BULLETIN NO. 4

Geological Society of Malaysia

June 1971, pp. 39 – 48

Joint Pattern and Faulting in Kinta, West Malaysia

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Abstract: The Kledang Range is interpreted as a granite horst. Its faulted boundary with the Kinta Valley has been later cut and offset by many minor wrench faults with a dominant northwesterly strike produced by an approximately east-west directed compressive stress. Other observed lineations are interpreted as conjugate shear joints and/or lateral shears forming second or third order structures associated with the wrench faults and also with possibly major northwesterly striking wrench faulting postulated elsewhere in West Malaysia. Quartz dykes have widened original tension joints. Some vertical movement in northwest striking fault planes is evidenced by the contours of the sub-alluvial valley floor and the watershed which crosses the northern part of the valley.

The Kinta Valley has aroused the interest of geologists from the time it first became known to them, about 1880, and its extraordinary richness in tin ore has long been known and exploited. Earlier interpretations of the structure and stratigraphy of Kinta were conflicting and were argued long and bitterly before an independent view was sought (Rastall 1927a, b). I wish neither to resurrect these arguments nor to start a fresh controversy but I cannot accept that all the problems involved have been settled. One of these problems is whether the form of the Kinta Valley is controlled by major faults or is essentially a fold structure. I contend that there is at least one major fault and would like to present the evidence in favour of this view.

In its general outline the geology of Kinta would seem to be well understood (Ingham and Bradford, 1960). The south-southwest trending valley is floored by crystalline limestone and locally important argillaceous strata. These are folded and often steeply dipping or overturned. They are entirely covered by a blanket of alluvial deposits except where this has been removed in opencast tin mines and where erosion has left residual limestone hills, isolated or in groups, rising precipitously from the surrounding alluvial plain. The valley sides are distinctly marked by a change in slope, formed to the east by the Main Range granite, and to the west by the granite of the Kledang Range.

These granites coalesce to the north and both appear to belong to the same intrusive episode. There is no marked difference in their chemistry or mineralogy (Ingham and Bradford, 1960, p. 55–60) and radiometric dates from the two granites are in close agreement. A Potassium-Argon age on biotite from the Kledang granite of Papan Quarry has been determined as 203×10^6 years and a whole rock Rb/Sr age on the same sample as 200×10^6 years. (N.J. Snelling, in correspondence). Recently, dates obtained from the Main Range granite included fine and coarse-grained granite from Kuala Dipang (200 and 230×10^6 years respectively); granite from Kampar ($180-200 \times 10^6$ years); pegmatite from Ampang New Village (200×10^6 years); and granite from the Cameron Highlands road (200×10^6 years) (J.D. Bignell, in correspondence). These dates place the granite intrusion at the very end of the Triassic according to recent estimates of the absolute age of the Triassic-Jurassic boundary (J.D. Bignell, in correspondence).

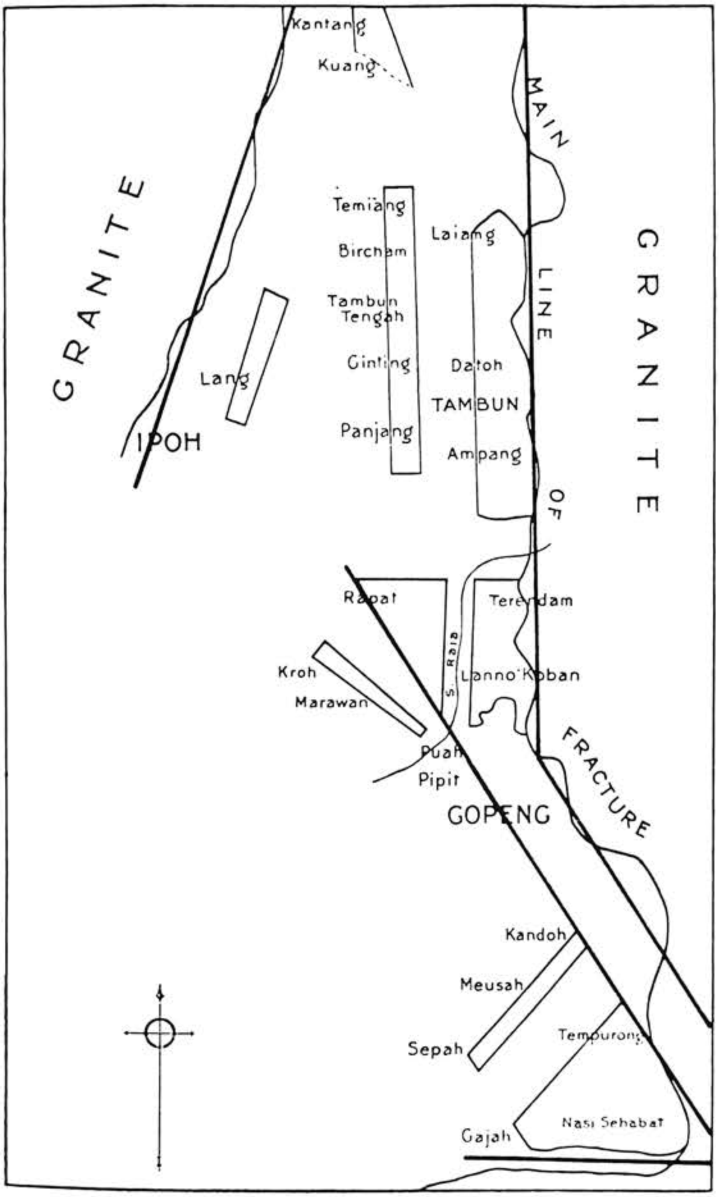

Fig. 1. Sketchmap showing lineation of limestone hill groups in Kinta and their relationship to the granite margins. Modified from Scrivenor (1913).

The nature of the granite boundary

The outcrop of the granite surface is known in some detail because of the frequent siting of tin mines near the limestone-granite contact. The nature of the contact has been discussed briefly by a number of authors. Scrivenor (1913) postulated that it was faulted on both east and west sides of the Kinta Valley. This followed from his erroneous assumption that the Gopeng Beds and associated alluvial deposits were 'Gondwana Clays' older than the granite. Thus the position of these clays around the bases of the limestone hills could be best explained by the presence of faults delimiting the hills or groups of hills. Scrivenor (1913) showed that the strike of these faults coincided with the general strike of the granite boundary surface (fig. 1) which was therefore itself faulted.

In later publications Scrivenor referred to the fault-bounded nature of the limestone hills in Kinta but gives no further discussion of the granite boundaries. However Rastall (1927b, p. 426) referred to the western side of the Kinta Valley as ". . . . a great fault or system of faults, which, broadly speaking, bounds the foot of the Kledang Range . . .". It is the site of a deep trough filled with alluvium rich in tin ore. Much of this ore is probably residual since lode tin ore in Kinta seems to be confined to the valley sides, along the granite contact (Willbourn, 1924). The deep trough formed along the contact on the west side of the Kinta valley could have been formed by intense solution of the limestone by ground water at the base of the granite ridge, perhaps increased by the production of sulphuric acid from the weathering of sulphides concentrated along the contact as suggested by Ingham (1949). However there appears to be no similar trough along the east side of the valley where a greater catchment area is present. Alternatively the trough could be explained by the presence of a fault. Major trough-like depressions in the limestone surface as opposed to cup-like depressions, are frequently associated with faults. A typical example in Tronoh Mine was described by Scrivenor (1913, p. 66–8).

The latest major work on Kinta geology dismissed the concept of a faulted granite boundary. The arguments against it were the correspondence of the strike of folds in the limestone with the outline of the granite and the complexity of the granite-limestone contact which, where exposed, appeared to be a normal intrusive one. (Ingham and Bradford, 1960, p. 83–5).

Our knowledge of the detailed structure and stratigraphy of the Kinta limestone is very incomplete but the strike on the western side of the valley is not particularly consistent with the granite boundary and in general, the beds strike north-south, or a little to the west of north. In the southern part of the valley near Kampar, the strike is north-northwest (Suntharalingham, 1968) and the beds young to the west. Repetition of two formations in this area indicate the presence of a strike fault, the Kampar Fault. The north-northeast trending Kledang granite can thus be seen to be discordant to the general structure of the country rock. Its eastern boundary is one of the most prominent topographic features of Kinta, rising steeply and abruptly from the valley side along a remarkably straight line some 29km (18 miles) long. This feature strongly resembles a fault scarp. The mapped contact shows departures from a straight line but these are for the most part small, mainly aligned northwest or west-northwest, and contrast with the grosser indentations of the granite outline of the east side of the valley. However the latter may be faulted in places: from near Gopeng south to the Chenderiang valley a prominent lineation divides the granite of Bujang Melaka from the main mass of granite to the east.

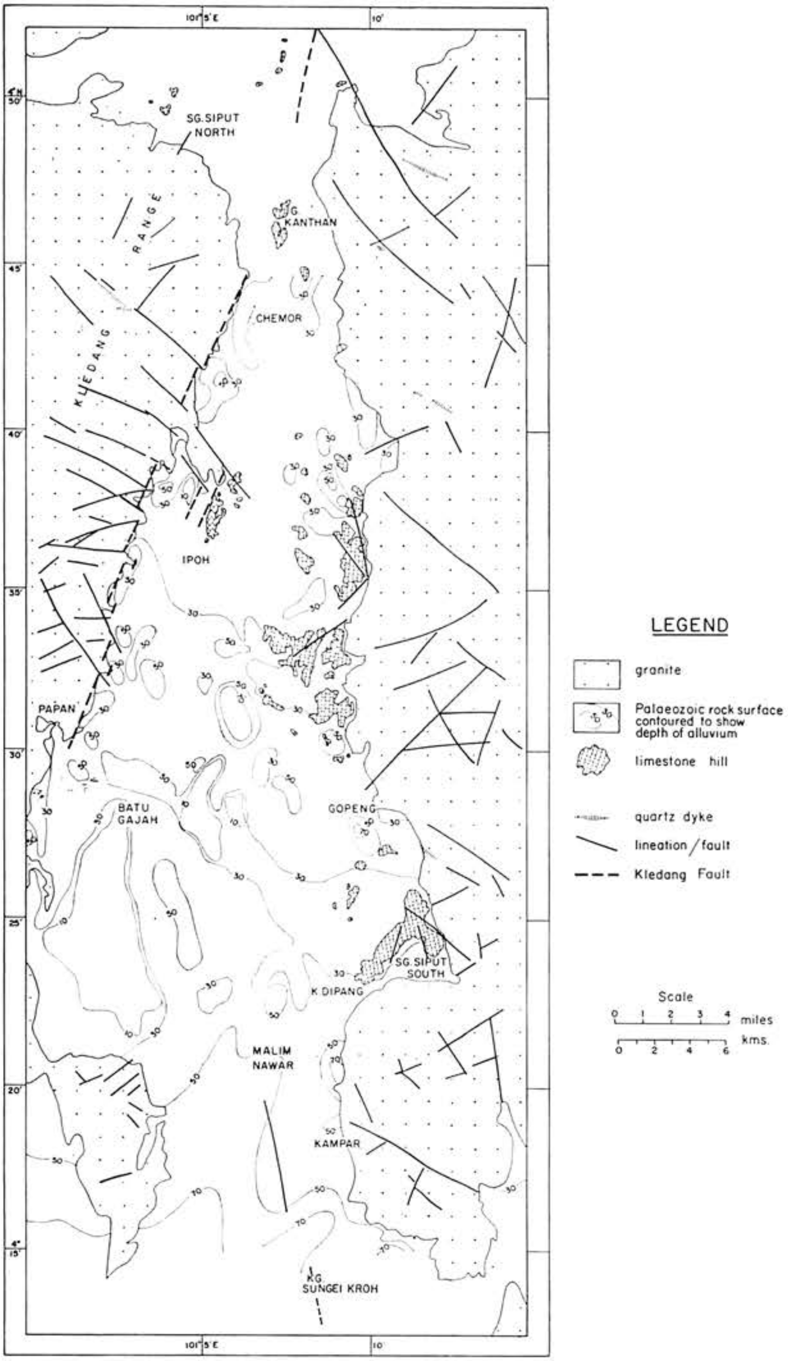

Fig. 2. Geological structure of the Kinta Valley. Based on Ingham and Bradford (1960) and aerial photograph interpretation.

Structures within the Main Range and Kledang granites

Very little has been written on this topic. Ingham and Bradford (1960, p. 86) remark "Jointing is common in both the limestone and the granite, but it is far too irregular to allow of any general interpretation." Study of aerial photographs has however given a pattern of lineations (fig. 2).

Figure 2 shows the main structural features of Kinta mainly as interpreted from aerial photographs. The numerous lineations are almost all negative topographic features, occupied by river valleys, and indeed they control the stream network in the Main Range and Kledang Range. The orientation of these lineations is far from irregular as shown when plotted on a rose diagram (fig. 3). The dominant strike is northwest, a subsidiary set striking east-northeast. These lineations may also be observed cutting the limestone hills in the valley.

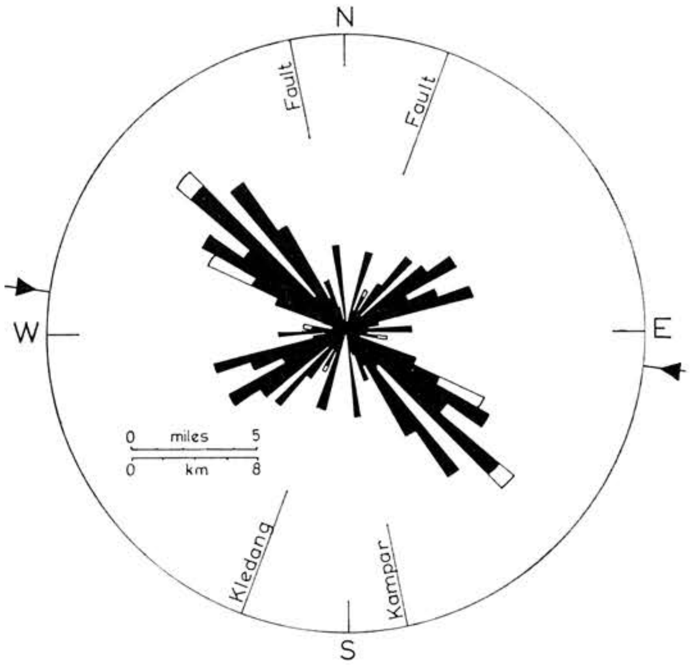

Fig. 3. Rose diagram of 98 lineations shown in figure 2. Declinations grouped into 5° sectors. Quartz dykes left blank. Arrowheads show direction of maximum compressive stress.

Associated with the northwest trending lineations, and sometimes forming continuations of them, are dykes of vein quartz. These do not contain other minerals although they may reach a considerable size. Gunong Pelantoh, northeast of Gunong Kanthan, is formed of a quartz dyke 300 meters (1000 ft.) thick with a shear wall over 300 meters high according to Savage (1937, p. 25).

A northwesterly striking lineation and associated quartz dykes are also found in other parts of the Malay Peninsula, notably to the north of Kuala Lumpur (Shu, 1969). Many of these lineations appear to be wrench faults.

In Kinta the lineations can be readily interpreted as conjugate shear joints. The stress field in which these joints formed would have the principle compressive stress bisecting the smaller of the angles subtended by the main joint directions. Thus, the principle stress was aligned 97°—277° (fig. 3). Quartz dykes were emplaced along and widened tension joints orientated parallel to the principle stress at the time of their

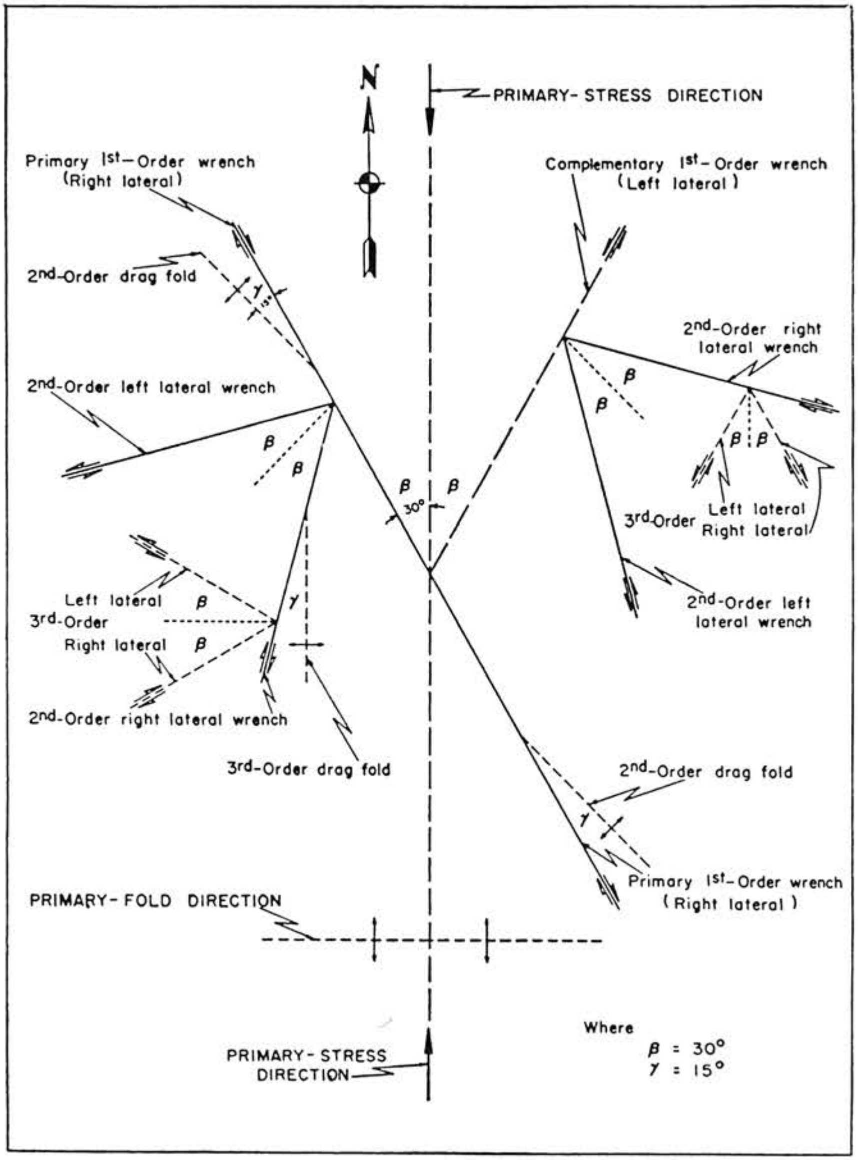

Fig. 4. Plan of wrench system under north-south simple compression. After Moody and Hill (1956, p. 1213).

formation. In Selangor similar quartz dykes are much brecciated showing that there has been intermittent movement of the adjacent rock masses (Stauffer, 1968). The Kinta dykes seem to be similar in texture. They have been described as "consisting of interlocking crystals of quartz, *varying widely in size* and often showing sutured edges under the microscope." (Ingham and Bradford, 1960, p. 67, my italics). One quartz dyke near Chemor appears anomalous. It strikes 26° and therefore cannot be interpreted as infilling a tension joint formed by a compressive stress orientated 97°. However it runs parallel to the margin of the Kledang granite and may fill a normal fault associated with that margin.

The northwest trending shear joints cut through the granite boundary in many places. The irregularity of the Kledang granite boundary would be explained by strike-slip movement along these shear joints converting them into fault planes and causing numerous offsets of an originally straight boundary. Thus the existence of a Kledang fault may be masked by minor wrench faults cutting across it.

If we accept that major wrench faulting has occurred in the Malay Peninsula (Burton, 1965, 1967a, b; Stauffer, 1968), we may also expect to find secondary structures related to the major movements. Moody and Hill (1956) have described the geometry of a wrench fault tectonic system. The theoretical pattern they produced assumes a first order wrench fault (or two conjugate wrench faults) at approximately 30° (angle β) to the principle stress direction. Movement along these faults may pro-

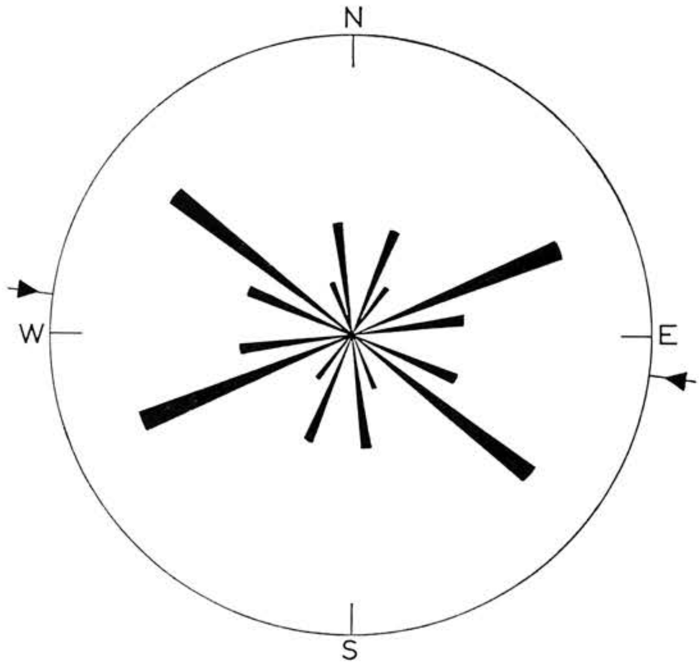

Fig. 5. Orientations of the two 1st, four 2nd, and two 3rd orders shears produced by a compressive stress directed 97°–277°, assuming $<\beta = 30°$, $<\gamma = 15°$. Declinations grouped into 5° sectors. After Moody and Hill (1956).

duce second order strike-slip faults orientated at the angle β to the secondary stress direction which itself lies at $90^\circ + \gamma^\circ$ to the first order wrench. The angle γ averages about 15°. Likewise third and higher order shears may develop (fig. 4). This pattern compares closely with the lineation pattern observed in Kinta (fig. 5), assuming a principle stress direction of 277° (fig. 3). Thus it may be argued that some of the principle northwest and/or east-northeast lineations in Kinta have moved parallel to their strike, that is they are wrench faults, and have produced the observed pattern of (second and third order) lineations. However no direct evidence of this movement has been obtained.

The sense of movement along lineations in the granite masses on either side of the Kinta valley is unfortunately difficult to determine. The only feature likely to show offsets that can be seen on the published maps or on aerial photographs are streams. These streams in many cases conform to a rectangular pattern determined by the compression joints so that apparent offsets can always be attributed to "jumping" of the stream from one joint to a parallel one along a length of the conjugate joint, rather than offset due to relative movement along the conjugate joint (fig. 6). A dominant sinistral (left lateral) movement along northwest striking faults has occurred in Selangor and this accords with an approximately east-west principle stress. Movement on the conjugate fault (northeasterly striking) would be dextral (right lateral). The lineations crossing the eastern margin of the Kledang granite may be interpreted as offsetting it (fig. 2). Of 12 such lineations four agree with the theoretical sense of strike-slip movement, four disagree, and four are equivocal because they could be identified with either a first order or a second order shear with movement in opposite senses. However movement in the same sense but unequal in amount along many parallel lineations may produce both dextral and sinistral offsets which cannot be used to evaluate the sense of movement on these shears.

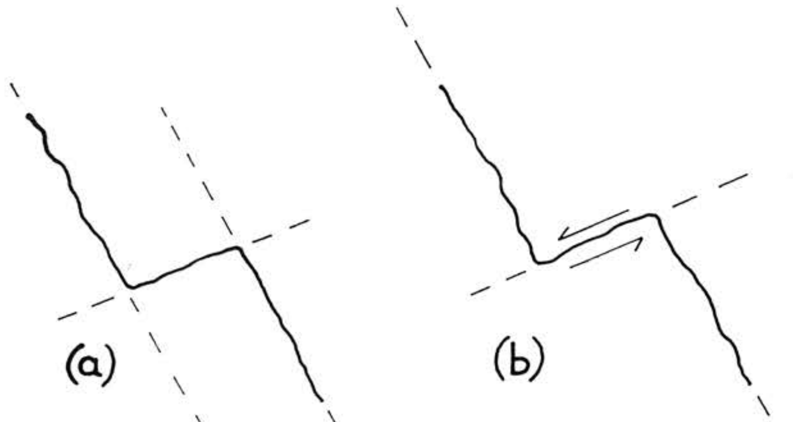

Fig. 6. Stream offset by (a) conjugate joint pattern; (b) strike-slip movement.

Structure of the valley floor

Ingham and Bradford (1960, p. 79) gave an isopachyte map of the alluvium in the Kinta Valley. This is remarkable in that it shows a well defined trough filled with from 30–70 ft of alluvium striking northwest from Sungei Siput South to Menglembu (fig. 2). This is bordered to the north and south by alluvium not exceeding 30 ft in thickness. A second, less well defined trough also runs approximately northwestwards from Kampar to Batu Gajah. Another peculiar feature of the Kinta Valley is the low watershed which crosses it in the vicinity of Gunong Kanthan, north of Chemor. Thus the drainage from the northern end of the Kledang Range and the Main Range opposite flows north to the Sungei Plus which cuts through the flank of the granite mass around Chenderoh to reach the Perak River. The main part of the Kinta Valley is drained southwards by the Sungei Kinta. These features could be explained by recent activity with a dipslip vector along northwest striking wrench faults which produced some uplift of blocks running obliquely across the valley.

Conclusions

The above considerations make it plausible that the west side of the Kinta valley is bounded by a major dip-slip fault separating folded Palaeozoic limestones from a horst of the Kledang granite. It is proposed to name this fault the Kledang Fault. Some faulting may be present along the eastern margin of the valley but it is likely that, for the most part, the granite contact there is a normal intrusive one.

The irregularity of the western boundary of the Kledang granite may be explained by strike-slip movement along numerous pre-existing shear joints. These were produced in both granite and limestone by a stress field with the principle stress varying somewhat in direction but averaging 97°—277°. This movement postdated the dip-slip movement of the Kledang Fault. Some of the tension joints produced by the stress field became filled with vein quartz to produce quartz dykes up to 300 meters (1000 ft.) thick. Similar structures are known further south in Selangor.

ACKNOWLEDGEMENTS

I am indebted to my colleagues in the Department of Geology, University of Malaya, for helpful discussions on various aspects of Kinta geology.

Dr. A.G. Smith (Sedgwick Museum) kindly read the typescript and suggested improvements.

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