An Analysis of Basin Asymmetry in the Klang Basin, Selangor

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Abstract: An analysis of the fourth order topographic basins within the drainage system of the Sungei Klang reveals that a number of them are asymmetrical. Basin asymmetry appears to be a reflection of structural control since the direction of maximum asymmetry follows certain preferred alignments, of which 30°, 105° and 140° are the most important. A distribution analysis using the nearest neighbour test indicates that those asymmetrical basins which follow the 105° direction have a tendency towards agglomeration. They are therefore distinctive compared with the basins aligned in other directions . which are distributed randomly. It is suggested that the randomly distributed basins have been superimposed and that their alignment partially reflects the geological conditions of rocks since removed by denudation, and that the basins aligned along 105° are the result of subsequent adjustments of the drainage to the present geological conditions.

INTRODUCTION

The Sungei Klang rises on the western slopes of the Banjaran Besar (Main Range) near Bukit Repin (4,400 feet) and flows south-westwards before being joined by the Sungei Gombak at Kuala Lumpur. In this paper the term Klang Basin is taken to include the Sungei Klang and all its tributaries. The basin lies within the western rainfall region of West Malaysia (Dale, 1959) and has a bimodal regime with peak flows coinciding with the rainfall maxima of April–May and October–November.

The highest land is in the north and north-west of the basin where igneous rocks form a dissected terrain with local relief as great as 2,000 feet. The central part of the basin consists of the Kuala Lumpur lowlands surrounded by low convex hills formed of granites and sedimentary rocks; the basin relief is as low as 400 to 600 feet. The lower parts of the basin form gently sloping and flat lands with local relief less than 200 feet.

GEOLOGY

The geology of the basin is varied and complex. Broadly there are igneous and metamorphic rocks in the north and north-east with a ridge of granite extending southwards to the west of Petaling Jaya. Sedimentary rocks form the southern and western parts of the basin (fig. 1).

Granites

These are a complex of porphyritic, biotite-, muscovite-, and pyroxene-bearing granites which were intruded into older sedimentary sequences in Mesozoic times.
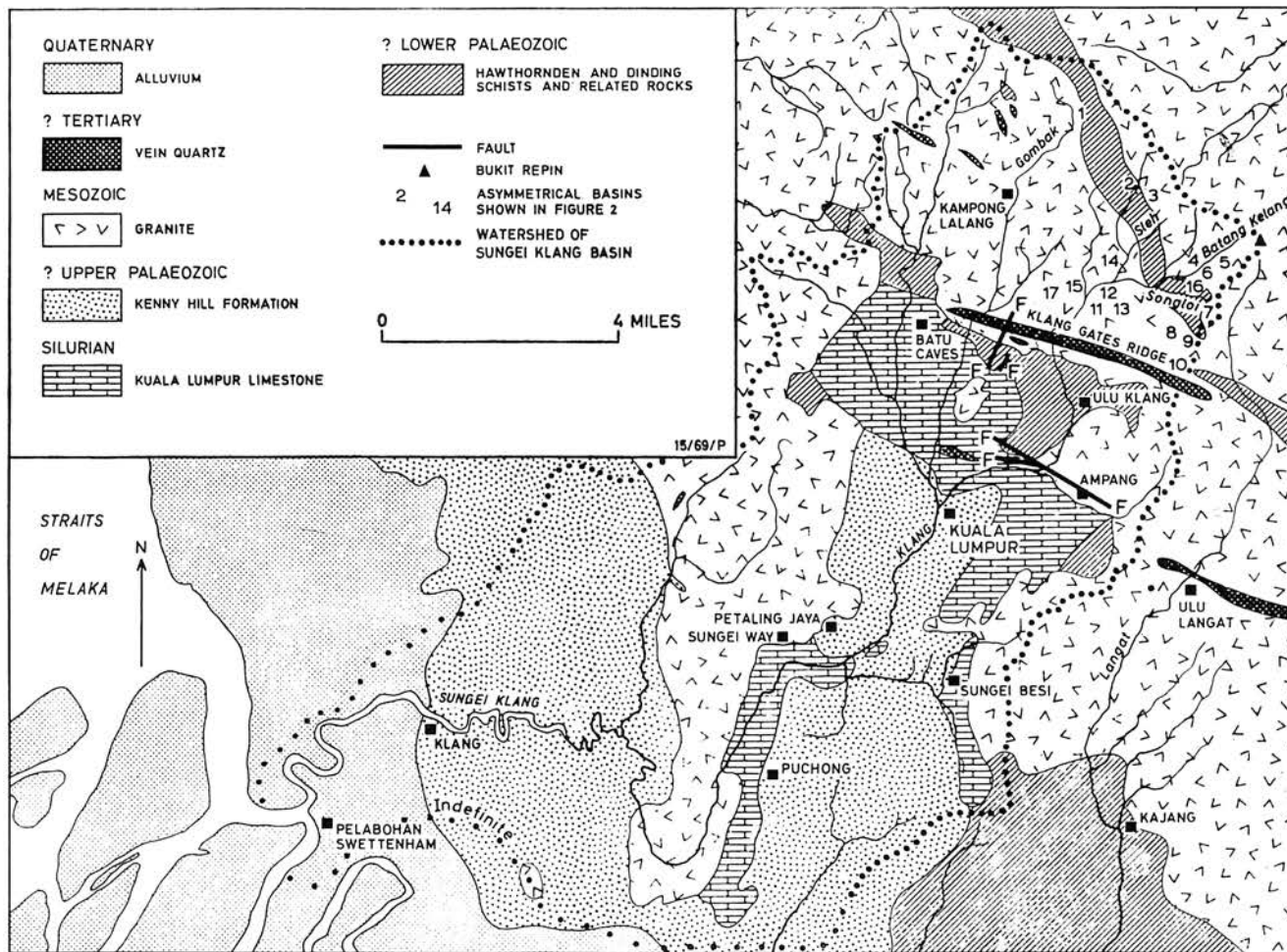
Fig. 1. Sketch geological and location map of the Sungei Klang Basin based upon Alexander (1956, 1965), Gobbett (1964) and Roe (1950).

A well established joint pattern is present and Alexander (1968) has observed three main sets of joints in the Bentong area, about forty-five miles north-east of Kuala Lumpur. Two of these joint sets trend east-southeast to east and north to northeast.

Quartz dykes

Vertical dykes of vein quartz occur within the granite along a marked 105° alignment. The most prominent of these later intrusions forms the Klang Gates Ridge which is breached by both the Gombak and the Klang.

Schists

Quartz-mica schists are overlain by graphite-bearing schists and they form an important outcrop south of the Klang Gates Ridge between Ulu Klang and Ampang.

Limestones and dolomites

These rocks together comprise the Kuala Lumpur Limestone. According to Gobbett (1964) they are Silurian in age and lie on top of the schists. The limestone forms a karst plain beneath alluvium in the structural basin of Kuala Lumpur and a residual forms the prominent hill mass at Batu Caves in the north of the basin.

Kenny Hill Formation

This unit consists of rudaceous, arenaceous and lutaceous sedimentary rocks in unknown stratigraphical sequence. The strata are mildly folded and faulted.

Superficial deposits

The western portion of the Klang basin and the Kuala Lumpur lowlands are covered with river alluvium laid down in the Quaternary. The rises in sea-level which accompanied each retreat of the higher latitude ice masses caused the rivers to aggrade their channels far inland with a consequent flattening of the lower and middle reaches of their long profiles.

BASIN ASYMMETRY

The asymmetry of low order drainage basins within the Klang basin was analysed with reference to fourth order sub-basins classified according to Strahler's system of stream numbering (1957, fig. 3). The identification of the basins was carried out on 1:63,360 maps of the Malaysian Survey (New Series, sheets 86, 93 and 94), which are known not to show first order channels. For most purposes their absence can be ignored (Leopold, Wolman and Miller, 1964, p. 141) and analysis may begin with the second order. Eyles (1966) indicates that a correction factor of one order must be applied to the stream network as depicted on Malaysian maps and this procedure has been followed.

The index of basin asymmetry which was used is based on the work of Schumm and Hadley (1961) and is defined as the ratio of 'x', the maximum lateral distance from the main drainage channel to the southern or western divide, to 'y', the maximum lateral distance from the same channel to the northern or eastern divide. In this paper the main drainage channel is the fourth order stream segment extended upstream along the longest third and then along the longest second and first order segments. A symmetrical basin has an index of 1.0 and basins showing marked asymmetry in the position of their trunk streams have indices of less than 0.5 or greater than 2.0.

Seventy-five fourth order basins were studied within the Klang basin and twenty-eight were found to be asymmetrical. These were located on both crystalline and sedimentary rocks. The occurrences within the Kenny Hill Formation were widely
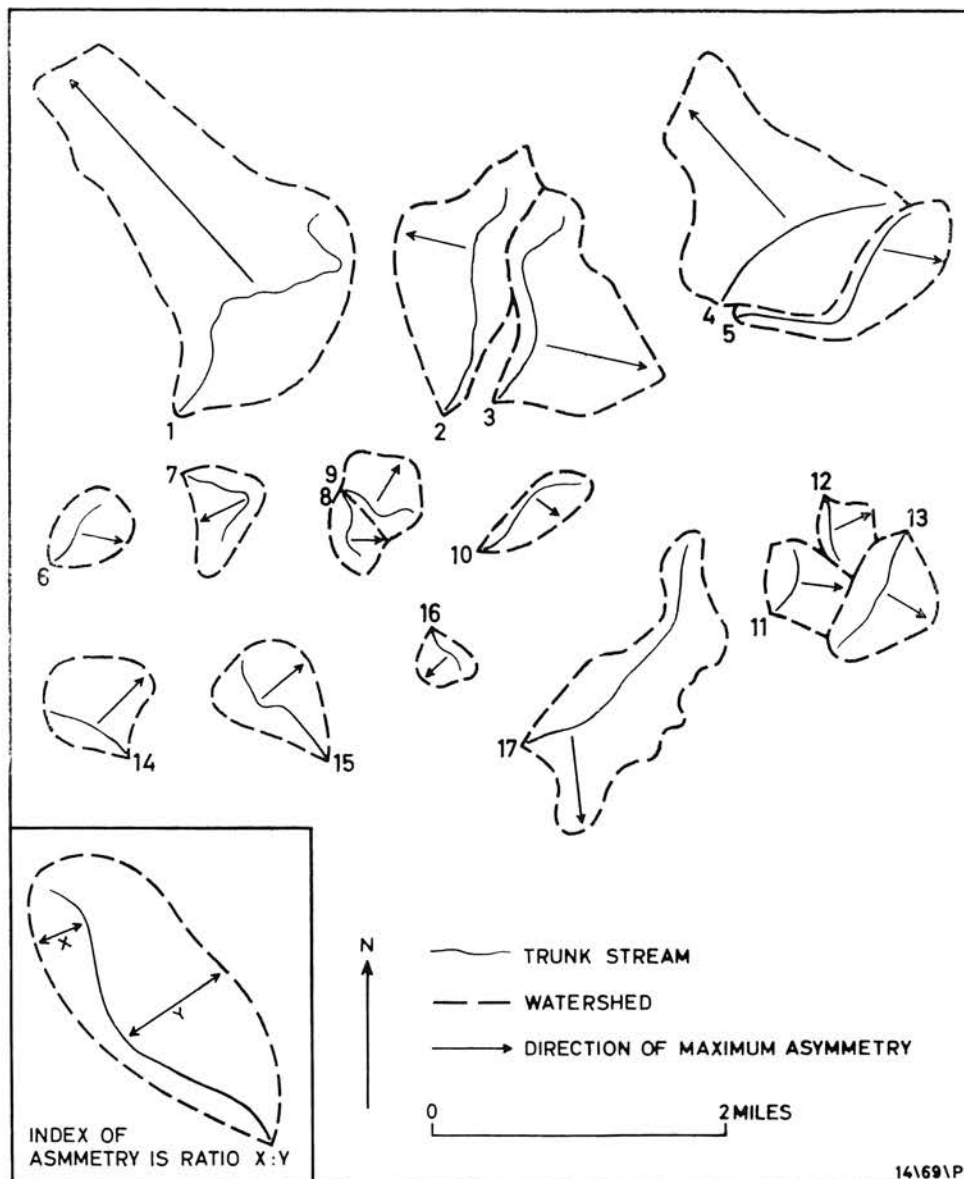

Fig. 2. Directions of asymmetry in fourth order basins located within the Klang basin. Inset shows the derivation of the index of asymmetry as the ratio x/y, where x is the maximum lateral distance between the main stream and the southern or western divide and y is the maximum lateral distance between the stream and the northern or eastern divide.

scattered in location and so attention was focused on those found within the granitic rocks of the upper Klang basin.

Distribution of asymmetrical basins

Within the upper Klang basin there are seventeen asymmetrical basins out of a total of forty-seven fourth order basins analysed. A location map of the trunk streams within the asymmetrical basins showing the direction of maximum asymmetry (fig. 2) by arrows reveals that the asymmetrical development of the basins closely follows certain alignments, of which three stand out as important: 30°, 105° and 140°.

The 105° alignment is known to correspond with a number of lithological boundaries within the Kuala Lumpur area (Stauffer, 1968). The Klang Gates Ridge follows this direction as do a number of faults, including the Ampang Fault to the south of the ridge. A second quartz ridge to the south-east in Ulu Langat is also in this alignment. The 30° alignment occurs elsewhere within the Banjaran Besar and Alexander (1968) finds it in the granitic rocks near Bentong; the Gombak Fault also follows this direction. The 140° alignment is less common outside of the Klang basin but may be interpreted as the 'grain' alignment to the 30° 'rift' direction, assuming these lineaments to correspond to a conjugate system of joints or shear planes (Holmes, 1965).

An examination of the drainage pattern of the whole of the upper Klang basin shows that these alignments are noticeable outside as well as inside the asymmetrical basins. A detailed study was made of a small area within the Klang basin, namely the area immediately surrounding the Klang Gates Ridge. Because of the limitation in terms of area size, the analysis was restricted to topographic basins of the third order. Delimitation of the basins was based on the 1:25,000 scale maps of the Malaysian Survey (sheet 94k) and on aerial photographs of the same scale. The latter were necessary to plot the stream pattern down to the detail of the rills which the smaller scale maps do not show. No asymmetrical basins were found, but the control exerted by the alignments on the drainage pattern is very clear. Some 58 per cent of the streams follow one of the three dominant alignments. The 30° direction is the most important, followed by the 105°, whilst the 140° alignment is relatively less marked (Table 1). The 30° and 140° directions tend to occur in the second and third order segments, that is in the main stream channels, whilst the 105° direction affects largely the first order segments and rills (fig. 3). Such a pattern is true of the drainage network of the whole of the upper Klang.

Table 1. Frequency of alignments of stream channels in the area of the Klang Gates ridge.

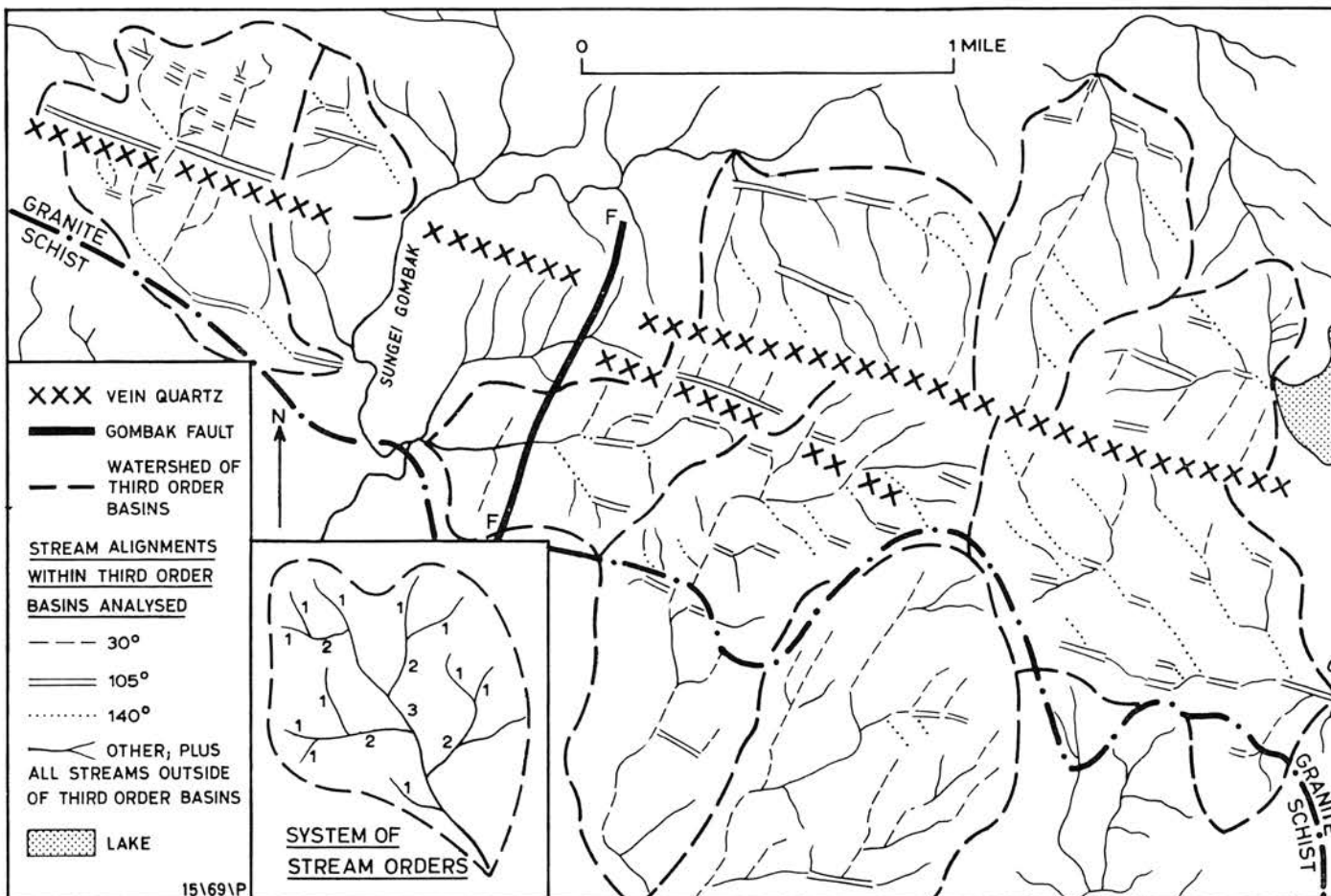| Alignment	Total length (miles)	Percentage of total length
30°	9.35	23%
105°	7.90	20
140°	6.00	15
Other	17.20	42
Total:	40.45	100

Fig. 3. Drainage features of the Klang Gates Ridge based on map and aerial photograph interpretation. Inset shows Strahler's system of stream ordering: all unbranched tributaries are first order; a second order is formed at the confluence of two first order streams; a third order at the confluence of two second order streams and so on.

The asymmetrical basins were divided into two groups on the basis of (a) those in the 105° alignment and (b) those in the 30° and 140° alignments. The distribution of the basins in each group was analysed by the nearest neighbour method (Getis, 1964) which compares the actual or observed distribution with an expected or random one. The procedure which was followed was to locate the asymmetrical basins in each group on a 1:63,360 scale map and to measure the distance from the mouth of each basin in a straight line to the mouth of the next nearest basin (its nearest neighbour). The average distance of the nearest neighbour is then calculated (rO). The expected or random distribution pattern of the asymmetrical basins is obtained by delimiting all the fourth order topographic basins within the upper Klang on a map of the same scale (1:63,360) and giving each basin an index number. Random number tables are then used to select an equal number of basins as were observed to be asymmetrical. These are taken to represent the expected distribution pattern of asymmetrical basins if they were developed randomly. The average distance of the nearest neighbour is then calculated for this expected distribution (r̄E). The nearest neighbour ratio (R) represents r̄O/r̄E, where r̄O is the average distance of the nearest neighbour in the observed distribution and r̄E is the average distance of the nearest neighbour in the expected distribution. A value of R equal to 1.0 indicates that the observed data are distributed randomly. Values less than 1.0 show a tendency towards agglomeration and ratios approaching 2.0 indicate a tendency towards dispersion. The method unfortunately has no significance test.

Table 2. Distribution analysis of the asymmetrical basins by nearest neighbour.

Alignment	Number in Sample	r̄O	r̄ E	r̄O/r̄E
105°	7	1.1	1.6	0.69
Other	10	1.6	1.5	1.07

r̄O = average distance of nearest neighbour (in miles) of the observed data.

r̄E = average distance of nearest neighbour (in miles) of the expected data in a random distribution.

The results of the nearest neighbour analysis (Table 2) show that the basins aligned along the 30° and 140° directions are distributed randomly, whereas those whose asymmetry follows the 105° direction tend towards agglomeration. An explanation of this distinction may be made on the assumption that drainage basins evolve in a random manner. Random walk tests (Leopold, Wolman and Miller, 1964, pp. 416–420) indicate that a theoretical and random evolution of drainage is closely adhered to by real drainage nets. Asymmetrical development of basins due to streams following chance lines of weaknesses such as joints and shear planes may therefore be expected to occur randomly, assuming the planes themselves to be distributed randomly. The drainage network is assumed to have evolved in this way on the slopes of the Banjaran Besar so that certain trunk streams became adjusted to the structural patterns along the 30° and 140° alignments. The control exerted by the 105° alignment is interpreted as a later development associated with the Kuala Lumpur fault zone, so that basins whose directions of asymmetry lie along this alignment are concentrated within the fault zone. Further, this alignment is largely ignored by the already established trunk streams and is followed by small tributaries developed later by headward extension along the lines of weakness.

APPLICATION TO DENUDATION CHRONOLOGY

The drainage nètwork of the Sungei Klang and its tributaries is in a 'steady state', as evidenced by the low dispersion of the bifurcation ratios of fourth order sub-basins about the mean value (Table 3). The bifurcation ratio analysed in this instance is the ratio between the number of second order segments in each basin and the number of third order streams as delimited on the 1:63,360 map sheets. The drainage pattern is closely adjusted to structure. In the upper part of the basin, on the crystalline rocks, the streams follow the alignments indicated above. The main tributary streams converge into the structural basin of the Kuala Lumpur lowlands. The drainage on the sedimentary rocks has a marked trellis pattern with basically north-south flowing sections, such as those between Kuala Lumpur and Petaling Jaya and again between Sungei Way and Puchong. Transverse to this direction are the east-west sections such as those between Petaling Jaya and Sungei Way and west of Puchong.

Table 3.   Bifurcation ratios of fourth order basins within the Klang Basin.

Number in sample	Mean bifurcation ratio	Standard Deviation
85	3.70	1.01

The bifurcation ratio is the number of streams of a given order in relation to the number of streams of the next highest order, expressed as $Rb = N_u/N_u + 1$, where R_b is the bifurcation ratio, N_u is the number of streams of a given order and $N_u + 1$ is the number of streams of the next highest order.

In spite of this general adjustment to structure there are a number of instances of discordance in the drainage net. Both the Gombak and the Klang breach the quartz ridge of Klang Gates. The case of the Gombak is interesting in that it does not follow the line of weakness of the Gombak Fault but crosses the ridge to the west of it. The Klang crosses the granite again in its lower course, west of Puchong.

The most likely explanation of the present drainage pattern is that of super-imposition. Streams would have started flowing as soon as the area rose above the sea in the Mesozoic era, at which time the granites lay intruded beneath as sedimentary cover. In time the drainage net developed on this cover was let down on to the underlying granitic rocks. The original stream pattern was most probably initiated on a cover of arenaceous rocks, similar to the Kenny Hill Formation and would have been let down on to the Kuala Lumpur Limestone and then on to the schists before ultimately reaching the granite.

The most probable drainage pattern on the sedimentary cover would have been a trellis network, and once the streams had removed the cover, their courses would have started to become adjusted to the structure of the schistose rocks. The trellis pattern would be broken up and a new pattern would gradually emerge. The analysis of the stream net on the schists to the south of the Klang Gates Ridge suggests that the 30° and 140° alignments are the dominant directions taken by the drainage on this rock. The 105° alignment is not common on the schists. It is suggested that this alignment is a later adjustment which took place when the drainage net was let down on to the granites, and that the alignment control is sufficiently strong within the Kuala Lumpur fault zone to have caused some basins to develop asymmetrically.

The trunk streams in the second and third order are therefore adjusted to a different alignment from their first order tributaries, the former representing the conditions of the schist cover and the latter the present conditions.

Some evidence of the original trellis pattern still survies in the upper part of the Klang basin. The Sungei Gombak has a marked north-south section in its course between Kampong Lalang and Batu Caves. The Sungei Klang takes an east-west course from the confluence of the Sungei Batang Kelang and Sungei Songloi to the confluence with the Sungei Sleh. The presence of these segments within an area where the streams are generally aligned to the structure is indicative of a former trellis drainage being broken up by new adjustments.

It is possible to postulate that all the structural alignments reflect conditions on the granite only. In his case, the 30° and 140° alignments reflected structural controls distributed randomly within the granite and the 105° direction corresponds to more recent movements along shear planes within the fault zone complex. This evolutionary sequence is considered less likely since the drainage network has attained a 'steady state' which recent fault-movements would be expected to have disrupted. It may be argued that under tropical climate conditions adjustments changing structural influences would be rapid and that following minor earth movements, the drainage would quickly re-attain its 'steady state'. However, the speed with which such adjustments occur may be slower than anticipated. The long period of weathering in situ which the rocks undergo in a tropical climate reduces all but the most resistant minerals to particles smaller than sand grain size. The further reduction of this material within the rivers is effected more rapidly through solution than by mechanical abrasion (Douglas, 1968). The size of the river's load is therefore such that the river possesses little abrasive power with which to erode and make fresh adjustments to its course. Even in mountainous terrain, where the bed load is coarser, the rivers cannot be expected to make rapid adjustments to new conditions.

It is most probable that some alignments are common to both the schists and the granites. Recent work by Dr. H.D. Tjia and by Mr. J.D. Bignell (personal communications) shows, for example, that the 30° direction is commonly followed by lineaments in the granites of Selangor.

The stream patterns found within the upper Klang basin consequently display evidence of all three stages in their superimposition: a trellis pattern developed on the original sedimentary cover; a pattern adjusted to alignments in the schists on which certain basins developed asymmetrically; and finally an adjustment to shear planes in the granitic rocks, sometimes along the same alignments as found in the schistose rocks, but with further asymmetrical development concentrated within the Kuala Lumpur fault zone. In the lower Klang the superimposition process is still taking place and the stream patterns remain adjusted to the structures of the sedimentary rocks, except that west of Puchong superimposition of the river across the granite has occurred. The evidence afforded by basin asymmetry analysis shows that certain structural controls manifest themselves in the stream pattern and that these developments reflected stages in the evolution of the drainage network.

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