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Geology, structure, mineralisation and geochemistry of the Penjom gold deposit, Penjom, Pahang

SONNY LIM TENG CHYE[1], SHARAFUDDIN MOHAMED[1], MONA SULAIMAN[1], G.H. TEH[2] AND JASMI HAFIZ ABDUL AZIZ[2]

[1]Specific Resources Sdn. Bhd.
PO Box 49, 27207 Kuala Lipis, Pahang
[2]Geology Department, University of Malaya
50603 Kuala Lumpur

Abstract: The Penjom Gold Mine lies within Permian rocks dominated by tuffs and sediments of the Padang Tengku Formation striking E-W with a 30° dip south, close to eastern boundary with the Triassic. A series of early intruded felsite sills have helped unravel the complex structural history of the mine.

The thrusting and assymetric folding of the Penjom Thrust cut by a series of N-S faults together with intense graphite alteration have controlled gold mineralisation. The favourable gold depositional sites are diverse and comprise dilational, chemical contrast and competency contrast sites. The diverse styles of mineralisation give rise to diverse widths, grades and orientations of individual ore zones.

The gold mineralising episode, which is associated with and overprints an earlier deposition of pyrite and arsenopyrite, was accompanied by quartz, carbonate and minor amounts of galena and sphalerite. EPMA analyses of the gold show slight variations in fineness from the three main centres of mineralisation, namely, Kalampong East/Hill Six, Jalis and Manik. EPMA study also revealed a gold-bearing graphite-ankerite-quartz intrusive rock.

GEOLOGY

The Penjom Gold Mine lies within Permian age rocks close to the eastern boundary with the Triassic (of the Jelai Formation of the Lipis Group), as mapped by the Geological Survey of Malaysia (Richardson, 1939). Both these sequences consist of sediments and associated volcanics.

The mine geology is dominated by a sequence of tuffs and sediments, which are assigned to the Padang Tengku Formation of the Permian Raub Group. In a regional sense this sequence strikes north-south and dips moderately to the east, however in the vicinity of the mine, the strike is E-W with a 30° dip to the south. The mine sedimentary sequence is quite diverse comprising tuffs, pebble conglomerates, sandstones, siltstone, shales, with calcareous varieties of the latter lithologies grading through to limestone units. A series of felsite sills were intruded early in the structural history and have suffered much the same deformation as the host sediments. These, together with the limestone units, provide stratigraphic markers which are used to unravel the geological picture.

STRUCTURE

The Penjom Thrust is a major linear feature sub-parallel to the Raub-Bentong suture which may be traced for over 100 km (Kidd and Fauzi Zainuddin, 2000). It is one of the main structural elements at the mine where it trends 035° and dips East at 40° (Fig. 1). It is an east to west thrust fault, which has also caused assymetric anticlinal folding immediately below the thrust plane. During fault movement carbon was mobilised along this structure and the rocks on either side of the Penjom Thrust are typically intensely carbon altered. Both the thrusting and associated assymetric folding have provided many potential dilational sites, particularly where a felsite sill is tightly folded.

Following thrusting and folding associated with the Penjom Fault, a series of N-S faults were developed which cut the Penjom Thrust which is downthrown to the east some 20 to 30 m. The N-S Faults which dip steeply East to 60°E appear to be the conduit for gold mineralising fluids which moved along or up these structures into the system where the metal was deposited in favourable sites (Fig. 2). It appears the Penjom Thrust with its intense graphite alteration acted as a barrier to the mineralisation — no mineralisation is recorded above the Penjom Thrust.

MINERALISATION

The favourable gold depositional sites are diverse and comprise dilational, chemical contrast and competency contrast sites. The richest and widest ore zones were developed in a dilation shadow above a tightly folded felsite band where the main N-S Fault intersects with the Penjom Thrust. Other rich and wide pockets of ore typically occur where the felsite is tightly folded close to a N-S Fault. These and other mineralisation sites are listed as follows:

- Dilation shadow above a folded felsite at the intersection of N-S and Penjom Faults.

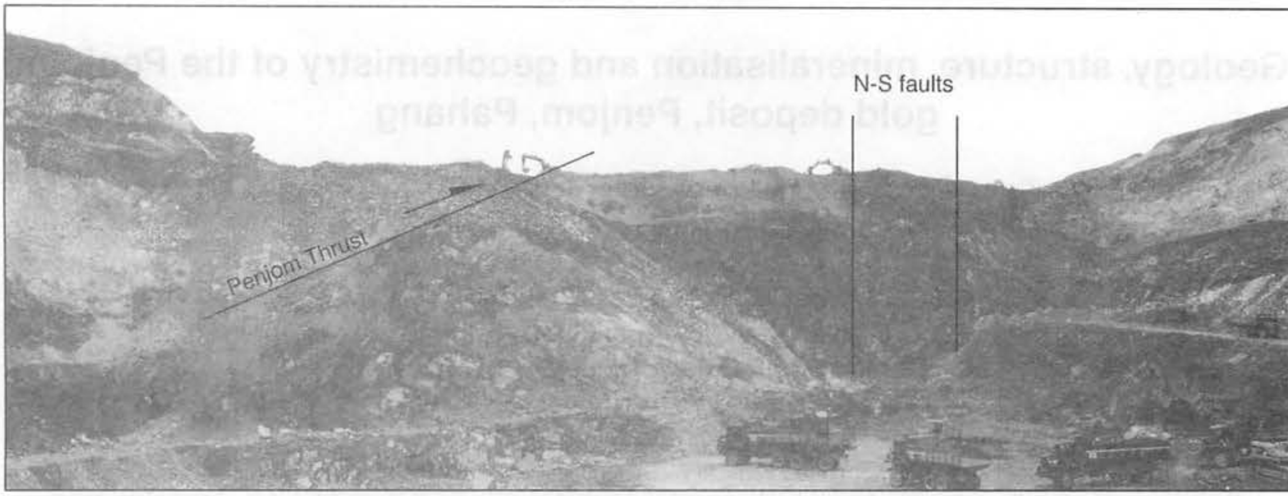

Figure 1. Within the Main Pit of Kalampong East looking southwards showing the eastward dipping Penjom Thrust which is cut by near-vertical North-South faults.

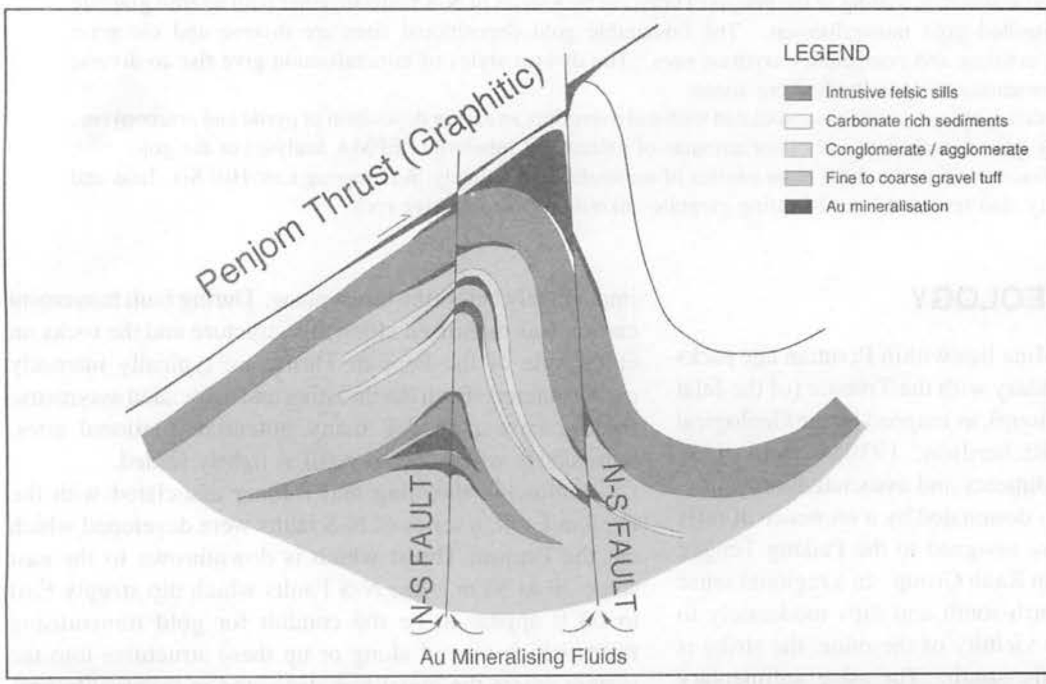

Figure 2. Idealised cross section showing the geological setting of gold mineralised at Penjom *(compiled by P. Fillis ~ 4 August 2000).*

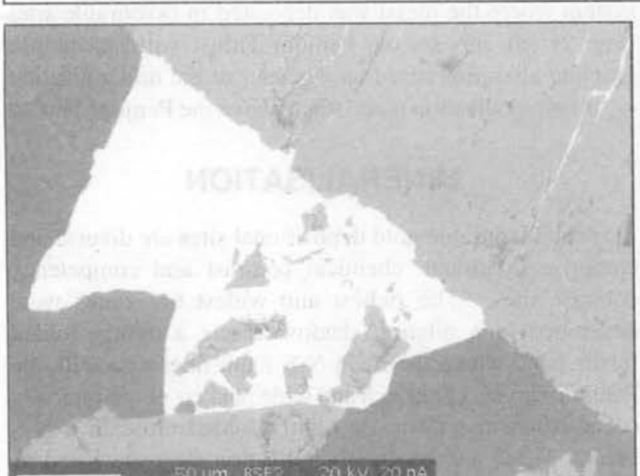

Figure 3. BSE image of quartz (dark grey) with gold (white) infilling fractures in arsenopyrite (grey). Some fractured arsenopyrite are caught in the gold. Kalampong East Pit.

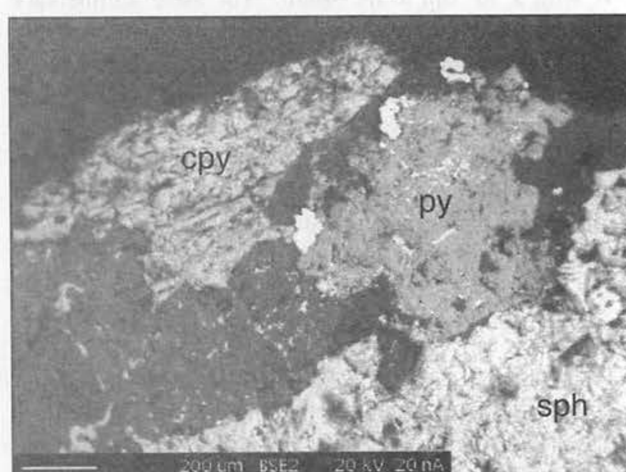

Figure 4. BSE image of gold-bearing (white) quartz-carbonate veinlet (dark grey) infilling fractures in chalcopyrite (cpy), pyrite (py) and sphalerite (sph), Kalampong East Pit.

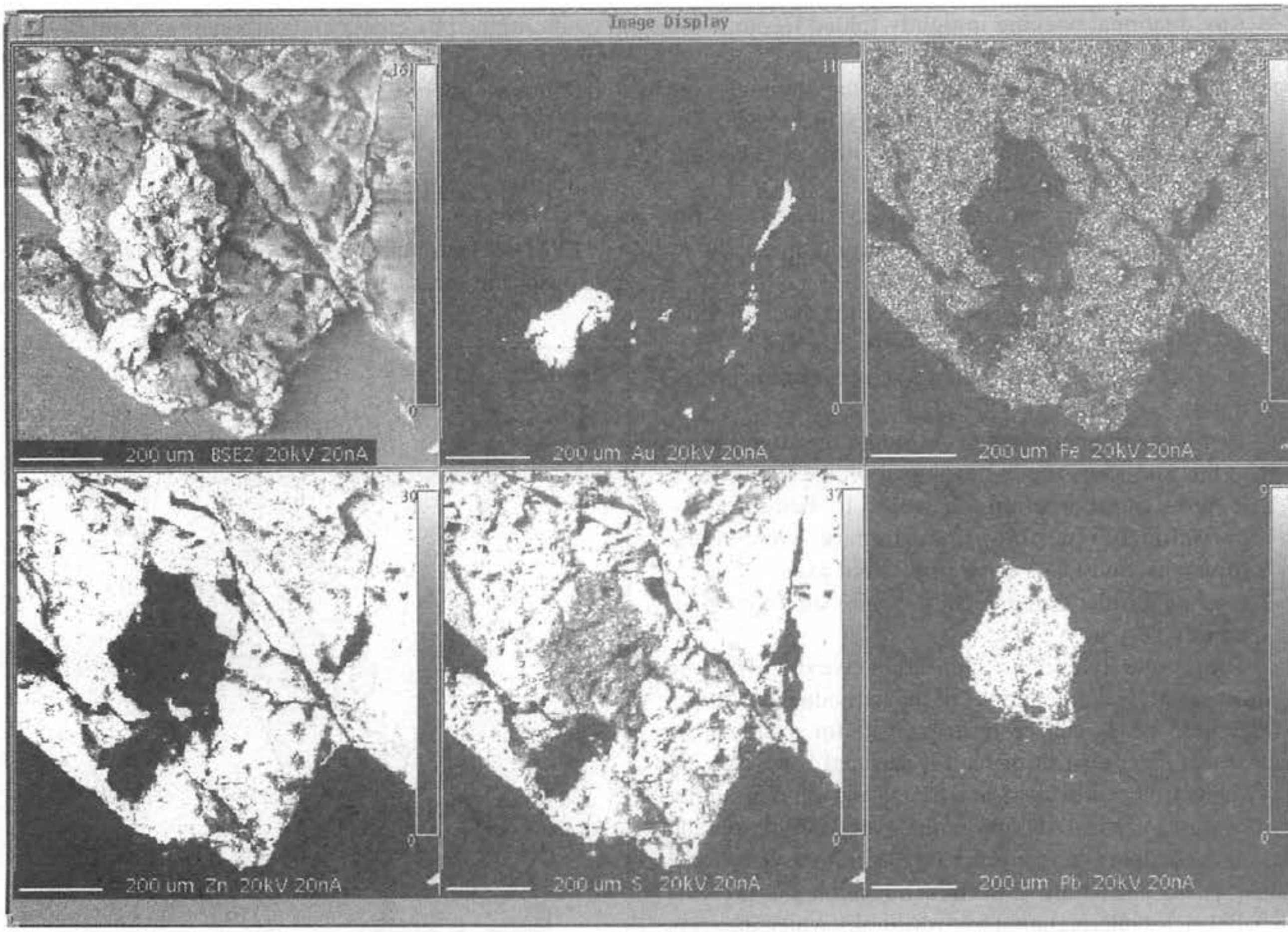

Figure 5. EPMA X-ray map of late gold (Au) and galena (PbS) infilling fractures in sphalerite (ZnS), Kalampong East Pit.

Table 1. EPMA analysis of gold (wt %) from the Main Pits at Penjom (KE - Kalampong East, J – Jalis, M – Manik) (Jasmi Hafiz, 2001).

Element	KE1	KE2	KE3	KE12	J4	J5	J6	J7	J8	M9	M10	M11
Au	92.2420	92.0840	91.6760	92.3910	86.2960	87.5200	85.7640	87.9740	88.3970	79.2500	80.1940	81.9560
Ag	8.5100	8.2180	8.8000	8.3170	12.1810	12.5030	12.3280	12.9160	12.6510	19.8910	19.6710	18.3950
Cu	0.0000	0.0000	0.0170	0.1050	0.0670	0.0540	0.0240	0.0000	0.0460	0.0150	0.0000	0.0000
Al	0.0040	0.0000	0.0060	0.0160	0.0140	0.0070	0.0000	0.0150	0.0080	0.0110	0.0040	0.0130
Fe	0.0000	0.0150	0.0000	0.0000	0.0000	0.0030	0.0070	0.0210	0.0580	0.0260	0.0000	0.0000
Si	0.0280	0.0250	0.0330	0.0330	0.0320	0.0420	0.0260	0.0290	0.0250	0.0230	0.0390	0.0360
Zn	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pb	0.0000	0.1520	0.0000	0.0000	0.0000	0.0000	0.0000	0.5040	0.3710	0.1130	0.0000	0.0000
Ca	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Si	0.0000	0.0190	0.0160	0.0170	0.0010	0.0030	0.0190	0.0033	0.0360	0.0430	0.0360	0.0040
C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
As	0.0110	0.0000	0.0270	0.0090	0.0000	0.0000	0.0370	0.0150	0.0000	0.0000	0.0000	0.0000
Total	100.7950	100.5130	100.5750	100.8910	98.5910	100.1320	98.2050	101.5070	101.5920	99.3720	99.9440	100.4040
Fineness	915.5350	917.9020	912.4170	917.4140	876.3060	874.9980	874.3320	871.9790	874.8020	799.3660	803.0240	816.6930
Average Fineness	915.8170				874.4834					806.3610		

- Any dilational opening in tightly folded felsite, close to a N-S Fault.
- Felsite contacts, particularly where the lithologies are tightly folded. Mineralisation is hosted in the sediments at the contacts rather than in the felsite itself and tends to fade away from N-S faults.
- Penjom Thrust. Mineralisation occurs at the intersection with the N-S Faults forming linear shoots plunging south at about 15° to 20°.
- Conglomerate ores — brittle fracture in a silicified incompetent unit, particularly in fold axes. Mineralisation is broad in the axis and thin on the limbs.
- Tuff hosted mineralisation — saddle reef style, again in the fold axes, thinly developed on the limbs.
- Ribbon quartz veining parallel to bedding — particularly in flaggy carbonate rich beds. Mineralisation tends to be in the fold axes.
- Isolated brittle fracture quartz veins in felsite — usually very high grade.

The diverse styles of mineralisation give rise to diverse widths, grades and orientations of the individual ore zones. Mineralised zones can be horizontal as for example the saddle reefs, yet contact or fault associated zones can dip anywhere from vertical to horizontal and dipping either east or west. Vertical ribbon veining over the fold axes and parallel to bedding can trend across the pit transverse to all other zones. The nature of the mineralisation thus presents a challenge for interpretation from drillholes which intercept some zones at a high angle and some which are drilled down dip or along strike. The mineralisation styles also present formidable grade control challenges.

Gold is associated with, and overprints, an earlier deposition of pyrite and arsenopyrite, both as disseminations and within fractures in the sulphides (Fig. 3). Thus it is largely a free milling ore. The gold mineralising episode was accompanied by quartz, carbonate, and minor amounts of galena and sphalerite (Figs. 4 and 5). Gold is also found within the lattices of these sulphides as well as intergrowths with tellurides and galena (Kamal Shah Ariffin, 1994), so that there is a small refractory component, as well as a proportion locked into graphite along the Penjom Thrust. Refractory and graphite hosted gold account for about 10% of total gold and is not recovered during processing.

Mineralisation is focused at three centres distributed along the Penjom Thrust from the north as follows: Kalampong East/Hill Six; Jalis; Manik; and is mined by open cut methods (Fig. 6). The Kalampong East and Jalis pits have merged into one, whereas Manik is 300 m SSE of Jalis and separated from it by a river. The three areas have been addressed separately with regard to resource estimation.

A black-spotted intrusive rock emplaced along the margins of the main felsite in the Manik pit and cross-cutting the earlier felsite at Kalampong East pit west wall was revealed by EPMA studies to be black phenocrysts of graphite rimmed by quartz and carbonate (ankerite). This intrusive rock is gold-bearing with the fine gold adhering to the rims of graphite or carbonate in preference to quartz (Fig. 7).

GEOCHEMISTRY

EPMA (electronprobe microanalyzer) analyses of the gold from the three different pits have slightly different

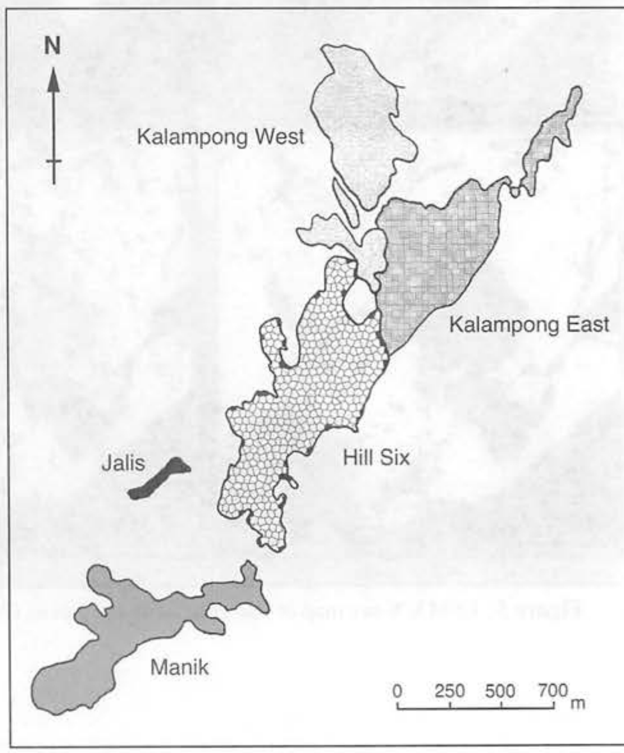

Figure 6. Map showing the location of mine pits Kalampong East, Jalis and Manik.

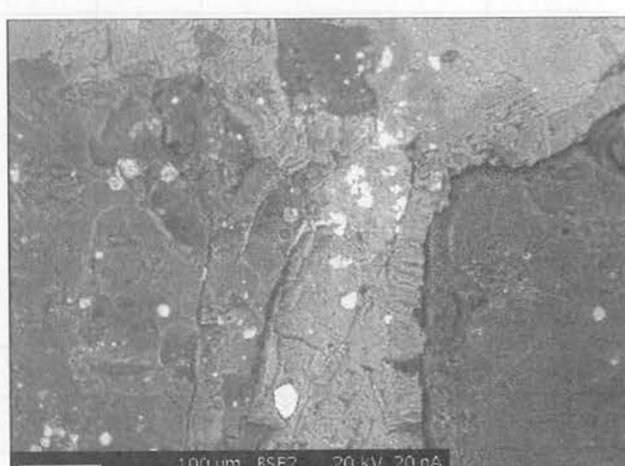

Figure 7. BSE image of late-phase gold-bearing (white) quartz-carbonate veinlet infilling fracture in graphite (dark grey). Gold is associated with the carbonate (lighter grey) while pyrite framboids appear in graphite, Kalampong East Pit.

fineness values, namely Kalampong East with 915.8170 fineness, Jalis with 874.4834 fineness and Manik with 806.3610 fineness (Table 1). The gold ores are invariably richer in Ag at Manik (~20 wt %) compared to Jalis (~12 wt %) and Kalampong East (~8 wt %). This variation may be related to a) the timing or emplacement of gold mineralisation, b) distance from the source of primary mineralisation and c) due to the influence of graphite and carbonates at the sites of gold deposition.

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