The Exploration History, Geology, and Exploitation of the Buduk Gold Mine, West Kalimantan: an example of a small gold mine operation in Kalimantan

Sejarah Eksplorasi, Geologi, dan Eksploitasi Pertambangan Emas Buduk, Kalimantan Barat: contoh sebuah operasi pertambangan emas kecil di Kalimantan

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ABSTRACT

West Kalimantan was the site of an extensive gold rush in the 18th century. There is considerable evidence of alluvial and eluvial gold mining throughout the Buduk KP, and the remains of Chinese settlements established by the miners can still be seen in the area. Dutch reports from the 1880’s record the Buduk area as being known to be very rich in gold, not only in alluvial/eluval deposits, but also in veins. Exploration activities completed include diamond drilling, Bangka drilling, geophysical programmes and geological surface mapping and sampling. Anomalous gold occurs in several areas, including Lim Tian, as an eluvial and alluvial area of mineralization on the northern flanks of the main hill and Kho San Poi, defined as the main primary zone of mineralization on the southern side of the main hill and restricted to a favourable zone striking generally west - northwest and dipping to the south, termed the SSC Horizon. A large number of other mineralised areas and anomalous zones occur within the concession area, including Kapunda, Burra Burra, and Wallaroo. The project area lies within a Mesozoic sequence of predominantly subhorizontal, sedimentary rocks, with a minor volcanic component, which is possibly equivalent to the Late Triassic - Early Jurassic Bengkayang Group. The Mesozoic sequence is intruded in the region by intermediate diorites, porphyritic andesites, and granodiorites of the Miocene, Sintang Intrusive suite. Structural and lithological control is evident in the mineralization. At least four phases of alteration are inferred for the area, including prograde and retrograde events. The hydrothermal event, with the accompanying mineralization and alteration cycles, has given rise to a number of mineralization styles, including a porphyry-style Cu-Mo event, a gold skarn event and possible peripheral, lower temperature mineralization event. Recent oxidation and weathering of the primary mineralization has resulted in an accumulation of eluvial and alluvial material that has been exploited for gold for the last several hundred years. Currently, a conventional heap leach operation has been established at the Buduk Gold Mine and it has been proposed to upgrade the circuit to a production rate of 10,000 ounces of gold/annum initially. The current process circuit can be easily upgraded in capacity, and the immediate aim is to establish consistent production at a rate of 10,000 ounces/annum from the Lim Tian eluvial resource through a revised heap leach process. A number of changes are proposed for the mining operations and the processing circuit to achieve this. The continued production at the Buduk Gold Mine, by using readily available and cheap processing techniques, will allow the expansion of the exploration programme to include the definition of the hypogene resources that may be available in the area. The re-establishment of exploration may also assist in the consolidation of the project documentation, which, as in this case and many others, has been poorly archived and much of the information has been lost. This exploration programme will focus on extending the present eluvial and alluvial resource into an oxide hard rock resource and the exploration of the hard rock sulphide resource at Kho San Poi.

**Keywords:** Buduk Gold Mine, eluvial, alluvial, vein
**SARI**


**Kata kunci**: Pertambangan Emas Buduk, eluvium, aluvium, urat

**INTRODUCTION**

The Buduk Gold Project area lies within the the Tujuh Belas Sub-Regency, Bengkayang Regency, Province of Kalimantan Barat (West Kalimantan) within Indonesian Borneo (Figure 1). The area is located approximately 100 km to the north of Pontianak, the capital city of West Kalimantan and is centred on E 109° 13’ 47” and S 00° 59’ 57”. The main point of access for the project area is via the city of Pontianak from Jakarta.

The concession area lies within generally a flat terrain, transected by two prominent hills, generally elongated in a west-northwest orientation and rising approximately 139 m above the surrounding terrain. A number of subdued hills and ridgelines occur in the surrounding area. The alluvial terrain surrounding the main hills is flat, with thick accumulations of sand and coarse gravel material.

This area has been pot-holed by illegal mining activities over the last ten years, predominantly by sluicing methods.

The Buduk Gold Mine is covered by a single production stage kuasa pertambangan (KP), or mining licence. This is supported by a processing and refining licence and a transportation and sales licence. The concession area is 1,108 hectares in size and covers the most prospective area for alluvial, eluvial, and hard rock gold mineralization.
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PROJECT HISTORY

West Kalimantan was the site of an extensive gold rush in the 18th century. Tens of thousands of Chinese miners were lured from agricultural areas of southern China. It is estimated that West Kalimantan produced one seventh of total world gold output at that time. Most mining activity was concentrated in the Sambas District, the area in which the Buduk Gold Mine is located. The activity increased steadily until the mid 19th century by which time most deposits became exhausted and miners moved north to Bau in Sarawak and east into the interior of Kalimantan.

There are records that Chinese miners first moved into the Buduk area in 1771. There is considerable evidence of alluvial and eluvial mining throughout the Buduk KP and the remains of Chinese settlements established by the miners can still be seen in the area. There are no reliable records of gold production at Buduk.

Dutch reports from the 1880’s record the Buduk area as being known to be very rich in gold, not only in alluvial/eluvial deposits, but also in veins. The reports note the common presence of the gold telluride sylvanite, and of a gold and silver-bearing bismuth mineral, making the Buduk mineralization unique in West Kalimantan. Copper was reported at Buduk including native copper in the eluvial workings.

The Chinese miners used their knowledge of hill slope irrigation techniques from rice farming in China to ingeniously mine the eluvial/alluvial deposits in West Kalimantan.

The hillsides at Buduk have been worked in a series of terraces with gold being washed using available water. An extensive system of dams and water channels was used to divert water to where it was most needed and these structures are still evident today. Extensive hill slope eluvial workings can be seen today in Kho San Poi, Lim Tian, Burra Burra, and Wallaru prospect areas.

Figure 1. Locality map of the Buduk Gold Mine in West Kalimantan.
An Amsterdam registered mining company, Sambas Gold Mines Co., produced 221 kg of gold between 1936 and 1940 after which mining was reportedly halted due to a lack of labour and access problems. They attempted a more mechanised approach to mining at Buduk than the Chinese. Several jaw crushers were transported to the area, six cyanide leach tanks were constructed on the eastern slope of Buduk Hill and small gauge railway tracks were laid between Lim Tian and Kho San Poi (approximately 2 km). The remains of these are still visible at Buduk. They attempted to mine the eluvial rubble at Lim Tian and Kho San Poi and reportedly dug several adits into primary ore at Kho San Poi.

Sporadic, limited, small-scale hydraulic mining continued after WWII but increased considerably in 1995 with the sudden influx of illegal miners from other districts in West Kalimantan. The illegal miners are reworking tailings left by previous Chinese mining efforts in flat-lying areas at the base of hilly terrain. They are employing simple hydraulic methods involving water pumps and primitive sluice boxes. Recovery is very low (10 - 20%) and the gold is generally very fine grained. Most of the recent mining activity has been concentrated along the swampy valleys along the eastern and northern slopes of Buduk Hill (Kapunda and Lim Tian) with minor operations at Kho San Poi, Kabang, and Wallaru.

RECENT EXPLORATION

The exploration history of the project involved several periods of testing of both hard rock and eluvial resources. Programmes completed include diamond drilling, Bangka drilling, geophysical programmes, and geological surface mapping and sampling (Castle, 2007).

Previous workers compiled reports, some of which are still available, including Levings (1989 and 1990), Ogierman (1990, 1991, 1997a and 1997b), and Rogers (1991 and 1992). A number of these documents were summarised in the Castle (2007) report, which is the basis of the exploration history outlined below.

Modern exploration commenced in 1986, with rock samples returning a peak value of 31.7 g/t gold. The potential for disseminated gold mineralization in a distal skarn setting associated with an inferred Miocene intrusive was recognized from the work. In 1988 a programme of tape and compass surveying, gridding, soil sampling, mapping and rock sampling, and a petrological study were completed. The results defined an east-west elongated gold soil anomaly at both Lim Tian and Kho San Poi with both remaining open to the west.

Anomalous gold occurs throughout the property from rock samples collected from numerous gossanous boulders, outcrop, and rock channel samples. Peak vertical channel results at Lim Tian were 4.7m @3.9 g/t Au and from a horizontal channel at Kho San Poi of 3.0m @3.9 g/t Au. Other rock sample results include a grab sample of pyrrhotite bearing skarn rock assaying 74.8 g/t Au.

A nineteen drill hole, 907.70m, diamond drill programme was carried out in 1989. This was followed in 1990 by a grid-controlled IP geophysical survey. In 1990, a five hole, 529.50 m diamond drill programme was completed to test targets outlined by the IP survey.

A programme of test pit sampling of the eluvial resource at Lim Tian was undertaken in early 1992 to confirm grades and provide metallurgical samples for a feasibility study of a proposed mining operation. In 1996, a widespread programme of surface geochemistry, diamond drilling of hard rock targets, Bangka drilling of the eluvial resource, and geophysical surveying commenced and a programme of grid-
controlled, bedrock sampling, utilizing a wacca drill, designed to cover the entire Buduk KP, was completed over the eastern portion of the KP (Wallaru, Burra Burra, Kapunda prospects).

A significant Au anomaly was outlined in the eastern portion of the KP in Wallaru. The anomaly (> 0.1 g/t Au) extends for 1.5 km in an east-southeast-west-northwest direction and is at least 500m in width (Figure 2).

Ground Magnetic, Induced Polarization, and SP surveys were carried out over the property during the 1988 - 1989 programme. Ground magnetic surveys showed a distinct change in the magnetic character between the eastern and western half of the grid. The western half exhibits a strong magnetic anomaly, seemingly due to magnetite and pyrrhotite skarn mineralization. The eastern half is magnetically quiet perhaps indicating lower temperature, dominantly pyritic mineralization.

A limited IP survey was undertaken in early 1997 to test for a hypothesized, intrusive, source to the lithologically-controlled mineralization at Kho San Poi and Lim Tian.

The survey outlined three anomalous zones in Mount Buduk:

1. The southern anomaly lies approximately 500 m to the south of extensive Chinese eluvial workings at Kho San Poi; the response of this anomaly is possibly associated with altered metasediments (for example skarn, sulphide silica replacement); this anomaly has never been drill tested,

2. The central anomaly is located in a small valley between Kho San Poi and Lim Tian; drill testing indicated this reflects weak to moderate stockwork development, with low grade Cu-Au-Mo mineralization, associated with a

Figure 2. Historical map showing the location of the gold anomalies defined by soil and auger sampling. The current lease boundary is shown to place the historical anomalies in perspective.
suite of feldspar porphyry and quartz diorite dykes; and,

3. The northern anomaly possibly reflects a shallow, lithologically, controlled, replacement/skarn mineralization.

An additional three lines, at 160 m spacing, were surveyed in the Wallaru and Burra Burra prospects, 1.5 km to the east of Mount Buduk. The survey returned similar anomalies to those at Mount Buduk. Three anomalies (chargeability and resistivity) have been interpreted which possibly represent lateral continuation of the zones outlined at Mount Buduk.

DIAMOND DRILLING

The 1989 drill programme of nineteen holes was completed to a maximum depth of 85.70 m and was mostly in the 30 to 60 m in range. The target model used was of shallow-dipping, lithologically controlled, Cu-Au, skarn mineralization in a Fortitude-style setting which was interpreted to extend north (Lim Tian) and south (Kho San Poi) from a supposed, source intrusive, below Mount Buduk. All drill holes were located at the northern and southern slopes of Mount Buduk.

Most drill holes at Lim Tian area intersected the eluvial resource (tailings from the original Chinese mining operations) at or near surface. Drilling to the south, at Kho San Poi, intersected gold-bearing sulphide/silica (±skarn mineralization) in four of the five holes completed, including a best intersection in hole BKD-16 of 5 m @37.2 g/t Au (including 1 m @173 g/t Au) and a significant, lower grade, intersection of 24 m @1.8 g/t Au in BKD-18 (Figures 3 and 4).

The Kho San Poi drilling indicated that gold mineralization is largely lithologically controlled and occurs associated with pyrrhotite and pyrite ± minor chalcopyrite in sulphide/silica replacement mineralization. A five drill hole programme in 1990 accounted for a total of 529.50 m of drilling. Four holes of this programme tested IP geophysical targets of which only one adequately explained the IP response. Most holes were located in the area between Kho San Poi and Lim Tian. Samples were only assayed for Au. Gold mineralization, even though over narrow widths, was still being encountered at +/120 m deep down-hole (DDH 22 best intersection 106.00-111.00 m, 5 m @1.14 g/t Au followed by 121.00-123.00 m, 2.00 m @2.20 g/t Au).

A more extensive diamond drilling programme was carried out in mid-1996 to 1997 and drilled a total of 4,693.00 m in forty diamond drill holes. Drilling focused on the northern and southern slopes of Mount Buduk at Kho San Poi and Lim Tian and on Mount Buduk itself. Drilling was initially targeted on locating a possible Au-Cu mineralised, porphyritic, intrusive source to the sediment-hosted mineralization at Kho San Poi and Lim Tian which was inferred to lie between the two areas, beneath Mount Buduk.

The deepest hole which targeted the intrusive was BKD-32, completed at 329.70 m. These initial holes did not encounter an intrusive body and only intersected minor, thin, porphyritic dykes. The longest intersection of an intrusive, in BKD-46, (30 m), has been petrographically described as a quartz porphyry. These porphyries/dykes may represent apophyses to a larger intrusive nearby.

Drilling did, however, intersect significant, lithologically controlled, gold-mineralization at Kho San Poi within a rhythmic, graded clastic unit termed the SSC Horizon (Ogierman, 1997a). Much subsequent drilling was aimed at defining this zone of mineralization. Information derived from
Evidence of Chinese eluvial workings between BKD-15,16 and BKD-55

Figure 3. Typical cross section of the Kho San Poi mineralization, showing the shallowly dipping mineralized horizon extending from Mount Buduk to the south (looking west).

Figure 4. Typical cross section of the Kho San Poi mineralization, showing the shallowly dipping mineralized horizon extending from Mount Buduk to the south (looking west, E302640, grid 50 m).
this drilling in Kho San Poi resulted in a reinterpretation of the geological setting of Buduk and a new mineralization target model based on sediment-hosted, Carlin-style, mineralization as seen at the nearby Bau goldfield in Sarawak, Malaysia.

Best intersections obtained include BKD-33 with 10 m @6.2 g/t Au and BKD-55 with 10 m @6.1 g/t Au. The zone of SSC Horizon-hosted mineralization at Kho San Poi is still open to both the east and west but has possibly been offset by a fault to the west. The zone can be traced through Buduk Hills to Kabang and Lim Tian but grades are generally lower and the mineralised interval is thinner in areas north of Kho San Poi.

It is likely that it was the SSC Horizon which was mined by the Chinese using simple hydraulic methods in the 18th and 19th centuries. They were able to do this because the horizon was most likely exposed at surface and subparallel to the hill slope at Lim Tian. The tailings from these operations comprise the current Lim Tian eluvial resource.

Primary, pyrrhotite, mineralization at Kho San Poi and subsequent overprinting, retrograde pyrite mineralization appears to extend laterally from the NNE trending feeder structures along the favourable SSC Horizon. Several holes located between Kho San Poi and Lim Tian encountered significant, low grade Cu-Au-Mo mineralization such as BKD-46 with 94 m @0.08 g/t Au, 0.13% Cu and 51 ppm Mo associated with low density stockwork veining hosted in sediments.

**ELUVIAL RESOURCE ESTIMATE - BUDUK**

In 1988, a programme of tape and compass grid-controlled, shallow (1 m) hand auger soil sampling was undertaken across the Mount Buduk. The results defined an east-west elongated gold soil anomaly at both Lim Tian and Kho San Poi. The anomaly at Lim Tian, on the north side of Mount Buduk, was regarded to represent a potential, mineable, eluvial/alluvial gold resource. The depth of this resource was determined by a programme of deep hand auger drilling in 1989 - 1990. A total of 48 deep auger holes were completed. The depth of the mineralised material varied from 1 - 6 m.

In 1991, several test pits were dug to provide a representative sample of the eluvial/alluvial mineralization for metallurgical testing. Twelve test pits were completed. Pits were designed to duplicate deep hand auger holes and diamond drill holes which were regarded to have representative mineralization. The average grade of composite samples made from the pits was 2.16 g/t Au. Metallurgical tests indicated the eluvial material at Lim Tian is amenable to vat or heap leaching techniques for gold recovery.

A Bangka drill programme was carried out in mid-1997 to confirm the results from the earlier sampling. The Bangka drill rig provides a much larger sample than the original hand augers and thus provides a more representative sample of the eluvial material. A total of thirty-three holes were completed at Lim Tian. The average grade of all mineralised intersections from the Bangka holes was 1.8 g/t Au (using a 0.5 g/t Au cut-off).

**CURRENTLY STATED RESOURCES**

The general resources and targets stated to be in the area are (Werner, 2008):

1. A lithologically-controlled, hard rock zone of sulphide-silica (+/- skarn) mineralization at Kho San Poi, varying in width from 2 to 10 m, extending down-dip for at least 100 - 150 m with a total strike length at this stage of
350m. The zone is open at both ends. A resource of 650,000 tonnes at 5 g/t Au has been inferred from the drilling results (approximately 100,000 ounces Au).

2. An oxidized, heap-leachable, eluvial gold Inferred Resource of 1.2 million tonnes @1.80 g/t gold up to 7 m deep at Lim Tian. This resource represents tailings from old Chinese hill-slope eluvial workings (approximately 70,000 ounces Au). The inferred resource has recently been calculated at 890,000 tonnes @1.53 g/t Au using a cut-off grade of 0.50 g/t Au, mainly due to poor survey control on the data and modification of the resources by illegal mining (Figure 5).

CURRENT FOCUS

There are several areas of mineralization defined in the concession area. The most important is the northern scree-elluvium and alluvial fields defined as the Lim Tian area. This area extends from the saddle between the two ridges in the area, spreading to the northeast as a blanket of old tailings, eluvial gossan with clay and accumulations of alluvial material at the base of slope and extending to the northeast across the river flats. This is the mineralization of most interest, with the bulk of the currently defined exploitable material lying in this area.

The second most important mineralized area is the Kho San Poi area, lying as an elongated body of eluvial, gossan, and alluvial material along the base of slope on the south side of the main ridgeline. This area has had limited testing for gold potential in the transported material but remains an attractive target for the expansion of the resource base at the property. This material is derived from the outcropping tip of the main Kho San Poi mineralized zone, which has been defined by a diamond

Figure 5. Block model of theLim Tian eluvial and alluvial deposit areas, showing the block distribution at >0.50 g/t Au.
drilling to a depth of approximately 150 m down-dip. The potential in this area lies not only within the transported material and gossans but also as a potential source of higher grade oxidised hard rock material and sulphide ore material.

Other less well-defined and explored areas, include the Burra Burra and Wallaru areas, lying within the alluvial flat areas to the east and southeast of the main ridge areas of Lim Tian and Kho San Poi. There is also a suggestion that other mineralization occurs between the saddle between Mount Tabang and Mount Buduk associated with intrusive porphyry and diorite bodies.

**LOCAL GEOLOGY**

**Rock Types**

The project area lies within a Mesozoic sequence of predominantly subhorizontal sedimentary rocks with a minor volcanic component, which is possibly equivalent to the Late Triassic - Early Jurassic Bengkayang Group (Figure 6). The Bengkayang Group in the type locality of Bengkayang generally comprises carbonaceous and tuffaceous clastics, including shales, sandstone, and turbidite sequences.

The Mesozoic sequence is intruded in the region by intermediate diorites, porphyritic andesites and granodiorites of the Miocene, Sintang Intrusive suite. Such intrusives outcrop near Buduk at mount Silobat (7 km northwest of Buduk), Simpadang (15 km west-northwest of Buduk) and Sambas (20 km east-southeast). All these intrusive complexes have associated occurrences of gold mineralization. It is likely that the dykes encountered in drillings at Buduk are of similar age to other intrusives in the area. The regional geological maps also show the Sintang Intrusive immediately within the concession area but the distribution and size is not considered accurate.

![Figure 6. Regional geology of the Buduk Gold Mine area.](image-url)
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Structures

Aerial photos show several strong, NNE trending, faults, cutting through the Buduk Hills. The strongest development of retrograde alteration, including clay and pyrite replacement of pyrrhotite, appears to be associated with these structures. The primary, silica-sulphide mineralization, hosted by the SSC Horizon, also appears to lens out away from the structures. This suggests the faults served a feeder system to both the original silica-sulphide mineralization and subsequent retrograde overprinting.

ALTERATION AND MINERALIZATION

At least four phases of alteration have been recognized in the petrographic studies (Bogie, 1997). The first two phases are potassic alteration, the earliest of which is possibly associated with the Cu-Au-Mo, stockwork-veining, between Lim Tian and Kho San Poi. The next stage is a propylitic alteration and the last is a late stage, retrograde event which results in extensive clay development and alteration of pyrite to pyrrhotite.

Significant silicification occurs throughout the Buduk Hills and is possibly associated with the potassic alteration events. Silicification is characterised by hornfels development in siltstone horizons. The silica-sulphide style of mineralization is also strongly associated with silicification.

There are several styles of gold mineralization at Buduk, as described by Ogieman (1997a):

- **Silica-Sulphide (+/- skarn)** is lithologically controlled by the SSC Horizon and consists of silica and pyrrhotite with minor pyrite and chalcopyrite and trace bismuthinite. Silicates include quartz, actinolite, with minor epidote. Mineralization is characterized by a strong association of Au with Bi and Cu. Mo, As and Sb are all very low. This is seen on either flank of the Buduk Hill at Kho San Poi and Lim Tian.
- **Cu-Au-Mo Stockworking** includes low density stockwork veining hosted by clastics and associated with dykes (qtz diorite + feldspar porphyry). Veins consist of quartz with minor pyrite, chalcopyrite and molybdenite. Mineralization is low grade (average 0.1 g/t Au and 0.1 % Cu). This style of mineralization is confined to the area in the middle of the Buduk Hills, near Mt. Buduk and Mt. Kabang.
- **The As-Sb style of mineralization** is still not well understood but is characterized by a strong As-Sb, bedrock auger anomaly, to the east of Mt. Buduk in the Wallaru and Burra Burra prospects. Fine-grained arsenopyrite crystals have been seen in outcrop and coarse stibnite has been observed in float. There is a strong association of As and Sb with Au and only minor Cu and trace Bi. Recent reconnaissance sampling at Wallaru returned 15.5 g/t Au from a sample of stockwork quartz veining, hosted by dacitic volcanics. This mineralization could be structurally controlled.

In addition to these styles of Au mineralization there are also many examples of quartz stockworking (+/- sulphides) seen throughout Buduk which occasionally contains gold mineralization. Bedrock exposures in old Chinese workings at Burra Burra contain several zones of quartz veinlets. Tailings from the illegal miners at Kapunda often show examples of vein quartz with sulphides (pyrite, sphalerite, stibnite). One example of quartz + pyrite assayed 32 g/t Au.
INTERPRETED GENESIS OF THE MINERALIZATION

The mineralization in the Buduk area is an example of a zoned replacement skarn deposit with oxidised primary mineralization forming extensive eluvial and alluvial deposits adjacent to the main zone of primary mineralization. This oxidised material has been exploited for several hundred years.

The presence of typical skarn mineralogy in the SSC horizon indicated the primary gold skarn is of a Fortitude Gold Skarn type. This evidence is coupled with the known occurrence of porphyry dykes below the main Buduk deposit and a number of areas around the main hill containing typical quartz veins hosted within the sediments and intrusives.

Gold skarns typically occur in calc-silicate rocks, with the presence of garnet and pyroxene zonation in relation to the prograde mineralization, whilst gold may be associated with a retrograde overprint on the prograde event. Gold skarns may contain other minerals and the presence of a specific set of geochemistry may not indicate anything more than associated minerals.

The SSC Horizon gold skarn at Buduk most likely was formed during the emplacement of the intrusives known to occur beneath Mount Buduk and Mount Kabang. These intrusives could be part of a much more extensive intrusive complex in the area, as the presence of quartz veining several km to the east of the main prospect showing the hydrothermal zone is quite extensive. The chemically more reactive SSC Horizon was preferentially silicified and mineralised along the length of the horizon but, more importantly, contain more intense mineralization in areas where fluids could enter the horizon. This could have been facilitated by fracturing associated with the movement of the north-northeast faults and dilation in the area between Mount Buduk and Mount Kabang.

The deposition of high grade gold in this horizon may have been part of a prograde or retrograde event. There is insufficient data to determine this and the drill core has not been preserved for further observation. The surrounding gold mineralization associated with quartz veins, including reports of copper and molybdenum in some sections of core, the presence of anomalous arsenic and antimony and other element combinations would be zonal signatures in time and space related to the main phase of intrusive activity and hydrothermal alteration.

Significant further work is required to answer these questions and the rejuvenation of the project with careful data collection and management may assist in filling in additional pieces of the mineralising story at Buduk.

Suffice to say, the oxidation and weathering of the primary skarn mineralization from the SSC Horizon have sustained gold production from the area for a long period of time.

GOLD PRODUCTION AND PRESENT PROCESS CIRCUIT

Production at the Buduk Gold Mine commenced in 2005, with one heap leach and three vats completed to date. To date, there has been some 2,500 ounces of gold produced from all of the leaching operations (Figure 7).

The ore material is delivered to the de-sliming plant by trucks from the mining area and the material is loaded to the hopper bin using a wheel loader. The material in the hopper is sprayed and puddled before entering the de-sliming screens. The de-
slimming unit is rated at 30 tonne/hour but often does not achieve this due to the feed system from the hopper to the screens.

The undersize is fed, by gravel pump, to a single 30” Knelson concentrator, with a treatment capacity of 50 tonne/day (5 tonne/hour) of undersize (-1.0mm) material. The concentrates from the Knelson are directly smelted to produce a dore bar. The tailings from the Knelson concentrator are stockpiled for later processing as they still contain approximately 0.5 ppm Au.

The oversize product from the de-sliming plant then reports to a transfer stockpile before being stacked to the heap leach pad for cyanide leaching or to a vat for irrigation. The de-sliming plant has only been operated recently, so earlier heaps and vats contained significant clay when stacked. In addition, an attempt to agglomerate the ore, although successful for the leaching characteristics, proved problematic from an operational viewpoint due to high rainfall on the agglomerated, albeit still uncured, ore.

The ore is stacked to the pads and vats by truck dumping. No crushing of the ore was undertaken.

Leaching is conducted by a dripper system, with solution from the barren pond being returned to the heap by pumps and pipes. The dripper system is placed at approximately 1 m interval lines and 50 cm spacing along the lines. The nominal flow rate is 30m³/hr through the circuit. Lime is intermittently added to the leach pile and the pile “fluffed” using an excavator to loosen the pile.

The cyanide is mixed in a HDPE-lined pond and the concentrated solution batch dumped into the leach circuit. This resulted in spikes in the cyanide concentration. Caustic soda is added to the circuit as a pH modifier.

The pregnant solution reported to the pregnant pond adjacent to the plant and the solution pumped through the CIC columns at a nominal rate at approximately 30m³/hr. The carbon within the columns adsorbed
the gold from the cyanide solution. Regular readings were taken from the tail of the CIC columns and when the tail started to rise above acceptable levels, the column was taken off-line and the carbon stripped. Three columns were active at one time during the adsorption process. Each carbon column contains approximately 1.5 tonnes of activated carbon.

The carbon is eluted within the columns by adding hot caustic and cyanide solution. The elution process takes approximately 24 hours per column. The eluate is then passed through an electro-winning circuit, where the gold is won onto a steel wool cathode. This steel wool is then acid washed and smelted to a dore bar using a gas furnace.

The stripped carbon may be acid washed in a washing column when fouled and returned to the CIC column. No carbon regeneration is carried out on site, with active carbon returned to Pontianak for re-activation when performance drops.

The dore bar is further refined on site by dissolution in aqua regia and the gold and silver components reprecipitated separately. The precipitate for the gold is again smelted to form a final gold bullion bar. The gold is sold locally in Singkawang to a local gold trader.

REVISED OPERATING PROCESS

General Description

The revised process proposed for the operation is similar to that already being undertaken. Theore has shown to be amenable to a standard heap leach operation, with the precious metals being removed from the oxidized ore by circulating a low strength cyanide solution through the stacked ore and being recovered in a CIC plant. Both heap leach and vat leach systems have been employed previously, with mixed results. The operation has been non-optimal, with a series of campaigns of mining and leaching. This has resulted in a poor and erratic cash flow for the operation and has also not allowed further detailed exploration to be conducted to define new resource and reserve areas.

The new flow sheet particularly focuses on heap leaching, rather than vat leaching. This is necessary to achieve the production rates targeted by the owner of 10,000 ounces/annum (Gunter, 2009).

Detailed Description

Pad Preparation

The pad requirements for each year of production will be approximately 1.7 ha. The pad area will be levelled to the required slope grade and a thin layer of clay material graded and compacted to ensure a smooth surface for the installation of the lining material, chosen to be 1.5mm HDPE. Thinner liners may be appropriate, with considerable cost savings but strength and durability may be an issue with the thinner linings (0.75mm HDPE). The perimeter of the pad will be constructed as a berm, at a height of 0.50 m, to ensure all solution is retained within the leach pad area. The berm will slope to a single V-notch weir before entering an open drain for the pregnant solution to return to the pregnant pond, adjacent to the plant.

Mining

Mining of ore will be by conventional excavator-truck configuration on a single
10 hr shift/day. The ore will be directly dumped into a hopper bin feeding the scrubber trommel. The hopper capacity will be 20 tonne. A grizzly should be installed at the hopper dumping point to ensure large material is excluded from the scrubbing process and to prevent damage to the scrubber trommel. The grizzly should pass only -300mm material. The oversize can be broken manually on the grizzly or removed to one side for breaking using an excavator hammer or small portable jack-hammer.

Mining will be continuous on a single defined and surveyed face. An advanced Mining advance needs regular survey. The mining will proceed in fixed mine blocks from the downhill side to the uphill side to avoid water trapping at the mining face.

Pre-stacking Treatment
The oversize material from the scrubber and de-sliming screen will report to an intermediate stockpile and the oversize +13 mm material will be crushed to -13 mm at a conventional jaw crusher feed rate of 50 tonne/hr with a secondary cone crusher. This will allow the crushing of 500 tonne/day for 28 days for a single cell to be completed at 22,000 tonnes/lift. The remainder of the leach material will be derived from the +1.0 -13 mm oversize from the screening plant.

Two units of Knelson Concentrator are proposed in the upgrade of the circuit and treat the undersize from the screens, nominally -1.0mm. The Knelson Concentrators will be located to a secured area as part of the gold room and the product is cleaned and smelted directly into separate dore bars for accounting and recovery tracking.

It is assumed that 50 - 60% of the ore will be +13 mm for crushing. The sizing of ore from various sources will vary but it is known that gossan ore does occur throughout the eluvial and alluvial material and a recent sample of boulder gossan retrieved from leach pad No 1 returned a gold assay of 11.00 ppm Au from fire assay with 50% of the gold still recoverable by a 24 hour bottle roll. This indicates that the return recoveries from the high grade ore may be compromised by the sizing of the gossan fraction.

Once crushed, the -13 mm ore will report to the same stockpile area as the oversize from the de-sliming screens. It is envisaged that the lime dosing will be added to the crushing conveyors and the de-slime oversize from a holding hopper and variable screw feed at 5 kg/tonne for pH control. This will ensure even mixing of the lime in the leach ore. This material will then be transported to the stacker conveyor for loading to the heap. Pre-stacking and stacking, like the mining operation, will be run on a single shift of 10 hr/day.

The ore will be stacked systematically, using a system of cells and lifts. There are four cells planned for each year production, each covering an area of approximately 4,100 m² and each cell will be lifted three times. This will ensure the leaching cycle continues throughout the year. The organisation of cells and lifts will allow a continuous cycle of leaching and stacking to be maintained throughout the year at 90% availability (330 days) and place enough ore on the pad to maintain production at a rate of 10,000 ounces/annum.

Heap Leach Operations
The cyanide solution will be applied to the stacked oxide ore using a pipe system arranged over the heap at 7m intervals between feeder pipes and for the length of the heap. Senniger wobblers will be placed at 7 m intervals along each feeder pipe. The pipeline pressure for the solution feed will be maintained at 15 psi to ensure optimum operation of the wobblers. Senniger No 11 wobblers have suitable specifications for the heap leach envisaged.
The heap leach will be irrigated at a rate of 7 l/m²/hr for a period of 55 days to irrigate the lift with approximately 34,000 m³ of solution to achieve a wetting rate of 1.5 m³/tonne of ore. There will be an overlap of approximately thirty days per cell. This equates to an application rate of 50 m³/hr. To achieve the desired production of 10,000 ounces per annum, there will be a requirement to increase the plant capacity by double to achieve the flow rates required. The cyanide strength in solution will be maintained at between 250 - 300 ppm and the solution pH maintained at 10.5 for optimum leaching efficiency.

Gold Recovery

The pregnant liquor is pumped from the pregnant holding pond and cycled through the CIC plant at a rate of 50 m³/hour. The carbon in each column will be loaded to a point where the tail of the pregnant liquor rises above normal tail levels. The liquor train will then be switched to alternate columns whilst the loaded carbon is stripped. The present CIC columns will be replaced to double their present capacity. Each CIC column will have a capacity of 3 tonnes of carbon and four tanks will be required. The carbon will be transferred to the stripping tank by a transfer pump and stripped/reactivated carbon immediately added to the newly emptied carbon column to be bought on line immediately if required. The stripping column will be within the secured gold room area, as will all other components of the stripping and electro-winning circuits.

The barren liquor from the CIC circuit will feed by gravity the barren solution pond. The barren solution will be circulated back to the heap leach pad, with cyanide and pH modification made to the solution from a 30% cyanide solution holding tank and a caustic tank. The cyanide will be added as a regular stream via a variable dosing pump to avoid spikes in the cyanide concentration in solution. The caustic solution will be added directly to the barren pond as required for pH modification.

The eluate from the stripping circuit will be feed through the electro-winning cells and the gold won onto steel wool cathodes. The cathodes will be smelted in a gas furnace to produce a dore bar. The barren eluate will be returned to the barren pond. Leaching will continue for 24 hours each day.

Metallurgical Testing and Assaying

The continued and routine testing of heap leach performance is essential to understand when changes are required in the operating system. There exists an on-site laboratory capable of conducting routine gold analysis by AAS methods and cyanide testing equipment (titration-based). Smaller, portable, laboratory equipment is also available, such as pH meters.

The solution from the heaps and ponds will be tested at six hour intervals for pH, cyanide concentration and gold concentration. Both pregnant and barren solutions will be monitored at a number of critical points. Careful recording will allow a systematic evaluation of production and heap performance. Samples should also be taken at regular intervals during the stacking process, with both crushed -13 mm material and +1.5 mm - 13 mm direct screened heap material being tested on a daily basis. This will allow a critical evaluation of the head grade of the material being added to each cell and, therefore, the final leaching characteristics.

Water Management

The heap leach area of approximately 16,000m², using an average rainfall of approximately 3 m/annum, will accumulate 48,000 m³ of run-off. A storm pond should...
be able to cater for the runoff from a 1:10 year storm event but the collection of such data at this location may be difficult. It is believed the evaporation rate may be approximately 1,000 mm/annum, which leaves approximately 2,000 mm/annum of run-off to store and neutralise in a storm water pond circuit. Water needed for the leaching circuit can be returned from the storm water pond as required, rather than using fresh water supplies.

The use of wobblers on the heap leach will assist in evaporating excess water and misting sprays are also available to assist in increasing evaporation. These can also be installed on the heap leach and operated during periods of hot weather to help control excess water build-up.

The storm pond should be clay lined and compacted, with rock sheeting placed on the surface to mitigate erosion. A large flat pond area is preferable to a small deep storm pond to assist evaporation.

CONCLUSIONS

The Buduk Gold Mine is an example of a small gold mine being established on an oxide resource, which was eroded from a poorly defined but well-known hypogene mineralized zone. In the case of Buduk, the extensive eluvial mineralization has supported gold mining over a long period of time. The presence of gold-bearing skarns, quartz veins, intrusives and geochemistry consistent with an intrusive related hydrothermal system indicates that there may be several styles of mineralization in the Buduk area.

At present, we prefer to assume that the system is a gold skarn associated with a porphyritic intrusive complex containing anomalous copper and molybdenum and the geochemical zonation is a feature of that intrusive and hydrothermal event as it evolved over a period of time and affected various rock units in the area. The presence of porphyry- style mineralization may be encouraging but the porphyry-style mineralization may only be considered a source of the gold skarn-type mineralization, rather than becoming the primary target for exploration. The presence of high-grade intercepts within the SSC Horizon is encouraging and, if the system is a typical skarn, then the mineralization may continue to some depth below the surface.

The continued production at the Buduk Gold Mine, by using readily available and cheap processing techniques, will allow the expansion of the exploration programme to include the definition of the hypogene resources that may be available in the area. The current process circuit can be easily upgraded in capacity and the immediate aim is to establish consistent production at a rate of 10,000 ounces/annum from the Lim Tian eluvial resource through a revised heap leach process. A number of changes are proposed for the mining operations and the processing circuit to achieve this.

The re-establishment of exploration may also assist in the consolidation of the project documentation, which, as in this case and many others, has poorly been archived and much of the information has been lost. This exploration programme will focus on extending the present eluvial and alluvial resource into an oxide hard rock resource and the exploration of the hard rock sulphide resource at Kho San Poi.

ACKNOWLEDGEMENTS

The author's thanks go to Renaissance Capital for allowing him to make a presentation on the Buduk Gold Project and to Justin Werner for numerous discussions on the history and the current status of the project. A large amount of data included in this paper has been gleaned from other reports as the
data is widely dispersed, particularly old exploration reports, and he apologize if he has not referenced all correctly or not referenced at all.

REFERENCES


