Geology and Mineralization Characteristics of Khamkeut Saen Oudom Gold Deposit, Bolikhamxai, Lao PDR

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ABSTRACT

The Khamkeut Saen Oudom (KSO) gold deposit is located at Bolikhamxai province, central Lao PDR. It lies within the Truong Son Fold Belt where there are several significant mineral deposits particularly gold and copper. At KSO deposit, the mineralization occurs as quartz - carbonate veins, minor stockworks and breccias. Major veins are trending almost E-W where it forms as single ore zone in the west and splays to three narrow veins at the eastern part of area. Several ore lenses are present along this E-W structure (e.g., Houay Keh, Nam Pan-east, Nam Pan-west). The gold mineralized veins/stockworks/breccias are mainly hosted by meta-sedimentary rocks (e.g., meta-sandstone, meta-siltstone and phyllite) of inferred Ordovician to Silurian age. At least three stages of mineralization have been identified namely; Stage 1, microcrystalline quartz - arsenopyrite - pyrite; Stage 2, quartz ± calcite - sulfides (arsenopyrite - pyrite - sphalerite - chalcopyrite - galena-pyrrhotite) - gold and Stage 3, quartz - chlorite - calcite. Alteration at KSO deposit is less pervasive and extensive and mainly characterized by quartz - calcite - sericite - chlorite and chlorite - sericite - calcite assemblages, and the both are developed in ore lenses. The quartz - calcite - sericite - chlorite alteration is featured by predominant presence of cryptocrystalline quartz, calcite, and sericite. EPMA analysis reveals that gold fineness of Houay Keh ore lens range 827 to 866 (represented by native gold) and Nam Pan ore lens range from 637 to 715 (represented by electrum).

Keywords: Gold, mineralization, fineness, KSO

1. Introduction

In Lao PDR, occurrences of major mineral deposits have been confined to the Troung Son Fold Belt (Fig. 1). Those deposits include Phu Kham Cu-Au skarn and Ban Houayxai epithermal Au-Ag deposits in the northern Lao PDR. Sepon in southern Lao PDR consists of at least two types of deposit namely; Cu skarn and sediment hosted Au types although all economic ores are present as secondary/oxide ores. The Khamkeut Saen Oudom (KSO) Au deposit is also located in central Lao PDR, approximately 200 km north of the Sepon deposit (Fig. 1). In Viet Nam, major mineral deposits that lie on the Troung Son Fold Belt include Phouc Son intrusion related Au and Bong Mieu Au skarn deposits. Another important fold belt in mainland SE Asia that contains major mineral deposits is Loei Fold Belt in Thailand, which has significant gold deposits such as Chatree epithermal Au-Ag and Phu Thap Fah Au skarn deposits.

The KSO Au mine is situated in Bolikhamxai province of central eastern Lao PDR (Fig. 1). It has length of mineralization vein zone for approximately 4.5 kilometres (Fig. 2). The deposit lies on the Truong Son Fold Belt that further extends to central Viet Nam (Fig. 1). Gold grade in ore ranges from 0.5 g/t Au through to 1.4 g/t Au for a potential total ounces ranging from 32,417 Oz Au through to 291,752 Oz Au (SRK, 2011).

2. Geologic setting

Lao PDR and its adjacent areas comprise three major tectonic terranes from east to west namely, South China Terrane, Indochina Terrane and Shan-Thai Terrane (Lepvrier et al., 2004; Metcalfe, 1995; Metcalfe, 2006); Fig. 2). The Truong Son Fold Belt (TSFB) lies along the northeastern margin of the Indochina Terrane and was formed as a result of the closure of Laos - North Vietnam Strait of Paleo-Tethys.

The major magmatism in TSFB includes granitic rocks ageing of 240 Ma to 270 Ma, which are widely distributed in central of Lao PDR and identified as S-type granite (Hoa et al., 2008; Lepvrier et al., 1997; Lepvrier et al., 2008). The Permo – Triassic volcano - plutonic rocks are generally extruded on/intruded into Ordovician - Carboniferous sedimentary rocks in northwestern of TSFB. The intrusive rocks include Permo – Triassic Nape Complex (NPC) and Cretaceous Poung Kuak Complex (PKC; DGM, 2000a). The NPC consists of medium - grained biotite granite and granodiorite and accompanied by porphyritic granite, granodiorite, aplite and pegmatite (DGM, 2000a). The PKC consists of medium - grained leucocratic granite (DGM, 2000a). In recent geochronological study revealed that both of NPC and PKC yield Triassic ages (Sanematsu et al., 2011).

Stratigraphically, the rocks in KSO deposit and stratigraphic columns of area near Lak Xao represent adjacent area. From bottom to the top, the sequent comprises Ordovician- Silurian Nam Houay Formation, Early- Middle Devonian Phon Keo, Early Carboniferous Boulapha, Late Carboniferous to Permian Khammouan and Nam Theun Groups, which is equivalent to Jurassic-Cretaceous Khorat Group (Fig. 1B).

The geology in and around the KSO deposit is predominantly covered by Ordovician to Silurian sedimentary rocks. The Ordovician stratigraphy in the Nape district and Nam Nhuong in the eastern Lao PDR can be divided into three sequences such as (1) early: non-fossiliferous black shales; (2) middle: fossiliferous shales which consisting echinoderms and trilobites, and; (3) late: sandstone consisting of large trilobites (Fromaget, 1927). Stratigraphically, the Silurian rocks consist of shale, fine-grained sandstone of Llandovery to Wendlockian age (Fontaine and Workman, 1978; Smith et al., 1996).

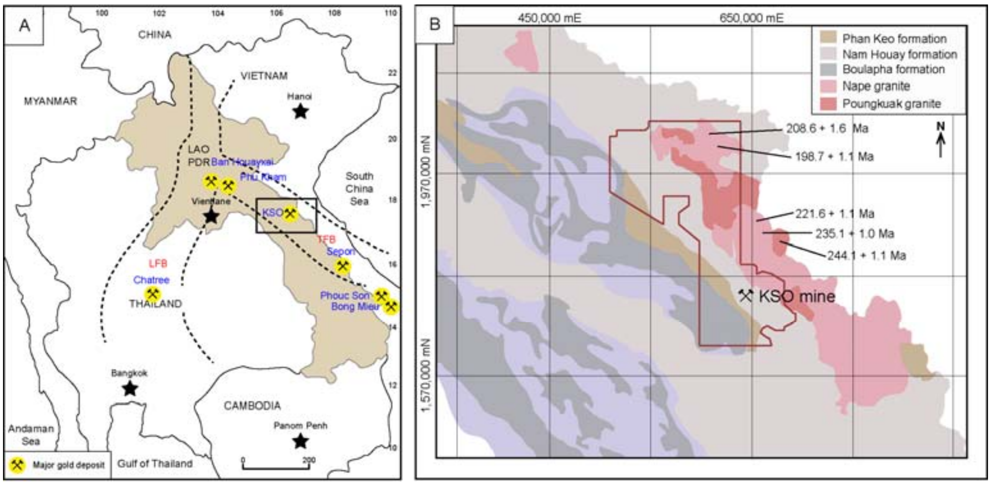


Figure 1. A. The map shows position of Khamkeut Saen Oudom mine in Bolikhamxai district, Central Lao PDR. The yellow circle indicates significant mineral deposits surrounding Khamkeut Saen Oudom mine, the study area (Tate, 2005), **B.** Regional geologic map with granite distribution in Truong Son Fold Belt and Kontum Massif of Lao PDR and Viet Nam. The $^{40}Ar/^{39}Ar$ ages of granitoid are shown in the map (Nakano et al., 2008; Sanematsu et al., 2011).

3. Deposit Geology

The oldest sedimentary rocks in the KSO area belong to Ordovician-Silurian Nam Houay Formation and they strike northwest - southeast and dip southwest (Figs. 1 and 2). In KSO deposit, the rocks of this formation can be divided into two main units, namely Sandstone dominated Unit (Unit 1) and Siltstone dominated Unit (Unit 2), Unit 1 is mainly found in the eastern part of deposit or Houay Keh pit, which is characterized by fine - grained sandstone and interbedded laminated siltstone (Figs. 2 and 3). Unit 2 is mainly observed in the western part of KSO mine area or Nam Pan pit and is characterized by siltstone and interbedded with thinly bedded fine-grained sandstone (Figs. 2 and 3). At Nam Pan pit, it is dominated by siltstones, whereas at the Houay Keh pit the rocks are dominated by fine - grained sandstone. The rocks of both Units are consistently striking northwest - southeast and dip southwest approximately 40°to 70° (Fig. 2).

Sandstones in the both units are similar in hand specimens and under microscope. It is pale grey to green grey, locally laminated and well sorted (Figs. 3 and4). Microscopically, sandstone consists mainly of quartz and feldspar with some chlorite after alteration of mafic minerals. Opaque minerals (mostly pyrite) and organic matter are also present. Quartz is the most predominant mineral and occurs as fine - grained particles ranging in size from 0.01 to 0.03 millimeters in diameter (Fig. 3C). Quartz constitutes about 50% and feldspar about 40 %. Muscovite consists about 7% (Fig. 3C). Opaque minerals make up about 2%. Feldspar is partly altered to sericite and calcite. Siltstones of the both units are also similar in naked eye. It is grey to dark grey, occasionally laminated and well sorted (Fig. 3D). Under microscope, the laminated siltstone consists predominantly of quartz, feldspar and clay minerals mostly sericite (Fig. 3D). Quartz and feldspar are less than 60 µm in diameter. Quartz constitutes about 50% whereas feldspar makes up about 35%. Opaque minerals (mostly pyrite) constitute about 5% and clay minerals make up about 10%. Chlorite consists approximately 3% (Fig. 3D).

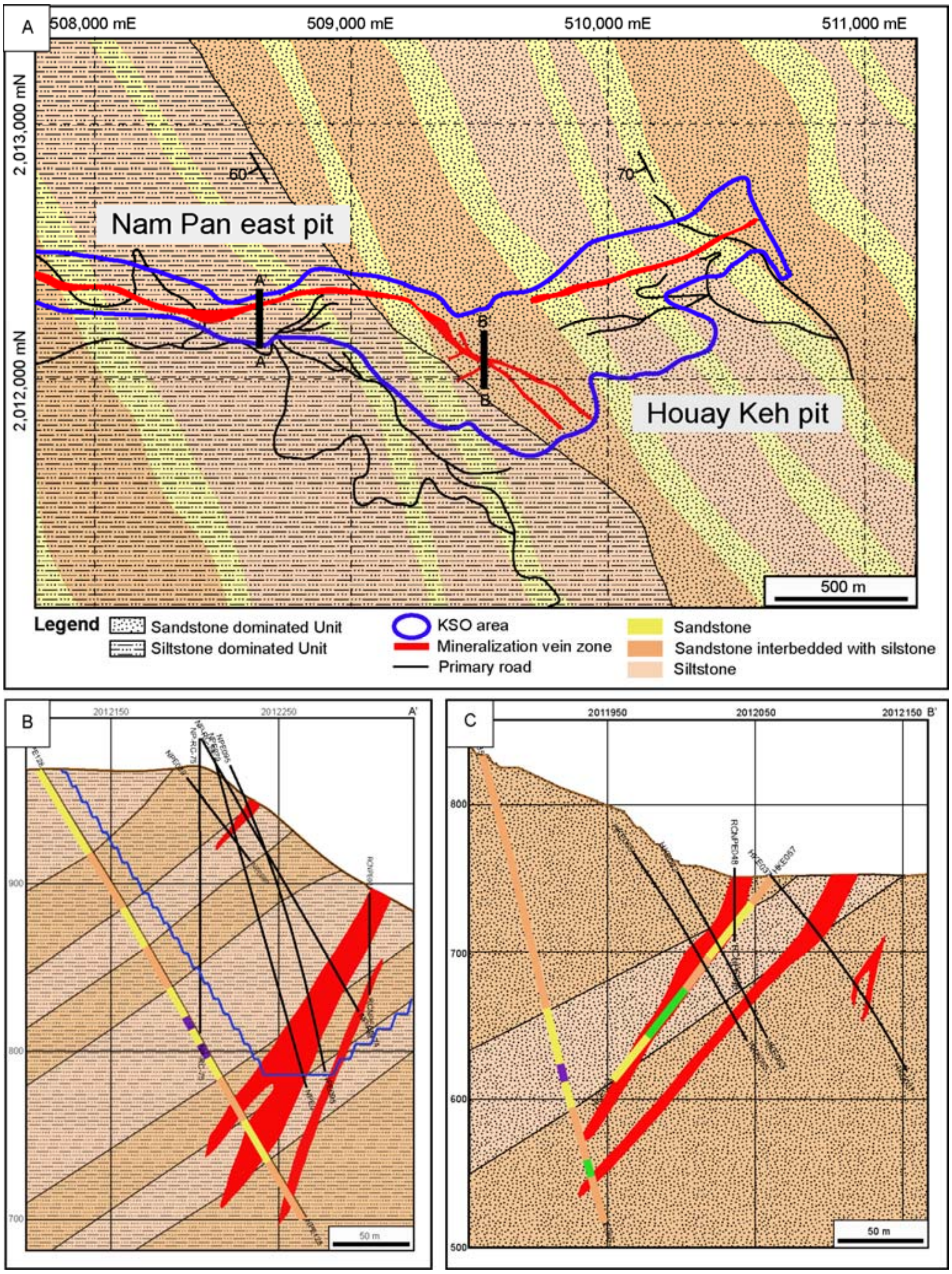


Figure 2. Interpreted geological map and cross sections of the KSO deposit, **A**. Geologic map showing rock units and main ore zone, **B**. Geologic cross-section along A-A’ and **C**. Geologic cross-section along B-B’.

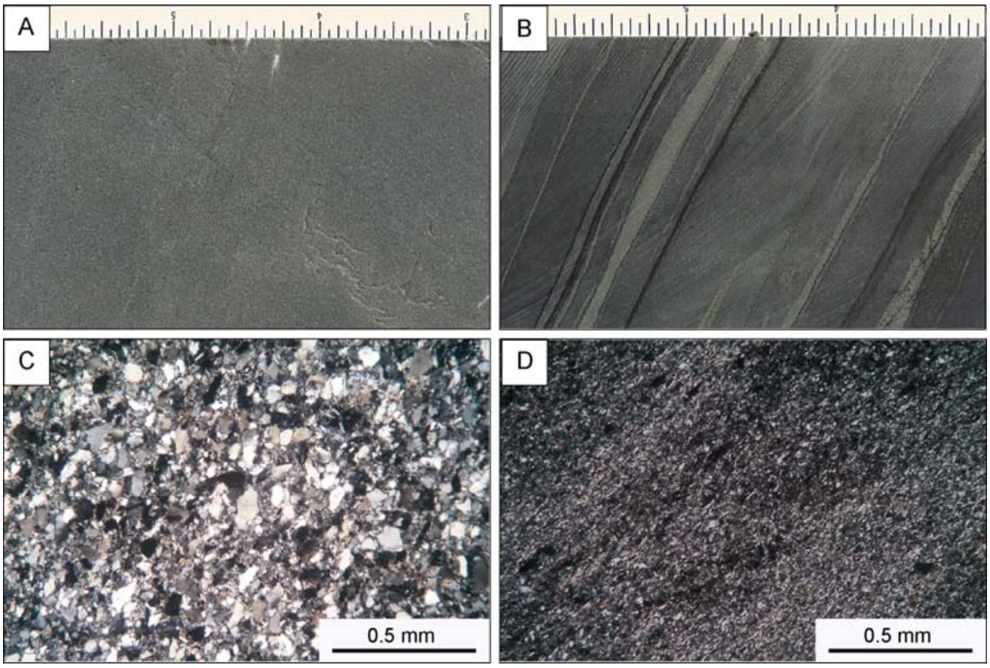


Figure 3. Characteristic features of sandstone and siltstone at KSO, **A**. Diamond drill core of fine-grained sandstone, **B**. Diamond drill core of laminated siltstone, **C**. Photomicrograph of fine-grained sandstone showing subangular to subrounded quartz and feldspar in clay size matrix, **D**. Photomicrograph of laminated siltstone showing quartz, feldspar and clay minerals.

4. Mineralization and Alteration

At KSO, gold mineralization mainly occurs as veins, minor stockworks and breccia. The main ore zones are confined to north-west trending faults (Fig. 4). Nam Pan West, Nam Pan East, and Houay Keh ore lenses (pits) are located on the main ore zone/faults, which extend at least for 4 km. It is likely to extend further to the east and west when scale of the fault is considered. Vang Kor ore lens which consists of few small pits located further to southwest of the main orebody is confined to a parallel structure (fault). Another ore lens is Houay Bong ore lens located in southeast of the area, and it seems to occupy a different structure (northeast-southwest). The main ore zone occurs as a single vein at Nam Pan pit striking east-west with steep dipping to south. This orebody splays into three discrete veins to east, at distance close to the Houay Keh pit (Fig. 4). Here, vein trend also changes the direction to northwest-southeast trending. At Nam Pan-west, this major vein is characterized by quartz - pyrite ± arsenopyrite-sphalerite - gold and is typically quartz-sulfide (pyrite - sphalerite ± arsenopyrite) ± gold at Nam Pan east. However, at Houay Keh it is characterized by quartz-carbonate-base metal (sphalerite, galena and chalcopyrite)-gold. At Nam Pan, the gold bearing veins locally contain some breccia clasts and tend to form as single vein, whereas at Houay Keh ore lens veins are clearly displayed as sheeted veins.

Based on cross cutting relationships, mineral assemblage and textural features at least three mineralization stages have been identified namely, 1) Stage 1: Microcrystalline quartz - arsenopyrite – pyrite, 2) Stage 2: Quartz ± calcite - sulfides (pyrite-chalcopyrite ± arsenopyrite - sphalerite- galena-pyrrhotite) – gold, 3) Stage 3: Quartz - calcite - chlorite (Table 1).

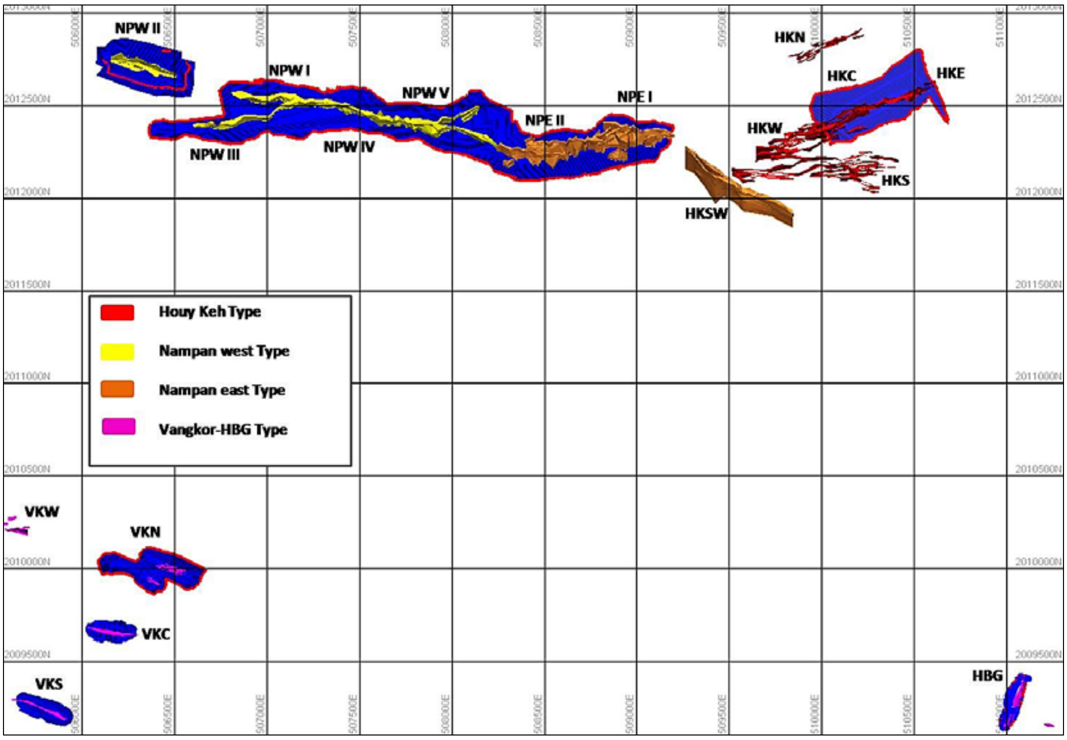
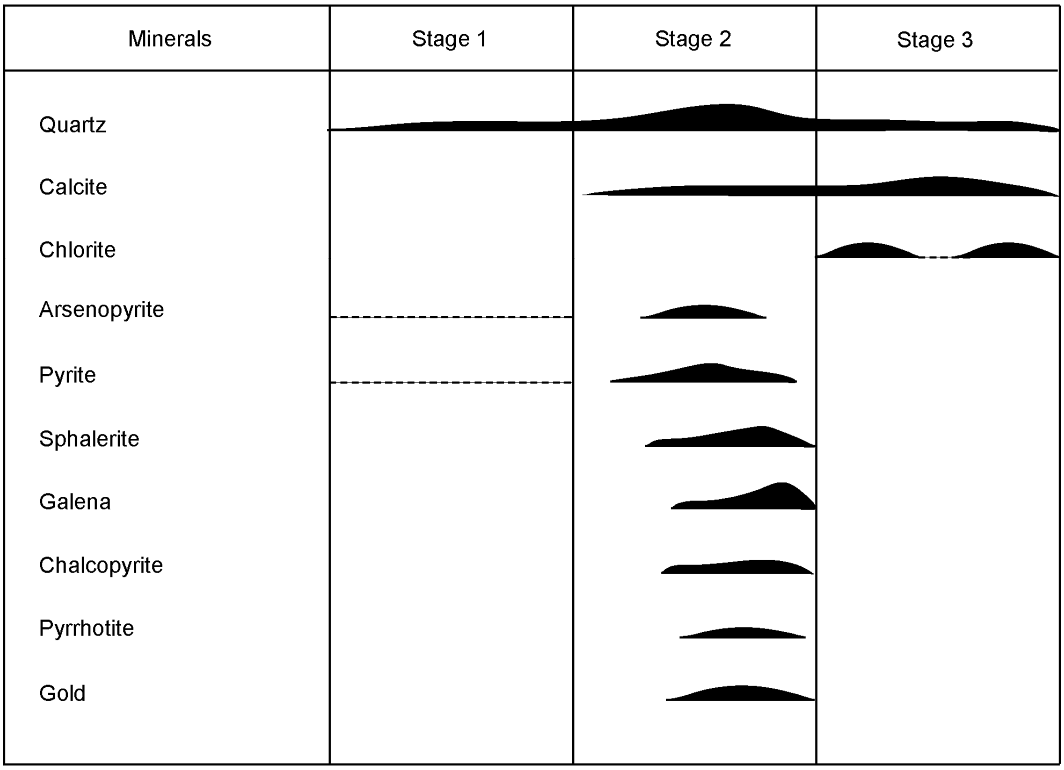


Figure 4. Mineralization vein zone of Khamkeut Saen Oudom area (SRK, 2011).

Table 1. Paragenetic diagram showing order of veins formation and the relative amount of mineral abundance (e.g., ore and gangue minerals) of infill Stage at KSO deposit.



Stage 1: Microcrystalline quartz - pyrite – arsenopyrite

Characteristic of Stage 1 is grey to pale white and aphanitic textured small veins. The veins consist of microcrystalline quartz and minor sulfide minerals including arsenopyrite and pyrite, which are located in center of vein. Occurrence of Stage 1 veins is mainly identified in the Nam Pan ore lens. Stage 1 veins are characterized by open space infilled fracture (Fig. 5A). In the drill core samples, it is pale grey to grey quartz vein (Fig. 5A). This stage composes mainly of microcrystalline quartz associated with minor fine-grained pyrite and arsenopyrite (Fig. 6A).

Stage 2: Quartz ± calcite - sulfides (pyrite - arsenopyrite - sphalerite - chalcopyrite - galena ± pyrrhotite) – gold

Stage 2 mineralization forms as veins and sheeted veins. For sheeted veins, which particularly occur at Houay Keh pit, range in thickness from 6 to 10 cm. Major sulfide minerals of Stage 2 include arsenopyrite, pyrite, sphalerite, chalcopyrite, galena and minor pyrrhotite. Quartz is major gangue mineral, which occurs as coarse – grained, subhedral to euhedral aggregates (Figs. 7B and D). Sulfide minerals (e.g., pyrite, arsenopyrite, sphalerite, galena and chalcopyrite; Figs. 5D and 6C) tend to occur at center of vein. Pyrite prefers to associate with sphalerite and galena. Chalcopyrite inclusions in sphalerite or known as "chalcopyrite disease" are commonly observed in vein samples from Houay Keh pit. Gold of Stage 2, forms both as free grain associated quartz and inclusion in pyrite and arsenopyrite.

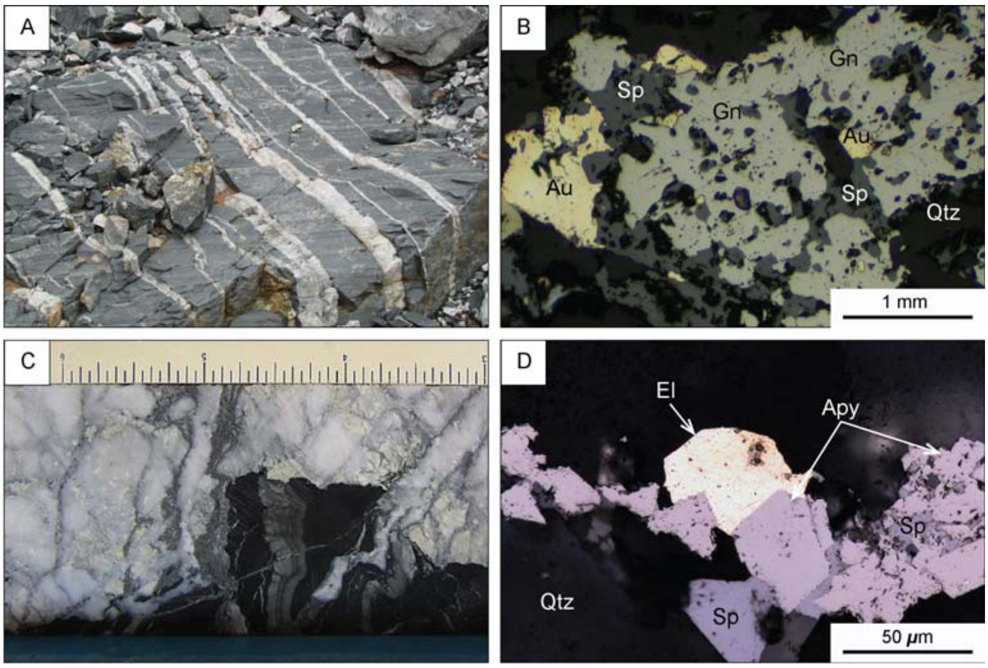


Figure 5. Characteristic features of Stage 2, **A**. Photograph of siltstone outcrop in Houay Keh ore lens showing sheeted veins in which each veins range in thickness from 6 to 10 cm. **B**. Photomicrograph of Stage 2 vein showing quartz, sulfides and gold mineral assemblage in vein from Nam Pan ore lens. **C**. Photograph of hand specimen showing banding-liked quartz ± calcite - sulfides - gold vein, Sample No. HKE-01, Houay Keh ore lens. **D**. Photomicrograph of Stage 2 vein showing electrum associated with arsenopyrite, sphalerite and quartz, Sample No. NPE128_282, Nam Pan ore lens. Abbreviation: Qtz = quartz, , Apy = arsenopyrite, Sp = sphalerite, Gn = galena, Au = gold, El = electrum.

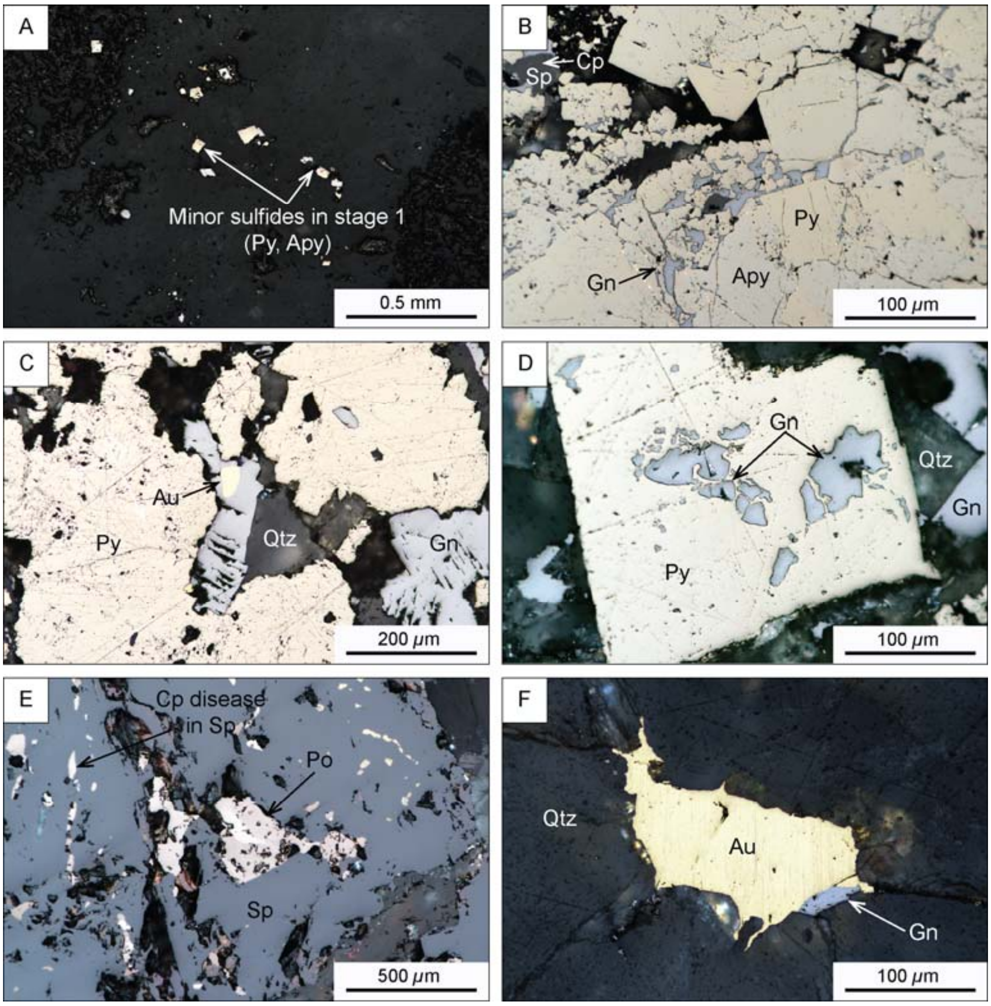


Figure 6. Photomicrographs showing mineralogical characteristic features of mineralized veins at KSO, **A**. Subhedral to euhedral pyrite of Stage 1 associates with quartz and arsenopyrite, Sample No. HKE085_266.9, Houay Keh ore lens. **B**. Stage 2 vein consisting of arsenopyrite intergrowth with pyrite, sphalerite, galena and chalcopyrite, Sample No. NPE090_110.4, Nam Pan ore lens. **C**. Gold inclusion in galena in association with pyrite and quartz of Stage 2, Sample No. HK-01, Houay Keh ore lens. **D**. Galena inclusions in large pyrite, Sample No. HK-01, Houay Keh ore lens. **E**. Coarse-grained sphalerite showing chalcopyrite disease texture and pyrrhotite inclusions, Sample No. HK-01, Houay Keh ore lens. **F**. Gold associates with galena and quartz in Stage 2 vein, Sample No. HK-01, Houay Keh ore lens. Abbreviation: Qtz = quartz, Py = pyrite, Apy = Arsenopyrite, Sp = sphalerite, Gn = galena, Cp= chalcopyrite, Po = Pyrrhotite, Au = gold.

Stage 3: Quartz - calcite – chlorite

Stage 3 vein is white to dark green consisting mainly of quartz, minor calcite and chlorite (Figs. 8A and B), which are often located at the rim or center of the vein. No sulfide has been observed in this stage. Stage 3 is mainly identified at Houay Keh ore lens in which size of the veins is quite narrow approximately 1 cm in width. Size of Stage 3 veins ranges from mm to few cm and the veins commonly occupy the north-south to northeast - southwest trending fractures.

Ore mineralogy

Sulfide minerals can be observed in both Stage 1 and Stage 2, and they include pyrite, arsenopyrite, sphalerite, chalcopyrite, galena, and pyrrhotite which are described in details below. Pyrite is the most abundant sulfide, which occurs in Stage 1 and Stage 2 veins. In Stage 1, it forms as fine-grained crystal (less than 50µm in diameter; Fig. 6A). Its shape is anhedral to subhedral and is commonly associated with quartz and minor arsenopyrite. Pyrite tends to form at vein selvage or where it contacts to the wall-rock. At Nam Pan pit, Stage 2 pyrite is normally associated with arsenopyrite and sphalerite (Figs. 6B and C). At Houay Keh pit, pyrite of stage 2 is the main sulfide and tends to associate with sphalerite, galena and minor chalcopyrite and pyrrhotite (Figs. 6B, C and D).

Arsenopyrite is the second most abundant sulfide in Stages 1 and 2. In Stage 1, arsenopyrite occurs as fine-grained, subhedral to euhedral crystals. Here, it associates with quartz and minor pyrite. Arsenopyrite in this stage forms as 50-100 µm crystals in diameter (Fig. 6A). At Nam Pan pit, Stage 2 arsenopyrite forms as the main sulfide mineral with subordinate amounts of pyrite and sphalerite (Fig. 5D).

Sphalerite is present only in Stage 2 veins at Nam Pan and Houay Keh pits. Sphalerite is generally associated with arsenopyrite and minor pyrite (Fig. 5D). At Nam Pan pit, sphalerite forms as anhedral to subhedral, fine- to medium-grained crystals (0.1 to 0.5 mm). It is characterized a dark brown grey color, and appears to be fine to medium grained in core samples (Fig. 5D). Sphalerite of Stage 2 of Houay Keh pit is generally associated with pyrite, chalcopyrite, pyrrhotite and galena (Fig. 6E). It forms as anhedral to subhedral, medium to coarse-grained crystals (0.2 to 0.8 mm).

Chalcopyrite occurs in minor amount and only identified in Stage 2 (Figs. 6E and 7). It usually associates with sphalerite and often displays “chalcopyrite disease texture” (Fig. 6E). Pyrrhotite occurs only in Stage 2 as inclusions in sphalerite. Galena is observed only in Stage 2 and relatively abundant especially at the deeper part of the Houay Keh pit. Galena is commonly associated with pyrite, sphalerite and chalcopyrite. Coarse-grained galena up to 1.5 mm in diameter has been observed in vein at the deeper level of the Houay Keh ore lens (Figs. 6B, C and D).

Gold is identified in stage 2 veins and is often visible in hand specimen or drill core in association with quartz and calcite. Gold also forms as microscopic sized grains associating either with quartz/calcite or sulfide minerals. Inclusions of gold in arsenopyrite and pyrite are also common (Figs. 5D and 7). In the Nam Pan ore lens, gold forms as electrum associated with arsenopyrite, pyrite and minor sphalerite (Fig. 5D), whereas at the Houay Keh ore lens, gold tends to be coarse - grained crystal and forms as native gold.

Gangue mineralogy

Quartz in Stage 1 is characterized by microcrystalline texture, and it forms along the vein contact, which is commonly associated with fine-grained pyrite and arsenopyrite (Fig. 7A). In Stage 2, quartz forms as elongated shape that is dominant texture and subhedral to euhedral of coarse- to fine-grained crystals (0.05 to 0.8 mm in length) which is generally associated with gold and sulfide minerals (Fig. 7B). Quartz in Stage 3 is subhedral to euhedral of coarse- to medium-grained crystals (0.2 to 0.5 mm in length) that are associated with chlorite and calcite (Figs. 7C and D).

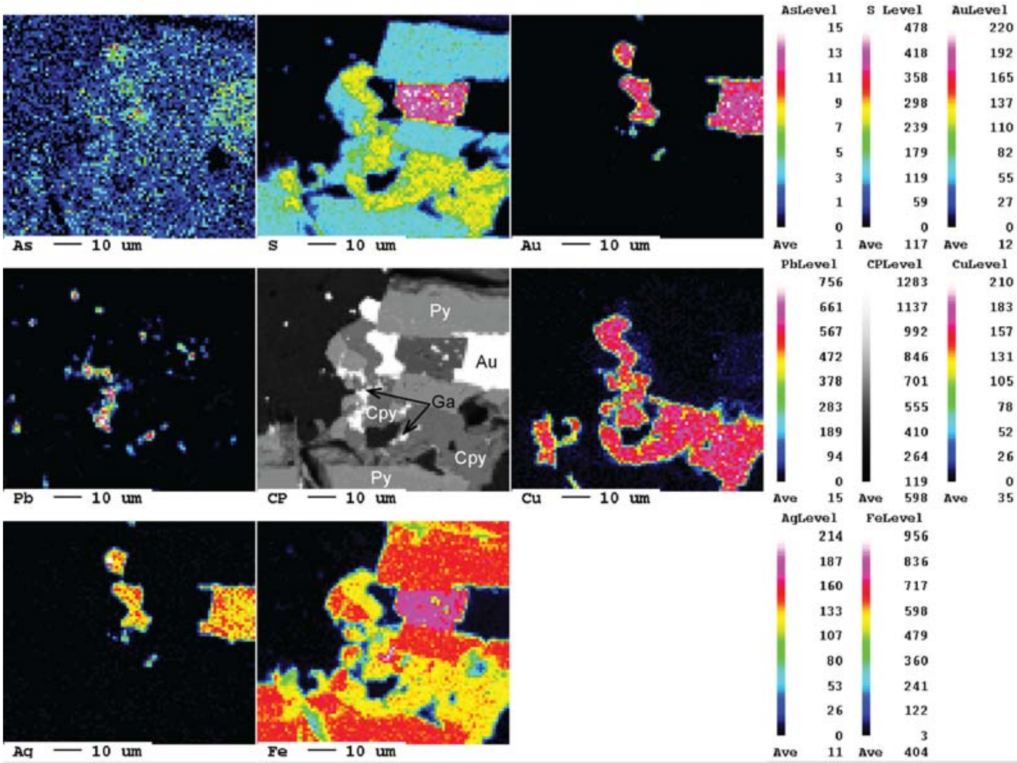


Figure 7. EPMA mapping shows gold intergrowth with chalcopyrite and pyrite in sample from Houay Keh ore lens. Abbreviation: Py = pyrite, Au = gold, Cpy = chalcopyrite, Ga = Galena.

Calcite is relatively abundant in Stage 3 in comparison to Stage 2. In Stage 2, calcite occurs in minor amounts in association with quartz, gold and sulfide minerals such as pyrite, sphalerite, galena and chalcopyrite (Fig. 7B). It commonly forms as approximately 0.1 to 0.3 mm in diameter and tends to occur at center of veins or open space filling fractures (Fig. 7B). Calcite is the most abundant in Stage 3 and tends to occur in center of the vein, after the comb-quartz. Here, it associates with quartz and chlorite (Figs. 7C, D and 8A, B).

Chlorite is particularly abundant in Stage 3 veins/veinlets. Numerous chlorite forms as tabular aggregated or layers-rich crystals. However, this vein stage does not contain any gold and sulfide minerals (Figs. 8A and B). In Stage 3, chlorite forms as minor fine- to medium-grained (0.05 to 0.4 mm in length) crystals associated with quartz and calcite (Figs. 8A and B). Chlorite usually occurs border of veins and is occasionally present at the center of veins (Figs. 8A and B).

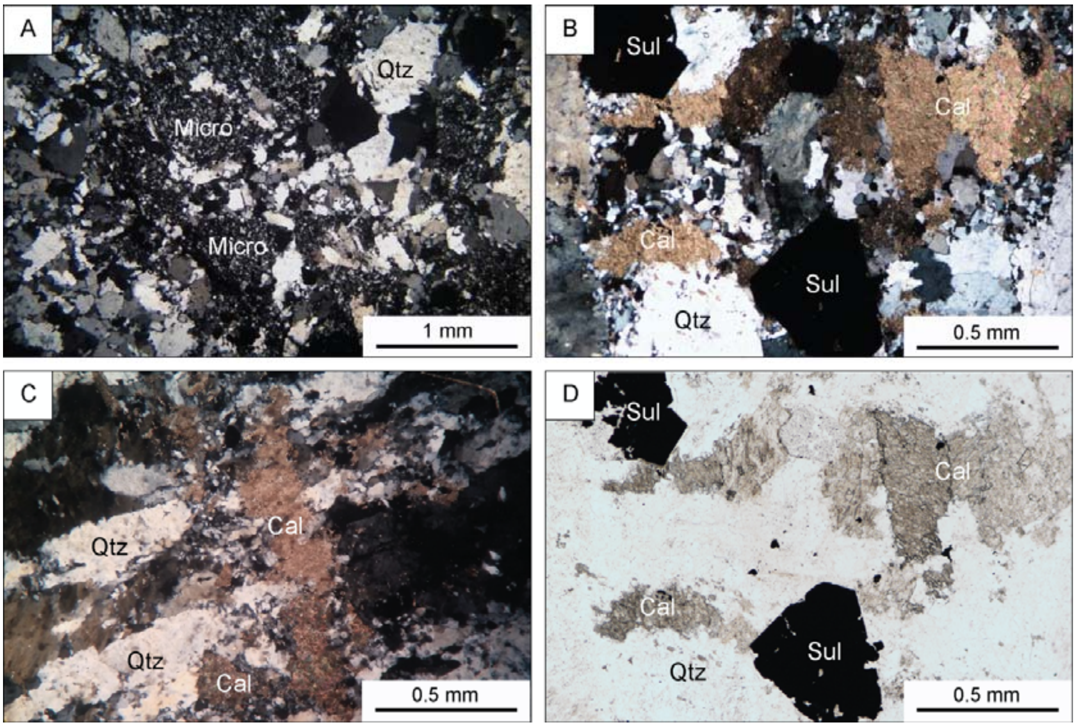


Figure 8. Characteristic features of quartz in different stages. **A**. Quartz in Stage 1 forms as microcrystalline quartz that associates with fine-grained pyrite and arsenopyrite, Sample No. TS4, Nam Pan ore lens. **B**. Quartz in Stage 2 occurs as elongated shape, euhedral to euhedral granular crystals which is closely intergrowth with sulfide minerals (pyrite) and calcite (CPL), Sample No. HKE057_26.7, Houay Keh ore lens. **C**. Quartz showing elongated shape in Stage 3 is generally associated with calcite and chlorite, which is in rim and center of vein, Sample No. HKE090_289, Houay Keh ore lens. **D**. Quartz in Stage 2 is closely intergrowth with sulfide minerals (pyrite) and calcite (PPL), Sample No. HKE057_26.7, Houay Keh ore lens. Abbreviation: Qtz = quartz, Cal = calcite, Chl = chlorite, Sul = sulfides.

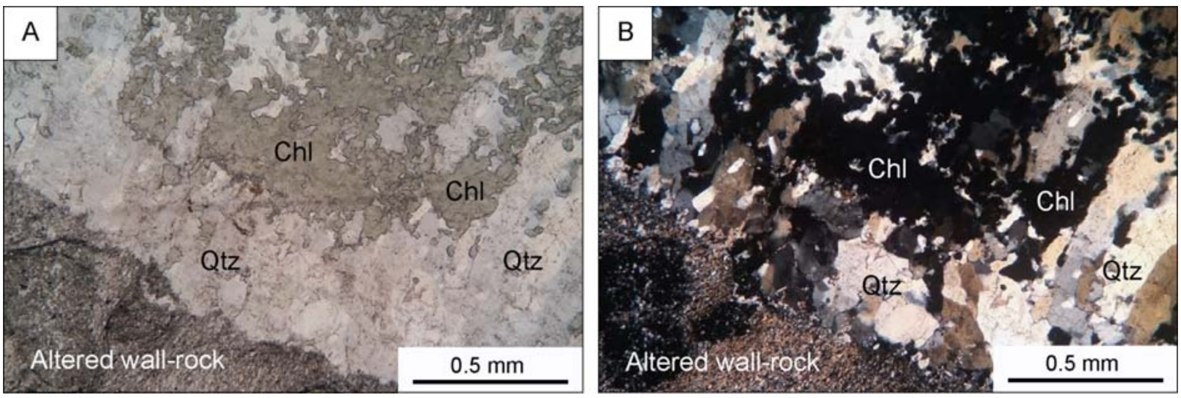


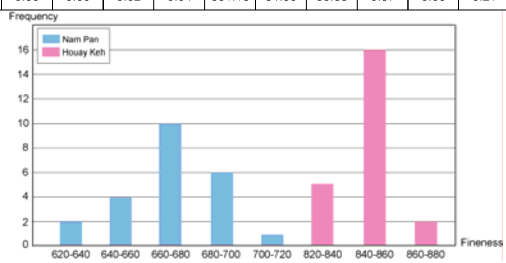
Figure 9. Characteristic features of chlorite in Stage 3 **A**. Chlorite is closely intergrowth with quartz and calcite (PPL), Sample No. HKE090_289, Houay Keh ore lens. **B**. Chlorite associates intimately with in quartz, which occurs as coarse-grained crystals (XPL), Sample No. HKE090_289, Houay Keh ore lens. Abbreviation: Qtz = quartz, Chl = Chlorite, Cal = calcite.

5. Gold Fineness

Gold crystals of represented samples from Nam Pan and Houay Keh ore lenses were analyzed using Electron Prove Micro Analyzer (EPMA). The analyzed results were then calculated using a formula of Au/(Au + Ag) provided by Marsden (2006) to obtain gold fineness. The results and their calculated gold fineness of gold bearing minerals from KSO deposit are given in Table 2. Au: Ag ratio of gold bearing minerals from Nam pan ore lens ranging from 2:1 to 3:1 with some analyzes contain bismuth mostly less than 1% and no significant amount of copper has been detected. In contrast, the analyzes of gold bearing minerals from Houay Keh have Au: Ag 4:1 to 5:1. In which haft of analyzes has little bismuth. Levitan (2008) suggests that the gold bearing mineral that has gold fineness ranging from 700 to 890 is classified as native gold whereas; that gold fineness ranging from 300 to 700 is classified as electrum. EPMA analysis revealed that gold bearing minerals from Nam Pan ore lens ranges 638 to 716 suggesting that they are predominantly electrum (Table 2). In contrast, the values of fineness from Houay Keh ore lens fall in between 827 to 866 suggesting they are native gold (Table 2).

Table 2. EPMA analyze of gold-bearing minerals in Stage 2 of the Nam Pan and Houay Keh ore lenses.

Houay Keh							Nam Pan						
Ag	Au	Bi	Fe	Te	Cu	Fineness	Ag	Au	Bi	Fe	Te	Cu	Fineness
15.12	85.37	0.73	0.00	0.04	0.01	849.50	26.45	60.06	0.70	0.07	0.22	0.00	694.25
14.70	85.33	0.71	0.00	0.02	0.00	853.01	25.49	59.21	0.57	0.09	0.09	0.00	699.10
14.54	85.57	0.86	0.01	0.08	0.01	854.75	26.17	59.07	0.69	0.03	0.01	0.03	693.00
14.32	82.81	0.81	0.02	0.10	0.00	852.57	26.54	60.27	0.70	0.00	0.11	0.05	694.29
15.17	83.46	0.75	0.01	0.10	0.01	846.24	27.97	56.51	0.69	0.01	0.17	0.00	668.87
13.47	87.13	0.75	0.00	0.00	0.03	866.11	28.94	57.27	0.69	0.10	0.07	0.00	664.29
14.88	83.93	0.86	0.00	0.00	0.00	849.39	29.18	57.13	0.54	0.00	0.14	0.04	661.95
15.30	84.41	0.00	0.00	0.06	0.00	846.55	29.18	57.20	0.74	0.13	0.18	0.03	662.20
14.83	84.91	0.01	0.00	0.07	0.01	851.35	23.79	59.87	0.79	0.67	0.16	0.00	715.61
14.39	84.36	0.00	0.00	0.06	0.01	854.24	28.62	57.90	0.63	0.04	0.15	0.00	669.19
13.56	85.62	0.10	0.01	0.02	0.02	863.29	28.49	59.00	0.76	0.00	0.02	0.00	674.33
14.85	86.22	0.00	0.00	0.16	0.00	853.03	29.56	57.83	0.90	0.11	0.11	0.01	661.74
15.32	85.11	0.05	0.04	0.03	0.00	847.50	29.37	57.56	0.54	0.03	0.17	0.01	662.16
14.19	84.12	0.05	0.00	0.06	0.00	855.63	29.96	56.17	0.75	0.12	0.08	0.03	652.11
16.98	81.20	0.00	0.01	0.03	0.02	827.08	29.67	53.66	0.59	0.50	0.14	0.00	643.97
15.62	80.21	0.00	0.00	0.05	0.03	837.04	29.65	57.05	0.53	0.33	0.19	0.01	658.03
15.39	82.54	0.00	0.00	0.05	0.00	842.81	26.04	48.00	0.69	5.29	0.18	0.00	648.32
16.21	82.34	0.04	0.00	0.07	0.01	835.47	29.19	57.41	0.67	0.07	0.25	0.01	662.91
16.44	82.94	0.00	0.00	0.09	0.00	834.55	29.03	58.00	0.83	0.09	0.14	0.01	666.46
16.03	82.89	0.00	0.00	0.11	0.00	837.97	28.88	57.20	0.76	0.06	0.13	0.00	664.51
14.43	85.91	0.00	0.02	0.04	0.01	856.22	25.91	57.71	0.62	0.21	0.09	0.01	690.10
14.40	83.41	0.00	0.01	0.06	0.00	852.78	31.73	55.85	0.55	0.03	0.23	0.00	637.68
14.48	82.79	0.06	0.00	0.02	0.04	851.18	31.56	55.83	0.57	0.00	0.21	0.01	638.85



6. Discussion and Conclusion

One of the key characteristics of orogenic gold deposit is hosted in metamorphic rocks (e.g., Selinsing orogenic gold-antimony deposit in Peninsular Malaysia; Makoundi et al. (2014)),although many of them occur in older rocks such as Archean rock and of higher metamorphic grades ranging from upper amphibolite to granulite facies. However, several gold deposits have similar characters to typical orogenic gold deposits are reported particularly in southeast Asia (e.g., Selinsing orogenic gold-antimony deposit in Peninsular Malaysia; Makoundi et al. (2014)). KSO gold deposit is also hosted in low-grade metamorphic rocks consisting of metasandstone and metasiltstone similar to Selinsing orogenic gold-antimony deposit in Peninsular Malaysia (Makoundi et al., 2014). Chae Sorn antimony-gold deposit in northern Thailand is another example in which antimony-gold bearing quartz veins hosted in metasedimentary rocks (e.g., meta-phyllite; Salam (1992). Second similarity to orogenic gold deposit of KSO deposit is geometry and nature of gold bearing quartz veins which tends to form as massive (absent of colloform, crustiform banding) and partly controlled by deformation (i.e., infilling fractures/faults), although at KSO deformation is less developed in comparison to typical orogenic gold deposits. Massive gold bearing quartz veins are similar to the orogenic gold type (Goldfarb et al., 2001; Groves et al., 1998; Groves et al., 2003). Furthermore, the main mineralization at KSO deposit forms as single major ore zone at Nam Pan-west and splays to three small discrete veins at Houay Keh ore lens. This pattern of ore zone is similar to various fault controlled deposits including orogenic gold deposits (e.g., SW Yukon and Interior in British Columbia, Yilgarn craton in W. Australia, Otago, South Island in New Zealand). The distinctive sheeted veins identified at Houay Keh ore lens in the east of KSO deposit could be similar to the pattern observed in the intrusion-related gold deposits (Hart et al., 2000). However, the absent of intrusion in adjacent area and no clear metal zonation found at KSO make the intrusion-related deposit style less likely. In addition, gold fineness study at Nam Pan and Houay Keh ore lenses reveals distinctive in which gold occurs at Nam Pan as electrum whereas at Houay Keh it as native gold. The native gold characteristic is consistent with orogenic gold deposit rather than epithermal or intrusion related gold deposits. Considering the hydrothermal alterations at KSO deposit, it reveals that this deposit has less pervasive and extensive alteration mainly characterized by (1) quartz - sericite - chlorite - calcite and (2) chlorite - sericite - calcite mineral assemblages, which is similar to orogenic gold deposit such as those in Reefton goldfield, South Island in New Zealand and Yilgarn block in Western Australia (Christie and Brathwaite, 2003; Eilu and Groves, 2001).

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