Discovery, geology and mineralisation of the Phu Kham copper-gold deposit Lao People's Democratic Republic

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Abstract. The Phu Kham copper-gold deposit is in the Lao People's Democratic Republic. The name translates literally as "Mountain of Gold". The deposit includes distal sulphide skarn, proximal silicate-oxide skarn and stockwork mineralisation styles that are spatially related to a series of intermediate porphyry dykes. The alteration assemblages, vein styles and intrusive associations of the deposit suggest that it represents the upper or distal portions of a classical porphyry copper-gold mineralisation system. At the present stage of evaluation, the deposit contains a combined indicated + inferred resource of 108 Mt @ 0.8% Cu & 0.3 g/t Au at a cut-off grade of 0.5% Cu (Pan Australian Resources annual report 2004) within a global resource of 311 Mt @ 0.5% Cu & 0.2 g/t Au at a cut-off grade of 0% Cu.

Keywords. Phu Kham, Laos, porphyry copper gold, skarn, carbonate replacement, stockwork

1 Regional geology

The Phu Kham deposit occurs near the intersection of the Loei and Truongson fold belts. These belts respectively form the west and northeast margins of the Khorat-Kontum terrane (Fan 2000). They contain deformed Palaeozoic volcano-sedimentary sequences and acid to intermediate intrusive suites (Fig. 1). Most of the Phu Kham mineralisation occurs in a sequence of intermediate volcaniclastics with interbedded Permo-Carboniferous limestones. In the deposit area, the host sequence is separated from a basement of redbeds and granitoids by a low angle fault. The age of the basement is unknown. Small diorite bodies and intermediate porphyry dykes intrude the basement and host sequence.

2 Discovery

The deposit was discovered in the 1994-97 period by Phu Bia Mining. The company is presently owned by Pan Australian Resources Limited (80%) and Newmont South East Asia Pty Ltd (20%).

The discovery was the result of traditional soil and rockchip follow-up of anomalous gold results from a regional BLEG stream sampling program.

The deposit was originally interpreted as a classical stockwork-disseminated porphyry copper-gold system. Detailed mapping and relogging of drillcore indicated that the majority of the host rocks are volcaniclastics, tuffs and skarn with only minor porphyry dykes. A drilling program based on the new geological model led to delineation of the orebodies currently under evaluation.

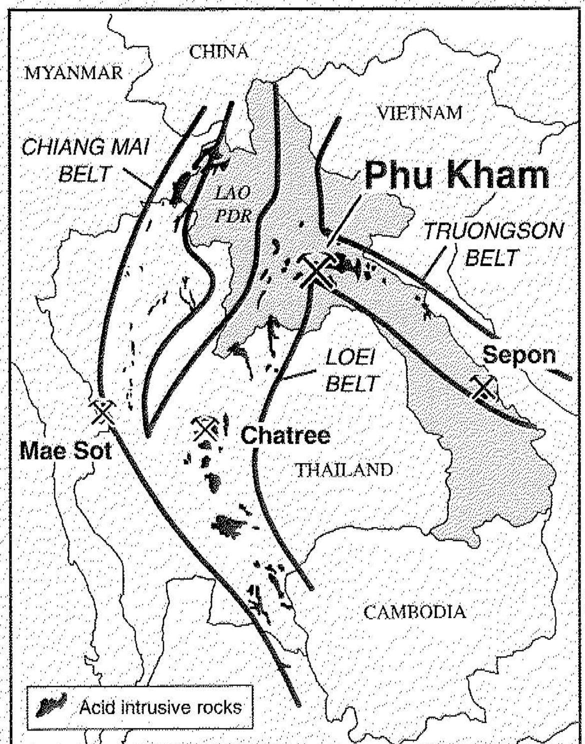

Figure 1: Regional setting of the Phu Kham deposit.

3 Lithology

In the immediate vicinity of Phu Kham, the basement rocks are dominated by distinctive maroon coloured redbed siltstones with thick lenses of arkosic conglomerate. The redbeds closely resemble some units of the Cretaceous Khorat Basin sequence in northern Thailand (K Zaw pers. comm.). However, evidence of at least two deformation events in the redbeds at Phu Kham suggests that they may be significantly older than the Khorat sequence.

A large body of muscovite-biotite granite defines the eastern limit of the deposit (Fig. 2). Redbed xenoliths in this body indicate that it is part of the basement.

Above the low angle fault, the mineralisation host rocks have been converted almost entirely to a sericite-quartz-pyrite mineralogy with moderate to strong foliation. These rocks were previously thought to be feldspar porphyries,

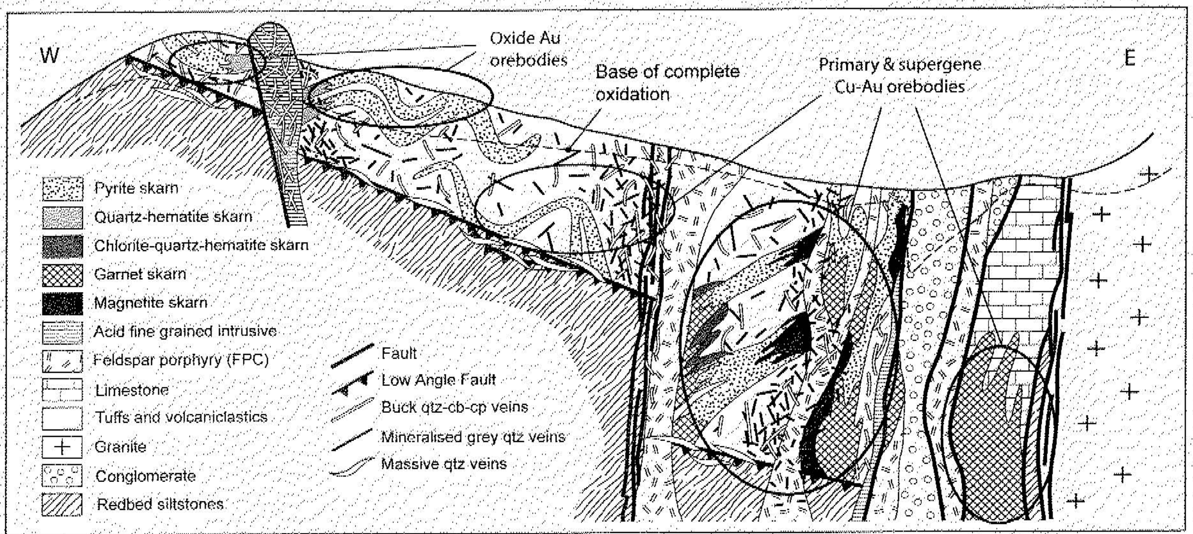

Figure 2: Schematic section through the Phu Kham Cu-Au deposit.

but crystal, lapilli and lithic textures preserved in many examples suggest they are tuffs and volcaniclastic sediments. A lack of quartz phenocrysts and only minor chlorite after mafic grains suggest that their original composition was intermediate.

Within the host stratigraphy, there are numerous units of banded to massive pyrite with varying amounts of interstitial quartz and sericite. These rocks are interpreted as distal skarn or sulphide replacement of calcareous sediment layers.

Several large outcrops of massive limestone occur in the district and a large block occurs between the deposit and the granite to the east. The limestones are probably part of the host sequence, but the exact stratigraphic relationship is unknown. A coral fossil from these limestones has been tentatively dated as Permian or Carboniferous in age (Cann 1997 unpublished).

A series of feldspar porphyry dykes (FPC) with 30-50% 4-8 mm feldspar phenocrysts has been identified in the eastern half of the deposit (Fig. 2.). Primary mineralogy is generally obscured by alteration. Up to 10% chloritised mafic grains can be identified in some examples. Fine-grained quartz is commonly present in the matrix. Textural gradations between FPC and leucodiorite have been observed. The dykes are much less deformed than the host sequence.

Several small plugs and dykes of acid fine grained intrusive (AFI) occur throughout the deposit area. These rocks have a fine saccharoidal texture and varying degrees of quartz-pyrite alteration. Some AFI bodies in drill intersections near the eastern margin of the deposit have aplitic textures. Sparse 2-4 mm quartz phenocrysts have been identified in some outcrops. Mapped exposures occur in north or east trending clusters, generally in the vicinity of steep dipping faults.

Numerous bodies of garnet and magnetite skarn have been intersected in the vicinity of FPC dykes (Fig. 2). Small bodies of granular quartz-hematite skarn occur on the contacts between some AFI intrusives and pyrite skarns. Narrow zones of chlorite-quartz-hematite skarn commonly mark the transition from garnet or magnetite skarn to volcaniclastic hostrock.

4 Structure

The low angle fault between the host sequence and the basement dips northeast at ~ 20°. The structure varies from a 30 cm shear to a 20 m swarm of unmineralised, massive quartz veins. The movement vector on this fault has not been resolved. The low angle fault is cut by a series of north to northwest trending vertical faults. Normal and reverse movement on these structures has preserved a thick block of the host sequence along the eastern side of the deposit (Fig. 2). The FPC dykes that control mineralisation appear to have intruded these steep dipping structures. Consequently, it is concluded that the mineralisation post-dates development of the low angle fault. Several steep structures strike east-northeast across the southern end of the deposit. These faults produce apparent sinistral and dextral offsets of up to 100 m in the north trending faults, indicating that they are the youngest set. An AFI dyke occupies one of these structures suggesting that it is younger than the other dykes.

The basement redbeds and the host volcanics have undergone at least two deformation events. The first event produced a penetrative phyllitic cleavage. This cleavage is axial planar in some small isoclinal fold hinges. The second event deformed the cleavage to produce folds with subhorizontal west-northwest trending axes. A weak third event is indicated by pressure shadows on sulphide grains

and minor kink folding. The low angle fault does not appear to be folded at the deposit scale, but may have small folds that cannot be resolved at the current density of drilling. The deformation events may correspond to three events between the Late Carboniferous and Late Cretaceous as described by Potisat (1996).

The lack of foliation in FPC dykes suggests the intrusive activity began after the first deformation. Early veins in the mineralisation system cut the foliation, but are commonly folded and boudinaged. Later mineralised vein types are less deformed suggesting that the mineralisation event may have spanned the second deformation.

5 Alteration

Almost all of the host sequence is affected by strong, pervasive phyllic alteration. The redbeds adjacent to the low angle fault and steep structures are also sericite altered, but the alteration rarely extends more than 10 m beyond the contact.

Strong K-feldspar alteration occurs within and around some FPC dykes. Minor secondary biotite has been observed in thin section (Ashley 2003).

Sulphide, magnetite and garnet skarns clearly replace calcareous units within the host sequence and some replace parts of the massive limestone block to the east. Magnetite and garnet commonly occur together. Pyrite skarn occurs as massive bodies and as replacement fronts overprinting magnetite. Quartz-hematite skarns appear to represent endoskarn development on the margins of AFI intrusives. The chlorite-quartz-hematite skarns probably represent replacement of impure limestones on contacts with volcaniclastic units.

Most of the mineralisation in the magnetite and garnet skarns is associated with a retrograde alteration assemblage dominated by hematite, carbonate, chlorite and pyrite. This assemblage usually occurs as narrow fracture and vein halos.

No examples of skarn alteration have been observed in the redbeds despite common calcareous units and adjacent FPC intrusives.

Small amounts of pyrophyllite and diaspore have been observed in similar sites to sericite. (Ashley 2004 unpubl.). In combination with traces of enargite, this suggests areas of high sulphidation environment in the system. It is concluded that these zone represent the deepest parts of a high sulphidation zone that overprinted the upper parts of a classical potassic-phyllic porphyry environment.

6 Mineralisation paragenesis

Mineralisation at Phu Kham occurs in several distinct skarn and veining events (Fig. 2).

The pyrite skarns contain bornite, chalcopyrite and tennantite occupying fractures within pyrite grains and pressure shadows on pyrite boundaries. Traces of low-iron sphalerite and galena have also been observed. Petrographic work has revealed small grains of native gold in association with chalcopyrite (Mason 1997 unpublished).

Mineralisation in the garnet and magnetite skarns occurs in small veinlets filled with chalcopyrite, pyrite, chlorite, magnetite, hematite and carbonate. Chalcopyrite is the dominant primary copper species, but bornite is usually present in trace amounts. The mode of gold occurrence is unknown, but good correlations between gold and copper grades suggest an association with chalcopyrite.

Quartz-hematite skarns on AFI contacts contain up to 10 g/t Au, but the primary mineralization mode is unknown since only oxidised examples are known. Veinlets of massive chalcopyrite have been observed in the chlorite-quartz-hematite skarns adjacent to massive garnet skarns.

Four significant vein sets have been identified at Phu Kham. These sets have distinctive styles and maintain consistent crosscutting relationships.

The earliest veins are characterised by grey, granular quartz infill. They are typically 3-10 mm thick with parallel sides. Some of these veins exhibit a vague laminar structure defined by trails of opaque inclusions or molybdenite parallel to the walls. They occur throughout the host sequence, but are most common adjacent to FPC dykes. These veins are typical of the early "A" type veins observed in many porphyry stockwork systems. They have been observed cutting the dominant foliation and undeformed FPC dykes. Consequently, these veins must have formed after the first deformation event. However, many veins in this set are folded or boudinaged by a later event. These veins contain the majority of the stockwork style Cu-Au mineralisation at Phu Kham, but the mineralisation is invariably an overprinting event. Chalcopyrite, bornite, tennantite and pyrite occur in highly irregular fracture networks throughout the vein quartz. Deformed veins appear most susceptible to this style of mineralisation. The mineralised fractures rarely extend outside the veins. In detail, the copper minerals consistently overprint pyrite as fracture fillings or partial replacements (Ashley 2004 unpublished).

Chalcopyrite and bornite are the most common primary copper species. Ratios range from heavily chalcopyrite dominant to heavily bornite dominant. Bornite-rich zones appear to have higher gold grades. Petrographic work suggests gold occurs as small native grains with chalcopyrite in fractures cutting pyrite grains (Townend 2004 unpublished).

Veins in the second set are filled with massive pyrite. They are typically 1-10 mm thick with parallel sides. Quartz pressure shadows between pyrite grains are present in most of these veins. They contain only traces of chalcopyrite and bornite.

The third vein event produced irregular pods of white buck quartz with interstitial patches of carbonate, chlorite and minor coarse chalcopyrite. Traces of bornite have also been observed. These veins do not appear folded or boudinaged. The veins occur throughout the deposit. They extend into the redbeds, but chlorite infill becomes more abundant and copper minerals become much less common. This suggests that the later parts of the hydrothermal system affected the redbeds, but they were an unfavourable host for mineralisation.

A final phase of quartz fibre veins with minor chlorite and carbonate infill cuts all other vein types. These veins are thought to represent the last deformation event that produced fibrous pressure shadows on sulphide grains. Despite similarities to the mineralised pressure shadows in some sulphide skarns, these veins are generally unmineralised.

Above the water table, copper is leached from both skarn and stockwork mineralisation. Gold remains in the oxide zones. Gossans after sulphide, magnetite and garnet skarns form the oxide gold resource that is currently under development. Stockworks generally have insufficient primary gold grades to produce economic oxide ore.

Below the water table there is a zone of supergene weathering. Copper leached from the oxide zone is reprecipitated in this zone as coatings of covellite, digenite and chalcocite on pyrite and primary copper sulphide grains. The greatest enrichment occurs where sulphide skarns cross the oxide/supergene boundary. In these areas, copper grades up to 10% have been encountered. Gold grades do not appear to be significantly enriched in the supergene zone.

References

Ashley PM (2004) Petrographic report on twenty samples of drill core from the Phu Kham copper-gold project, Laos. Consultants report for Phu Bia Mining

Ashley PM (2003) Petrographic report on five drill core samples from the Phu Kham Cu-Au deposit. Consultants report for Pan Mekong Exploration

Cann J (1997) Memorandum Re: Thin Section of Coral Appendix 2 in Mason D (1997) Petrographic Descriptions and Interpretation for Twenty Drill core Rock Samples, Long Chieng Track Prospect (Lao PDR). Mason Geoscience Pty Ltd Report for Phu Bia Mining Ltd.

Fan P (2000) Accreted terranes and mineral deposits of Indochina. Journal of Asian Earth Sciences 18: 343-350

Mason DR (1997) Petrographic descriptions and interpretation for eleven drill core rock samples, Phou Kham Prospect, Lao P.D.R. Consultants report for Phu Bia Mining Ltd

Potisat S (1996) Gold Exploration and Mining Opportunities in Thailand. Thailand Mineral Resources Development Division Document:1-17

Townend R 2004 Screening, and TBE separations of two composites. Polished section examination of TBE SKS. (39059/G20; 39060/G21). Consultants report for Phu Bia Mining Ltd. Via Independent Metallurgical Laboratories Pty Ltd.