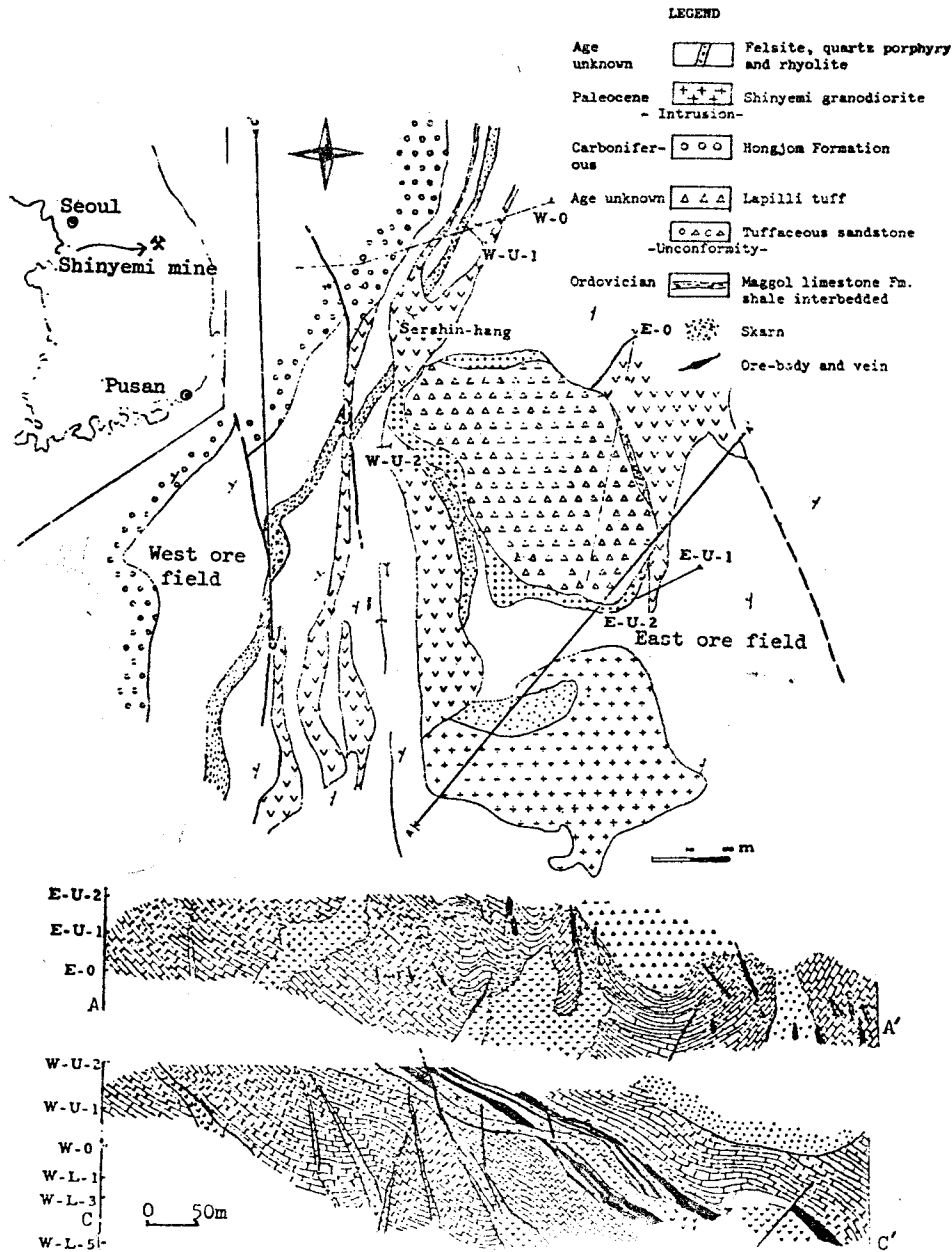
LEGEND

Age		
Age unknown	Felsite, quartz porphyry and rhyolite	
Paleocene	Shinyemi granodiorite	

- Intrusion-

Carbonifer-ous	Hongjom Formation
Age unknown	Lapilli tuff
	Tuffaceous sandstone

-Unconformity-

Ordovician	Maggol limestone Fm. shale interbedded

Skarn

Ore-body and vein

Seoul

Shinyemi mine

Pusan

W-0

W-U-1

Sershin-hang

E-0

W-U-2

West ore field

E-U-1

E-U-2

East ore field

Fig. 1 Geologic map of Shinyemi ore deposits(after Kim and Kim, 1978)

divided into the east and the west orebodies. Secondarily, samples in the west orebodies were taken to examine the variation of sulfur isotopic compositions of sphalerites within a given horizon at the bedded skarn orebody. Thirdly, coexisting sulfide minerals, especially sphalerite and galena pairs from the east New B orebody, were sampled to estimate isotopic temperatures by use of various experimental sphalerite–galena isotopic fractionation curves as a geothermometer. Powdered samples were also taken from the floation mill. Most of the ore mineral samples of the mine

were selected by means of hand picking under binocular microscope. Concentration of some pyrites were treated with HCl to dissolve calcite. Pure mineral samples were easy to obtain from the east orebody because they are of the coarse grained aggregates of skarn ores. However, the east orebody samples were difficult for hand picking as they are of extremely fine–grained ones. Coexsisting sphalerite–galena samples from the New B orebody from the east orebodies were easily obtained for isotope geothermometry. However, it was not possible to obtain sulfide pairs from the west. Coexsisting sulfide pairs were identified by texural relations under the ore microscope. Sulfide mineral samples examined include sphalerite disseminated in granodiorite, pyrite in felsite and limestone, and pyrrhotite in hornfels, all of which were available only in the west orebodies.

Seventy on mineral separates were analyzed, which include 41 sphalerites, 11 galenas, 6 chalcopyrites, 2 pyrrhotites, 5 molybdenites, 2 arsenopyrites, and 4 pyrites.

The samples for $\delta^{34}S$ analyses are converted to SO_2 gas through the following procedures: After powdering of sphalerite, galena and pyrrhotite, these were tranformed to H_2S by treatment with 6 N HCl. The H_2S gas was then passed through the mixture of 10% cadmium acetate and 10% sodium carbonate anhydrous solution to precipitate CdS, which was in turn treated with 5% $AgNO_3$ solution to form Ag_2S.

In case of pyrite, molybdenite and chalcopyrite, each of sulfide samples was treated by Lunge solution (1 HCI: 3 HNO_3) to produce solubles SO_4^{2-} in the water bath. And then $BaSO_4$ was made from the SO_4^{2-} solution by adding 10% $BaCl_2$ The $BaSO_4$ was reduced to BaS using graphite at 1000°C. Ag_2S precipitation was also obtained by the same method as mentioned above.

A Nier–Mckinney type mass spectrometer, Variation Mat CH-7, was used for the measurement of isotope ratio for the SO_2 gas. The analytical result were expressed as $\delta^{34}S$ in ‰. deviation from Canyon Diabro meterorite.

$$\delta^{34}S = \left[\frac{^{34}S/^{32}S(sample)}{^{34}S/^{32}3(standard)} - 1 \right] 10^3$$

The reproducibility for $\delta^{34}S$ measurements is better than ±0.1‰.

Isotopic composition of the sulfide ores: The sulfur isotopic data of the various sulfide minerals from the Shinyemi ore deposits are given in Table I. The $\delta^{34}S$ values determined for 71 samples in overall range from −10.1 to +5.0‰ with a mean value of +2.1‰ relative to the Canyon Diablo standard. The $\delta^{34}S$ values for sphalerite range from −10.1 to +2.1‰, galena +2.9 to +3.8‰, chalcopyrite +3.5 to +5.0%, pyrrhotite −0.6 to +4.2‰, and molybdenite +0.2 to +4.3 ‰.

Plots of $\delta^{34}S$ values for these sulfide minerals fall markedly into two groups, those for the east orebodies and west orebodies, as shown in Fig. 2. Sulfide minerals from the west orebodies, which are bedded orebodies, show a relatively wide range of $\delta^{34}S$ values, from −10.1 to +2.5‰. One the other hand, most sulfides from the east orebodies, which are mostly of small pipes and veins, exhibit a narrow range, +5.0 to +2.7‰.

The difference between the two ore fields, the west and east, in sulfur isotopic composition may be a indicative of differences in stage of mineralization and environment of ore formation from the view point of ore deposition. As previous work by Kim and Kim (1978) pointed out, the west orebodies are thought to represent an early stage of mineralization compared with the east orebodies, concluding that there were two stages of mineralization and types of ore deposition took place in the Shinyemi mine; (1) early bimetasomatic skarn, formation, and (2) later infilterational sulfide deposition. In the Shinyemi ore deposits, isotopic data are characterized by the fact that $\delta^{34}S$ values of the west orebodies are lighter than those

of the east orebodies as shown in Fig. 2. For example, in the west orebodies, sphalerite from sphalerite–calcite vein which cuts across the magnetite orebody have a +4.3‰ of δ^{34}S value which is heavier than those of sphalerite from bedded skarn orebody. It indicates that the δ^{34}S value of sphalerite depends on the type of orebody.

Kim and Nakai (1980) suggested that the difference in δ^{34}S range of two different types of orebodies depend on their depositional conditions including oxygen fugacity and temperature. In this repect, they considered the same source of sulfur in two orebodies.

δ^{34}S values of sphalerite desseminated in granodiorite range from +4.2 to +4.4‰ and those of the massive orebodies also show a similar

Table. 1 Isotope data of sulfide minerals from the Shinyemi mine

Sample No.	Mineral	δ^{34}S (‰)	Remarks ·
111	sp	+4.5	E–U–1, New B orebody
	gn	+3.5	(coexisting mineral pairs)
112	sp	+4.4	ditto
	gn	+3.5	
	cp	+5.0	
113	sp	+4.7	ditto
	gn	+3.8	
114	sp	+3.9	E–U–1 New B orebody
	gn	+3.1	
115	sp	+4.7	E–U–1, New B orebody
	gn	+3.5	(coexisting mineral pairs)
	cp	+4.8	
116	sp	+4.2	ditto
	gn	+2.9	
	cp	+4.4	
125	sp	+4.4	E–O, New B orebody
	gn	+3.4	(coexisting mineral pairs)
117	sp	+4.4	E–O, sphalerite disseminated in the Shinyemi granodiorite
118	sp	+4.2	ditto
119	sp	+4.3	ditto
120	gn	+3.4	E–U–2, No 3 orebody
	gn	+3.2	ditto
122	gn	+3.4	Dongshin-hang, New A orebody
123	sp	+4.3	E–U–1, Namup
124	mo	+4.3	E–L–2, molybdenite orebody
126	sp	+4.4	E–L–2, New A orebody
127	sp	+3.6	E–L–3
128	sp	+4.0	E–L–2
	sp	+4.2	
	cp	+3.5	
130	po	+4.2	E–O, pyrrhotit-calcite vein
131	py	+4.1	E–O, pyrite in limestone
132	py	+4.7	E–O, pyrite in granodiorite
133	py	+6.6	E–U–2 pyrite-calcite vein
134	py	+4.1	Dongshin-hang

135	sp	+3.6	E–L–3
136	sp	+3.0	E–L–2
137	aspy	+6.1	E–O
225	cp	+3.4	E–L–1
211–1	sp	+1.0	W–O
211–2	sp	+1.0	W–O
212	sp	−0.9	W–L–1, B
213	sp	+2.5	W–L–1
214	sp	−0.9	W–L–1, B
215	sp	−0.7	W–L–2–1
216	sp	−0.9	W–L–2–2
218	sp	−0.1	W–L–3
219	sp	−1.9	W–L–3
220	sp	−1.3	W–L–5
217	mo	+0.2	W–L–5
221	sp	−1.2	W–L–5–O.
222	sp	−0.9	W–L–5–A
223	sp	+4.3	Sershin-hang, sphalerite-calcite
	aspy	+4.5	Vein imbedded in magnetite orebody
224	po	−0.6	W–L–3
226	sp	+1.4	Sample from the flotation mill
227	mo	+0.5	ditto
228	gn	+2.5	ditto
229	mo	+0.4	W–L–2
230	mo	+2.4	W–L–3
231	sp	+0.9	W–U–2
232	sp	+0.7	W–U–2
233	sp	−2.4	W–I–U
234	sp	−2.1	W–U–1
235	sp	−1.9	W–O
236	sp	−0.8	W–O
237	sp	−0.9	W–O
238	sp	−4.9	W–L–6
239	sp	−10.1	W–L–6
240	sp	−7.6	W–L–6
241	cp	+3.0	E–L–2

E; East ore field samples, W; Samples from the West ore field

sp; sphalerite, gn; galena, cp; chalcopyrite, mo; molybdenite. py; pyrite, aspy; arsenopyrite

range, +3.9 to +4.7‰. This similarity of $\delta^{34}S$ values between the two ore fields can be an indication of identical origin of sulfur for these orefields. It may be noteworthy that the isotopic values the bedded skarn orebodies without showing variation of $\delta^{34}S$ with depth through the orebody (Fig. 3).

Isotopic geothermometry

Several samples of coexisting sphalerite and galena were taken from the New B orebody of the east orebodies to estimate the isotopic temperatures. After identification and separation of the coexiting sulfide minerals under ore microscope, each of mineral species was analyzed isotopically. Isotopic data and isotopic temperatures estimated by various experimental curves are listed in Table 2.
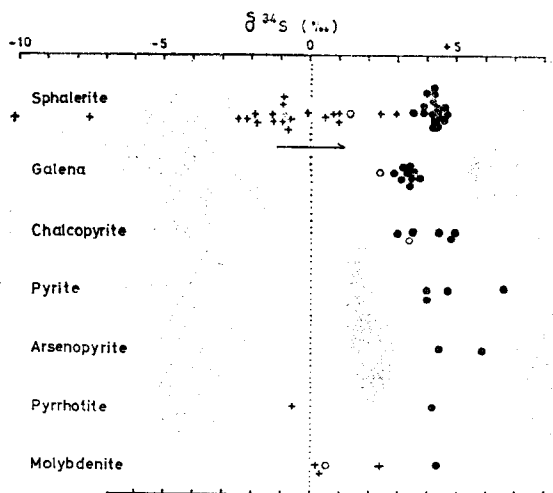
A distribution of $\delta^{34}S$ values between sphalerite

Fig. 2   Distribution of δ^{34}S va ue for sulfide minerals from
the Shinyemi mine.
● Values from the East ore field
+ Values from the West ore field
○ Samples from the flotation mill
→ Trend toward later stage

and galena shows an equilibrium relation in
isotopical aspect as seen in Table 2, that is, all
samples of sphalerite are heavier in δ^{34}S value
than those of galena.

As shown in Table 2, isotopic temperatures of
New B orebody of the Shinyemi mine were ob-
tained to be 417–506°C when based on the ex-
perimental curve of Kiyosu (1973), or 395–540°C
when based on the curve of Grootenboer and
Schwarcz (1969). Using the isotopic equilibrium
fractionation of Ohmoto and Rye (1979), the
formation temperature of the New B orebody was
calculated as 472–623°C. Temperatures of 491–
609°C by the curve of Czamanske and Rye (1974)
and 311–675°C by the curve of Kajiwara (1971)
are also calculated. The experimental curves for
sphalerite–galena sulfur isoiope fractionations
by many workers are not in good agreements as
pointed out by Rye (1974). Therefore, it is inevitable
to chooses one which is the most reasonable. Garnet
(pyroxene)–epidote assemblage in skarns from
New B orebody are assumed to have formed
about 400–500°C basesd on Zharikov's results

(1970). Considering the mineral assemblage of
the Shinyemi skarns, however, it is unlikely to
have the temperature range higher than 600°C.
Judging from these facts, the range of formation
temperatures of sulfide ores in the east orebodies
of Shinyemi is estimated to be 400–540°C, which
may be appropriate for the skarn formation. If
this is true, the experimental curves of Grooten-
boer and Schwarcz, 1969) and of Kiyosu (1973)
seem to be fit to estimate the formation tem-
peratures of the Shinyemi deposits. However the
formation temperatures of the west orebodies
appear to be over about 550°C, that is estimated
based on the skarn mineral assemblages and
isotopic temperatures. Therefore, it follows that
the formation temperature of the west orebodies
is higher than that of the east. Above conclusion,
of course, is based on the higher temperature and
earlier stage of skarnization rather than those of
the later sulfiede mineralization.

Comparision with other lead-zinc deposits in Korea

The 177 sulfide mineral samples from 10 lead–
zinc deposits, 10 copper deposits, 4 tungsten
molybdenum deposits and 2 iron deposits in Korea
were analyzed for δ^{34}S (Kim and Nakai, 1980).
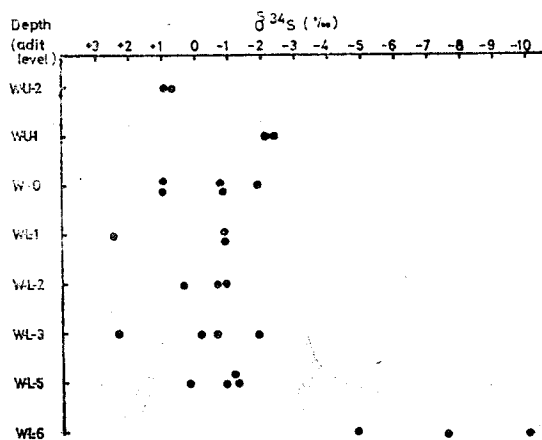These δ^{34}S values are presented in Fig. 4, where

Fig. 3 δ^{34}S variation of sphalerite from the upper (W-
U-2) to lower (W-L-6) level in the west orebody
of the Shinyemi ore deposits.

Table. 2 Isotope temperature of the New B orebody from the Shinyemi east orefield.

Sample No.	Locality	$\delta^{34}S_{sp-gn}$	1) Kiyosu(1973)	2) Grootenboer and Schwarcz(1969)	3) Czamanske and Rye(1974)	4) Kajiwara and Krouse(1972)	5) Ohmoto and Rye(1979)
111	E–U–1	1.1	457(°C)	480	524	580	537±29
		0.9	506	540	609	679	623±32
113		0.9	506	540	609	679	623±32
115		1.2	436.2	440	491	543	503±27
116	E–L–2	1.3	417	395	461	511	472±27
125	E–O	1.0	480	500	563	621	577±30
Isotope temperature range			417–506	395—540	491—609	511—760	472—623°C
Experimental temperature range			50–340	340—690	275—600	250—600	

1) Isotope temperature calculated from Kiyosu (1973); $\delta^{34}S_{sp-gn}=8.91\times10^5/T^2(°K)-0.57$
2) Calculated from Czamanske Grootenboer and Schwarcz (1969).
3) Calculated from Czamanske and Rye (1974); $\delta^{34}S_{sp-gn}=7.0\times10^5/T^2(K)$
4) Calculated from Kajiwara and Krouse (1971); $\delta^{34}S_{sp-gn}=8.0\times10^5/T^2(K)$
5) Calculated from Ohmoto and Rye (1979); $T=(0.85\pm0.03)\times10^3/(\delta^{34}S_{sp-gn})^{1/2}$

whose of the Shinyemi deposits are also added. The $\delta^{34}S$ values in Fig. 4 give a narrow range between about +2.0 and +7.0‰, except for the Sambo lead–zinc mine. This figure indicates the hydrothermal range by Heyl and Landis (1974), and strongly suggests that these sulfides are to be igneous origin according to Ohmoto and Rye (1979). Geological and field evidences also support the above interpretation.

Shinyemi has similar $\delta^{34}S$ values to other lead–zinc–copper deposits in South Korea (Fig. 4). Especially, Yeonhwa 1 and 2, Ulchin, Imok, Yujon and Janggun, which are located near and/or around the Shinyemi, are analogous to the Shinyemi in terms of sulfur isotopic composition, formation temperature and other geological setting. In general, $\delta^{34}S$ value for sphalerite tend to gradually increases from the eastern most Ulchin mine via the Yeonhwa to the Shinyemi mine with increasing geolgical age of the related igneous rocks along the Taebaegsan metallogenic belt (Kim and Nakai 1980).

A $\delta^{34}S$ value (+5.7‰) of the SO_4^{2-} in the thermal water from Baegam hot spring of the Taebaegsan metallogenic belt appear to be comparable to the $\delta^{34}S$ value of sulfiede minerals (Kim and Nakai, 1981). This is close to the value plotted in acidic volcanic thermal water range of Japan by Rafter and Mizutani (1967).

Discussion

An account for the origin and environment of ore formation is one of the principal aims of the present investigation. It is a basic problem to distinguish the ore types between igneous and sedimentary origin in terms of both theoretical and practical aspects.

To discuss the ore genesis of Shinyemi deposits, the isotope data of coexisting sphalerite and galena pairs from 20 ore deposits in the world, which are clear in origin, were selected. A number of plots of $\delta^{34}S$ values for sphalerite versus galena of the coexisting mineral pairs is shown in Fig. 5. In the diagram, plotted points of isotope values are divided roughly into two groups: one is −3 to +9‰ of $\delta^{34}S$ sp and about −5 to +5‰ of $\delta^{34}S$gn, the other is about +12 to +17‰ of δ^{34}sp and +7 to +15‰ of $\delta^{34}S$gn. The diagram indicates that distribuiion of $\delta^{34}S$ values for the stratabound and/or startiform types appeared relatively in wide range and scattered form. Examples are Heath Steele B–1 orebody, New Brunswick, Canada, Main Broken Hill Lode, Australia, Pine Point, Canada and Sierra de
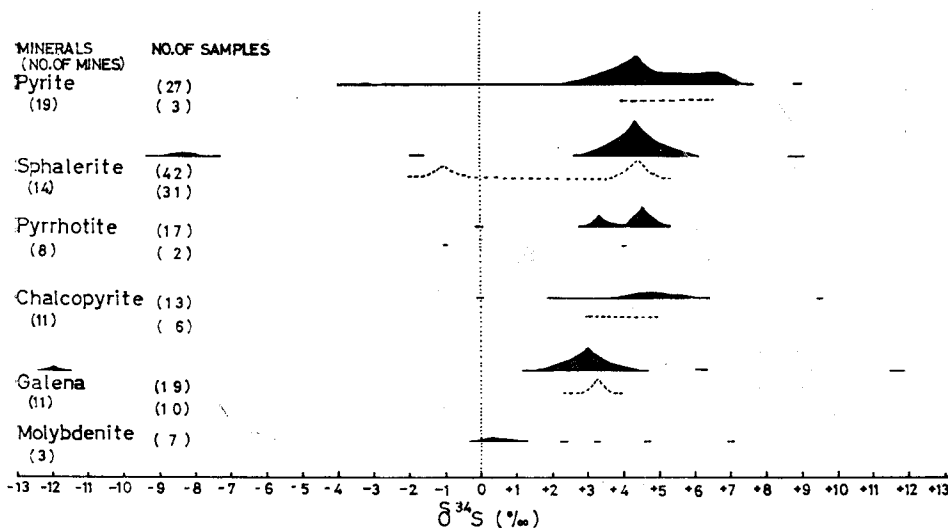
Fig. 4   Schematic presentation of sulfur isotopic data of the Shinyemi ore deposits, and of 10 lead–zinc mines, 10
copper mines, 4 tungsten and molybdenum mines, 2 silver mines, Korea (Kim and Nakai 1980)
Lead-zinc mine; Yeonhwa 1, Yeonhwa 2, Ulchin, Okryong, Janggun, Imok, Yujon, Yongduck,
Chungdo and Sambo mines.
Copper mine; Dongjom, Milyang, Illkwang, Yongho, Nokdong, Jangheung, Bonghwang, Kumryong,
Keodo, Kukjon mines.
Tungsten and molybdenum mine; Okbang, Daihwa, Namhai, and Dalsung mines. Silver mine; Bupyong,
and Juchon mines.
Iron mine; Dongnam and Mulkum mines.
Dotted line indicates the data of the Shinyemi.

Cartegena, Spain. On the other hand, it shows a narrow range of $\delta^{34}S$ value in pipe and vein types and contact deposits. According to the theoretical and experimental works, the nearer the plotted points fall to the straight line, the higher the temperature of formation of ore minerals as marked temperature scale after Ohmoto and Rye (1979). In Fig. 5, plots of the isotope values of Shinyemi, which represents relatively high temperature, fall near those of Taishu hydrothrmal vein deposits in Japan $\delta^{34}S$ values mostly centered in the range from 0 to $+7‰$ suggest the hydrothermal, contact metasomatic and volcanogenic deposits in origin.

Sulfide minerals from various leas–zinc–copper deposits, including Yeonhwa, Ulchin, Okryong, and Janggun in the Taebaegasan metallogenic belt most of which formed under similar geological conditions, have a similar range from $+2$ to $+7‰$ in $\delta^{34}S$ values. This implys that they may be

same in sulfur source derived from acidic crustal magma (Kim and Nakai, 1980).

Kim and Nakai (1980) pointed out that the Shinyemi mine have a single source of metasomatic and hydrothermal ore fluids originated mainly from magmatic source by carbon and oxygen isotope studeies of carbonate minerals.

From the various points of view, origin of the Shinyemi ore deposits may be interpreted as the typical contact metasomatic deposits related to the Shinyemi granodiorite and acidic dikes.

Conclusion

The Shinyemi deposits are grouped two types: the east orebodies and west orebodies on the basis of occurrence. The west oreboies occur in the upper part of the Maggol limestone formation which is interlayered by hornfelsic slate layers. These orebodies are of flat–lying bedded type and are concordant with the host sedimentary forma-
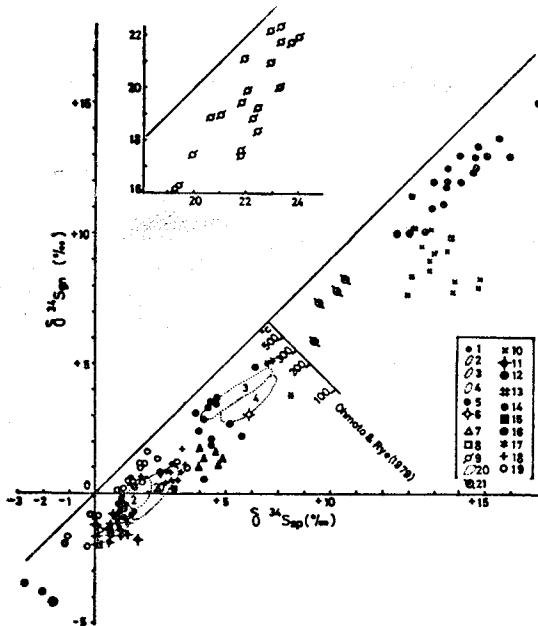
Fig. 5 Plots of $\delta^{34}S$ values for sphalerite vs galena, coexisting mineral pairs, from the various types of mineral deposits. Plotted data from Friedrich et al., (1964), Tatsumi (1965), Anger et al., (1966), Sasaki et al., (1966), Sasaki et al., (1969), Kajiwara et al., (1969) Lusk et al., (1969), Groves et al., (1970), Kajiwara (1971) Rye (1974) Robinson (1974), Both et al., (1965), Kiyosu et al., (1977), Corsin et al., (1980).
1, Shinyemi, (present study), 2, Kamioka, Japan, 3, Taishu, Japan, 4, Toyoha, Japan, 5, Heath Steele B-1 orebody, Canada, 6. Kosaka, Japan, 7. Shakanai No. 1 Japan, 8, Yatani, Japan, 9, Pine Point, Canada, 10. Booty mine, Upper Mississippi Valley district, 11 Providencia Mexico, 12, Rex Hill Mine, Tasmania, 13, Rammelsberg, Germany, 14, Sierra de cartegena, Spain, 15, Casapalca, Peru, 16, Creede, Colorado, 17, Hill mine, Illinois, 18 Tui Mine, New Zealand. 19, Main broken Hill Lode, Australia, 20, Darwin ore deposit, California, 21, Valle del Temperio, Italy.

tions. On the other hand, east orebodies are characterized by small pipes and veins occuring mostly along fissures of lower part of the Maggol formation.

Sulfur isotope composition ($\delta^{34}S$) of the various sulfide minerals from the Shinyemi ore deposits ranges from -10.1 to $+5.0‰$, in which a range of the west orebodies is -10.1 to $+2.5\%$, and of the east orebodies $+2.7$ to $+5.0\%$.

Examined isotopic characters from the deposits are summarized as follows:

1) Sulfide minerals of the west orebodies, early mineralized bedded type, have lighter isotope values of $\delta^{34}S$, while those the east orebodies, later mineralized pipe and vein types, have heavier isotope values.

2) Sulfide minerals from both the orebodies and igneous rocks have similar isotopic compositions providing an evidence to suggest a same source of sulfur as the magmatic origin.

3) Isotopic temperature obtained from coexisting sphalerite–galena mineral pairs appeared to be about 400–540°C.

4) $\delta^{34}S$ values of sulfide minerals from 20 ore deposits in the world were plotted for galena versus sphalerite in coexisting mineral pairs in order to examine the origin of ore deposits. This diagram shows that sulfide minerals of the stratiform and stratabound deposits (sedimentary origin in general) including Mississippi Valley type, have a wide range in $\delta^{34}S$ value, while hydrothermal veins, pipes and contact deposits, have a narrow one. No isotopic values showing $\delta^{34}S_{sp} < \delta^{34}S_{gn}$ exists in the coexisting mineral pairs. A narrow range of the $\delta^{34}S$ values for the Shinyemi sulfides is comparable with those of the contact deposits, pipes and veins plotted in this diagram, and this may support the origin of the Shinyemi deposits to be a contact metasomatic type, which is generally related with the Shinyemi granodiorite.

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新禮美鑛床産 硫化鑛物의 硫黃同位元素成分 및 同位元素地質溫度에 關한 研究

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요약 : 新禮美鑛床은 太白山鑛化帶西部에 위치하여 Cambro-Ordovician 紀의 莫洞石灰岩과 新禮美花崗閃綠岩 (60m. y.) 의 접촉부에 발달하는 接觸交代鑛床이다. 鑛石鑛物은 閃亞鉛石, 方鉛石, 黃銅石, 輝水鉛石, 磁鐵石이며 자류철석, 황철석, 유비철석, 백철석, 회중석도 소량 수반된다. 스카른鑛物은 石榴石, 輝石으로 되어 있고 소량의 綠簾石, tremolite, phlogopite도 포함된다. 鑛床은 産出狀態, 鑛物의 成分, 硫黃同位元素成分에 의해 西部層狀스카른鑛體와 東部 pipe 및 脈狀鑛體로 나누어진다. 71個의 硫化鑛物의 硫黃同位元素値($\delta34S$)는 −10.1~+5.0‰이며 西部層狀鑛體(早期鑛化)의 硫化鑛物의 $\delta34S$ 는 −10.1~+2.5‰, 西部 pipe狀 및 脈狀鑛體(後期鑛化)의 것은 +2.7~5.0‰이다. 이같은 東西部의 差異는 $\delta34S$ 값이 광물의 種類에 關係없이 鑛化作用의 時期와 産出狀態 및 鑛化溶液의 침전환경등의 차에 의한 것으로 해석된다. 또 이 $\delta34S$ 범위는 국내의 火成起源의 硫化鑛床産 200여개 硫花鑛物의 $\delta34$ 범위 +2~+7.0‰과 거의 같은 범위에 들어간다. 閃亞鉛石 -方鉛石同位元素地質溫度計에 의하면 東部의 新鑛體 B 의 생성온도는 400~540°C이며 이는 스카른광물의 광물조합에서 얻은 결과와도 비교적 잘 일치한다.

여러 資料에서 검토 해본 결과 新禮美鑛床은 전형적인 接觸交代鑛床이며 熱水鑛液의 起源은 新禮美花崗閃綠岩에 연관되어 있는 것으로 해석된다.