Geologic and Petrographic Investigations of Khao Phanom Pa Area, Phichit Province, Northcentral Thailand

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Abstract

Khao Phanom Pa area (1 km^2) in Phichit Province, north-central Thailand has been a site of interest due to a gold rush since 1997. Two kinds of gold deposits were discovered – primary deposit in the hard – rock mountain and the secondary deposit in colluvial sediments. The purposes of this project are to document detailed geology and alteration and to provide petrographic investigation of the area which bears gold deposits. 105 rock samples were collected and 41 pieces of rock slabs were selected for petrographic analysis and thin section study. A new geological map shows that the Khao Phanom Pa study area is dominated by various kinds of igneous rocks. Pyroclastic rocks (tuff and lapilli tuff) of the latest Permian (250±6 Ma) were observed to have been intruded by microdioritic rocks. The microdiorite stocks were later cross-cut by trachytic andesitic dike. Metamorphic rocks were found in locally as calc-silicates and skarnoids. Altered volcanic rocks including retrograde skarnoids, silicified lapilli tuff and micro-diorite show strongly pervasive and selective alteration styles. The latter seems to be more common, and there are four kinds of vein – style alteration viz. epidote – chlorite – sulfide vein, quartz vein, quartz- calcite vein, and calcite vein. Quartz-carbonate and quartz veins are quite more abundant and they appear to be major host of gold. Unconsolidated colluvial and alluvial sediments are also observed to contain appreciable amounts of gold in the surrounding low-lying areas. Non-visible gold was found only from ore assay analysis of altered rocks and quartz veins whereas the visible gold was found by panning around Khao Phanom Pa alluvial area. Gold deposit at Khao Phanom Pa can be classified as low sulphidation epithermal deposit. Gold may have occurred contemporaneously with the vein – style alteration. Volcaniclastic host rocks were first subject to metamorphism as calc – silicate rocks and followed by metasomatism as skarnoids. Subsequently, intense alteration associated with multiple episodes of epithermal alteration assemblages took place.

Keywords: Gold, volcaniclastic, alteration, Pichit, Thailand, petrography

1. Introduction

The study area which occupies an area of about 1 sq km is located in the central part of the >1,200 km long, north-south trending Loei - Pethchabun - Ko Chang volcanic belt. This volcanic belt lies along the western edge of the Khorat Plateau and extends to northern Lao PDR (Fig. 1). This belt has been a focus of interest due to the discovery of several mineral deposits and occurrences, such as base metals, iron, and gold (Jungyusuk and Khositanont, 1992, James and Cumming, 2007). The Akara epithemal gold mine in Pichit and Thung Kham gold mine in Loei are situated in the upper part of this volcanic belt.

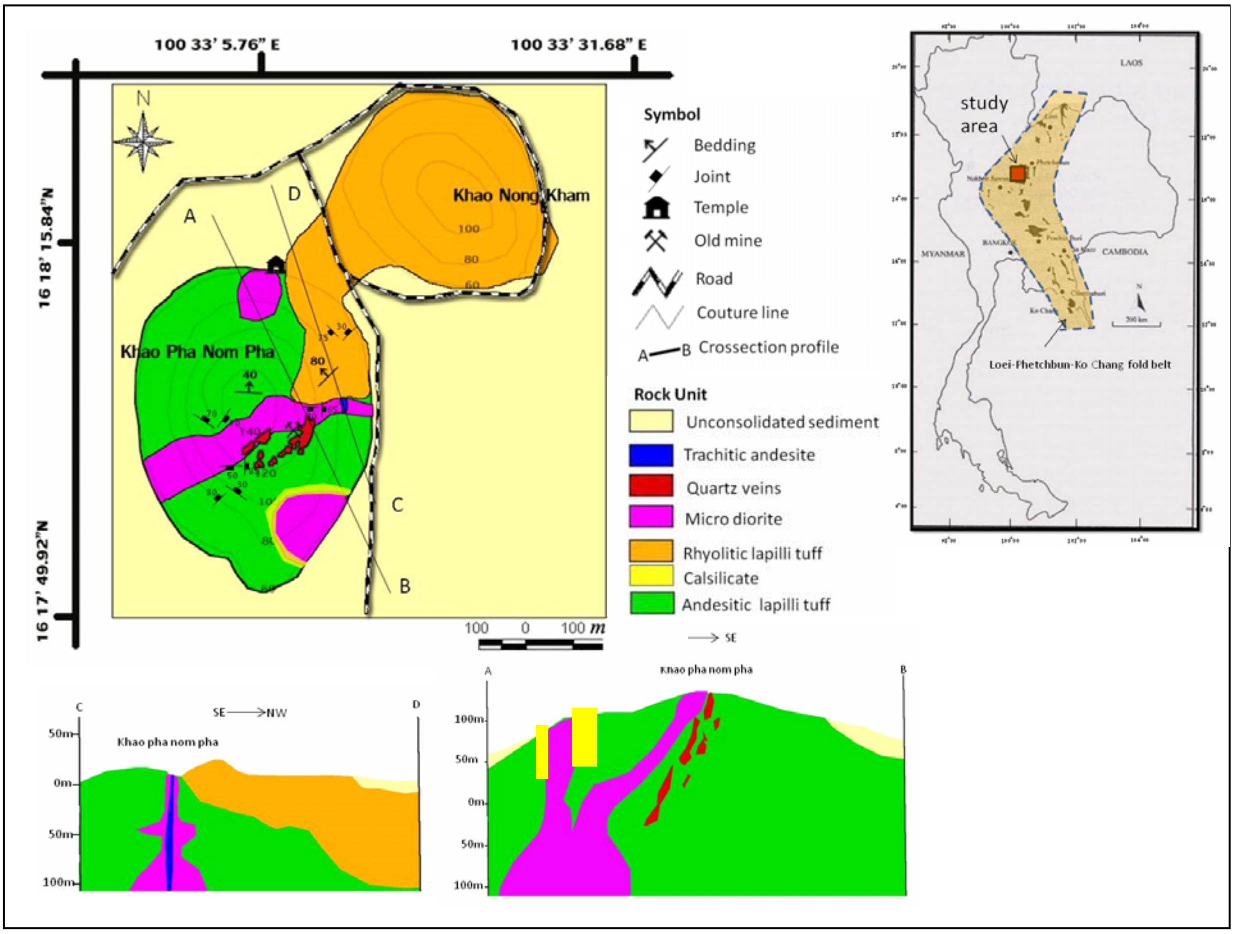

Figure 1. Geologic map and idealized cross section of Khao-Phanom Pha, Amphoe Wang Sai Phun, Phichit, Thailand (based on the topographic map sheet Amphoe Wang-sai-phun, 5141 IV Series 7017).

A few studies have been done so far for the reconnaissance geological mapping and mineral potential investigations within and around the study (Chonglakmani and Sattayarak, 1984, Preamanee and Phuthaing, 2003). Department of Mineral Resources (or DMR, 2001) reported that the study area is occupied by Permo-Triassic volcanic rocks of various types. Visible gold was found in the strongly altered volcanic rocks and unconsolidated sediments, mainly placer deposits. Possible reserve of gold in placer is estimated to be about 0.06 million ounces (DMR, 2001). Sillitoe (2003) made a summary on alteration and mineralization at Khao Phanom Pa area. Later Crossing (2004) made a regional geologic map for the Akara mine area and its vicinity. Diemar et al. (2000) applied geophysical and geochemical surveys for detecting the gold mineralization of Akara area. Salam et al. (2004), Salam (2006), and James and Cumming (2007) reported the geology, alteration, ages, and mineralization of Akara gold deposit. Recently Marhotorn et al. (2008) and Nakchaiya et al. (2008) studied detailed petrochemistry and geochemistry of some volcanic and plutonic rocks of the main Akara mine and nearby region.

The study area includes Khao Phanom Pa Mountain and the nearby flat lying areas to the east where gold has been discovered by local villagers. Gold has been discovered at the study area since 1980s' (Sillitoe, 2003). Since then the gold rush which has occurred intermittently and problems arose when local villagers were injured and several died due to flashed floods and improper and illegal mining activities. Such case leads to a study to identify host rock potentials for gold mineralization at this area. The study area is located about 7 km northwest of the Akara main open pit where 4.5 million ounces of gold were mined (James and Cumming, 2007). Because Khao Phanom Pa area has never investigated in detail, therefore the objectives of this research work are to document detailed geology and petrography of Khao Phanom Pa area and to identify types of alteration associated with host rocks and Au mineralization.

2. Materials and Methods

2.1 Sampling Sites and History

The Khao Phanom Pa area (about 1 sq km) is located in Thub Khlor District of Pichit Province, northcentral Thailand. The study area has two contrasting physiography - one comprising two small hills and the other including low - lying area with a gentle slope toward the east (Fig. 1). Two hills in the study area are Khao Phanom Pa in the south and Khao Nong Kham in the north (Fig. 1). Both hills have almost the same size and altitude with an average elevation of about 120 m above the mean sea level. These two hills are surrounded by the low – lying flat area where a gold rush has taken place continuously since1997. More than one ton of gold was extracted illegally by local villagers and explorers. The study area is located about 7 km north of the Akara main pit where gold and silver have been exploited.

2.2 Methodology

Geological field survey was carried out during a dry season in 2009. This was done following remote sensing interpretation and reviews of both published and unpublished works and maps. Detailed mapping was performed along with rock sampling. About 115 specimens of the least weathered rocks were collected along the east – west transects across the hills. They were then prepared for semi-polished rock slabs to determine types and sequences of alteration. 41 rock samples were selected for thin – section study and petrographic synthesis. X-Ray diffraction analysis was done in some unusual rocks and minerals. Evolution of alteration and associated mineralization constitutes a major part of discussion.

3. Results

3.1 Geology and Petrology of Igneous Rocks

Fig. 1 illustrates the detailed geology of the Khoa Phanom Pa study area and its schematic cross section. The hilly area is occupied largely by igneous rocks (Figs. 2 and 3) with minority of metamorphic rocks (Fig. 3) whereas the low – lying area is covered with the Quaternary unconsolidated sediments which are both colluvial deposits nearby the hills and alluvial deposits along the active stream banks.

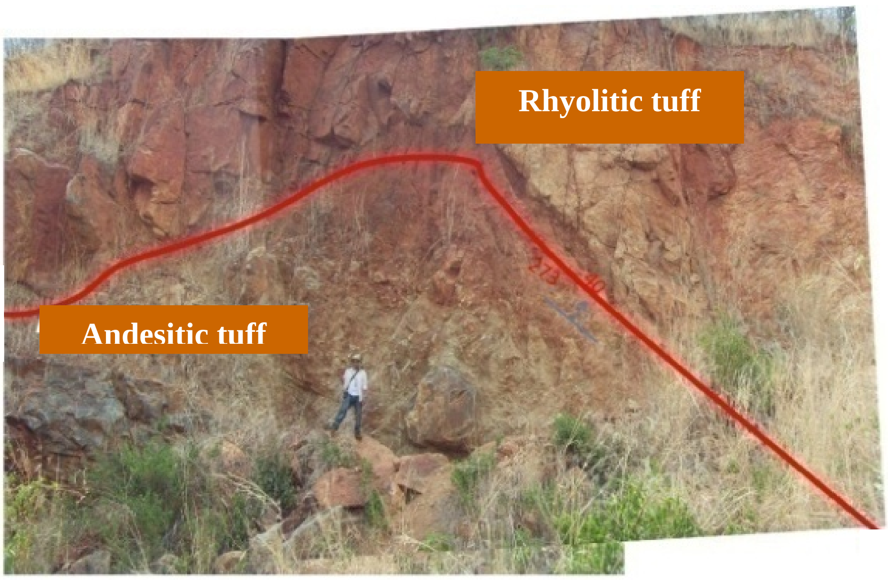

Figure 2. A sharp contact between andesitic tuff and rhyolitic tuff at the eastern quarry of Khao Phanom Pa.

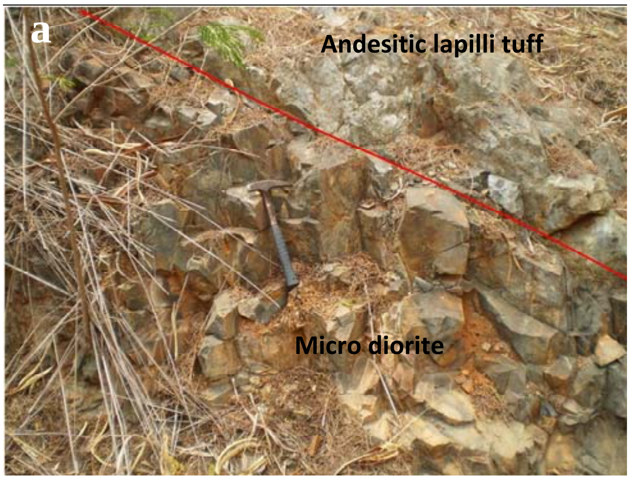

Figure 3. (a) An exposure of andesitic lapilli tuff (upper) and cross-cutting microdiorite dike (lower) at central part of Khao Phanom Pa Contact zone between andesitic lapilli tuff (lower) and rhyolitic lapilli tuff (upper) units at Khao Phanom Pa. (b) A large exposure of trachytic andesitic dyke (with the attitude of 340°/85°) cross- cutting microdiorite stock at the quarry of Khao Phanom Pa.

The igneous rocks consist principally of volcaniclastic and dike rocks (Figs. 4a and b). Among the rocks exposed, tuff and lapilli tuff are common volcaniclastic. Two types of volcaniclastic rocks can be determined based on both field and petrographic investigations; they fall within the range of felsic to intermediate compositions. The older unit is andesitic lapilli tuff and the younger unit is rhyolitic lapilli tuff. Fig. 2 displays the contact between two units which can be observed clearly at the outcrop scale. The geology of the study is shown below.

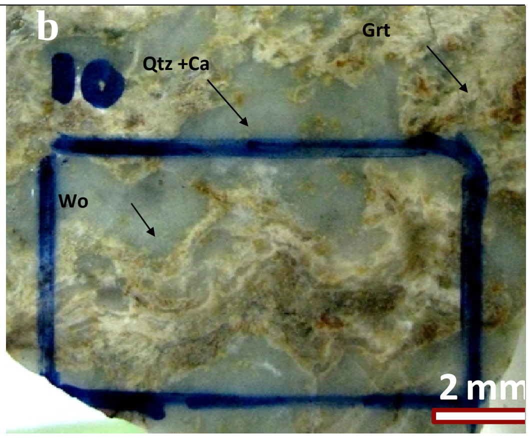

Figure 4. (a) A large float rock of wollastonite –- garnet – epidote skarnoid cut across by veins of quarz-calcite assemblage (white – colored) at the foot hill of Khao Phanom Pa hill. (b) Rock slab showing wollastonite –garnet –epidote skarnoid invaded by quartz – calcite vein. Note that this slab is derived from the above sample (a).

Andesitic lapilli tuff is found mainly as natural exposures at Khao Phanom Pa. The rocks are massive to well-bedded. The attitudes strike largely in the east – west direction and dip predominantly to the north and north-northeast direction at moderate angles. The maximum thickness is estimated to be at least 80 m. Mesoscopic investigation reveals that the tuff is usually blackish green, fine- grained and contains abundant rock fragments of andesite and rhyolite. It has mesocrystalline, porphyritic, flow and alteration textures (Figs. 5a and b). Phenocrysts are stubby Ca-Na plagioclase and hornblende whereas groundmass includes mafic glass, devitrified glass, chlorite, opaque, and microlite.

Rhyolitic lapilli tuff overlies the andesitic tuff. This rhyolitic tuff occupies much of Kao Nong Kham and the northeastern of Khao Phanom Pa as natural exposures on the hills. It occurs as massive rock and bedded rock with strong silicification. It has the thickness of at least 100 m. The rock is pinkish gray to white gray, show mesocrystalline, slightly porphyritic and flow textures. Under thin sections, it consists largely of rhyolite fragments, quartz, Na plagioclase, and K-feldspar. Groundmass includes felsic glass, microlite, devitrified glass and rare opaques (Fig. 5c).

In the study area, there are two kinds of dikes and stocks viz. microdiorite and trachytic andesite. The microdiorite occurs as dikes and small stocks. It cuts across both types of volcaniclastic rocks in the east – west strikes with moderate dipping angles. Microdiorite is well exposed as a quarry front (10x25 m) to small outcrops (0.5x1m) in the north of Khao Phanom Pa. Its thickness ranges variably from <1 up to 20 m. It can be traced almost continuously for more than 300 m. The rock is black to blackish blue and has phaneritic, holocrystalline, slightly porphyritic, intersertal, and intergranular textures (Fig. 5d). Major mineral compositions are opaques, Ca – Na plagioclase, K-feldspar, chlorite, quartz and actinolite.

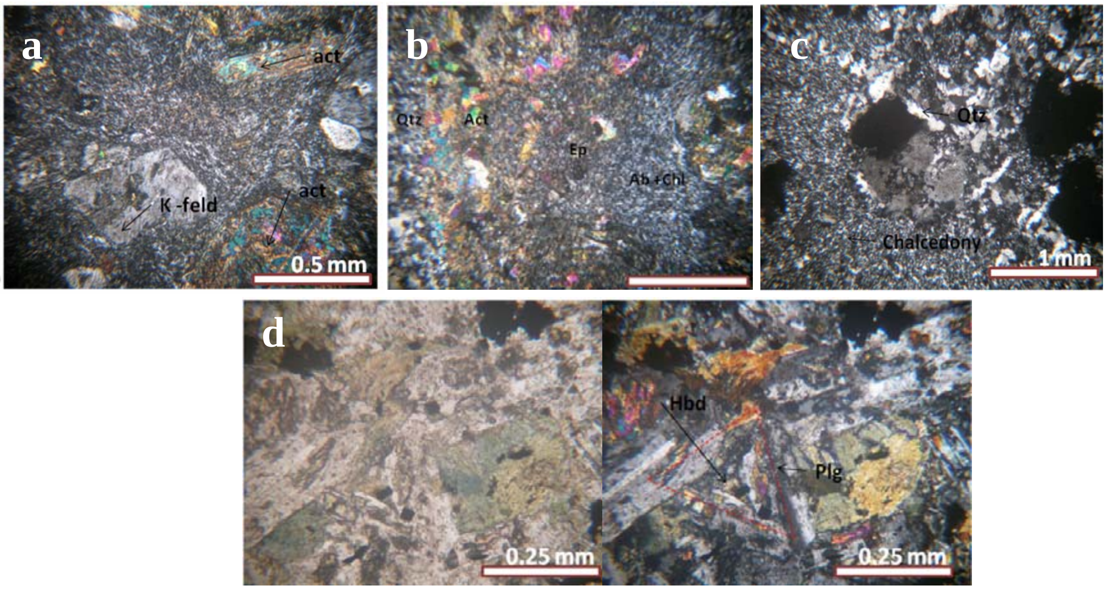

Figure 5. Photomicrographs of andesitic lapilli tuff sample showing (a) relict flow texture in partly silicified groundmass which encloses K?-feldspar phenocryst. (Under polarized light with crossed Nichols), (b) quartz vein (left) and wall – rock alteration of actinolite -epidote-albite -chlorite-opaque assemblage (middle to right). (Under polarized light with crossed Nichols), (c) rhyolitic lapiili tuff sample showing small vein quartz and silicic alteration material (quartz-chalcedony) enclosing the earlier-formed phenocryst (interpreted as plagioclase) totally replaced by pervassive silicification. (Under polarized light with crossed Nichols), and (d) microdiorite sample showing intersertal texture with hornblende surrounded by plagioclase. (Under polarized light with crossed Nichols - right and uncrossed Nichols - left).

The trachytic andesite is observed as dikes which are found abundantly only at Khao Phanom Pa as small outcrops (with the maximum size of 1x2 m). The rock is found cross cutting microdiorite. Its attitudes strike almost north – south and dip at steep angles to the north. Thickness of this dike rock is less than that of the microdiorite dike. The very common thickness is about 1.5 m. The dike can be traced locally to about 10 m. Its textures are characterized by hypocrystalline, porphyritic, flow and trachytic textures. Rhyolite rock fragments are found in some outcrops and rock slabs, suggesting that the dike also younger than the rhyolitic tuff. Quartz and Ca-Na plagioclase constitute the major mineral constituent, and groundmass includes volcanic glass, microlite and quartz (Fig. 6).

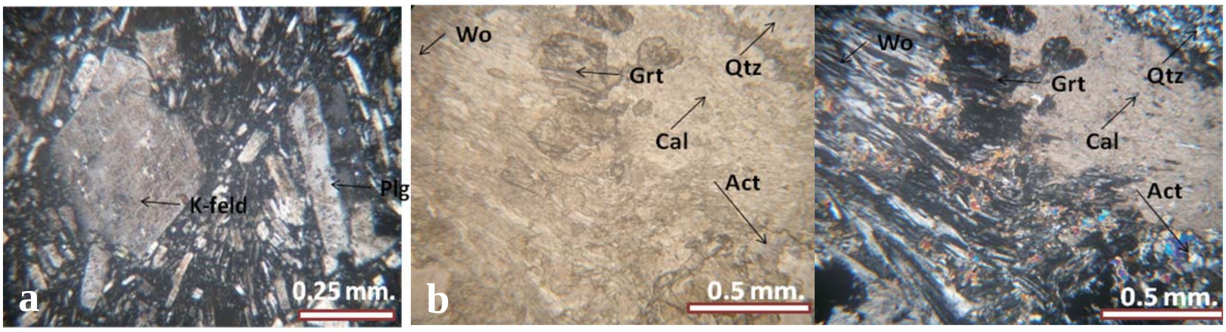

Figure 6. Photomicrographs of (a) trachytic andesite sample showing well – defined trachytic texture and a K-feldspar phenocryst surrounded by glasseous groundmass with an alignment of microlite and small plagioclase. (Under polarized light with crossed Nichols) and (b) calc-silicate sample showing granoblastic texture with calc-silicate mineral assemblage (quartz-wollastonite-garnet-calcite-actinolite-pyroxene) and embayment texture (Grt = garnet, Cal=calcite, Act=actinolite, Wo =wollastonite and Qtz = quartz) (Under polarized light with crossed Nichols - right and uncrossed Nichols - left).

3.2 Geology and Petrography of Metamorphic Rocks

Metamorphic rocks are also found locally in the study area. They are observed only in the southeastern part of Khao Phanom Pa. Large exposures (3 x 5 m) are situated at the contact zone between andesitic tuff and microdiorite stocks. The contact zone has the average thickness of about 50 cm and can be traced for more than 50 m. Two types of metamorphic rocks are recognized - one is calc-silicate rock and the other is skarnoid, based on the classification recommended by Meinert (2004).

The calc-silicate rock always occurs at the contact zone. Textures range from fine-grained, equigranular, granoblastic to medium – grained poikiloblastic textures (Fig. 6). Normally these rocks are grayish green to brownish green and light brown. Mineralogically, the rock consists chiefly of garnet, wollastonite, tremolite, pyroxene, and quartz with minority of chlorite, epidote and opaques.

The skarnoid (Fig. 4) always occurs in a close proximity with alteration and vein systems within the host rocks. The skarnoid is pinkish to brownish green, massive and dense. Petrographically, it invariably shows medium-grained granoblastic texture, however in some samples, the skarnoid display coarse – grained, inequigranular texture. It consists largely of quartz, chlorite, actinoliote, epidote and albitic plagioclase. A few sulfide grains, which are usually cubic pyrite crystals, are also recognized sporadically. The skarnoid is a retrograde rock and have occurred by metasomatism of andesitic tuff and microdiorite.

3.3 Alteration

There are two systems of alteration encountered in the field, viz. pervasive system and selective system. The latter is more common and frequently occurs as veins and veinlets. The pervasive alteration occurs when the whole tuffaceous rocks are completely altered. So in some parts it has irregular zones (and patches) with the thickness varying from 0.2 cm to 50 cm. Selective zone is present as materials filled in fractures.

At least, 6 types of vein types are recognized, they are on order of timing as (1) quartz-chlorite-epidote-opaque veins, (2) quartz-epidote veins, (3) Au-barren quartz veins, (4) quartz-calcite-actinolite-opaque veins (± Au), (5) quartz-calcite-actinolite-epidote-albite-opaque veins (± Au), and (6) Au-barren calcite veins. Some alteration assemblages and cross – cutting relationships (Figs. 6 and 7) are shown on both mesoscopic (a) and microscopic (b) scales.

3.4 Gold Mineralization

Gold can be found as visible and non-visible grains. The visible gold is always small (usually <1mm) and irregular in shape (somewhat anhedral crystal forms). Fig. 8a shows a float rock containing gold grains embedded in quartz – calcite vein (2 cm thick) at Khao Phanom Pa. Gold – bearing volcanic breccias are also recognized at Khoa Fig. 8b shows large gold grains found by panning in the alluvial placer nearby the Khao Phanom Pa hill. Invisible gold at Khao Phanom Pa has also been recognized in strongly altered volcaniclastic rocks as shown in the reports of Diemar et al. (2000), Sillitoe, (2003), and Preamanee and Phuthaing (2003). In this study, the paragenetic sequence of minerals were described and classified together with stages of alteration and vein systems. We subdivide ore-gangue paragenesis into three stages, including pre-ore mineralization, syn-ore mineralization and post-ore mineralization. Detailed explanation of these paragenetic sequences, alteration, and vein styles are displayed in Fig. 9.

4. Discussions

4.1 Age and Stratigraphy of Associated Rock Units

Based on stratigraphic correlation, DMR (2003) assigned the age of volcanic host rocks in the study area as Permo –Triassic. Sillitoe (2003) reported the K-Ar age of fine-grained muscovite (or sericite) from gold – bearing quartz vein to be 250± 6 Ma which is approximately the latest Permian. So it is quite possible that the age of volcanic host rocks must be contemporaneous with Au mineralization. So in this case we consider that the age of volcanic activity must be the latest Permian.

4.2 Type of Gold Mineralization

The presence of Au ores as well as quartz and calcite leads us to consider the gold deposit of the study area to be epithermal. The associated mineral assemblage, such as chlorite, epidote and albite, is similar to those of the Akara mine (Charusiri et al., 2003, Cumming, 2004, James and Cumming, 2007) and Phillippines (Sillitoe, 2000). Low sulphidation is likely for this kind of epithermal deposit due to the presence of quartz and sericite. Therefore, such epithermal gold deposit at the Khao Phanom Pa study area is almost similar to that of the Akara mine. However, the occurrence of visible gold is quite different from that of the Akara mine, suggesting the higher temperature of formation than that of the Akara mine.

4.3 Evolution of Magmatism and Gold Occurrences

Based on our result, evolution of magmatism and related gold occurrences at the Khao Phanom Pa can be inferred. The calc alkaline volcanism (Nakchaiya et al., 2008) of the latest Permian gave rise to the andesitic lapilli tuff and followed by the rhyolite lapilli tuff. Subsequently, calc-alkaline intrusion (Mahotorn et al., 2008) occurred and yielded micro-diorite stocks and dikes which cross – cut volcaniclastic rocks. Such minor intrusion was responsible for the formation of calc- silicate rocks. Fractures and faults developed and served as channel ways for hydrothermal fluids which perhaps derived from intrusion. Then the volcanic host rocks were deeply altered and some parts of the host rocks were metasomatized to be skarnoids. Hydrothermal alteration (quartz-chlorite-epidote-actinolite-albite –pyrite assemblage) was strongly pervasive in some parts, and some developed as vein style alteration. At present it is difficult to specify sources of fluids if they derived from volcaniclastic rocks with the minor intrusion as a heat source or mixed with meteoric (or sea) water. Au ores may have been precipitated in quartz – calcite veins as primary gold ores of epithermal deposits. More than one stages of hydrothermal alteration associated with ores were recognized. However, strong weathering and erosion processes may have triggered a down-slope movement and transportation of weathered rocks to form the secondary gold ores as colluvial deposits and alluvial placers nearby.

Gold mineralizations at the Khao Phanom Pha are epithermal and low sulphidation, almost similar to those of Akara mine (Salum et al., 2004). The main host rock in this area is andesitic volcaniclastic rock that was subject to cal-silicate alteration and characterized by multiple hydrothermal alteration assemblages and quartz-carbonate (chlorite-actinolite-epidote) replacements, veins and breccias.

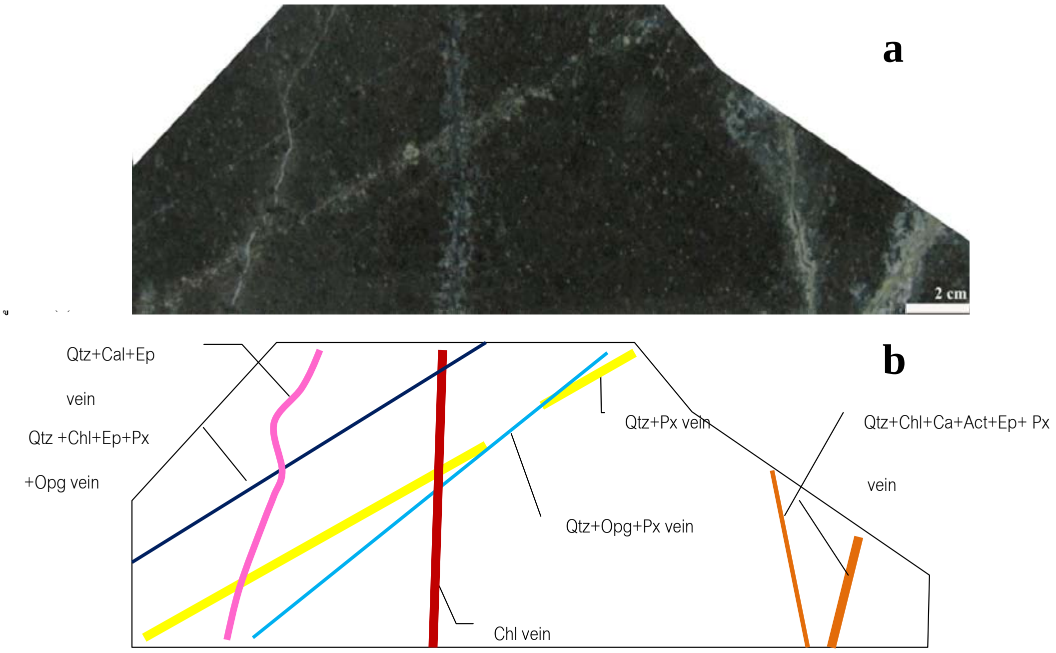

Figure 7. (a) Rock slab of andesitic lapilli tuff collected from Khao Phanom Pa (a) showing several assemblages of veinlets. (b) Sketch of rock slab (in a) showing – earlier formed assemblage of Qtz –Chl-Px -Ep-opg vien crossed cut by the Qtz-Px vein, then by the Chl-rich (qtz) vein, by the Qtz-Opg-Px vein, and by the late assemblage of Qtz-Cal-Ep vein.

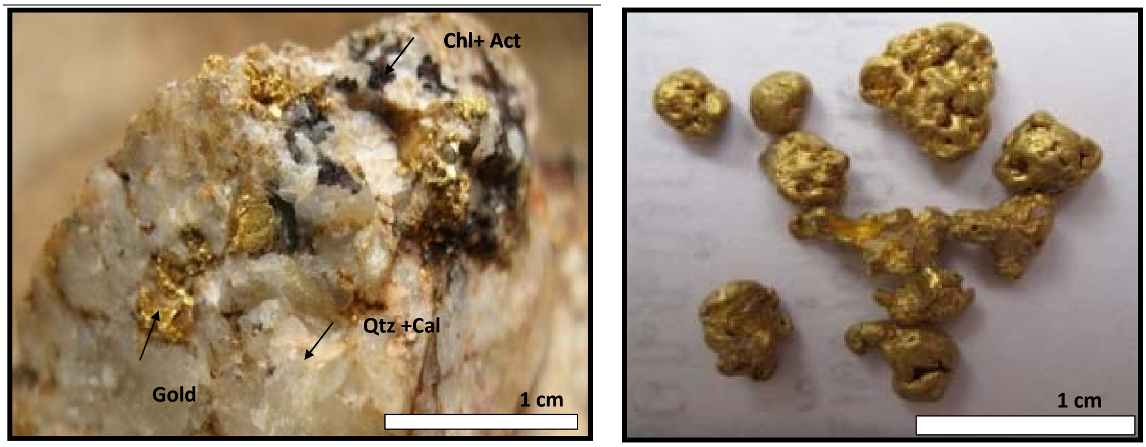

Figure 8. (a) Gold nuggets (up to 0.5 cm in diameter) in quartz vein with – calcite –chlorite - actinolite – epidote – quartz assemblage. (b) Gold nuggets (up to 0.5 cm in size) collected from villagers' panning along the stream, east of Khao Phanom Pa**.**

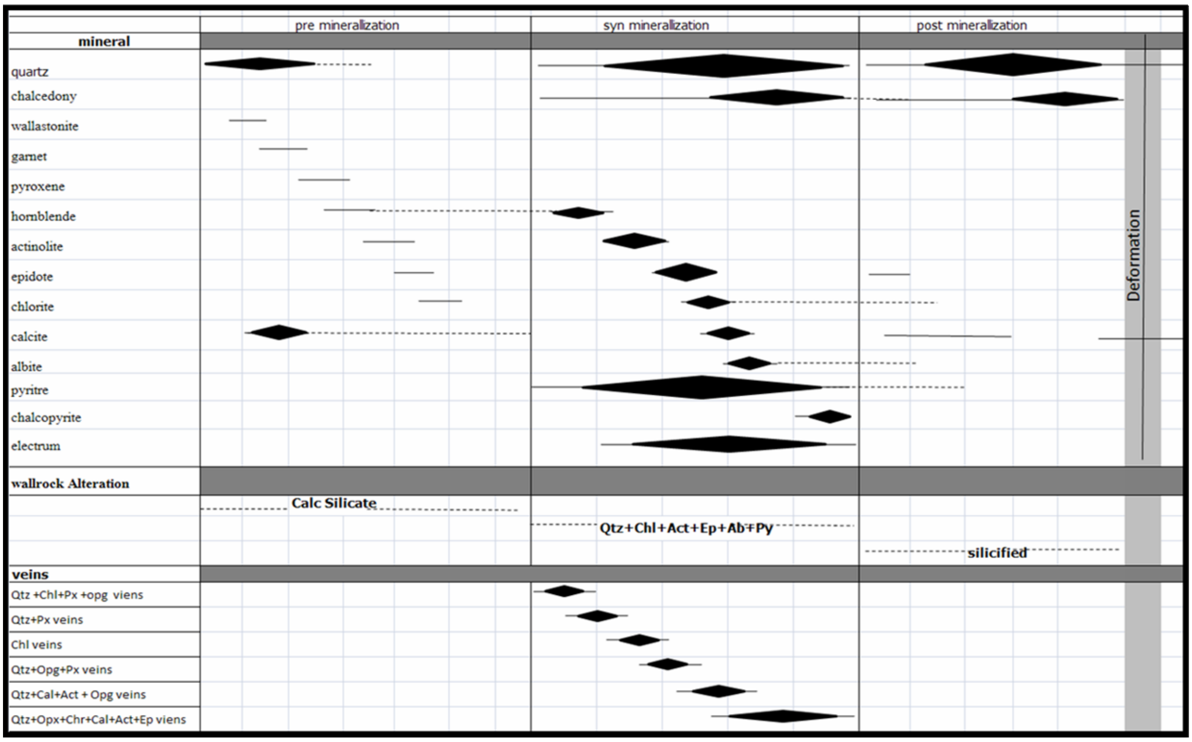

Figure 9. Paragenetic sequence (of mineral, alteration and vein) and 3 stages of wall – rock alteration (pre-minerallization, syn-minerallization and post-mineralization).

6. Conclusions

Visible and non – visible gold ores at the Phanom Pha and nearby area, northcentral Thailand, were discovered as primary ores in volcaniclastic rocks and secondary ores in alluvial deposits. These volcaniclastic rocks are considered as host of gold and show several episodes of alteration by small intrusive bodies. The most important alteration zones are quartz – carbonate, quartz – epidote-chlorite and quartz (or silicified). These minor intrusions are thought to be heat source responsible for genesis of calc-silicate rocks and skarnoids. Hydrothermal fluids which may have been derived from volcaniclastic source and either mixed with meteoric water or sea (and ground) water require further studies. However, it is concluded that the Au deposit is of epithermal-type mineralization. It is also recommended that geochemistry of volcanic rocks is required for deciphering relationship between mineralization associated with magmatism and tectonic setting.

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