



## **EPMA characterisation and geochemistry of gold deposits of Peninsular Malaysia — genetic implications**

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**Abstract:** The highly automated electronprobe microanalyzer (EPMA) was used as a tool to characterise gold from the Raub-Tersang-Selinsing-Penjom, Rusila-Lubuk Mandi, and Jeli-Sokor areas in Peninsular Malaysia with the aim of characterising the various primary and alluvial gold deposits and tracing the alluvial gold grains to their primary sources.

Gold from quartz-veins and their associated country rocks were sampled and studied in terms of their morphology, size, inclusions, associated minerals and geochemistry. Alluvial gold and tailings in the surrounding areas were also sampled to study their association with the primary occurrences.

The common mineral associated with gold in the quartz veins in all the areas sampled is pyrite. At Bukit Koman monazite was also found together with arsenopyrite and a Cu-Sb-S mineral in the gold veins. At TRA Mining, Selinsing, arsenopyrite together with a Pb-Fe-As-S mineral are associated with gold. At Specific Resources, Penjom, there is galena, chalcopyrite, sphalerite together with silver in the gold veins. At the limestone quarry at Kechau, galena is associated with chalcocite ( $Cu_2S$ ), and Cu-Sb-S and Cu-Zn-Sb-S minerals.

In Terengganu, at Rusila it was demonstrated that alluvial gold grain sizes nearest to the primary gold veins average 3.05 mm long and 2.5 mm wide while those furthest away tend to average to about 0.81 mm long and 0.7 mm wide. On the whole grains which are longer than 1 mm tend to be prismoidal in shape while those less than 1 mm are generally spherical. In the Raub-Tersang-Selinsing-Penjom area in Pahang, the alluvial samples from Sg. Ulu Tersang, a river in SE Selinsing and Sg. Terenggun and tailings samples from Kg. Pulai (Tersang) and NW Penjom generally show a bimodal distribution with dominant lengths averaging 0.4 mm for the major distribution and 1.0 mm for the minor. In Kelantan the dominating sphericity of the alluvial samples collected in the Jeli area is prismoidal, and this differs from the samples in the Sokor area which have sphericity that ranges from subdiscoidal to discoidal. Gold grain size studies show that the samples from Sokor are fine grained which range from 0.1–0.3 mm for the lengths and the widths of the samples collected from Sg. Tui and Sg. Sokor, whereas the grain size of the samples from Jeli are bigger with an average length of 0.7 mm for samples from Sg. Pergau and an average particle size of 0.8 mm long and 0.4 mm wide for samples from Sg. Tadoh.

In Terengganu, at Rusila the average Au content is 90.30% and silver is 10.46% for the gold from the veins (a fineness of 896.1889) while the alluvial gold average 88.52% Au and 10.32% Ag (a fineness of 895.5889). In Pahang, Primary gold at Bukit Koman, Raub has a fineness of 956.679, at TRA Mining, Selinsing the fineness is 881.7301, at Specific Resources, Penjom the fineness is 903.7245 and at the limestone quarry at Kechau, the fineness is 951.1200. The alluvial gold at Bukit Koman has a fineness of 982.8318, at a river in SE Selinsing the fineness is 930.9519 at Sg. Ulu Tersang the fineness is 944.0056 and at Sg. Terenggun (NW of Penjom) the fineness is 924.4767. The tailings at Kg. Pulai, Tersang show fineness of 976.5234 and those at NW Specific Resources have fineness of 891.8836. In Kelantan, EPMA studies show that the geochemistry of the gold grains are different for the 2 main areas. In the Jeli area, the 3 areas sampled in Sg. Pergau show average fineness of 922.9157, while the 2 areas in Sg. Tadoh average 923.7250. In the Sokor area, the fineness values are less than 900.000 and the average fineness values show a larger spread, the 2 areas in Sg. Tui average 845.1322, whereas the 2 areas in Sg. Sokor average 894.0914.

Geochemical EPMA analysis of the gold grains revealed that silver is present in the gold in different amounts from different areas. It can be demonstrated that fineness is a useful character for tracing the primary sources of gold from the panned alluvial gold samples further downstream. Preliminary results

showed that the primary and alluvial gold and silver contents at Rusila-Lubuk Mandi are more-or-less the same suggesting that alluvial gold grains come solely from the primary mineralisation at Bukit Lubuk Mandi while the fineness at the Bukit Koman-Tersang-Selinsing-Penjom and Jeli-Sokor areas are different and distinctive of each locality.

EPMA characterisation of the gold for the various localities in Peninsular Malaysia has proved to be very useful in tracing the primary source areas, providing the fineness values, as well as furnishing one with the knowledge of associated minerals and inclusions which can be better addressed during gold recovery.

## INTRODUCTION

Gold is precious and usually occurs in very small, minute quantities as primary gold in mineralised quartz veins and secondary gold in alluvial deposits. The electronprobe microanalyzer (EPMA) has turned out to be the ideal tool for both physical and geochemical characterisation of primary and secondary gold.

The highly automated Cameca SX-100 electronprobe microanalyzer (EPMA) was used as a tool to study the gold from the Raub-Tersang-Selinsing-Penjom, Rusila-Lubuk Mandi, and Jeli-Sokor areas in Peninsular Malaysia with the aim of characterising the various primary and alluvial gold deposits and tracing the alluvial gold grains to their primary sources.

Gold from quartz-veins and their associated country rocks were sampled and studied in terms of their morphology, size, inclusions, associated minerals and geochemistry. Alluvial gold and tailings in the surrounding areas were also sampled to study their association with the primary occurrences.

## MATERIALS AND METHODS

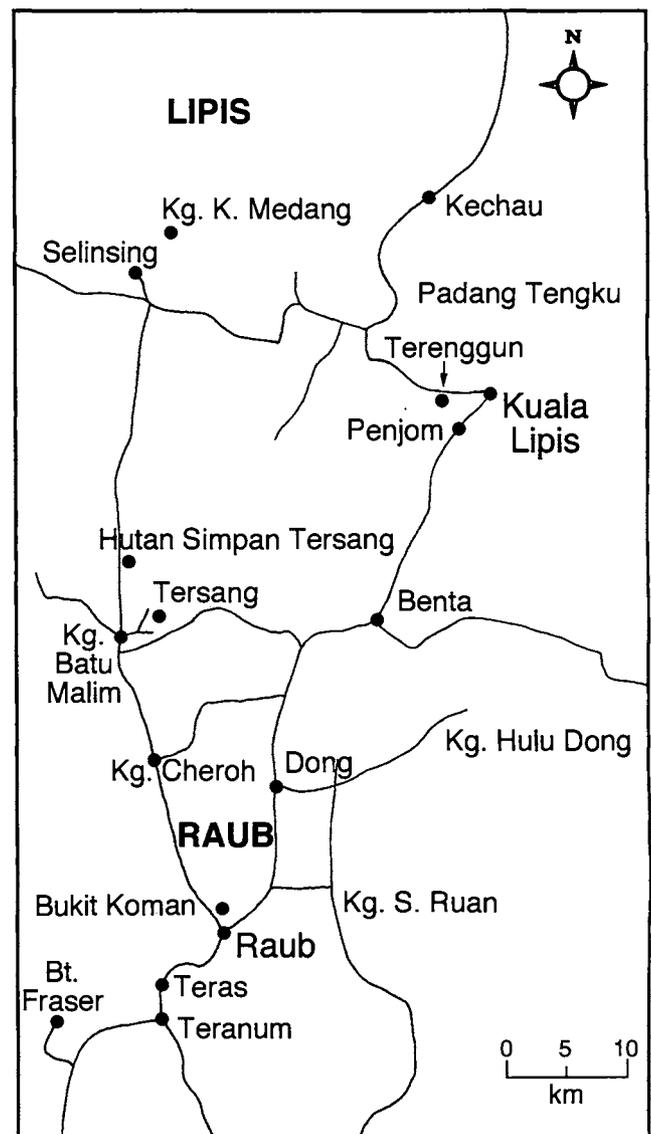
In the study, gold was collected from the Raub-Tersang-Selinsing, Kechau and Penjom areas in Pahang (Helmi, 1997), Rusila area in Terengganu (Zulpakar, 1997) and the Jeli-Sokor areas in Kelantan (Anisalihawati, 1999) (Figs. 1, 2 and 3). The samples include primary gold from gold-quartz veins from the various deposits and secondary gold was panned from the many rivers in the vicinity of the above-mentioned areas and some tailings samples in the vicinity of Tersang and Penjom were also studied (Teh *et al.*, 1997; Teh *et al.*, 1998; Teh and Anisalihawati, 1998)

The secondary, alluvial gold grains were mounted on carbon tapes and their morphology studied in detail on the EPMA after preliminary petrological microscope and binocular examination (Fig. 4). Some of the bigger primary gold samples were chipped off from the quartz veins and studied in the same manner (Fig. 5).

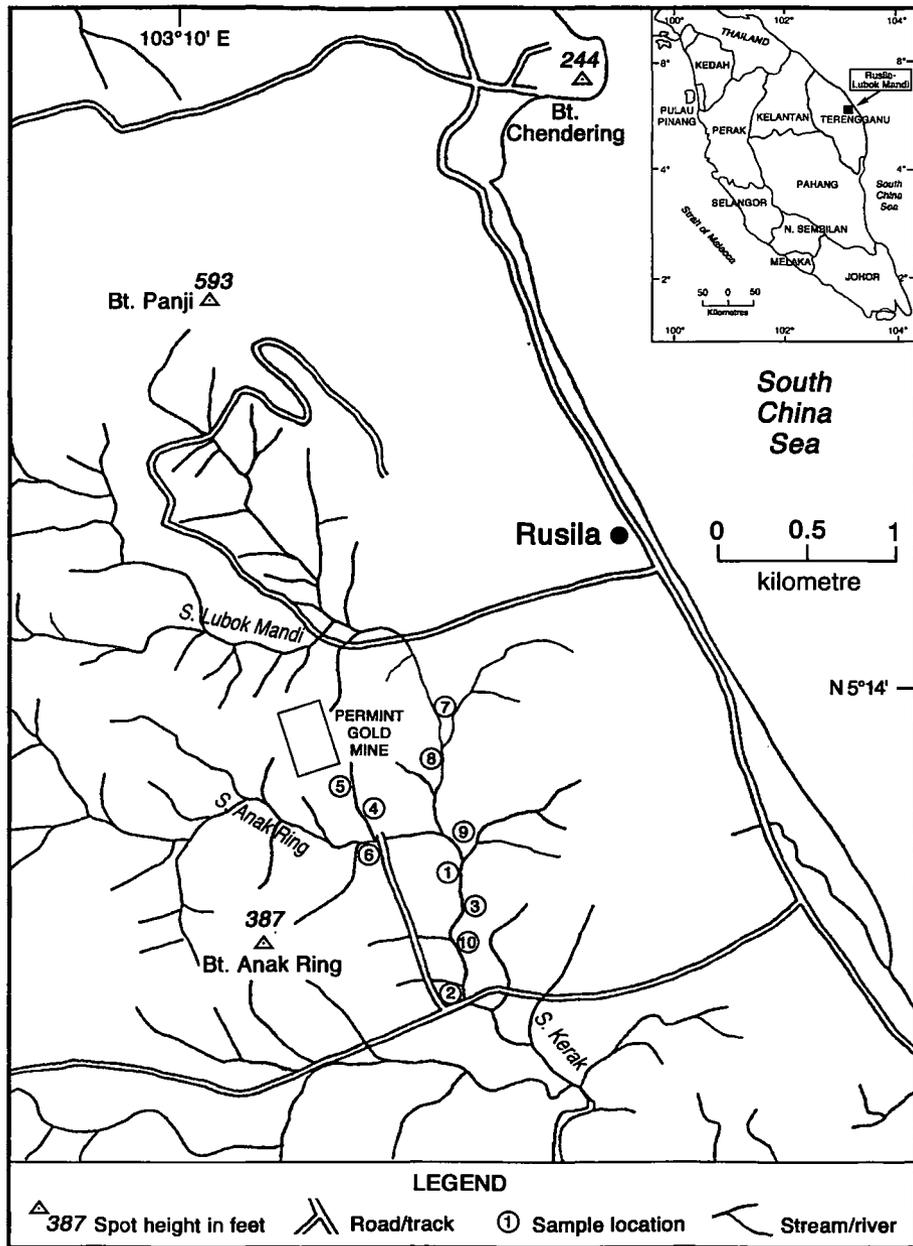
After the morphological studies, the gold samples were then mounted in resin and polished

thin sections were prepared for analysis with the EPMA utilising the fully integrated energy dispersive spectrometer (EDS), for fast full spectrum scan of elemental compositions, and the conventional wavelength dispersive spectrometers (WDS), for accurate composition determinations.

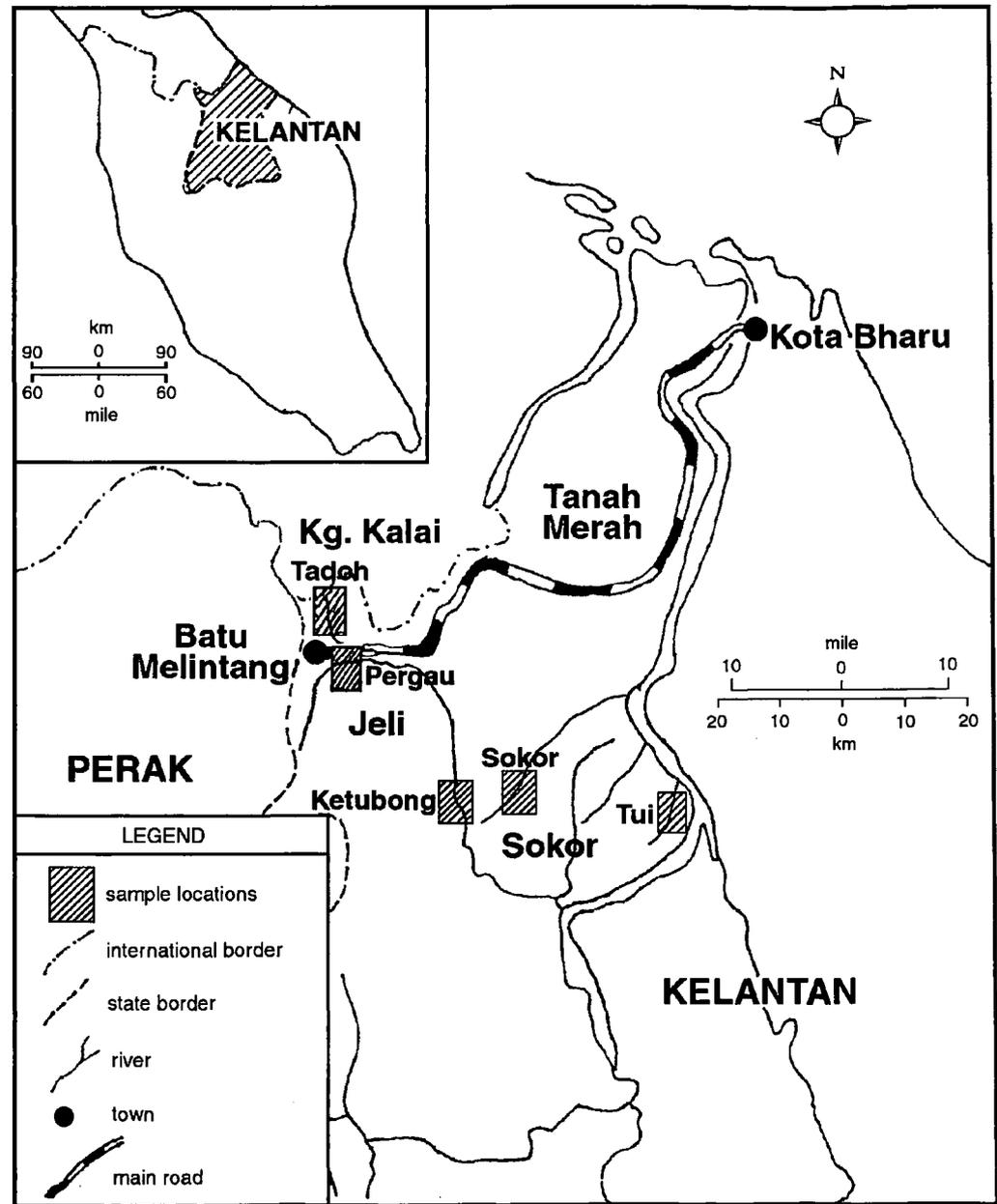
The EPMA available at the Geology Department, University of Malaya is a highly automated Cameca SX100 which is workstation-



**Figure 1.** Sketch map showing the location of the Raub-Tersang-Selinsing-Penjom area in Pahang.



**Figure 2.** Map showing the location of the Rusila-Lubok Mandi area in Terengganu. The numbers 1-10 are sample spots for the alluvial samples for size analysis (refer to Fig. 8).



**Figure 3.** Map showing the location of the Jeli-Sokor area in Kelantan.



**Figure 4.** Gold grains of minimum to maximum size from Sungai Lubok Mandi (sample spot 7, Fig. 8) showing roundness from subrounded to rounded and sphericity from subprismatic to prismatic.

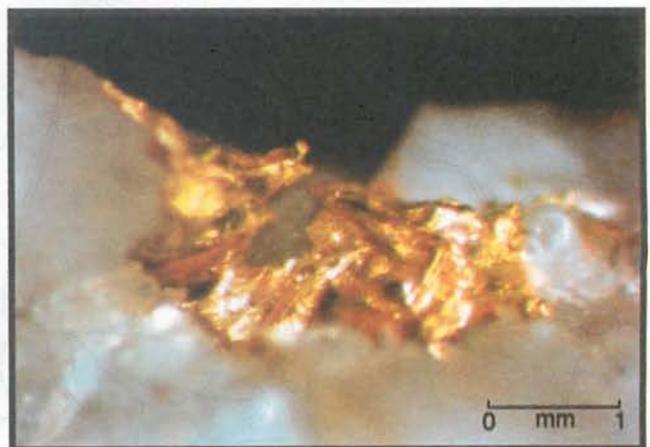
based, with full instrument control coupled with quantitative, qualitative and imaging software via windows and multi-task user environment.

Besides optical viewing, the EPMA can acquire secondary electron (SE) images for better differentiation of topography as well as backscattered images (BSE) for elemental composition differentiation (Fig. 6).

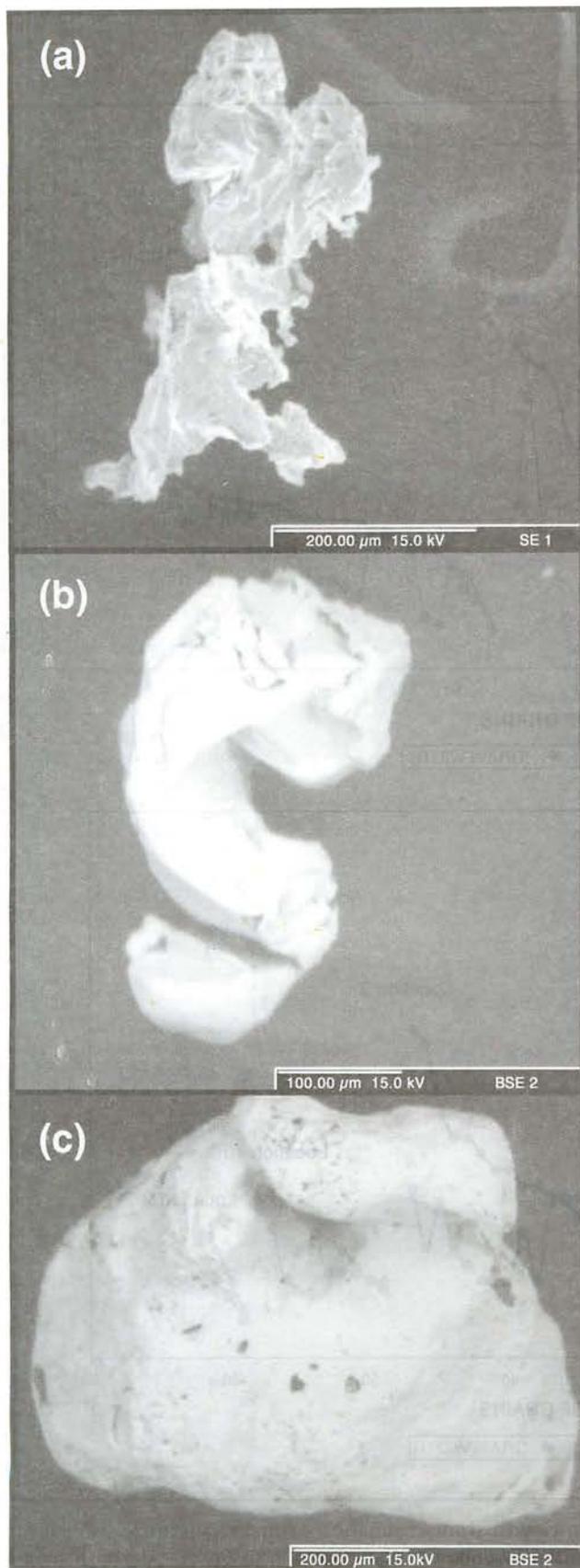
## RESULTS AND DISCUSSIONS

The common mineral associated with gold in the quartz veins in all the areas sampled is pyrite (Fig. 7). At Bukit Koman monazite was also found together with arsenopyrite and a Cu-Sb-S mineral in the gold veins. At TRA Mining, Selinsing, arsenopyrite together with a Pb-Fe-As-S mineral are associated with gold. At Specific Resources, Penjom, there is galena, chalcopyrite, sphalerite together with arsenopyrite in the gold veins. At the limestone quarry at Kechau, galena is associated with chalcocite ( $\text{Cu}_2\text{S}$ ), and Cu-Sb-S and Cu-Zn-Sb-S minerals.

In Terengganu, at Rusila it was demonstrated that alluvial gold grain sizes nearest to the primary gold veins average 3.05 mm long and 2.5 mm wide while those furthest away tend to average to about 0.81 mm long and 0.7 mm wide (Fig. 8). On the whole grains which are longer than 1 mm tend to be prismatic in shape while those less than 1 mm are generally spherical. In the Raub-Tersang-Selinsing-Penjom area in Pahang, the alluvial samples from Sg. Ulu Tersang, a river in SE Selinsing and Sg. Terenggun and tailings samples from Kg. Pulau (Tersang) and NW Penjom generally show a bimodal distribution with dominant lengths averaging 0.4 mm for the major distribution and



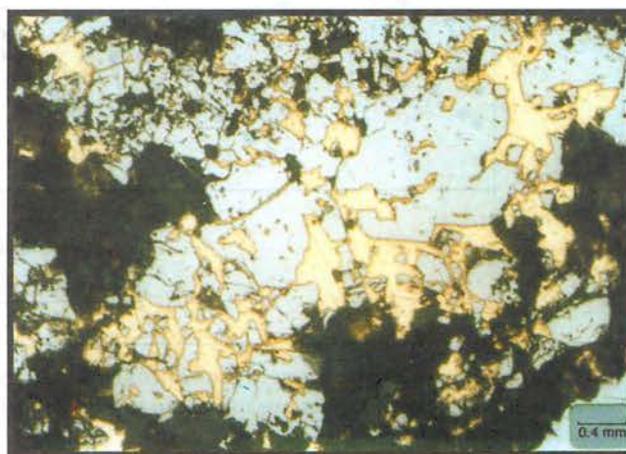
**Figure 5.** Primary gold associated with quartz, showing sharp, jagged outline. Kg. Pulau, Tersang.



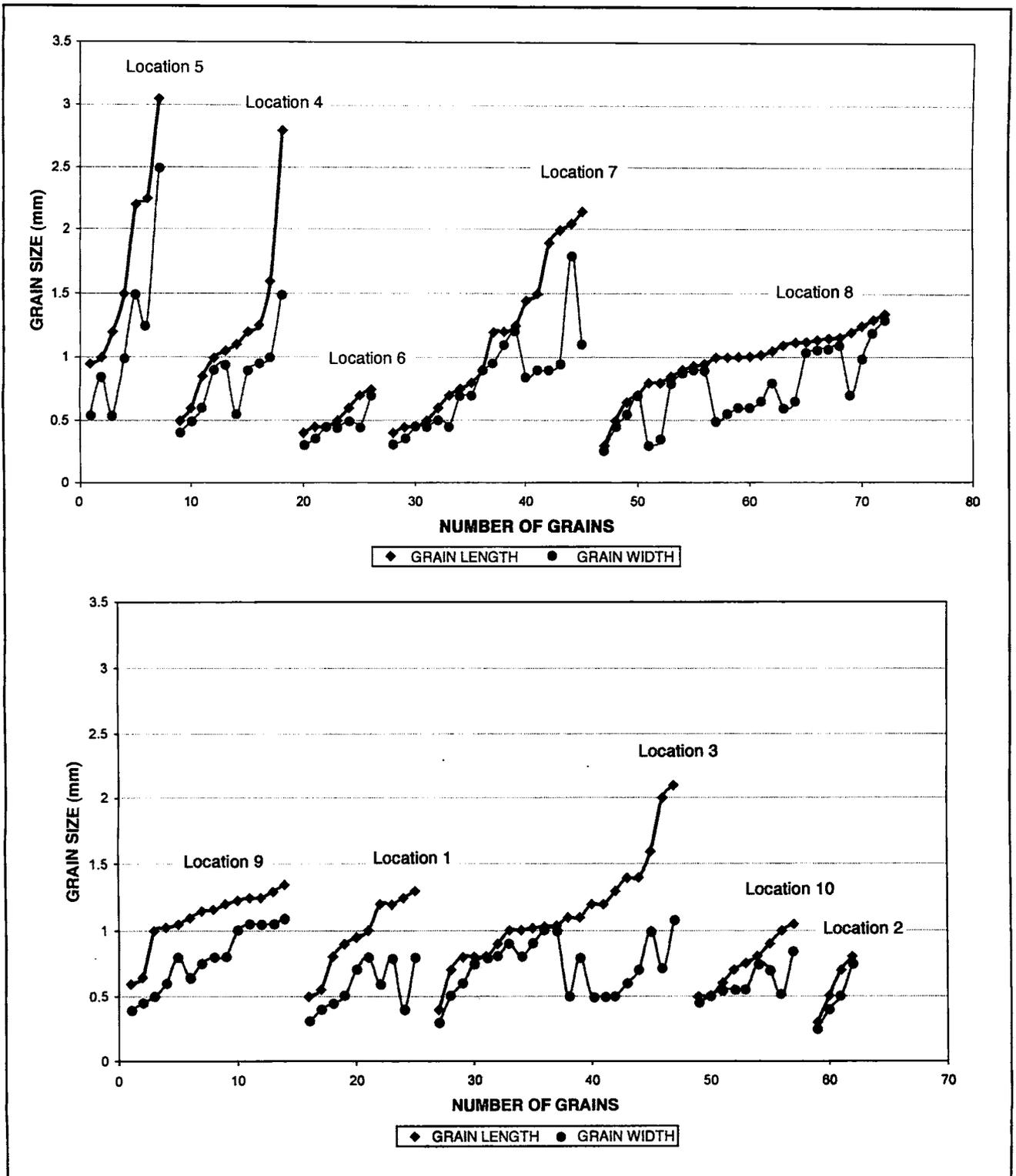
**Figure 6.** (a) EPMA Secondary electron (SE) image of primary gold grain showing jagged, angular surface. Kg. Pulai, Tersang. (b) EPMA backscattered electron (BSE) image of gold grain with smoothed surfaces. Tailings area, Kg. Pulai, Tersang. (c) EPMA backscattered electron (BSE) image of alluvial gold grain with rounded surfaces. Sungai Lubok Mandi.

1.0 mm for the minor. In Kelantan the dominating sphericity of the alluvial samples collected in the Jeli area is prismoidal, and this differs from the samples in the Sokor area which have sphericity that ranges from subdiscoidal to discoidal. Gold grain size studies show that the samples from Sokor are fine grained which range from 0.1–0.3 mm for the lengths and the widths of the samples collected from Sg. Tui and Sg. Sokor, whereas the grain size of the samples from Jeli are bigger with an average length of 0.7 mm for samples from Sg. Pergau and an average particle size of 0.8 mm long and 0.4 mm wide for samples from Sg. Tadoh. On the whole, the samples from the Jeli area comprise grain sizes that are larger when compared to the samples from Sokor area.

At Rusila the average Au content is 90.30% and silver is 10.46% for the gold from the veins (a fineness of 896.1889) while the alluvial gold average 88.52% Au and 10.32% Ag (a fineness of 895.5889) (Table 1). Primary gold at Bukit Koman, Raub, has a fineness of 956.6790 (average 95.40% Au, 4.32% Ag), at TRA Mining, Selinsing the fineness is 881.7301 (average 87.45% Au, 11.73% Ag), at Specific Resources, Penjom the fineness is 903.7245 (average 90.02% Au, 9.59% Ag) and at the limestone quarry at Kechau, the fineness is 951.1200 (average 95.31% Au, 4.89% Ag). The alluvial gold at Bukit Koman has a fineness of 982.8318 (average 98.23% Au, 1.72% Ag), at a river in SE Selinsing the fineness is 930.9519 (average 93.30% Au, 6.92% Ag), at Sg. Ulu Tersang the fineness is 944.0056 (average 93.23% Au, 5.73% Ag) and at Sg. Terenggun (NW of Penjom) the fineness is 924.4767 (average 91.44% Au, 7.47% Ag). The tailings at Kg. Pulai, Tersang show fineness of 976.5234 (average 95.67% Au, 2.30% Ag) and those at NW Specific Resources



**Figure 7.** Polished section showing late gold infilling fractures and spaces between pyrite (light grey) grains. Main Pit, Permint Goldmine, Rusila.



**Figure 8.** Graphs showing the gold grain sizes collected from various distance from their primary source area (Permint Gold Mine area). Sample spots are indicated in Fig. 2 with location 5 nearest to source and location 2 furthest. Rusila-Lubok Mandi area.

**Table 1.** Average gold-silver content and fineness of gold samples from Terengganu, Pahang and Kelantan.

STATE	LOCATION	TYPE OF DEPOSIT	AVERAGE Au (%)	AVERAGE Ag (%)	FINENESS
TERENGGANU	Rusila	Primary gold	90.30	10.46	896.1889
		Alluvial gold	88.52	10.32	895.5889
PAHANG	Bukit Koman, Raub	Primary gold	95.40	4.32	956.6790
		Alluvial gold	98.23	1.72	982.8318
	Tersang	Alluvial gold ( <i>Sg. Ulu Tersang</i> )	93.23	5.73	944.0056
		Tailings gold ( <i>Kg. Pulau</i> )	95.67	2.30	976.5234
	TRA Mining, Selinsing	Primary gold	87.45	11.73	881.7301
		Alluvial gold	93.30	6.92	930.9519
Specific Resources, Penjom	Primary gold	90.02	9.59	903.7245	
	Alluvial gold	91.44	7.47	924.4767	
	Tailings gold	88.02	10.67	891.8836	
Limestone quarry, Kechau	Primary gold	95.31	4.89	951.1200	
KELANTAN	Jeli area	Alluvial gold ( <i>Sg. Pergau</i> )	83.69	6.99	922.9157
		Alluvial gold ( <i>Sg. Tadoh</i> )	82.23	6.79	923.7250
	Sokor area	Alluvial gold ( <i>Sg. Tui</i> )	77.70	13.41	845.1322
		Alluvial gold ( <i>Sg. Sokor</i> )	80.20	9.50	894.0914

have fineness of 891.8836 (average 88.02% Au, 10.67% Ag). EPMA studies show that the geochemistry of the gold grains are different for the 2 main areas. In the Jeli area, the 3 areas sampled in Sg. Pergau show average fineness of 922.9157 (average 83.69% Au, 6.99% Ag), while the 2 areas in Sg. Tadoh average 923.7250 (average 82.23% Au, 6.79% Ag). In the Sokor area, the fineness values are less than 900.000 and the average fineness values show a larger spread, the 2 areas in Sg. Tui average 845.1322 (average 77.70% Au, 13.41% Ag), whereas the 2 areas in Sg. Sokor average 894.0914 (average 80.20% Au, 9.50% Ag).

Geochemical EPMA analysis of the gold grains revealed that silver is present in the gold in different amounts from different areas (Table 1). It can be demonstrated that fineness is a useful character for tracing the primary sources of gold from the panned alluvial gold samples further downstream.

## CONCLUSIONS

The EPMA has proved to be a useful tool for the characterisation of primary and alluvial gold because of its ability to deal with small or minute samples where the morphology and size of the gold grains can be accurately determined to show variation from different areas and the variation in the geochemistry and fineness of gold could point to different sources or episodes of gold mineralisation in a particular area.

Preliminary results showed that the primary and alluvial gold and silver contents at Rusila-Lubuk Mandi are more-or-less the same suggesting that alluvial gold grains come solely from the primary mineralisation at Bukit Lubuk Mandi while the fineness at the Bukit Koman-Tersang-Selinsing-Penjom and Jeli-Sokor areas are different and distinctive of each locality. EPMA characterisation

of the gold for the various localities in Peninsular Malaysia is very useful in tracing the primary source areas, providing the fineness values, as well as furnishing one with the knowledge of associated minerals and inclusions which can be better addressed during gold recovery.

### ACKNOWLEDGEMENT

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