

The Discovery of the Nam San Copper-gold Deposit, Phu Kham, Laos

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ABSTRACT

The Nam San copper-gold deposit was discovered in 2011 and is a likely blind extension of the Permian age Phu Kham structurally deformed porphyry/skarn copper-gold deposit.

The Nam San mineralisation is hosted within a dominantly sericite altered schist unit located to the north of the current Phu Kham open pit operation and is overthrust by an allochthonous barren cover sequence of limestone, granite and sandstone. Reinterpretation of the Phu Kham geology developed the concept of a possible telescoped porphyry copper-gold system at depth. Initial drilling intersected remobilised copper mineralisation in a basal conglomerate, confirming the concept. A reconnaissance vector array induced polarisation (IP) survey identified a deep chargeability anomaly from which a drilling target was developed from 3D inversion modelling of a detailed follow up dipole-pole-dipole anomaly. Drilling of the chargeability anomaly intersected the blind Nam San copper-gold mineralisation beneath the thrust cover sequence.

The key discovery parameters are the result of an integrated exploration program that included reinterpretation of the local stratigraphy, which developed the concept of a deep blind orebody, IP surveys capable of penetrating through the barren cover and a commitment to a deep directional drilling program to test these concepts and targets. The inferred resource remains open at depth, and further assessment will most likely be through underground development.

INTRODUCTION

The Phu Kham copper-gold deposit is located at latitude 18°55' and longitude 102°55' in the north of Laos, within the Mineral Exploration and Production Agreement concession held by Phu Bia Mining (PBM). PBM is 90 per cent owned by PanAust and ten per cent by the government of Laos. Operations at Phu Kham commenced in 2005 with gold production from a heap leach operation. First production of copper-gold-silver concentrate was in 2009. The most recent mineral resource estimate was completed in mid-2011 for a total resource of 207.4 Mt of 0.60 per cent Cu, 0.26 g/t Au and 2.31 g/t Ag. An expansion of the mill capacity to maintain annual metal production to compensate for a decrease in mine head grade led to a decision to accelerate the brownfield exploration program.

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GEOLOGY

At the regional scale, Phu Kham is located within a zone of convergence of the Loei and Truongson volcano-sedimentary foldbelts, which developed during the Palaeozoic and Mesozoic periods, as confirmed by U-Pb dating of zircons (Kamvong, 2013). Both belts are characterised by moderate to intense folding and faulting. The belts are metallogenically significant as they host all of the known gold and base metals deposits in Thailand and Laos, including the Chatree gold deposit and the Phu Kham and Sepon copper-gold deposits respectively.

The Phu Kham host sequence forms the upper plate of a thrust fault. Several phases of faulting and folding control the present geometry and distribution of mineralisation. Beneath the thrust is a basement of barren redbed siltstones and arkosic conglomerate intruded by Silurian granite. On the eastern flank, a large block of the host sequence has been preserved by downward movement by a series of vertical faults that intersect the thrust. At Phu Kham South, the West Block Fault truncates mineralisation on the western flank. All block faults, porphyry stocks, skarns and volcanoclastics were later truncated by a large north-east-dipping, south-west-verging thrust fault, as shown in Figure 1.

Importantly, at about 220 Ma, it is likely that the Phu Kham deposit was completely covered by an allochthonous block of barren limestone, granite and sandstone emplaced by a south-west-verging thrust fault. While subsequent erosion has exhumed the deposit, burial prevented excessive erosion and has contributed to the preservation of the majority of mineralisation.

The Phu Kham deposit is predominantly hosted within a schist that was probably a volcanoclastic of intermediate composition. It is part of a package of deformed hydrothermally altered tuffs, volcanoclastics and carbonate sediments of Permo-Carboniferous age. Disseminated and quartz vein-hosted mineralisation occurs within schist, altered tuffs, volcanoclastic sediments and porphyry dykes. Most of the mineralisation consists of pyrite, chalcopyrite \pm bornite as fine fracture networks overprinting an early set of grey granular quartz veins. Fine disseminated molybdenite may occur locally within veins (Tate, 2005).

The dominant alteration mineral is sericite, particularly in the schists. Orthoclase is the principal representative mineral of potassic alteration associated with the subvolcanic intrusions.

Pyrite skarns occur throughout the deposit, while magnetite and silicate skarns are confined almost exclusively to the downthrown fault block. Skarns occur as partial to complete replacement of carbonate units and are spatially related to the emplacement of a hornblende diorite porphyry and smaller feldspar porphyry dykes. Distal pyrite skarns grade into proximal magnetite, silicate and hematite skarns in the vicinity of porphyry dykes. In the oxide zone, significant leaching has occurred, leaving a small gold enriched cap. Below the water table, supergene copper enrichment occurs mainly as chalcocite.

The sericite+pyrite+quartz altered schist is considered to represent the phyllic zone of a deformed porphyry copper-gold deposit. Isotope inclusion and petrochemistry studies (Kamvong, 2013) support this interpretation of a deformed porphyry copper-gold deposit model.

EXPLORATION

A brownfield drilling program commenced in late 2009 to explore for extensions to the known Phu Kham deposit. A drilling program of some 20 diamond drill holes was designed to trace the extent of the known mineralisation northwards by drilling 100 m \times 100 m spaced fences of diamond drill holes angled at 60° from west to east to an average depth of approximately 300 m.

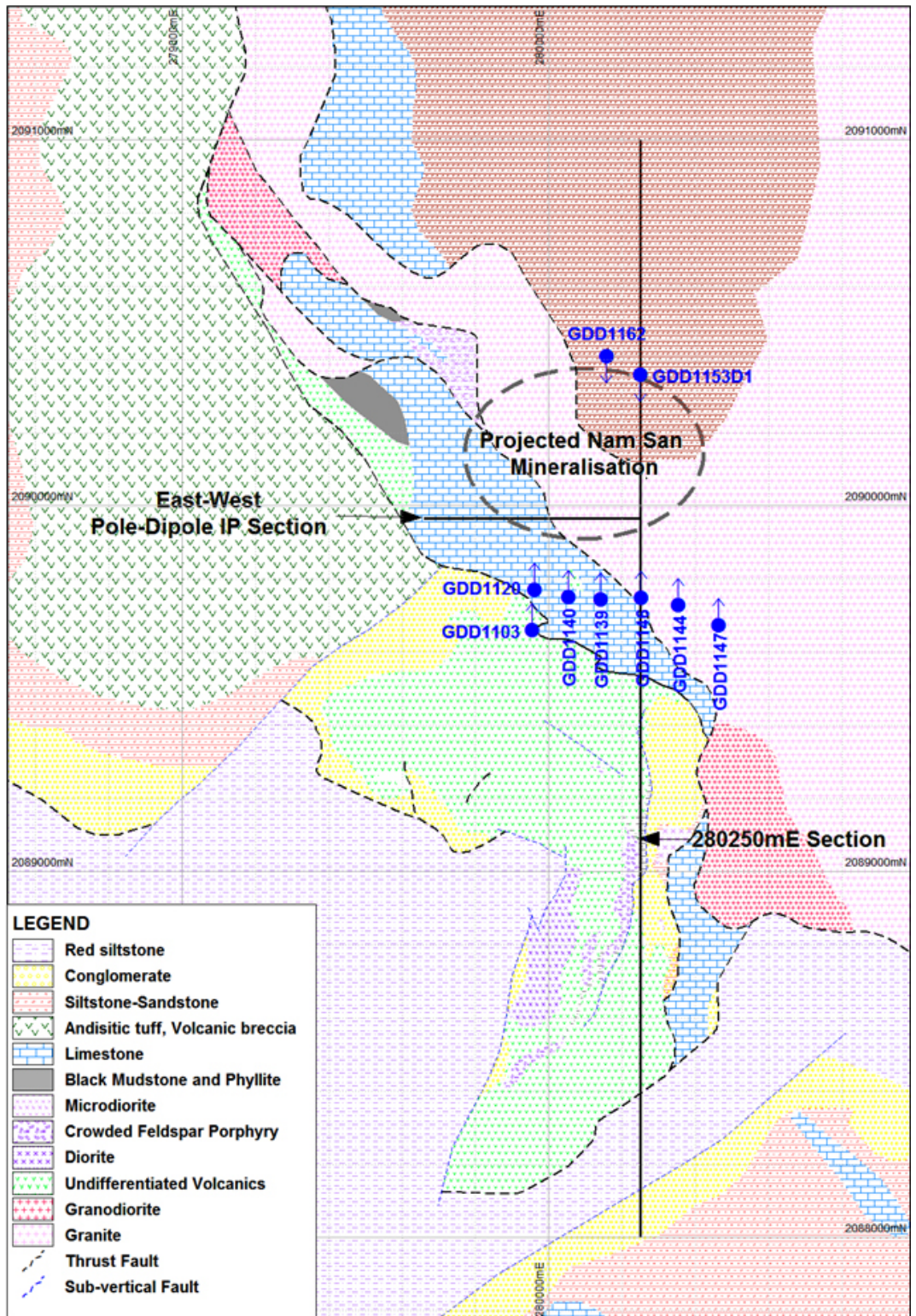


FIG 1 – Phu Kham local geology and Nam San mineralisation projected to surface.

Some drill holes completed close to the northern pit limit returned moderately mineralised intercepts in the schists, but the majority of drill holes ended in barren limestone and conglomerate. The conglomerate is considered to represent the basal stratigraphic unit of the mineralised stratigraphic section. The potential appeared to be limited by the relatively narrow intersections and because the conglomerate was intersected at relatively shallow depths. The drilling program was consequently terminated as it was clear that a more detailed understanding of the stratigraphy and structure was required to conduct a more efficient and effective drilling program.

A review of the deposit geology was subsequently undertaken, which required relogging of drill core and district scale geological mapping. Additional samples were also collected for U-Pb age dating to check the ages of key stratigraphic units. This confirmed that the mineralised and deformed Phu Kham volcanoclastic unit is tightly interfolded with a typically barren conglomerate, with the possibility of the occurrence of non-outcropping mineralisation lying beneath the allochthonous thrust block located to the north-east. The presence of late-stage advanced argillic alteration (pyrophyllite-quartz-pyrite) superimposed on the northern part of Phu Kham generated the concept of a possible telescoped porphyry Cu-Au system with an as-yet undiscovered high-grade deposit at depth (*cf* Far South East and Golpu deposits). Also, there was considerable potential for the preservation of a significant block of mineralised Phu Kham schist to the north-east under the thrust cover sequence. Although of technical high risk, both concepts were considered to be attractive exploration propositions.

A drilling program was designed (Tucker, 2010) to test for both possibilities. Drill hole GDD1103 was drilled on a northern (360°) azimuth and intersected 38 m at 0.68 per cent Cu and 0.48 g/t Au from 358 m within a strongly hematite altered subfacies of the conglomerate package. This style of mineralisation had not previously been encountered and was interpreted to have been remobilised from a deeper or more distal source, possibly occurring below the thrust cover. These results were considered to be encouraging.

In order to better define potential drill targets, an induced polarisation (IP) survey was completed to detect chargeability anomalies potentially representative of deeper sulfide mineralisation. IP was shown by earlier gradient array surveys to have a direct correlation with the mapped surface Phu Kham Cu mineralisation, and, in addition, the gradient IP response was open to the north of the Phu Kham grid. Surveying further north in the Nam San area required a different array due to the high topographic relief and in order to penetrate at depth below limestone and granite cover. The chosen reconnaissance array was vector IP (Logan, 2012) with a 2 km EW transmitter dipole and 100 m X and Y receiver dipoles on an approximate 200 m spacing. This detected a phase zone at depth that follow-up 100 m dipole size pole-dipole array IP further detailed. Three-dimensional IP modelling using Geotomo RES3DIP inversion software produced the set of phase isosurfaces shown in Figure 2 and successfully enabled the intersection of economic Cu and Au at depths of up to 700 m.

Drill hole GDD1120 (279950 mE/2089773 mN) was subsequently drilled at a 360° azimuth to follow up the mineralisation intersected in GDD1103 and to test the main DD IP chargeability anomaly. While GDD1120 did not intercept mineralisation similar to that intersected in GDD1103, it did intercept a previously unknown blind extension to the Phu Kham orebody. This is considered to be the Nam San 'discovery' drill hole. The high-grade zone consists mainly of bornite and occurs at the contact between the Phu Kham schist and the conglomerate. Mineralisation was subsequently intersected in step out drill holes at 100 m intervals to the east in GDD1139, GDD1140 and GDD1143. The most significant mineralised intersections are shown in Table 1.

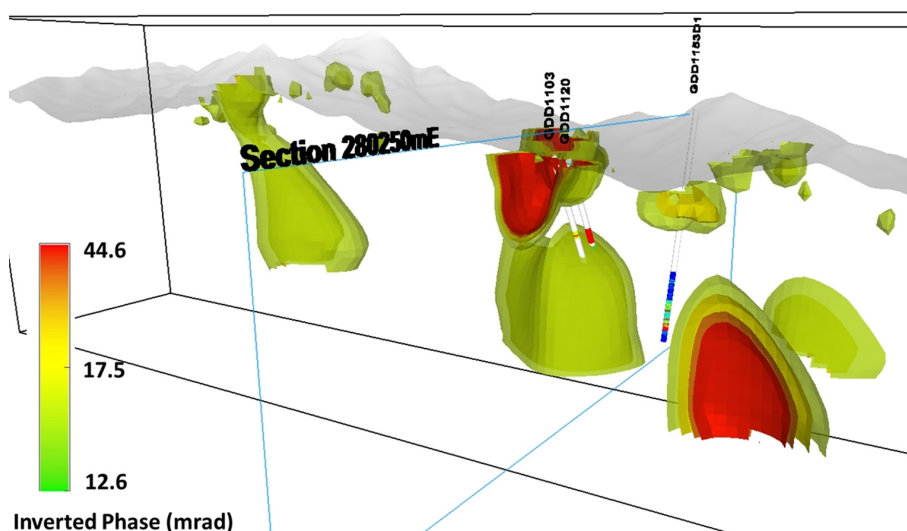


FIG 2 – Three-dimensional view looking to the NW over the Nam San 3D inverted phase model (in mrad) from east to west trending pole-dipole induced polarisation arrays. Drill hole traces show Cu with red at and above one per cent.

TABLE 1

Nam San best drill hole intersections.

Drill hole	Interval (m)	From (m)	Cu (%)	Au (ppm)
GDD1103	38	358	0.68	0.48
GDD1120	78 ^a	336	1.50	0.31
GDD1139	70	456	1.09	0.88
GDD1140	22	446	0.71	0.08
GDD1143	42 ^b	522	1.71	0.38
	44	620	1.10	0.28
GDD1144	26	767	1.15	0.56
GDD1146	54	772	1.61	0.53
GDD1162	28	816	0.64	0.26
GDD1153D1	128	824	0.79	0.21

a. Includes 22 m (340–362 m) at 3.37 per cent Cu; b. Includes 12 m (538–550 m) at 2.83 per cent Cu and 0.31 g/t Au.

Gold grades were generally 0.3 g/t with minor silver. Locally high-grade zones of bornite mineralisation were intersected at the conglomerate/schist contact and are best developed in areas of tight folding, resulting from remobilisation of hypogene sulfide mineralisation.

Mineralisation has been confirmed to date along a strike of approximately 600 m, although drilling to the west demonstrated that the mineralised stratigraphy wedges out. Drill holes GDD1144, GDD1146 and GDD1147 intersected mineralisation at similar depths and indicate that the mineralised unit is plunging to the north-east.

In order to achieve optimum intersections through the mineralisation, a directional drilling program using Navi-Drill™ equipment commenced, with holes drilled from north to south through the thrust cover sequence (Figure 3). Seven parent and 12 daughter drill holes were completed for a total of 4900 m. An inferred mineral estimate of approximately 20 Mt at 0.83 per cent Cu and 0.3 g/t Au was calculated. The deposit remains open at depth.

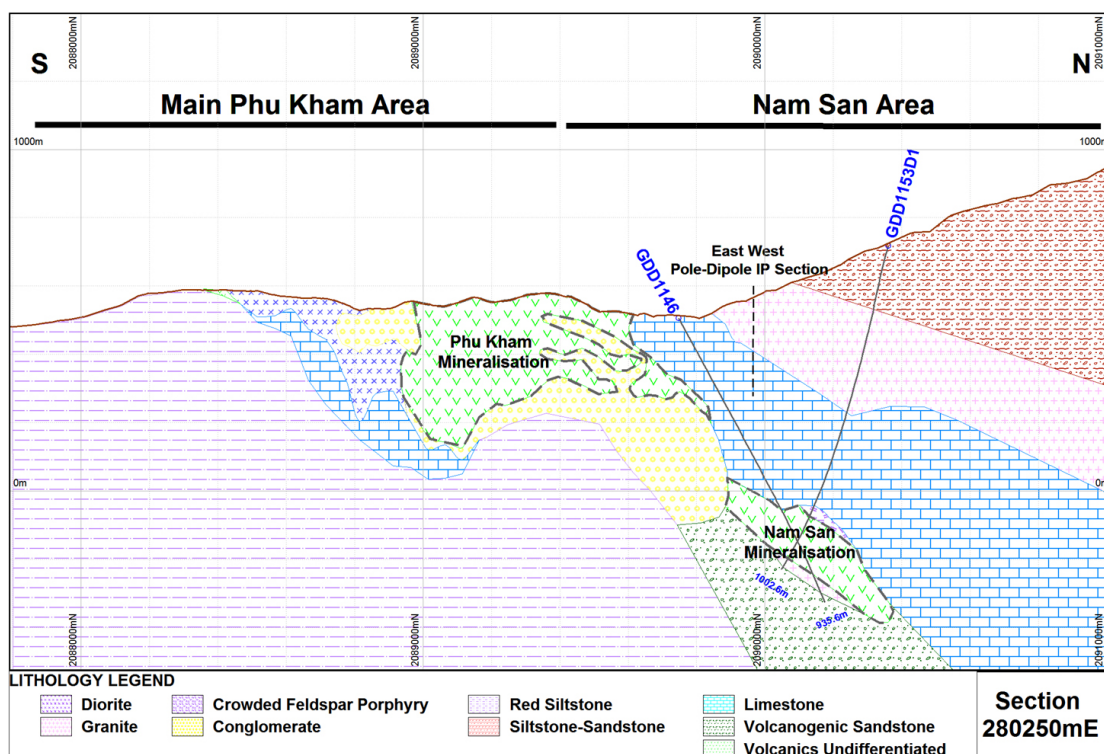


FIG 3 – Section line 280250 mE showing schematic Nam San mineralisation and drill holes relative to Phu Kham.

CONCLUSIONS

The Nam San deposit was discovered as a result of a brownfield exploration program designed to locate additional ore for the Phu Kham mine. Several factors were critical in the discovery process. These included a reinterpretation of the geology model and a ‘what if?’ exploration philosophy that led to the generation of conceptual blind targets beneath the barren thrust allochthonous units. The use of IP as an effective targeting tool provided significant confidence to proceed with the deep directional drilling program. Ongoing management support was also a critical factor.

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REFERENCES

- Kamvong, T**, 2013. Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei and Truong Son fold belts, Thailand and Laos, PhD thesis (unpublished), ARC Centre of Excellence in Ore Deposits, University of Tasmania, Hobart.
- Logan, K**, 2012. Recent exploration success using geophysics in Mongolia and Laos, in *PDAC 2012: International Convention, Trade Show and Investors Exchange*.
- Tate, N**, 2005. Discovery, geology and mineralisation of the Phu Kham copper-gold deposit Laos People’s Democratic Republic, in *Proceedings Eighth Biennial SGA Meeting* (eds: J W Mao and F P Bierlein), pp 1077–1080 (Springer: Berlin).
- Tucker, B**, 2010. Nam San (Phu Kham North) deep target drill proposal, internal Phu Bia Mining memo.