Characteristics of the Stanniferous Alluvium in the Southern Kinta Valley, West Malaysia

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Abstract: The Kinta Valley is a large alluviated tract in the State of Perak, flanked by granite ranges east and west. Bedrock in the valley itself is mainly crystalline limestone, with minor clastic metasediments. The valley is drained by the southward-flowing Kinta River (with a gradient of about 5 ft/mi), and its tributaries, the main ones entering from the east. Thickness of alluvium in the valley increases southward from about 20 feet near Ipoh to more than 100 feet in the southern part, giving a southward slope for the bedrock surface of about 10 ft/mi. Before artificial deviation, the Kinta River had a sinuosity of about 1.3, transitional between a straight and a meandering channel.

Thirty-eight alluvial tin mines near Kampar were examined and their alluvial sections studied. The unconsolidated deposits exposed included 'granite wash' (partly eluvial); stratified sand, silt and clay; peat and peaty sediments; and mine tailings. Multiple, graded depositional sequences, up to a maximum of four, were characteristic. The sections at three mines are described in detail.

Some 139 samples from 27 mines were analyzed for size distribution (by sieving) and for heavy mineral content (by bromoform separation). Heavy mineral content ranged from 0.05% to 3.2%, with a mean of 0.59%. Scatterplots show that a high content of heavy minerals tends to be associated with coarse mean grain size (Mz) and with low or negative values of skewness (Sk$_I$), but the relationships are not simple and no single parameter is a good index to heavy mineral concentrations.

Many characteristics of the unconsolidated deposits (including the graded depositional sequences; current bedding and other primary structures; abundance of organic material; and generally positive skewness values) are compatible with and strongly suggestive of fluvial deposition. It is likely that the deposits, apart from eluvial and residual portions, represent the channel and topstratum deposits of a river or rivers of low to transitional sinuosity.

INTRODUCTION

The Kinta Valley alluvium is of considerable economic importance, as about 50 percent (Ingham and Bradford, 1960, p. 1) of Malaysia's tin production is derived fromed the hydroclastic valley sediments. The present study was initiated in order to obtain a better understanding of the formation of the alluvium and its heavy mineral content. It is hoped that the results of the study will be useful to the mining industry.

The Kinta Valley is located in the State of Perak near the western margin of the Malay Peninsula (figure 1). The valley is an alluviated valley with a shape similar to an open-ended ellipse. Limestone and relatively minor amounts of schist form the bedrock within most of the valley, while granite ranges form the margins of the valley.
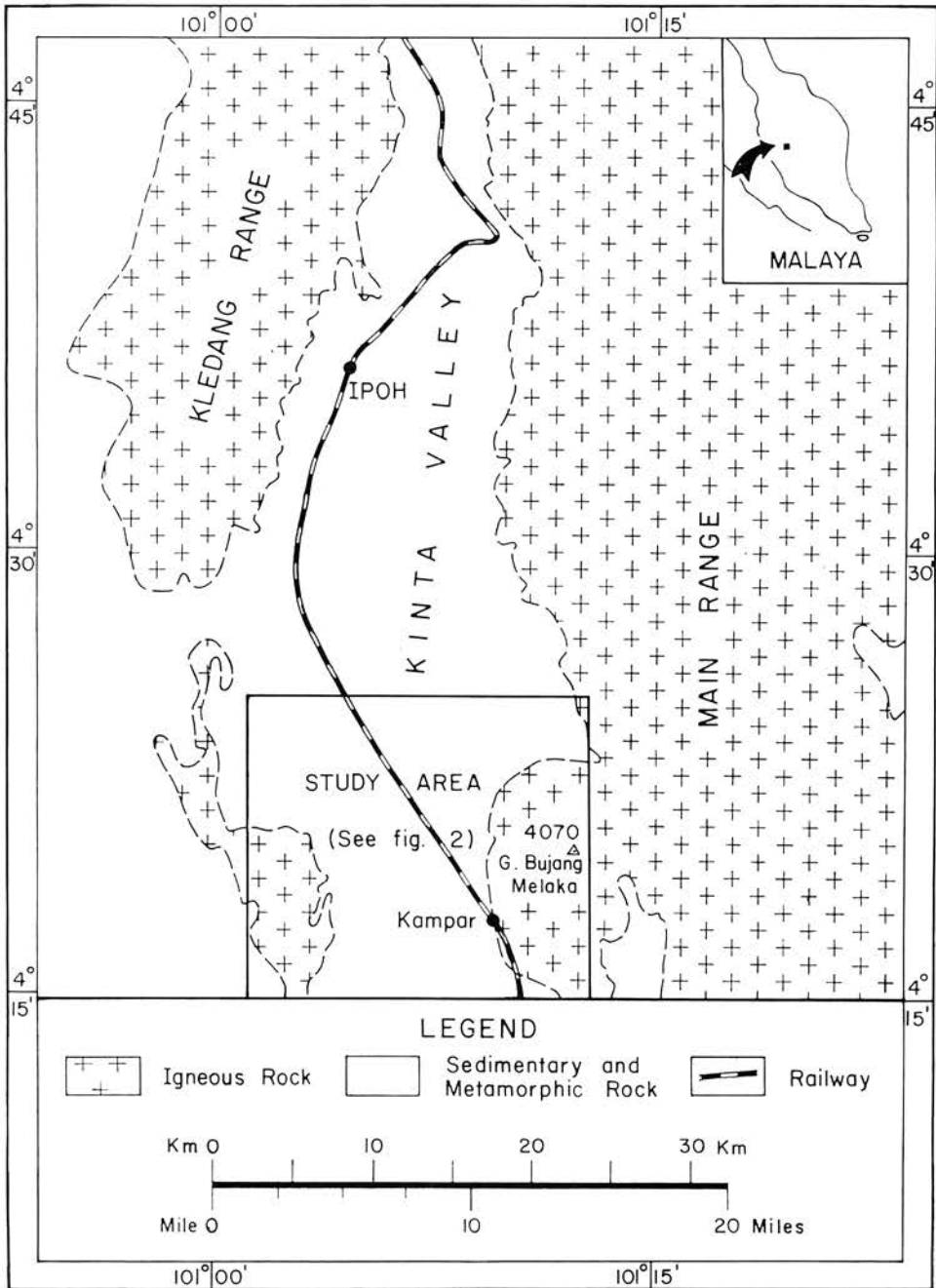
Fig. 1. Index map fo the Kinta Valley region. Government of Malaysia copyright is reserved.

Review of Previous Work

Considerable information is available on the geology of the Kinta Valley, and this was summarised by Ingham and Bradford (1960). However, they did not mention several papers that are of considerable interest to the present discussion. These and other papers will be briefly discussed below, but serious readers of this report are urged to consult the original works for a full appreciation of them.

J.B. Scrivenor (1930) described what he considered to be marine sponge spicules in Holocene rhyolite ash from localities along the Perak River near Kuala Plus, and (1931) noted the existence of similar remains from a lake near Kroh, at an altitude of 1000 feet. To account for these he speculated that sea level was then at least 200 feet higher than at present, and that an arm of the sea once extended up the Perak River valley to Kuala Plus, and possibly beyond. He believed that the Kroh remains were wind blown from lower levels.

Oakley (1940) examined some of the samples supplied by Scrivenor from localities along the Perak River, and suggested that the sponge remains were not of organic origin. He also noted some diatoms in the samples and identified them as fresh water species. Oakley thus suggested that the ash and tuff deposits had formed under fresh water conditions.

Scrivenor for a time (1942, 1943) maintained his belief that the 'sponge spicules' were from marine organisms, and that there was thus evidence for a sea 200 feet above the present level. However, he later (1946) stated that his previously described sponge remains from the Perak ash were "not necessarily of marine origin", and that they could not be considered as evidence for a 200-feet sea level. And finally Scrivenor (1949) restated his opinion that evidence for a sea 200 feet higher than present was lacking, and that the maximum sea level indicated was only about 50 feet higher than present.

Walker (1955), in a paper dealing mainly with the Kinta Valley alluvium and its formation, recognized the following types of alluvium: boulder beds, old alluvium, young alluvium, and organic mud and peat. He stated that the boulder beds were probably formed at a time when the sea was 250 feet above its present level. It is surprising that Walker suggested a sea level 250 feet above present, without mentioning Scrivenor's later beliefs, particularly his view (Scrivenor, 1949) that the boulder beds (or Gopeng Beds) were formed when the sea was about 300 feet below its present level.

Other evidences of relative sea level changes have been reported. Fitch (1949) deduced emergences on the order of 10 to 20 feet along the east coast of Malaya. Burton (1964) ascribed unconsolidated clays, sands and gravels ('high level alluvium' or 'older alluvium') in Johore and Singapore to an early Pleistocene sea standing about 250 feet above present level. Keller and Richards (1967) reported a peat core from the Malacca Strait, 24 km north of Port Swettenham, from a depth of 26.5 meters, which was dated by radiocarbon at 10,000±200 years and which they believed could be correlated with an eustatic sea level rise in late Quaternary times. From other evidence Keller and Richards (1967) believe there was no crustal movement involved in the recent submergence, and that the Malacca Straits area has been a stable platform for at least the last 10,000 years.

GENERAL VALLEY CHARACTERISTICS

The predominant sedimentary rock in the valley bedrock is a crystalline variety of limestone. Schists, shales, and quartzites are much less common. The limestone forms well defined troughs and pinnacles on the valley floor, but particularly near the eastern margin of the valley it often rises abruptly to form shear, cliffed hills that rise as much as 2000 feet above the valley floor.

The sedimentary rocks in the valley are margined by two granitic mountain ranges. To the west, the Kledang Range rises to 2,466 feet, and gradually falls to less than 250 feet before disappearing under sediments to the south. Further south, in the vicinity of Tanjong Tualang, granite is again exposed, and it is believed that this granite is a southern extension of the Kledang Range.

To the east the Main Range rises to 4,803 feet alongside the valley. Near Kampar town Gunong Bujang Melaka, an elliptical appendage to the Main Range, rises to 4,070 feet. The Bujang Melaka granite is situated due east of the Tanjong Tualang granite. These two granitic masses form the narrowest part of the valley in its southern portion.

RIVER DESCRIPTIONS

The drainage pattern in the Kinta Valley is generally dendritic (figure 2). The Kinta River and its main tributaries, Sungei Raia and Sungei Kampar, have headwaters far up in the Main Range. The smaller tributaries, Sungai Chemor, Sungei Choh, Sungei Pinji, Sungei Teja, Sungei Talam and Sungei Chenderiang originate from the lower slopes of the Main Range. The rivers entering the valley from the west are relatively minor, the only important ones being Sungei Johan and Sungei Tumboh.

Gradient

The gradient of the Kinta River between a point north of Ipoh to latitude 4° 15' is about 5 feet per mile. Below Teluk Anson, where the Kinta River joins the Perak River, the gradient lessens considerably to about 0.75 feet per mile.

Ingham and Bradford (1960) indicate the average bedrock depth north of Ipoh is on the order of 20 feet. To the south, drilling results near latitude 4° 15' indicate the bedrock depth varies between 110 to 140 feet. If the average bedrock depth here is about 125 feet, the slope of the valley floor is approximately 10 feet per mile. Similar values have also been mentioned by Richardson (1947).
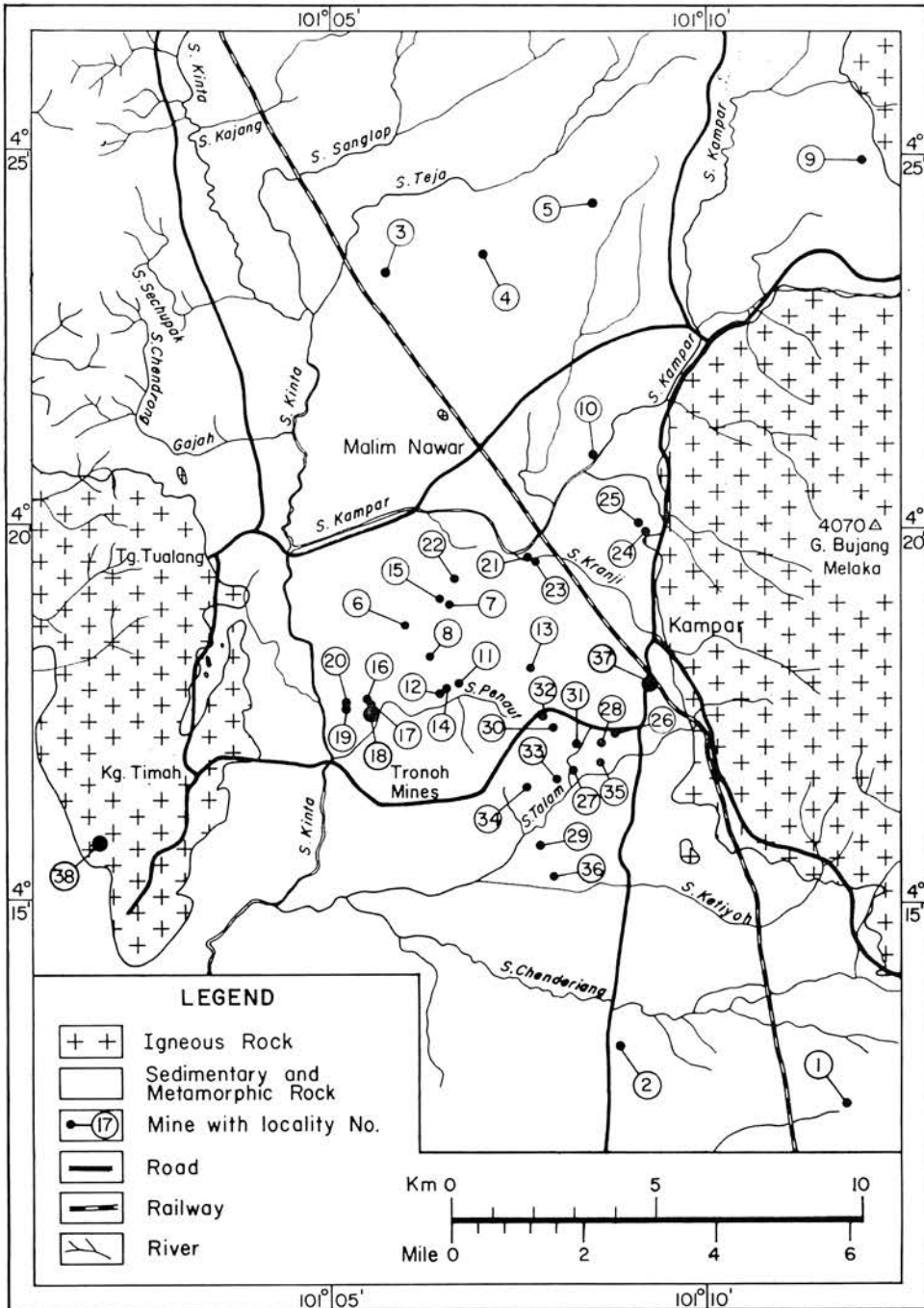
Fig. 2. Map of southern Kinta Valley, showing locations of opencast mines studied. Government of Malaysia copyright is reserved.

Sinuosity

The sinuosity of the Kinta River was determined from a 1927 geologic map by the formula:

$$\text{Sinuosity} = \frac{\text{stream length}}{\text{valley length}} \quad \text{(Schumm, 1963)}$$

A straight stream would have a sinuosity of 1.0. The 1927 map was used in the hope of obtaining more accurate results, because the Kinta River has been deviated artificially many times, and the majority of these deviations occured after the map was published. The sinuosity value, was determined to be 1.26, or about 1.30. This value, according to Schumm (1963), would be considered as transitional between a straight and a regular meandering channel.

CHARACTERISTICS OF THE ALLUVIUM

Thirty-eight alluvial tin mines were studied in the vicinity of Bujang Melaka (figure 2). Alluvial features exposed in the mines include varying numbers of depositional sequences, eluvial and/or alluvial unconsolidated granite wash beds, peat and organic—rich beds, stratified sand, silt and clay sequences, and mine tailings.

Multiple depositional sequences are a characteristic feature of the alluvium. It appears that the southern part of the valley has experienced a maximum of four periods of deposition. About half of the exposures displayed three or four depositional sequences and the rest had either fewer than three or a questionable number of sequences. Examples of these multiple depositional sequences will be described later in this paper.

Granite wash

Unconsolidated granite wash, or alluvium derived from weathered granitic rocks, is present in about a quarter of the mines and ranges in thickness from 10 to 40 feet. It is commonly found in the lower portions of the alluvial sections and normally forms the thickest bed or series of beds in a particular mine. In hand specimen it closely resembles a weathered granite, and can be easily mistaken for such, except for the presence in outcrop of current bedding, and the lack of quartz and tourmaline veins. Granite wash is typically white to pinkish gray, graded, current bedded, very coarse to coarse grained sand, commonly rich in heavy detrital minerals. If forms the ore zone in most of the mines where it occurs.

Walker (1955) referred to these deposits as "Old Alluvium", and he believed they had formed in a lake, sea or large estuary. However, sedimentary structures including larger current bedding (figure 3), are more suggestive of a fluvial origin.

Peat and other organic material

Peat and organic-rich beds are widespread in the valley, and were found in about a third of the localities. The organic deposits are not continuous from mine to mine, and commonly only one such layer is present. Bed thickness at different localities varies from 2 to 25 feet. The organic debris often contains a considerable amount of fine silt and clay called neckron clays by Walker (1955). He believed these accumulated in open water of at least 1 meter's depth. The organic deposits are commonly associated with the "Young Alluvium" described by Walker (1955), but also found with his "Old Alluvium".
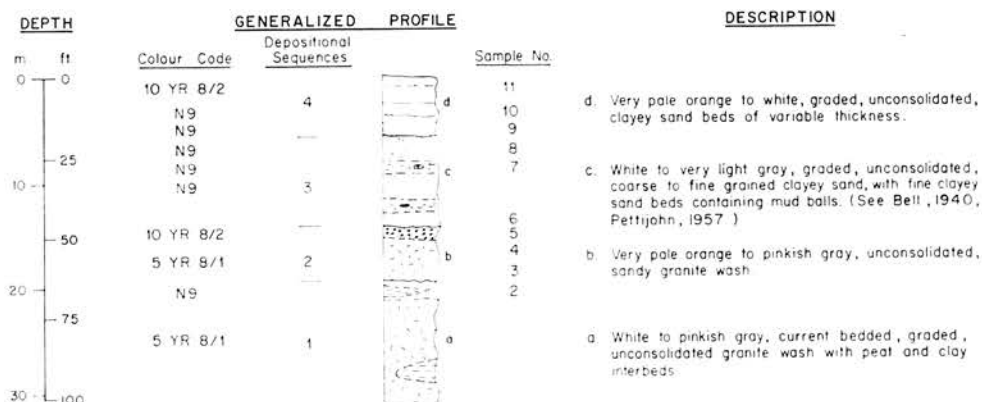
Fig. 3.   Generalized stratigraphic profile at locality 37. Government of Malaysia copyright is reserved.

Sand, silt and clay beds

Sand, silt and clay beds similar to deposits termed "Young Alluvium" by Walker (1955), were observed in more than 80% of the localities visited. These sediments are associated with the granite wash at 5 localities, being either above or interbedded with the granite wash. Mine tailings commonly overlie the sand, silt and clay sediments.

These sediments are almost always horizontally bedded and are commonly composed of graded, unconsolidated sand, with interstital silt and clay. Uncommon pebble beds exist, commonly composed of milky, subrounded to rounded, hard, resistent quartz pebbles. Mud balls (Bell, 1940; Pettijohn, 1957) are uncommonly associated with fine-grained sediments. The mud balls average 5 to 8 cm. in diameter, but lack the armored appearance mentioned by Bell (1940). It should be emphasized that mud balls are characteristic of fluvial depostion. They were described in undivided top stratum deposits on flat (unimpeded) flood plains by Mansfield (1938), Jahns (1947) and Allen (1965).

Mine tailings

Mine tailings in the Kampar area consist of tailing sands and tailing slimes. Two types of tailing sand were recognised: gravel pump mine operations produce graded, horizontal beds that are about 1 foot thick, while dredge tailings are commonly crossbedded. Tailing sands are generally light brown to very pale orange, unconsolidated, medium to coarse grained sand, with little slit and clay. In contrast, tailing slimes are typically medium to dusky brown, thin-bedded, poorly consolidated clay and silt. These slimes commonly overlie the tailing sands.

SAMPLING METHODS AND TREATMENT OF SAMPLES

Sampling

Figure 2 shows the locations of the mines visited. All were in the vicinity of Bujang Melaka. An effort was made to study localities more or less forming traverse lines across the valley, but this was limited by the location of mines, with suitable exposures.

Nearly horizontal channel samples were collected from selected beds exposed in the alluvial profile. The channel samples were about 4 feet long, 2 inches wide and 3 inches deep. The samples collected were not statistically random.

Laboratory treatment

One hundred and thirty nine samples from 27 mines were treated in the following manner: The dried samples were partially disaggregated by gently working the sediment with a wooden pestle in a wooden tray. The samples were then split into two portions, one weighing about 800 grams, and the other weighing between 50 and 100 grams.

The 800 gram samples were partially panned, and the heavy minerals further separated using bromoform. The percentage of heavy minerals was calculated and the individual minerals optically identified and their percentages calculated.

The 50 to 100 gram samples were gently disaggregated further with a wooden pestle in a porcelain mortar. They were then sieved for 10 minutes on a Ro-Tap shaker, through Tyler sieves spaced at intervals of about 1ϕ.

Colors and color codes were determined for some of the samples by comparing the sediment with a standard Rock Color Chart (Goddard, 1963).

Statistical Calculation

From the sieving results cumulative percentages were calculated and plotted on arithmetic probability paper. Grain size parameters were calculated according to the formulae proposed by Folk and Ward (1957).

Fig. 4.   Current bedded granite wash at locality 37.

Mean size

The graphic mean grain size (M_z) of the samples was determined by the formula:

$$M_z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

(Note: $\phi = \log_2 mm = -3.322 \log_{10} mm$)

Standard deviation

The standard deviation of the grain size has been suggested as a measure of sorting by Krumbein (1938), Otto (1939) and Imnan (1952). Folk and Ward (1957) proposed the Inclusive Graphic Standard Deviation, using the formula:

$$\sigma_1 = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

A verbal scale is often useful and has been suggested as:

σ_1 under 0.35: very well sorted
σ_1 0.35 to 0.50: well sorted
σ_1 0.50 to 1.00: moderately sorted
σ_1 1.00 to 2.00: poorly sorted
σ_1 2,00 to 4.00: very poorly sorted
σ_1 over 4.00: extremely poorly sorted

Skewness

For calculations of skewness Folk and Ward (1957) suggest Inclusive Graphic Skewness as determined by the formula:

$$Sk_1 = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

This parameter can assume values between -1.00 and $+1.00$, symmetrical curves having a value of 0.00. Verbal limits have been suggested as:

Sk_1 -1.00 to -0.30: very negative skewed
Sk_1 -0.30 to -0.10: negative skewed
Sk_1 -0.10 to $+0.10$: nearly symmetrical
Sk_1 $+0.10$ to $+0.30$: positive skewed
Sk_1 $+0.30$ to $+1.00$: very positive skewed

Kurtosis

Folk and Ward (1957) proposed a parameter Graphic Kurtosis (K) with the formula:

$$K_G = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$$

Gaussian curves have $K_G = 1.00$. Verbal limits for the kurtosis values have been suggested as:

K_G under 0.67: very platykurtic
K_G 0.67 to 0.90: platykurtic
K_G 0.90 to 1.11: mesokurtic
K_G 1.11 to 1.50: leptokurtic
K_G 1.50 to 3.00: very leptokurtic
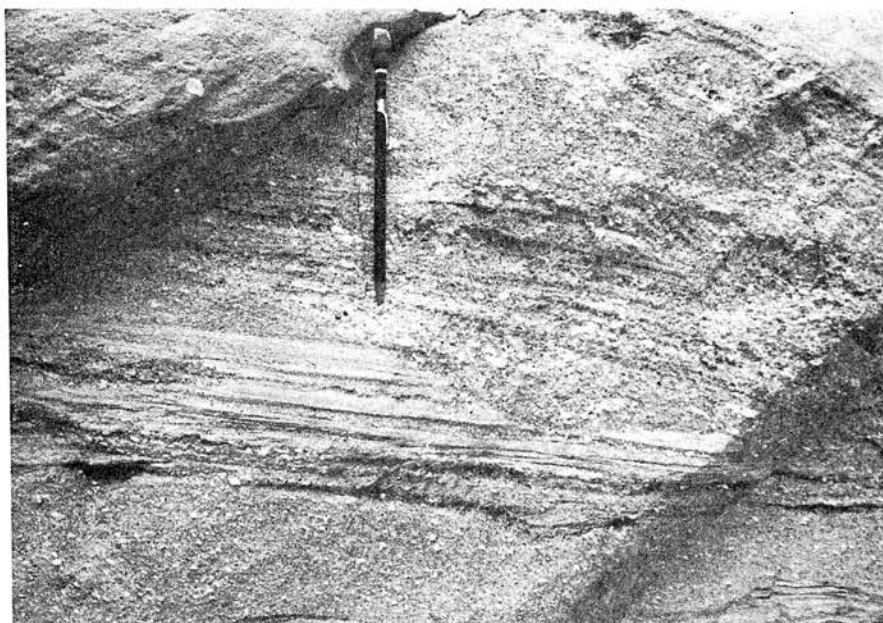K_G over 3.00: extremely leptokurtic

Fig. 5.   Cut-and-fill current structures in granite wash at locality 37.

The distribution of K_G values thus determined is very non-Gaussian, and to approximately normalise them the following formula was suggested:

$$K'_G = \frac{K_G}{K_G + 1}$$

Gaussian curves would have $K'_G = 0.50$.

SELECTED EXAMPLES OF MINE PROFILES AND GRAIN SIZE DATA

Three localities have been selected as generally representative of the thirty-eight sites visited. The first locality (37) is located near the eastern margin of the valley. The second (18) is located well out on the valley floor, and the third (38) is located still further to the west (figure 2).

Locality 37

This locality is situated along the eastern margin of the Kinta Valley, south of Kampar town, and near a point where a relatively large stream canyon exists in the Bujang Melaka granite (fig. 2). The alluvium consists of four graded depositional sequences.

Figures 3 and 6 show the alluvial profile at this locality, and Table 1 gives details of the mechanical analysis of samples.

Stratigraphy and sediment texture

The basal sequence overlies crystalline limestone pinnacles, and is about 40 feet thick. The sediment is predominantly whitish to very light grey, graded, unconsolidated granite wash, with subordinate clay beds and lenses. Angular to subangular quartz
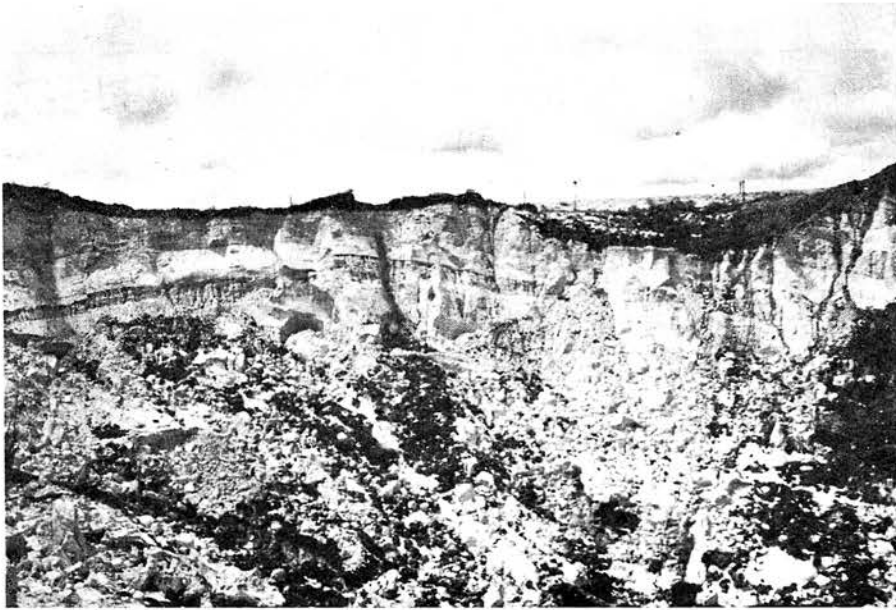
Fig. 6.   Alluvial profile at locality 37, looking to the west. Section totals about 100 feet in thickness.

grains about 6 mm in size, and highly weathered feldspar about 12 x 20mm, are widely dispersed throughout the sediment. Current structures (figures 4 and 5) are well displayed. The top of the sequence is represented by interbedded clay and peat, which has a sharp contact with the overlying sequences.

The second sequence is about 18 to 20 feet thick, and consists predominately of granite wash. Here the granite wash is somewhat finer grained than in the basal unit, and weathered feldspars and clay are more common. At the top is a coarser grained lens containing a few 6-mm, angular to subangular quartz pebbles, which marks the upper boundary of the sequence.

The third sequence is about 30 feet thick, and consists mostly of graded, unconsolidated, sandy granite wash. The uppermost portion is composed of plastic clay-rich sand. The most interesting features of this sequence are two distinct relatively fine grained beds of unconsolidated clayey sand, which contain mud balls (Bell, 1940; Pettijohn, 1957) near their lower margins. Overlying these two beds the clay-rich, plastic sand forms the contact with the fourth sequence.

The fourth depositional sequence is about 18 feet thick and consists of four unconsolidated clayey sand beds of variable thickness. The lowest bed is coarser grained than the other three. The third bed consists of a somewhat better consolidated clay-rich sand. The top bed consists of clayey sand with some organic material near its upper margin. This top bed also contains a few angular to subangular iron-stained quartz pebbles that are about 6 mm in diameter.

Table 1. Samples from Locality 37.

Depositional Sequence	Sample No.	% Heavy Minerals	Meanϕ M	Satndard Deviationϕ σ	Skewness Sk	K'
4	37–11	0.34	0.45	1.47	0.18	0.522
	37–10	0.39	0.98	1.41	0.37	0.528
	37–9	0.36	0.29	1.23	0.12	0.563
3	37–8	0.19	2.03	1.48	0.27	0.510
	37–7	2.12	2.07	1.34	0.04	0.563
	37–6	0.83	0.82	1.45	0.27	0.517
2	37–5	0.99	0.52	1.48	0.22	0.556
	37–4	0.49	1.06	1.42	0.31	0.526
	37–3	0.55	0.77	1.35	0.27	0.522
1	37–2	0.41	2.58	1.40	−0.03	0.440
	37–1	3.20	0.24	1.55	0.26	0.528

Results of analyses (*see Table 1*)

Two samples were collected from the basal sequence. The first sample, collected in granite wash about 20 feet above the crystalline limestone, had the largest heavy mineral content (3.20%) encountered in the entire study. The second sample, collected from finer grained clayey sand at the top of the sequence, contained considerably less (0.41%) heavy minerals. The granite wash displays good evidence of fluvial deposition, while the presence of peat indicates relatively quiet conditions existed when the fine grained material was deposited.

Three samples were collected from the second depositional sequence. The highest of these was collected in a channel deposit, and is a distinctly coarser grained, somewhat poorer sorted variety of granite wash than the two lower samples. This sample also has the highest content (0.99%) of heavy minerals of the three.

Three samples were collected from the third depositional sequence. The basal sample, from granite wash, is the coarsest but did not contain the largest percentage of heavy minerals. The third sample was collected at the top of the unit in a stiff, plastic, clay-rich, fine grained sand.

The middle sample is distinctly different from the other two. It is the finest grained, best sorted, lowest positively skewed, and most leptokurtic of the three. It also contains the second highest content (2.12%) of heavy minerals encountered in the study. The skewness value for this sample is also considerably lower than for the other two, indicating it contains a lower percentage of fine material. This particular bed lies more than 70 feet above the limestone bedrock. Although the nature of the bedrock under placer deposits is believed to play an important role in the concentration of heavy minerals (Ingham and Bradford, 1960; Tyrrell, 1912), it seems unlikely that it exercised a significant control at this level.

A sharp and well-defined contact separates the third from the fourth depositional sequence. Three samples were collected from separate beds in this sequence. The lowest sample is coarser grained and somewhat better sorted than the other two. The heavy mineral percentages of the three are closely similar.

It can be seen from Table 1 that there is no simple relationship between the heavy mineral content and the size parameters for these samples. The two samples with the most heavy minerals are the coarsest and the second-finest from this locality. Nor do they show distinctive similarities in any of the other parameters.

Locality 18

This locality is not far east of the present course of the Kinta River (fig. 2). In general the alluvial profile here consists of four graded depositional sequences (figure 7). Table 2 gives the results of analyses of samples from this locality.
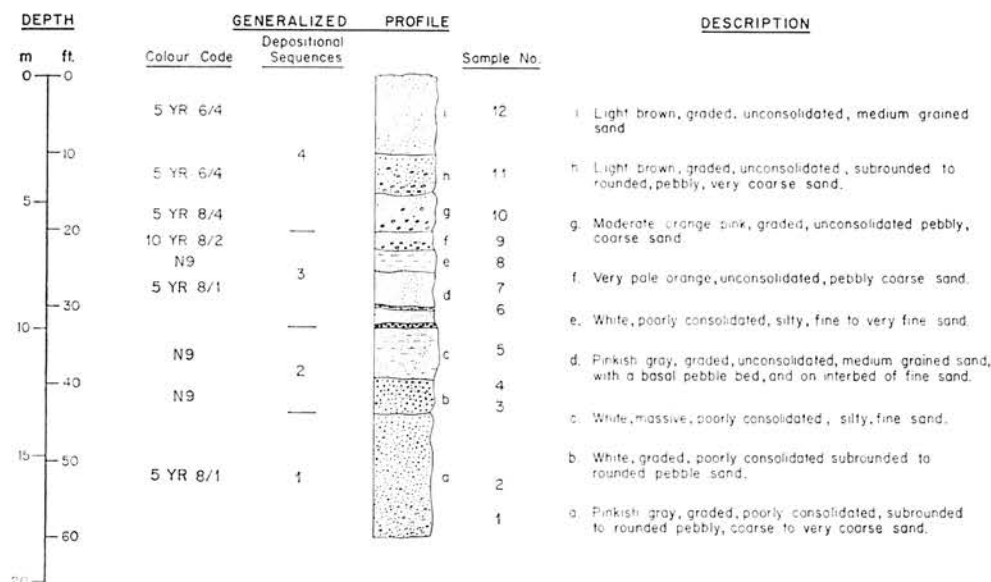

Fig. 7. Generalized stratigraphic profile at locality 18. Government of Malaysia copyright is reserved.

Stratigraphy and sediment texture

The basal sequence was deposited on a relatively even surface of contorted schistose rocks. It consists of about 15 feet of current bedded, graded, pinkish-grey, unconsolidated, very coarse to coarse, subrounded to rounded pebbly sand. The pebbles are hard and resistant quartz, $1\frac{1}{2}$ to 2 cm in diameter, and are relatively more abundant near the base of the unit. The sediment towards the top of this sequence is a slightly finer grained, somewhat better consolidated, coarse grained sand, with scarce quartz pebbles, 1 to $1\frac{1}{2}$ cm in diameter. At the top of this is a sharp contact with the overlying sediments.

The second sequence is about 10 feet thick and consists of two beds. The lower bed is about 4 feet thick and consists of current bedded, white unconsolidated pebbly

sand. The pebbles are grey to white, subrounded to rounded, hard quartz, $1\frac{1}{2}$ to 2 cm in diameter. They are more common in the lower portions of the bed. The upper part of the bed is a pinkish-grey, better consolidated, fine pebbly sand. The pebbles here are of similar quartz, and 5 to 9 mm in diameter. Overlying this sediment across a sharp contact is a second bed about 6 feet thick, consisting of white, massive, poorly consolidated, silty, fine grained sand. At its top is again a sharp contact with the overlying sediments.

The third sequence is about 13 feet thick, and is made of up three main portions. The lowest portion is about 7 feet thick, and consists of graded, pinkish-grey, unconsolidated, medium grained sand. It has a 6-inch thick basal pebble bed, and another 6-inch thick, fine sand interbed. The sediment which overlies the basal pebble bed and surrounds the fine sand bed consists of graded, pinkish-grey, unconsolidated, medium-grained sand. The second portion of this sequence consists of a 3-foot thick bed of white, poorly consolidated massive, silty, fine to very fine sand. The third and top portion consists of a very pale orange, unconsolidated, pebbly coarse sand. The pebbles are pinkish-grey, hard, subrounded to rounded quartz with a maximum diameter of 1 cm.

The fourth sequence is about 20 feet thick, and made up of three distinct beds. The lowest bed is about 4 feet thick, and composed of moderate orange pink, graded, unconsolidated pebbly coarse sand. The pebbles are very pale orange, hard, subrounded to rounded quartz, with a maximum diameter of $1\frac{1}{2}$ cm. The overlying bed is 5 feet thick, light brown, graded, unconsolidated pebbly, very coarse sand. Pebbles are confined to the lower portion of this bed, and are moderate orange pink, subrounded to rounded, hard, resistant quartz, with a maximum diameter of $2\frac{1}{2}$ cm. The topmost bed in the profile is about 11 feet thick, and composed of light brown, graded, unconsolidated, medium-grained sand. Near the top of this bed some organic material is present, and the sediment is a very low grade loam.

Results of analyses (*see Table 2*)

Two samples were collected from the lowest sequence. The lower contains a higher percentage of heavy minerals, but is also considerably coarser grained, poorer sorted, more negatively skewed and more platykurtic than the upper.

Three samples were collected from the second sequence, which consists of two distinct beds. The sediment in the lower bed, represented by two samples, is coarser grained, poorer sorted, more negatively skewed and more leptokurtic than the sediment in the upper bed.

The lowest sample is the richest in heavy minerals, and otherwise differs from the second sample mainly in its poorer sorting. One sample very poor in heavy minerals is from the overlying silty, fine sand bed. The lower bed represents a channel deposit, but the finer sediment in the upper bed was probably deposited in an abandoned river channel, as a channel-fill deposit (Allen, 1965). At this locality, then, the channel sediments contain greater concentrations of heavy minerals than the channel-fill sediments.

Four samples were collected from the third sequence. The highest sample is the only one with a relatively high percentage of heavy minerals. It is a poorly sorted pebbly coarse sand from the top bed of the sequence. This sediment was deposited in a stream channel and is the coarsest grained in this sequence.

Table 2.   Samples from Locality 18.

Depositional Sequence	Sample No.	% Heavy Minerals	Mean ϕ M	Standard Deviation ϕ ϕ	Skewness Sk	K′
4	18–12	0.36	1.47	1.34	0.14	0.528
	18–11	0.20	−0.16	2.14	−0.02	0.505
	18–10	0.81	0.66	1.69	0.03	0.519
3	18–9	1.26	0.78	1.72	0.08	0.522
	18–8	0.20	2.86	1.17	−0.02	0.519
	18–7	0.18	1.36	1.24	0.21	0.528
	18–6	0.06	2.33	1.52	−0.05	0.426
2	18–5	0.08	2.17	1.54	0.04	0.464
	18–4	0.16	0.79	1.41	−0.02	0.533
	18–3	0.97	0.84	2.20	−0.26	0.556
1	18–2	0.66	0.99	1.20	0.03	0.565
	18–1	1.08	−0.63	2.20	−0.16	0.444

The fourth depositional sequence is composed of three beds, and one sample was collected from each bed. The basal sample contains the highest percentage of heavy minerals, and is coarse-grained, poorly sorted and nearly symmetrical. The second sample is even coarser, and more poorly sorted, but contains less heavy minerals.

The figures in Table 2 suggest that coarse, poorly sorted, negatively-skewed sediments tend to have the highest heavy mineral content. But there are conspicuous exceptions, such as the second highest sample, which show again that no simple rules based on size parameters will predict heavy mineral content, even within one sequence.

Locality 38

This locality is about 3.3 miles west of the Kinta River. In general, the alluvial profile consists of three graded depositional sequences (Figure 8). Table 3 gives the heavy mineral percentages and the results of the mechanical analyses of samples from this site.

Stratigraphy and sediment texture

The basal sequence consists of two beds. The lower bed, which overlies porphyritic granite bedrock, is about 4 feet thick, and consists of pale yellowish brown, somewhat carbonaceous, unconsolidated medium and fine-grained sand. Organic fragments about 1 to 2 inches long are dispersed throughout the bed. A few lenses of finer grained, dark yellowish-brown sediment are also present. Over-lying this basal bed is a poorly consolidated (7 foot thick) bed of pale orange, massive, silty fine to very sand. The sediment in this bed is plastic and contains little organic material. It forms a sharp contact with the overlying bed.
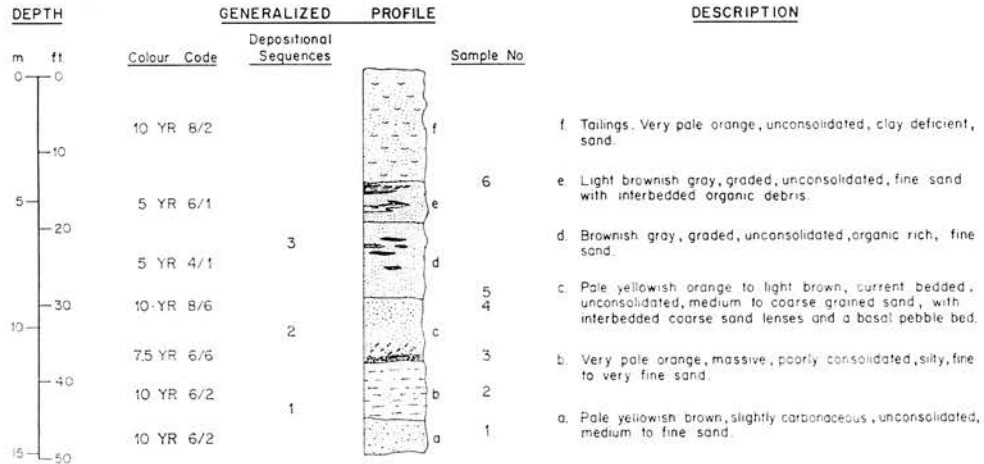
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Fig. 8. Generalized stratigraphic profile at locality 38. Government of Malaysia copyright is reserved.

The second sequence consists of one 8-foot thick bed. The sediment in this bed is pale yellowish-orange to light brown, current bedded, unconsolidated, medium to coarse-grained sand. Lenses of coarser grained sand are interspersed in medium-grained sand. A pebble layer near the base of the bed contains rounded to subrounded pebbles of hard resistant quartz, about 2 cm in diameter. The sediment near the top of the bed is somewhat finer grained.

The third sequence of deposition is represented by two graded beds of brownish-grey, unconsolidated, organic-rich, fine sand. The lower bed is about 10 feet thick and contains considerable organic material inter-bedded with the sand. This organic debris forms a sharp contact with the overlying bed. This second bed is about 5 feet thick, and near its upper horizon is also organic-rich, forming a sharp contact against the overlying mine tailings.

The mine tailings are about 15 feet thick, and consist of very pale orange, stratified, unconsolidated, rather clean medium to coarse-grained sand.

Results of analyses (see Table 3)

Two samples were collected from the first sequence. The lowest sample contains only 0.12 percent heavy minerals. The next higher sample contains 0.37 percent heavy minerals and was collected from finer grained, better sorted, positively skewed, slightly more leptokurtic sediment.

Two samples were collected from the overlying bed. The lower sample contains a slightly higher percentage of heavy minerals than the higher sample. The lower sample is coarser grained, poorer sorted, more negatively skewed, and more leptokurtic than the higher sample. In this particular instance, therefore, the coarser and more negatively skewed sample shows the larger concentration of heavy minerals.

The third sequence consists of two beds, and one sample was collected from each bed. The lower sample, collected near the basal horizon of the lower bed, was fine-

Table 3. Samples from Locality 38.

Depositional Sequence	Sample No.	% Heavy Minerals	Mean ϕ M	Standard Deviation ϕ σ	Skewness Sk	K′
3	38–6	0.02	2.17	0.92	−0.14	0.561
	38–5	0.15	2.33	1.07	−0.31	0.602
2	38–4	0.16	1.44	1.05	−0.12	0.552
	38–3	0.25	1.15	.117	−0.18	0.582
1	38–2	0.37	2.64	1.24	0.19	0.492
	38–1	0.12	1.97	1.56	−0.07	0.492

grained and very negatively skewed. The higher sample, obtained from near the top of the higher bed, was slightly coarser grained and negatively skewed. The two samples show little difference in heavy mineral content, the lower sample containing 0.15 percent and the higher sample 0.20 percent.

STATISTICAL RESULTS

Frequency Distributions

Heavy minerals. Heavy mineral concentrations in the 139 samples range from 0.05 to 3.20 percent. The mean is 0.59 percent, and the standard deviation 0.50 percent. The data form a polymodal distribution curve with the largest clustering of samples occurring between 0.05 and 0.70 percent. Secondary modes were located at about 1.5 percent, 2.0 percent and 3.2 percent.

Mean size. Mean size (M_z) values range between -2.1ϕ and $+2.8\phi$. The mean of the values is $+0.35\phi$, and the standard deviation is 0.55ϕ. The distribution is unimodal, the largest clustering of values being between -0.2ϕ and $+1.6\phi$. This range corresponds to very coarse to medium-grained sand.

Standard deviation. Graphic standard deviation (σ_I) values range from 0.75 to 2.73ϕ-units, and form a unimodal distribution. The mean standard deviation is 1.35ϕ-units and corresponds to poorly sorted sediment. Two-thirds of the samples had values between 1.05 and 1.65ϕ-units. It is interesting to note that these values are considerably larger than those expected from beach deposits.

Skewness. Skewness (Sk_I) values range considerably, from -0.36 to $+0.44$, and form a unimodal distribution. The values have a mean of $+0.09$, and a standard deviation of 0.10. Thus two-thirds of the values are between -0.01 and $+0.19$. Most of the samples are fine skewed (positive).

Skewness values have been recognized as sensitive to environments of formation. Most river sediments ,with a few exceptions, have been found to be positively skewed (Friedman, 1961; King, 1966). This positive skewness is believed to result from the un-

idirectional character of the transporting medium (King, 1966). In contrast, due to winnowing processes active in a beach environment, beach sands usually are negatively skewed (King, 1966).

Kurtosis. The normalized graphic kurtosis (K'_G) has been used in the analysis of the data. These values range from 0.42 to 0.61 (K_G: 0.72 to 1.56), and form a trimodal frequency curve. The (K'_G) values have a mean of about 0.50 ($K_G = 1.0$), with a standard deviation of 0.03. Two-thirds of the (K'_G) values fell in the 0.47 to 0.53 (K_G: 0.89 to 1.13) range, which corresponds essentially to the mesokurtic class.
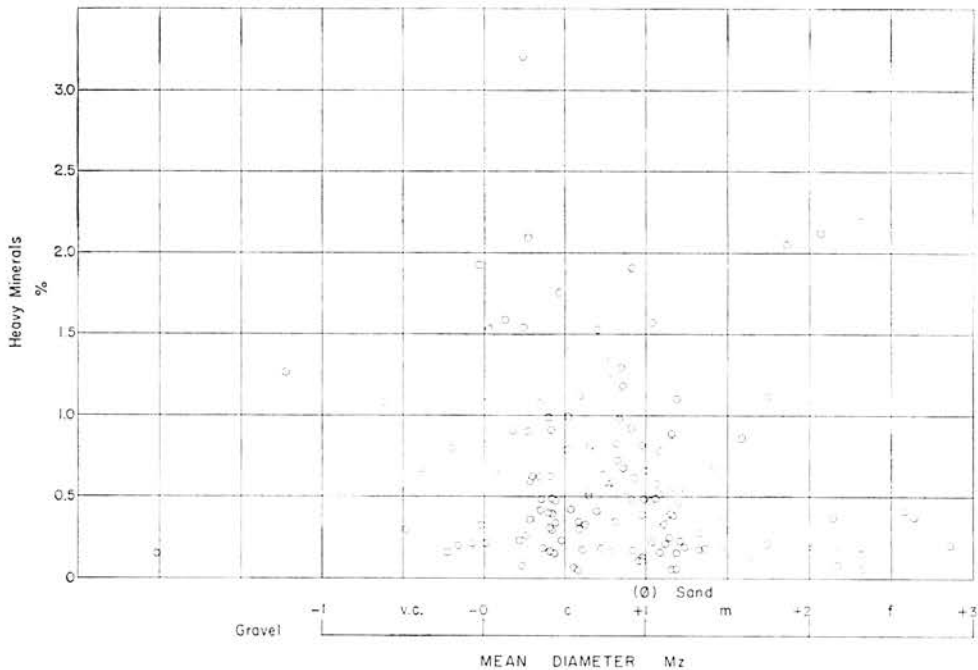

Fig. 9.   Scatterplot diagram of heavy mineral content versus mean size (Mz). Government of Malaysia copyright is reserved.

Parameters Versus Heavy Mineral Percentage

Mean size vs. heavy mineral percent. Figure 9 is a scatter-plot diagram of mean size (M_z) versus the heavy mineral percentage. The range of the points is considerable, but some evidence exists for higher concentrations of heavy minerals in coarser grained alluvium. Out of ten samples with a mean size (M_z) finer than $+2\phi$, only 1 has more than 0.5 percent heavy minerals, whereas of 78 samples in the $+1\phi$ to 0ϕ range, 42 have heavy mineral percentages greater than 0.5 percent.

Standard deviation vs heavy mineral percent. Figure 10 is a scatterplot diagram of the standard deviation (σ_1) values versus the heavy mineral percentages. Out of 139 samples, all but 11 are within the poorly sorted range (σ_1 from 1 to 2). Within this relatively narrow range there is little evidence of any trend or relationship between these two variables.
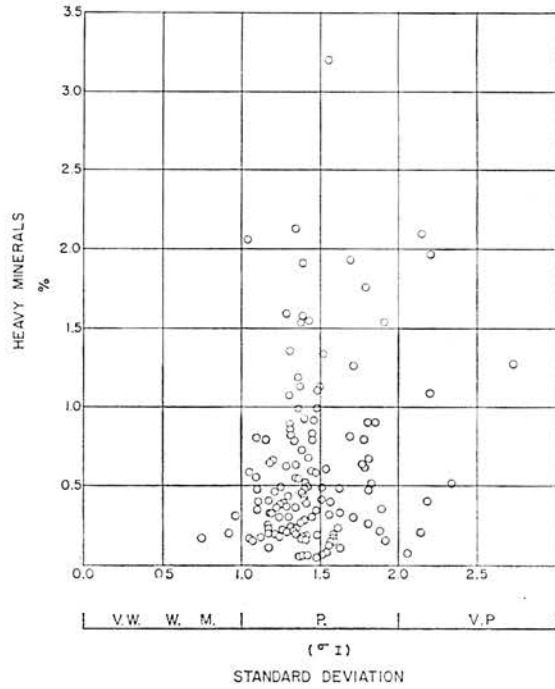
Fig. 10. Scatterplot diagram of heavy mineral content versus graphic standard deviation (σ). Government of Malaysia copyright is reserved.
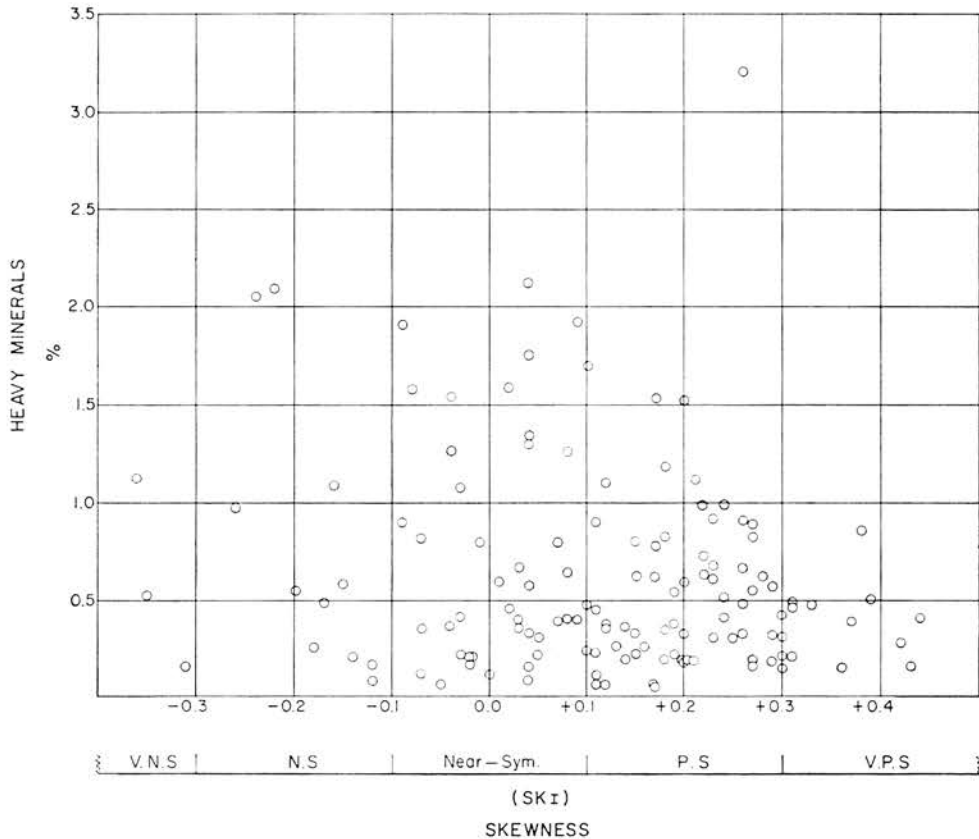

Fig. 11. Scatterplot diagram of heavy mineral content versus graphic skewness (Sk$_1$). Government of Malaysia copyright is reserved.

Skewness vs heavy mineral percent. Figure 11 is a scatterplot diagram of skewness (Sk_1) values versus the heavy mineral percentages. As was noted above, the majority of the skewness values (Sk_1) are positive. The range of values shown in figures 11 is wide, but the major trend suggests samples with low or negative skewness (Sk_1) values have better chances of containing higher heavy mineral concentrations than samples with high Sk_1 values.

Kurtosis vs heavy mineral percent. Figure 12 is a scatterplot diagram of the normalized kurtosis (K'_G) values versus the heavy mineral percentages. This scatterplot shows no strong relationship, but slight tendency for the samples richest in heavy minerals to be in the central part of the Kurtosis range, that is mesokurtic or midly leptokurtic.
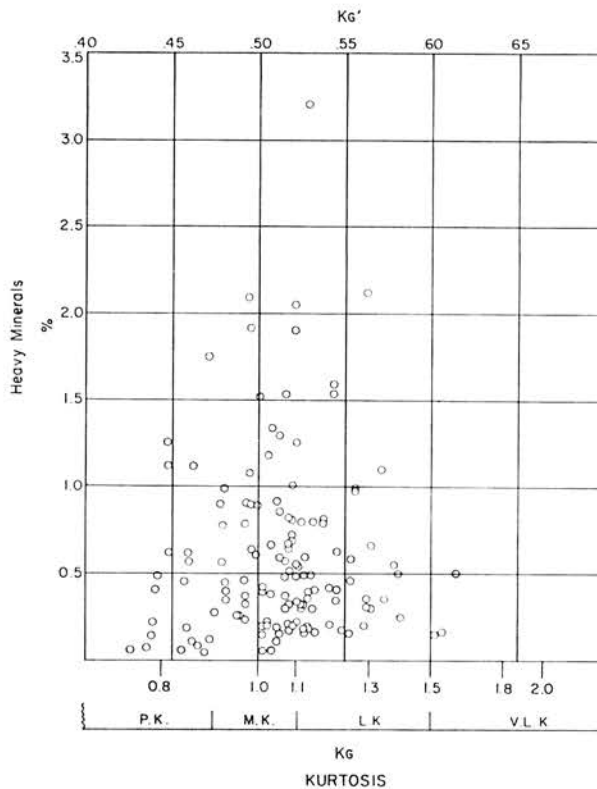

Fig. 12.   Scatterplot diagram of heavy mineral content versus graphic kurtosis (K_G and K'_G). Government of Malaysia copyright is reserved.

Statistical Summary

From the above data and discussion it is apparent that no single parameter can be consistently associated with and related to heavy mineral concentrations. The parameters do measure certain characteristics of alluvial sediments, but these evidently do not relate in a simple manner to heavy mineral percentages.

Certain trends mentioned above are useful, however, in stating general characteristics of the alluvium. Evidence exists that greater percentages of heavy minerals might be expected in relatively coarse-grained sediments. There is also evidence that samples with low skewness values may contain relatively high percentages of heavy minerals. If these two trends are valid they could be somewhat useful to the alluvial prospector. Mean size values would tend to increase towards the source of the sediments. Sediment with low skewness values would be expected more frequently in lateral accretion (channel) deposits than in vertical accretion (topstratum) deposits.

The parameters studied lack a high correlation with heavy mineral concentrations, and therefore further research is necessary to establish a "heavy mineral sensitive" parameter. Such a parameter might be a combination of grain size data, distance from the source, height of the sample above bedrock, heavy mineral grain size, and perhaps other factors. Such a parameter would be of considerable use in the exploration for and exploitation of alluvial minerals.

GENESIS OF THE KINTA VALLEY ALLUVIUM

This interpretation of the depositional environment is generally based upon sedimentary characteristics of the alluvium. The most diagnostic characteristics are considered to include:
  (1) characteristic features of lateral and vertical accretion deposits;
  (2) the widespread presence of peat deposits;
  (3) small scale current structures; and
  (4) predominance of medium to coarse-grained sandy sediments that are commonly poorly sorted and positively skewed.

The existence of features suggesting bed-load (including channel-bar and point-bar) deposits and top-stratum deposists strongly suggests a fluviatile origin for the valley sediments. These structures are found both near the granite margins and further out in the valley, and their widespread occurrence further suggests that stream activity has been very widespread in the valley.

Peat and other organic deposits are well documented in the Kinta Valley. These deposits suggest a humid climate that was capable of producing a dense flora, such as exists in areas surrounding the valley today.

The widespread occurrence of peat and the presence of large volumes of medium to coarse-grained, poorly sorted, alluvial deposits indicates the depositing streams were probably of low velocity, medium size, perhaps aggrading, and carrying bed-loads of medium to coarse-grained sand. Large volumes of suspended material must have been present to allow the development of the topstratum deposits. The medium to coarse-grained stream loads fostered the development of channels with straight to transitional sinuosities (Schumm, 1963). Such streams were perhaps somewhat free to migrate, and to develop flood plains of low relief (Allen, 1965).

Hence, the development of the valley sediments is considered to have been from a fluvial origin. This interpretation is supported by the assembled evidence above, which was based upon structure, texture and composition of the alluvial sediments.

CONCLUSION

The Kinta River has a gentle gradient of about 5 feet per mile, but the slope of the bedrock is on the order of 10 feet per mile. The sinuosity of the river was determined to be transitional between a straight and a regular meandering channel.

General features of the alluvium include a maximum of four depositional sequences, eluvial and/or alluvial granite wash, peat and other organic deposits, stratified sand, silt and clay sequences, and mine tailings.

Laboratory results indicate that of the parameters examined mean size and skewness values are the most sensitive to the heavy mineral percentages. There is an indicated need for a single heavy mineral sensitive parameter.

The alluvial deposits in the Kinta Valley display a wide range of features that could have originated from fluvial processes. The placer tin deposits are thus believed to have formed under fluvial conditions. This origin should be considered when planning exploration programs.

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