Repeated Mineralization Ages and Remobilization of Elements in Gold ore Deposits from the Chonsan, Rumoh, and Chokei Mines

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Abstract: Explorations of three mines, the Chonsan (Korea), Rumoh (Malaysia), Chokei (Japan) mines were done for Au-veins. Veins were accepted structural control of basement.

At the Chonsan mine in northwest Korea, auriferous ore veins are embedded in Rangnim Gneiss Complex and Ryonhwasan Granitic rock series of Archean Era, and in Namgang Type intrusive rocks (dolerite etc.) of Proterozoic to Paleozoic Era. The auriferous quartz veins contain paragenetic minerals of sphalerite-galena-pyrrhotite-magnetite-pyrite-graphite.

At the Rumoh mine in eastern Malaysia, auriferous ore veins are embedded in late Jurassic Krian Formation and Tertiary granite. The auriferous quartz calcite veins contain paragenetic minerals of realgar-orpiment-cinnabar-arsenopyrite-pyrite.

At the Chokei mine in northwest Japan, auriferous ore veins are embedded in Tertiary Green Tuff, Triassic green rock (basement), and Tertiary granite. The auriferous quartz veins contain paragenetic minerals of pyrrhotite-galena-magnetite-pyrite.

Although each geological occurrence is different among three auriferous mines, each ore veins are controlled by older tectonic lines, and repeated mineralization ages were clarified in three mines. This phenomenon corresponds to "Rejuvenation or Palingenesis of Mineralization". As to element of Au, "Remobilization or Reconcentration of Element" must be discussed. Au shows different behavior to Base metals of Cu-Pb-Zn.

Introduction

In order to study genesis of ore deposits, it is important to analyze structural control in the mineralized area. For this analysis, we must clarify history of magmatic activity, occurrence of faults, and interpretation of mineralization ages. The writer has studied "Rejuvenation or Palingenesis" and "Remobilization of Elements" for a single auriferous ore deposit.

The Chonsan mine is situated at west of Mt. Chonma (1169m), north Pyongan Province,
Democratic People's Republic of Korea. There are famous Unsan and Daeyudon gold mines which were developed since 1895, near here. This mine is situated at 15km west of the Unsan mine. This region has been developed during nearly one hundred years as gold production area (Fig. 1). Recently, the Unsan mine was reported by TAKASHIMA and KISHIMOTO (1987).

The Rumoh mine is situated at Bau of old mining town, at 35km south of Kuching City, Sarawak Province, Eastern Malaysia (formerly North Borneo). This mine region is a famous ore deposits area which has produced gold, antimony, and mercury since 1820 (Fig. 5) (Kim, 1992).

The Chokei mine is situated at southeast slope of Mt. Chokeimori (942.8m), along the boundary between Akita and Aomori Prefectures, Northeast Region, Japan. Nagao deposit of gold-silver ore veins is situated at 5km west of here, and Funauchi and Oppu deposits are situated at 10km east of here. The Chokei mine was developed in the 18th century, and tunnel of 550 total length was made, but this mine has not been developed for nearly 200 years (Kim and ANZAKI, 1979).

Occurrence of Deposits

The occurrence of the Chonsan mine

The gold deposits were embedded in augen gneiss and migmatite of Rangnim Gneiss Complex and Ryonhasan granitic rock series of Archean Era in northwest Korea. Gold-bearing quartz veins are accompanied by the paragenetic minerals of sphalerite, galena, arsenopyrite, pyrite, pyrrhotite, and chalcopyrite. The Rangnim Gneiss Complex consists of sericite-chlorite gneiss, siliceous gneiss, graphite gneiss, two mica gneiss, and partly garnet-cordierite gneiss, beside augen gneiss and migmatite. The gneisses and migmatites are distributed with N-S direction. The Ryonhasan granitic rock series consists of gneissose granite, leucocratic granite, and biotite granite. Some dyke rocks of metadolerite or metagabbro, diorite-porphyrite, lamprophyre, and felsophyre of Namgang Group, intruded into...
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Fig. 3 Geological sketch map of the Chonsan mine and surrounding area, by Chyonma, G. S. P. (1986). A squire figure is area of the Chonsan mine.

Rangnim formation, Agn 1–Agn 4 [Agn 1: Sericite-Chlorite gneiss, Agn 2: Siliceous gneiss, Agn 3: Graphite gneiss, Agn 4: Biotite gneiss (partly contain, garnet-cordierite gneiss).]
Ryonhwasan granite, r 1A–mg A [r 1A: Gneissose granite, r 2A: Leucocratic granite, r 3A: Biotite granite, mg A: Migmatite]

basement rocks of Archean Era (CHONMA, 1986). Intrusive age of the Namgang Group is regarded as Proterozoic to Paleozoic Era (Academy of Korea, 1987 and 1989). Geologic structure and folding structure are not perfectly clear, because the gold ore deposits are embedded in migmatite region. Faults with NW-SE direction, such as Chonma-Yonsan Fault and Kuksongryong-Kunjirhyong Fault, are developed (Figs. 2 and 3).

Pegmatitic veins and gold-bearing quartz veins have two directions of N-S, NW-SE. The N-S direction is parallel to that of Rangnim Gneiss Complex of Archean Era, and the NW-SE direction indicates intrusion of veins along faults of NW-SE direction. Intrusive rocks of Namgang Type (Proterozoic to Paleozoic) have also the similar directions of intrusion (Fig. 4).

Gold ore deposits developed in crossing places of veins of N-S direction and No. 9 vein of NW-SE direction. The veins are distributed along direction of gneissosity of basement gneisses such as siliceous gneiss, biotite gneiss (partly garnet cordierite gneiss) and migmatite. Dikes of dolerite are distributed in migmatite and gneissose granite. Some fracture zones developed along the dikes of dolerite, and gold-bearing quartz veins occur and are associated with chloritization and silification.

The fracture zones show inclination of 45°–70° for SW direction. Paragenetic minerals in the gold-bearing quartz veins are sphalerite-galena-pyrrhotite-pyrite-chalcopyrite. The veins are cut
Fig. 4 Geological plan and profiles of the Chonsan mine, by Chyonma, G. S. P. (1986). A is geological plane, B and C are profiles. Rangnim formation (Agn 2–Agn 4) and Ryonhwasan granite (r lA-mg A), are the same as those in M2.3. N-S direction vein is Sambatkor vein and NW-SE direction vein is No. 9 vein.

D: Dolerite, Sl: Chlorite shear zone, A: Auriferous quartz vein, Dr: Drilling point, Ad: Adit

by No. 9 vein of NW-SE direction, and they cover and disappear. The No. 9 vein consists of migmatite, gneissose granite, and dolerite, etc., and some gold-bearing quartz veins developed along its fracture zone. Alterations such as chloritization, graphitization, silicification, and pyritization are associated with this vein.

The fracture zone has steep inclination of 70°–85° for NE direction. Paragenetic minerals of the vein are mainly arsenopyrite-pyrrhotite-pyrite-graphite, and this vein is poor in Pb-Zn-Cu (KANG, 1987).

It is considered that the No. 9 vein is not a normal magmatic or metasomatic vein. It might have been a certain kind of vein-formed Au-rich zone. Because the No. 9 vein consists of migmatite and gneissose granite of Archean, and of dolerite of Proterozoic to Paleozoic age. Therefore, it is considered that the No. 9 vein must have been caused by a kind of Repeated Metasomatism. The first stage metasomatism (from older Archean sediments to migmatite and or gneissose granite) occurred in younger Archean age. The second stage of metasomatism occurred during dolerite intrusion of Proterozoic or Paleozoic age.

The dolerites intruding into vein and No. 9 have phenocrysts of hornblende, pyroxene, and plagioclase, and these phenocrysts were replaced to aggregates of chlorite, epidote, biotite, quartz, leucoxene, and magnetite, by uralitization and sassuritization. The quartz veins were strongly brecciated and accompany pyrite, marcasite, and chal
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The occurrence of the Rumoh mine

The ore deposit is distributed along the Tertiary granites which include the Krian formation of the later Jurassic and the Tai-parit fault in the direction NE-SW. The fault zone is developed along 4km in length.

Deposit, characterized by epithermal mineral assemblage, was composed of orpiment-realgar-arsenopyrite-calcite-auriferous quartz (Fig. 5).

The Rumoh mine was composed of the Krian formation, the Bau limestone formation and Pedawan formation which were formed in from the late Jurassic through Cretaceous, and of the Tertiary granites intruded into them.

The Krian formation which belongs to basal part of the Bau limestone formation, has been distributed along the Tai-parit fault. It mainly consists of medium to coarse grained sandstone and trachytic andesite gravels, and shales. The volcanic material was mainly amygdaloidal andesite with abundant sericite and iron ore, and because of its similar petrography to that of andesite occurring in the upper Triassic Serian volcanic formation by PIMM (1967). HON (1990) treated Krian formation as jasperoid phases.

According to the data from drilling core, fragments which are considered to be of the Krian formation are distributed in a quartz-calcite vein which was derived from Tertiary granite in the form of xenolith. The size of breccia was 200mm ~ a few mm, and it was intruded in an arborescent form by quartz vein.

The Krian formation of breccia was in 4 ~ 5 separated layers, and had nearly vertical dip. This occurrence was interpreted that it was formed by an uplift from the bottom with Tai-parit fault movement (Fig. 6).

The Bau limestone formation is a thick sequence of massive, poorly to moderately fossiliferous...
erous pure limestone. The formation in one place was thicker than 540m, the total thickness was unknown by WOLFENDEN (1965). The formation is distributed unconformably on the Upper Triassic Serian Volcanic Formation and passed conformably up into the Lower Cretaceous Pedawan Formation, partly with interfinger relation. The horst type mountainous area is mainly composed of the Bau limestone formation.

The Pedawan formation consists of marine sedimentary rocks, predominantly shale and mudstone, with subordinate sandstone, and rare conglomerate and tuff. According to PIMM (1967), the base of Pedawan formation is composed trachytic andesitic tuff breccia. The Pedawan formation in the study occurs as a hollow place surrounded by Tai-ton fault running NW-SE direction and Tabai fault running NE-SW direction.

The Tertiary granitic rocks are composed of mainly microgranodiorite, and dacite-porphyry. As field occurrence, it represents in stocks, thick dykes, and sheets, lithofacies of microgranodiorite. Whereas in dykes and sheets, the lithofacies of dacite-porphyry are present. The differences in lithofacies, are interpreted as products of fractional crystallization of Tertiary granitic magma. In the early stage, it occurs as microgranodiorite and in the later stage as dacite-porphyry. In microgranodiorite, there are accompanied with contact metamorphism, and of dacite-porphyry with hydrothermal alteration. Later facies were related to the mineralization.
As an important structural movement in this mine, the folding movement in the direction ENE in the later Cretaceous period was pointed out and in succession the fault movement in the direction NE-SW which followed the intrusive activities of the Tertiary granite across this folding movement were pointed out by HON (1981). The Tertiary granites were distributed in 20km echelon-like structure, for NE-SW direction with 1.4 km width.

Accompanied to the fault in the direction NE-SW, faults in the direction NW-SE were formed and still interpreted as the movement in the same period. For lack of detailed data, it is presumed that the Quarternary igneous activity, as a distribution of intrusion breccia dyke and a hot spring activity was existed. The Tertiary granites were intruded by this dyke which was composed of angular fragments of hornfelsed sedimentary rocks in a matrix of porphyry. As a hot spring, they well out 40°C temperature. It is interpreted that cooling process of the Tertiary granite continued to the Quarternary.

Ore deposits show vein-like occurrence and are developed along the Tai-parit fault. Auriferous quartz is microcrystalline, 0.01 - 0.04mm in size, and thus it is hard to observe under the microscope of 800 - 850 time (WOLFENDEN, 1966).

In chemical analysis, the ratio of Au/Ag is 4:1 - 5:1. The ore is classified into A - C type. A type is reddish, brownish, and purplish gray in color and show the paragenesis of realgar-orpiment-hematite-calcite-auriferous quartz manganocalcite. B type which is reddish, brownish, and gray and shows the mineral paragenesis, hematite-limonite-cinnabar-realgar-orpiment-clay mineral-auriferous quartz. C type is dark gray one adhered with reddish brown clay in place showing the mineral paragenesis, manganocalcite-calcite-arsenopyrite-stibnite-auriferous quartz. Gangue minerals are composed of quartz-calcite-sericite-barite-stibnite-arsenopyrite.

As the hydrothermal alteration of the ore deposit, from the microscopic description, carbonatization and silicification where the auriferous quartz was replaced with calcite and a calcite was replaced with auriferous quartz. These were counted as main alterations (KIM, 1992).

Auriferous ore deposits in Bau mining area are divided into the low temperature type ore deposits and the high temperature type deposits depending on the paragenesis of accompanied minerals. Low temperature type consists mainly of calcite-realgar-orpiment-quartz-barite and high temperature type mainly of stibnite-barite-galena-arsenopyrite-sphalerite. The target of exploration in mining is low temperature type ore deposits.
The occurrence of the Chokei mine

Geology of this mine region consists of Triassic sediments (Matsumae Formation), the lowest formations of Tertiary Green Tuff bed (Shiritakazawa and Fuzikuragawa Formations), and Tertiary granite (IWAI, 1965). Gold ore deposits are embedded in volcanic tuff breccia of the lowest Tertiary Green Tuff, and in granite which intruded the tuff breccia (MMAJ, 1981; MITI, 1985).

The Triassic sediments consist of slate, chert, and green rock. The Tertiary Shiritakazawa formation consists of tuff breccia and intercalating andesite lava. It breccia consists of Tertiary andesite in main and partly of Triassic slate and chert of basement. Tertiary Fuzikuragawa formation consists of tuff breccia and tuffaceous sandstone, and represents strike of N-S direction. Diorite porphyry and quartz porphyry intruded into the Tertiary Fuzikuragawa formation along faults in direction of NW-SE, and dikes of rhyolite and andesite showing flow structure (Fig. 8).

Gold ore veins are accompanied with quartz porphyry of NW-SE direction at summit of Mt. Chokei, and quartz veins of E-W direction are formed in a stream of Izumisawa. An old tunnel developed 200 years ago
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Fig. 9 Geological plane and profile of the old adit area.
(1) old tunnel and drilling point, 1. old tunnel; 2. drilling point. (2) geological plane, (3) profile of NS direction

shows a direction of NW-SE from summit of mountain to a stream of Kanayamazawa, and in addition a small tunnel was made in E-W direction.

At summit of mountain, ore veins of quartz vein or clay vein are embedded in tuff breccia and quartz porphyry which were suffered by mineralizing alteration (Fig. 9). The quartz veins have breadth of 40 to 10 cm, and are accompanied by iron sulphides of pyrite-marcasite-magnetite etc. The clay veins exhibit reddish brown color, and contain sericite-montmorillonite-chlorite-potash feldspar, as well as iron sulphides. Bluish gray colored alteration zone was caused by silicification and pyritization, and contains pyrite-galena-sphalerite. Aplitic veins of breadth of 1m to 20cm, were derived from quartz porphyry.

In a stream of Izumisawa, quartz veins were suffered by silicification and pyritization, and a mineralized zone developed in breadth of 2m in E-W direction. This zone was strongly fractured and exhibits brownish color (Kim, 1978).

Repeated Mineralization Ages and Remobilization of Elements

Three mines above mentioned are different each other in their historical tectonic belt and in their geological occurrence. According to a map of "Formation Age of Granitic Crust in Asia" (Sato, 1981), northwest Korea, east Malaysia, and northeast Japan belong to China-Korea old Continent (Archean) (Kim, 1964; Sato and Kim, 1979), Indosinian Orogenic Belt (Triassic), and Himalayan or Alpine Orogenic Belt (Mesozoic ~ Tertiary), respectively. But, Workman (1979) regarded east Malaysia as Himalayan Folded Belt.
A dotted line is Igneous activity and a solid line is mineralization age.

These three auriferous deposits were not formed by a single mineralization, but were by Repeated Polymineralization derived from different Orogenic Magmatic Cycles (Table 1).

Auriferous deposits consisted of an Element Mineral, not like Base Metals of Cu-Pb-Zn, could make a certain mineralization rejuvenated or revived, and even a single auriferous deposit was formed by remobilizations of Au element in different orogenic mineralization ages. Similar interpretations were already reported by several authors (for example, Dept. of Geol. of Nanjing Univ., 1974; HANNINGTON et al., 1986; ICHIGE et al., 1991; FURUNO et al., 1992; CHOI, 1992; So et al., 1993).

According to Nanjing Univ., metallic ore deposits of W, Sn, Mo etc. in southeastern China, were interpreted as polycyclic mineralizations from Precambrian → Paleozoic → Mesozoic Eras.

The most prominent example is the Rumoh mine in Malaysia. It is inferred that the Rumoh auriferous deposits were formed by syngentic mineralization caused by basic volcanic activity of Triassic age, and furthermore by repeated mineralization caused by Neogene Tertiary granitic activity.

Geological occurrence of the Chokei mine is somewhat similar to that of the Rumoh mine. However, geological occurrence of the Chonsan mine is different from other two mines, because the age of country rock of the Chonsan mine is Archean. From the investigation on this Archean auriferous deposits it could be concluded that it is necessary to consider repeated mineralization ages and analyze older tectoniclines in Archean rock bodies to determine younger (Proterozoic or Paleozoic) mineralization age.

Metallogenic setting for the Chonsan mine

An occurrence of ore veins from the Choyak mine (the Sansei), which is similar to an occurrence of an ore vein (No. 9 - Sambatkor vein) from the Chonsan mines, was reported by SHIMAMURA (1936). The ore veins of N-S direction from Choyak mine consist mainly of minute quartz
grains, containing arsenopyrite-pyrite, and accompany black ore in their fracture zones. Furthermore, there are another ore vein of NW-SE direction containing minute arsenopyrite, and the other ore vein of E-W direction containing pyrite-galena-sphalerite. These ore veins are regarded as different ore veins of different geological ages, and the ore veins occur in granite-gneiss region of Archean Era and are interpreted as Korean-type gold ore deposit (TATEIWA, 1976).

Gold-bearing quartz veins from the Chonsan mine occur in some fracture zones of migmatite of Rangnim Complex and of gneissose granite of Ryonhwasan, and they are intruded by dolerites of Namgang type. Some dome structures are found in the migmatite area, and gneissosity of migmatites has directions of NW-SE and N-S. Some ore bodies rich in gold are distributed in crossing places between No. 9 vein of NW-SE direction and Sambatkor vein of N-S direction. Gold ore veins were under structural control of migmatites, and some dolerite dikes intruded along fracture zones parallel to gold ore veins. Chlorite and graphite are included in the fracture zones, and chloritization and silicification were accompanied.

Gold is included in angular fractured quartz grains which are white to gray in color, and gold mineralization occurred probably with close connection to magmatic activity of dolerite. However, may pegmatite veins are associated with gneissose granites of Ryonhwasan type, which had injected into migmatites of Rangnim Complex of Archean Era. Furthermore, those pegmatite veins are closely associated with mineralized zones of gold. Different mineralized ages of gold have been ascertaind in the Chonsan mine. This repeated mineralization ages are also considered for geological occurrence of gold ore veins of the Choyak mine.

Metallogenic setting for the Rumoh mine

The ore deposits were embedded in the Krian formation and the dyke of Tertiary granite, along in the direction NE-SW, Tai-parit fault. Interpreted by WILFORD (1955), that the ore fluids were formed related to granite activity, ascended along fault, and the Krian formation played as a caprock. Although, the occurrence of deposits, the ore formed syngenetically with the Krian formation and contained with lenticularity. For this reason, interpreted as three mineralization ages for origin of deposits (Kim and AOKI, 1993). Fig. 7 shows the structural development of the Rumoh area as follows in 1 ~ 5.

1. Upper Jurassic : Sedimentary period of Krian formation as the lowest stratum of Bau limestone, and the lower stratum of the Pedawan formation. The late Triassic Serian volcanic formation was eroded. Sea-floor volcanic activities could be observed at the lower stratum of the Pedawan formation and the stratum of dacitic tuff alternated with stratum of radiolarite shale. The Krian formation and Pedawan formation had been dealt with as the cap rock, but this report deals with them as the syngenetic ore deposits with a low temperature mineral paragenesis.

2. Upper Jurassic ~ lower Cretaceous : Sedimentary period of the Bau limestone and the Pedawan shale.

3. Upper Cretaceous ~ Paleogene : Period of folding movement in the direction ENE, and Bau anticline was formed. The Krian formation was distributed with Tai-parit fault. It could be interpreted that an igneous activity began to start deep in the faults.

4. Miocene : Period when the fault movement of NE and NW directions occurred and followed igneous activity of Tertiary granite with collapsed basin. Deposit with high temperature paragenesis as skarn type was formed. Mineralization mainly occurred in microgranodiorite. It is the second mineralization ages.

5. Quaternary : The structures of horst and graben developed noticeably with the Plio-Pleistocene movement. The mineralization period formed as hot spring activities accompanied to the cooling of Tertiary granite. Mineral paragenesis is low temperature type. It is the third mineralization ages.

Auriferous quartz-calcite vein was suffered structural movement by Tai-parit fault, and formed ore deposit as like rejuvenation.

Metallogenic setting for the Chokei mine

The gold ore deposits of this mine have paragenetic minerals of pyrite-marcasite-magnetite-chalcopyrite-galena etc., and they belong to an epithermal vein-type ore deposit which has mineralization alterations such as sericitization,
calcitization, and silicification etc. It was interpreted by the author that gold mineralization was closely associated with magmatic activity of diorite porphyry, and quartz porphyry which were members of granitic rocks of Neogene Tertiary age (Kim, 1978). This interpretation is similar to that for the Oppu mine near here (Funayama and Abe, 1967).

However, the Triassic sedimentary formation is distributed near this region. Gold ore deposits are embedded in green rocks of Triassic age in the Nagao and Funauchi ore deposits near here, and they have paragenetic minerals of Au-Ag-Pb-Cu-Zn. Yamaoka (1976) discussed that these vein type gold ore deposits had relationships not only with the mineralization caused by Tertiary granite, but also with the mineralization by basement rocks of Tertiary green tuff.

Therefore, repeated mineralization ages of gold ore deposits from the Chokei mine, must have been the following two ages: 1) mineralization by Triassic green rock volcanism, and 2) mineralization by Neogene Tertiary granite, just same to the Rumoh mine from Malaysia.

Conclusion

In prospecting of auriferous deposits of vein type, it is important to study and to discuss the structural control of ore deposits (Nakamura and Miyahisa, 1976; Kubota, 1991). In this case, it is also important to prospect older tectonic lines which were influenced by movement of basement rocks, among many various faults and fracture zones.

The writer has taken notice for problem of Rejuvenation or Palingenesis of mineralizations as to ore veins associated with tectonic lines. This problem is related to a theory of Palingenesis or Rejuvenation of ore deposits (Watanabe and Sekine, 1956).

A problem of repeated mineralization ages has been studied in order to solve the problem of Palingenesis of ore deposits. Especially, an element mineral such as Au, not like base metals such as Cu-Pb-Zn, has a character to be remobilized easily. Thus a problem of remobilization of Au element has been studied in fields in detail.

Three auriferous mines studied in this paper have different geotectonic occurrences, namely,

1) Archean subcraton and Proterozoic or Paleozoic remobilization, 2) Triassic basement and Tertiary-Quaternary remobilization in mixed zone between Circum-Pacific and Eurasia orogenic belts, and 3) Triassic basement and Neogene remobilization in Island Arc. However, the repeated mineralization ages and remobilization of Au element, are common in three mines.

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天山，ルモウ，長慶などの金鉱床における繰り返された
鉱化期と元素の再濃集について

金 容 義

要旨：鉱脈型の金鉱床において構造規制を検討する場
合，基盤岩の運動に影響された古い構造線にともなう鉱
脈が，鉱化作用の若返りとして解釈される。

天山（D. P. R. K.）では，鉱脈が始生代の同意層群と蓮花
山花崗岩類および，原生代から古生代にかけて貫入する
南江岩群に胚胎する，関連鉱脈－方鉱鉱－磁磁鉱鉱－磁
鉱鉱－黄鉱鉱－石英を共生鉱物とした石英脈である。

ルモウ（マレーシア）では，鉱脈が後期ジュラ紀のKrian
層と貫入した第三紀花崗岩に胚胎する，鷹冠石－輝黄－
辰砂－硫磁鉱鉱－黃鉱鉱を共生鉱物とした合金石英－方
解石脈である。

長慶（日本）では，鉱脈が第三紀グリンタフおよび基盤
岩である三畳紀の緑色岩そして貫入した第三紀花崗岩に
胚胎する，磁磁鉱鉱－方鉱鉱－磁磁鉱鉱－黄鉱鉱を共生鉱
物とした石英脈である。

三つの鉱床は，地質産状が異なるも，古い構造線に鉱
脈が支配されており，繰り返された鉱化期が明かにされ
た。Au元素の場合，Cu－Pb－Znのようなベースメタル
と異なり，再濃集について検討される。