Geological Society of Malaysia, Bulletin 46
May 2003; pp. 319–328

The morphostructures of Kinta Valley karst

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Abstract: The trend of Kinta Valley karst structure is mainly along the 310°-350° with minor directions of about 030°, 040°, 055°, 070° and 085°. These trends originated from tectonic stresses and are observed to have controlled the formation of certain karst features such as dolines, wangs, caves and collapse.

Abstrak: Tren struktur kars Lembah Kinta yang utama adalah sepanjang 310°-350° dengan arah minor lebih kurang ke 030°, 040°, 055°, 070° dan 085°. Tren ini berasal dari tekanan tektonik dan diperhatikan telah mengawal pembentukan fitur-fitur kars tertentu seperti dolina, wang, gua dan runtuhan.

INTRODUCTION

The trends of the structures of the Kinta valley are largely north-south. A number of geologists had ascribed the formation of the Kinta Valley to block faulting occurring at the contacts between the granites and the meta-sedimentary rocks (Gobbett, 1973).

Gobbett also shows that the orientation of lineaments from Main Range and Kledang Range is far from irregular but somehow shows the dominant strike of northwest with the subsidiary set striking east-northeast (Fig. 1). He concluded that these lineations may also be observed cutting the limestone hills in the valley.

Photo lineaments study was done on all of the limestone hills in the study area (Fig. 2). Detailed studies were done on two hills: Gunung Tempurung and Gunung Rapat and combined with detailed field studies on these two hills, the origin of the hills and other important features associated with it was interpreted. As for the other hills, interpretation was based on the lineaments studies.

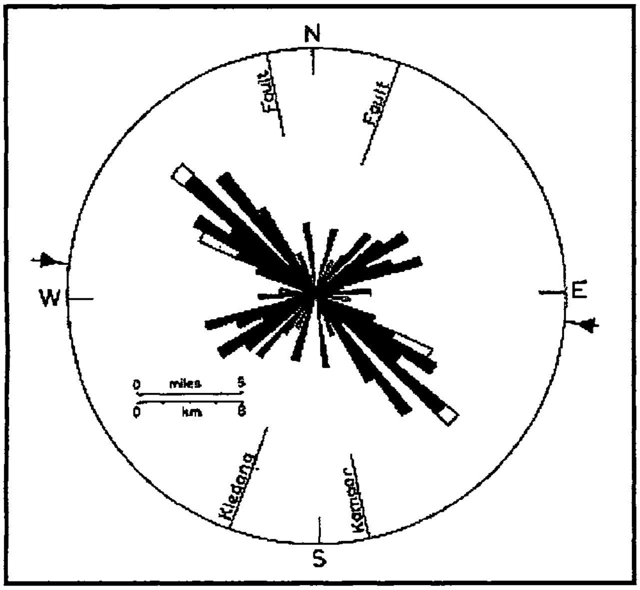

Figure 1. Rose Diagram of 98 lineaments from KintaValley. Orientations are grouped into 5° sectors. Quartz dykes are left blank. Arrowheads show direction of maximum compressive stress (after Gobbett, 1971).

METHODOLOGY

Interpretation of aerial photographs of the study area and its surroundings to determine the fracture system, topography and drainage pattern. These photographs were taken during 1965 under the Colombo Plan with a scale of around 1:25,000 (Table 1).

Graphical Presentation of the Lineaments

Measurements in the field are plotted in Rose Diagrams for Gunung Rapat and Gunung Tempurung. Negative lineaments are also plotted in rose diagrams by frequency as well as length (in kilometers). The diagrams are plotted from lineaments of limestone towers and cockpit and surrounding rocks of each group of hills:

a) Eastern Sungai Siput/Kinta Valley
   1. Gunung Tempurung and surrounding small hills (Fig. 3)
   2. Gunung Rapat, Gunung Lanno, Gunung Terendum and surrounding small hills (Fig. 4)
   3. Gunung Datok and surrounding small hills (Fig. 5)
   4. Gunung Kanthan, Gunung Kuang and surrounding (Fig. 6)

b) Western Sungai Siput/Kuala Kangsar
   1. Pulau Kemari area (Fig. 7)
   2. Bukit Kemuning and surrounding (Fig. 8)
   3. Gunung Pondok area (Fig. 9)

c) Lenggong (Fig. 10)

Except for Western Sungai Siput and Gunung Pondok area, plots on the adjacent granite are separated, so that comparison of the lineament can be made between these two types of rocks.

Results

Joints which are mainly taken from the west exit and the middle part (Fig. 3) of the Gunung Tempurung show major trends along 030°-210°, 070°-250°, 130°-310°, 150°-330° and 160°-340° (Fig. 11). Plots of joints measurements mainly taken on the west part of Gunung Rapat (Fig. 4) show major trends of fracture systems along 060°-240°, 070°-250° and 130°-310°, 140°-320°, 160°-340° (Fig. 12). Plots of the frequency and length of the negative lineaments are shown as inserts. Gunung Tempurung shows that major strikes are 050°-230°, 060-240, 140°-320°, 150-330, and 160°-340° [Fig. 3, insert (a1) and (a2)for limestone and (b1) and (b2) for granite], whereas from Gunung Rapat, major strikes are 040-220, 140°-320° and 160°-340° [Fig. 4, insert (a1) and (a2)]. G. Lanno shows major trends along 040-220, 130°-310°, 150°-330° and 160°-340° [Fig. 4, insert (b1) and (b2)]. Plot for granite in this area are shown in insert (c1) and (c2). Gunung Datok and other small hills in the north and the west shows major strikes of 030°-210°, 040°-220°, 150°-330°, 160°-340° and 170°-350° (Fig. 5, insert (a1) and (a2) for limestone and (b1) and (b2) for granite). Gunung Kuang, Gunung Kanthan and Pulau Kemiri area shows major trends along 010°-190° and 020°-200°, 150°, 160° [Fig. 6, insert (a1) and (a2) for limestone and (b1) and (b2) for granite].

Table 1. List of aerial photos that are used in the study.

Location	Roll Number	Line Number	Print Number
Ipoh	C-6 C-5 C-5	L31N L30S L29N	40-45 93-98 115-130
Sungai Siput Utara	C-5 C-5	L30S L29N	87-91 115-127
Padang Rengas	C19A	L21N	30-33
Lenggong	C-95 C-6	L24N L25S	9-13 112-114
Bujang Melaka	C-12A	L32N	10-17

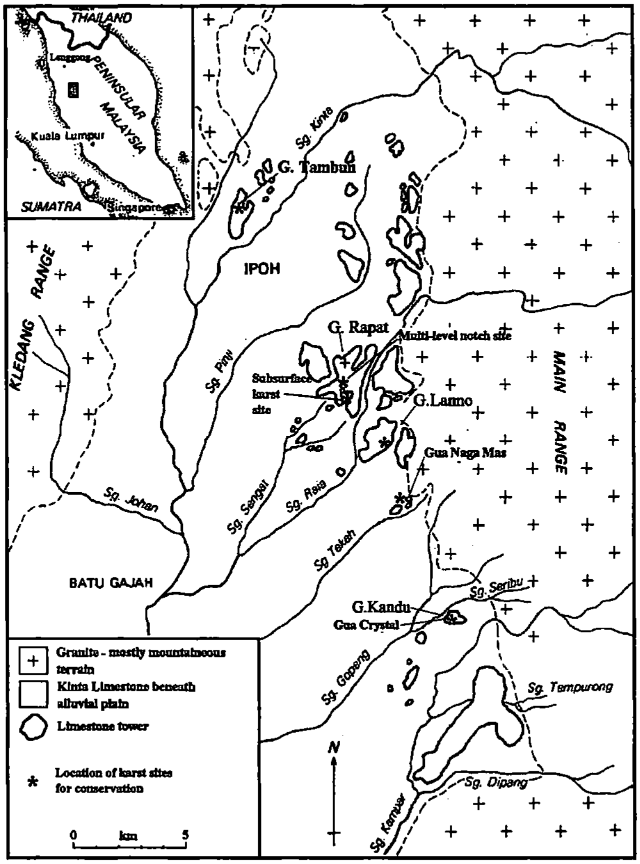

Figure 2. Part of the study area. Sungai Siput and Gunung Pondok areas are located to the north and northwest, respectively of this area.

Whereas in the Sungai Siput area, plot of the joints and lineaments of the limestone hills are combined with those from the surrounding schist shows major fracture systems along 040°-220°, 130°-310°, 150°-330° and 160°-340° [Fig. 8, insert (a1) and (a2)]. Gunung Pondok area shows major trends along 100°-280° and 110°-290° [Fig. 9, insert (a1) and (a2)]. In Lenggong, major lineament direction strikes along 130°-310° [Fig. 10, insert (a1) and (a2) for limestone and (b1) and (b2) for granite].

General comparisons between lineament frequency and length are given in Table 2. Similar frequency and length pattern are observed in granite [4(c1) and (c2), 8(a1) and (a2)] and mixture [9(a1) and (a2), 10(a1) and (a2)]. Except for Lenggong area which shows similar pattern, all the other limestone areas show some anomalies between the frequency and lengths. The writers are of the opinion that one of the reasons for the anomalies is some amount of lineaments in the limestone have been destroyed by extensive dissolution, especially in the wangs area in the Kinta Valley. Therefore, longer lineaments usually are not visible or probably covered by alluvial sediments in the wangs area. Whereas in Lenggong where the karst is less developed, similar pattern is observed.

RELATIONSHIP BETWEEN KARSTIC FEATURES AND LINEAMENTS

Major lineament sets and directions obtained from the Rose Diagrams of the frequency and length of the negative lineaments are tabulated in the Table 3. Regional fault zone, local fault zone and undefined fault zone which are based on the frequency and length of the negative lineaments are recognized. The occurrence of this fault zones on the limestone hills are indicated in the table.

Numerous studies on karst concluded that structure plays a major role in determining the formation of the karst features (Song, 1989; Rossi, 1989). The relationship between the various karstic features and the lineaments of Gunung Rapat and Gunung Tempurung are given in Table 4 and Table 5, respectively. The relation of karstic features to the lineaments for other smaller limestone hills, mainly on the alignment of the dolines/wang and collapse plane

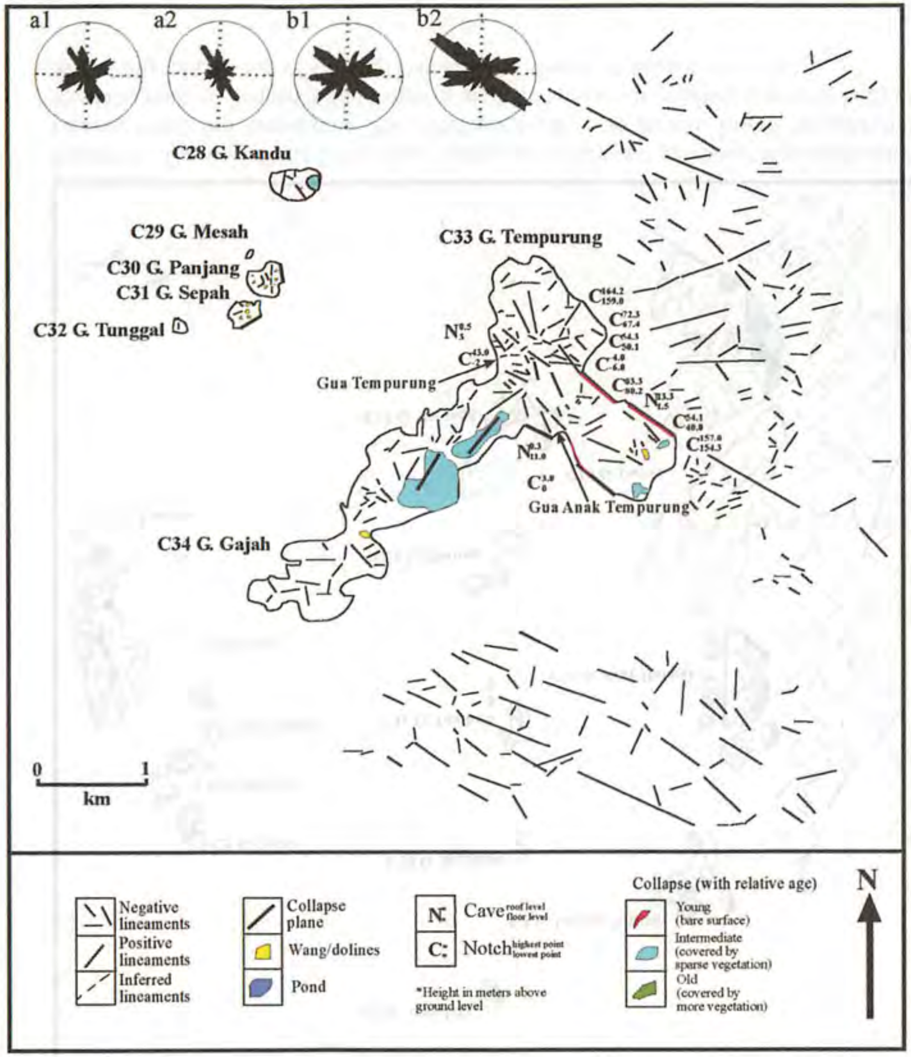

Figure 3. The lineaments from aerial photograph study and geomorphological features of Gunung Tempurung and surrounding. Inserts (b1) and (b2) are Rose Diagrams of frequency and length of negative lineaments in granitic bodies MainRange in the east and Bintang Range in the south. Total number of lineaments = 199. Inserts (a1) and (a2) are Rose Diagrams of frequency and length of negative lineaments in Gunung Tempurung
Total number of lineaments = 150.

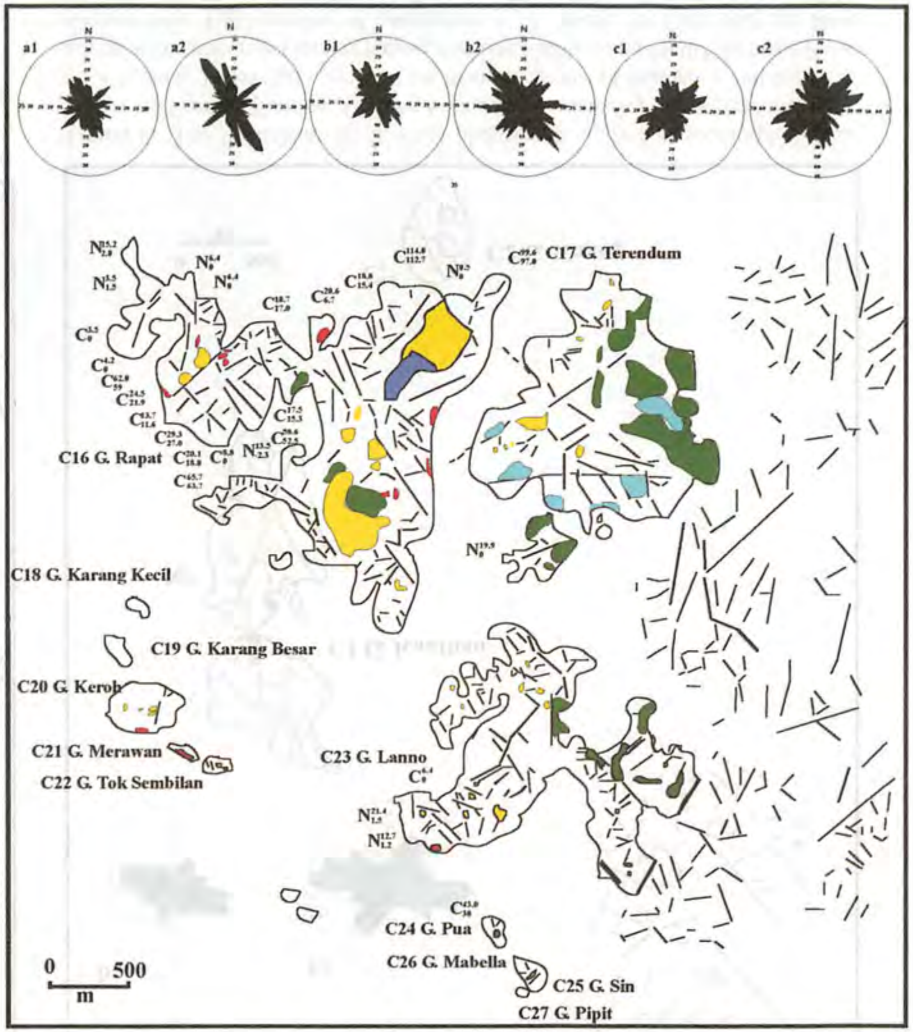

Figure 4. The lineaments from aerial photograph study and geomorphological features of Gunung Rapat, Gunung Lanno and surrounding. Please refer to Figure 3 for legend. Inserts (b1) and (b2) are rose diagrams of frequency and length of negative lineaments in Gunung Lanno, Gunung Terendum and adjacent smaller limestone hills. Total number of lineaments = 142. Inserts (a1) and (a2) are sose diagrams of frequency and length of negative lineaments in Gunung Rapat. Total number of lineaments = 123. Inserts (c1) and (c2) are rose diagrams of frequency and length of negative lineaments in adjacent granitic body of the Main Range, in the east of Gunung Lanno and Gunung Terendum. Total number of lineaments = 151. Inserts (a1) and (a2) are Rose Diagrams of frequency and length of negative lineaments in the Gunung Datok and surrounding. Total number of lineaments = 57.

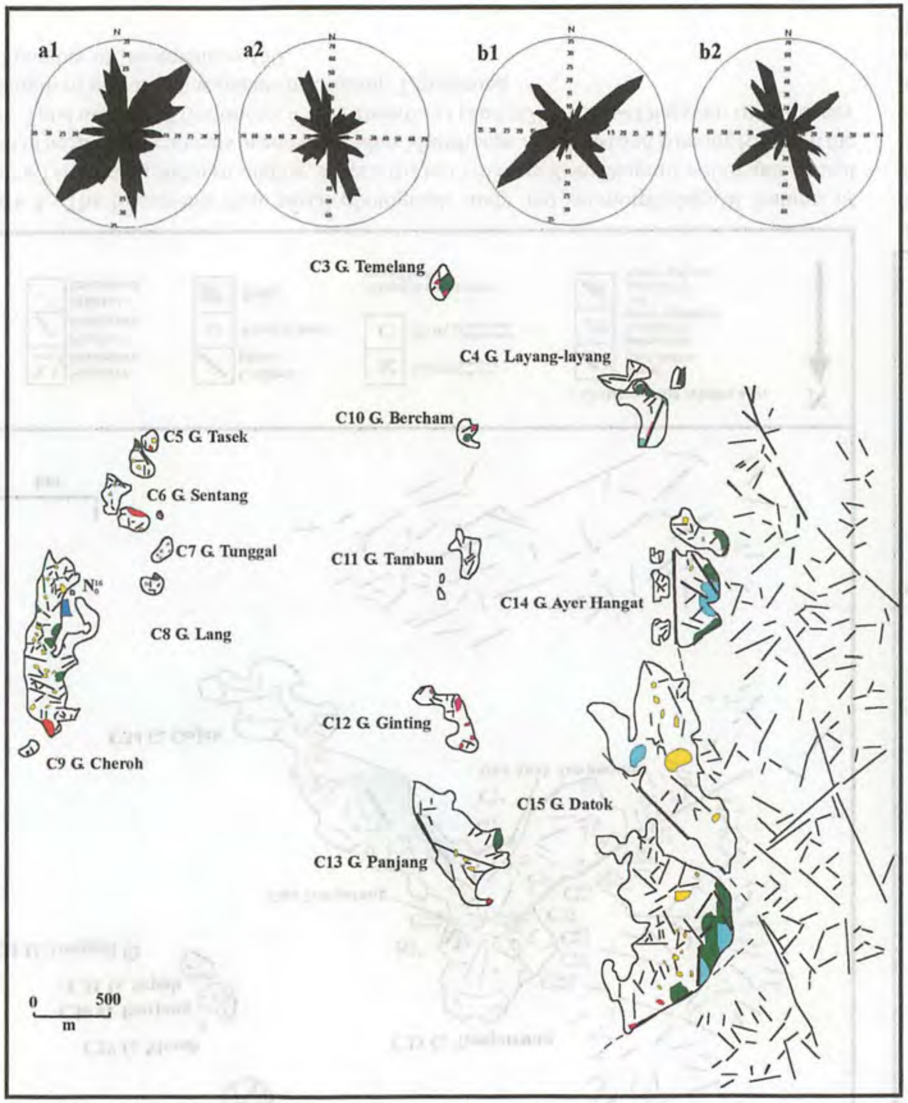

Figure 5. The lineaments from aerial photograph study and geomorphological features of Gunung Datok and surrounding. Please refer to Figure 3 for legend. Inserts (b1) and (b2) are Rose Diagrams of frequency and length of negative lineaments in adjacent granitic body of the Main Range, in the east of Gunung Datok. Total number of lineaments = 162.

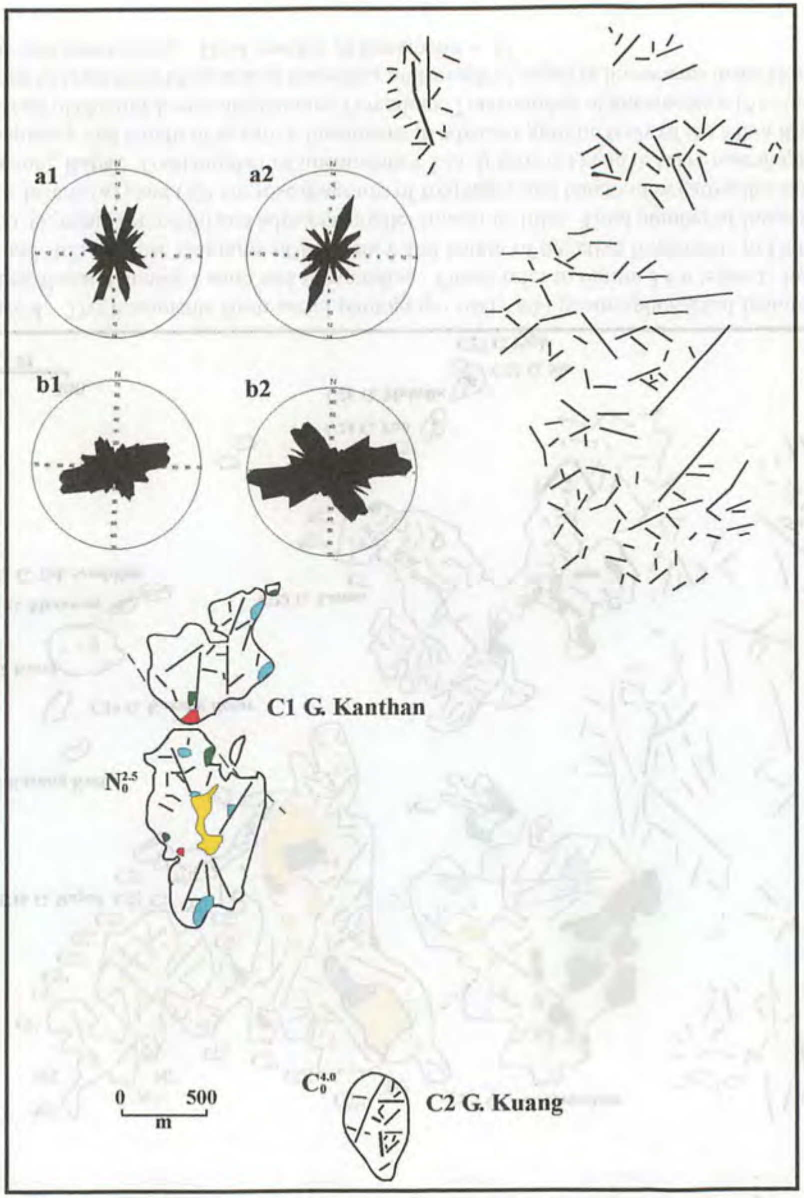

Figure 6. The lineaments from aerial photograph study and geomorphological features of Gunung Kanthan, Gunung Kuang and surrounding. Please refer to Figure 3 for legend. Inserts (a1) and (a2) are Rose Diagrams of frequency and length of negative lineaments in Gunung Kuang, Gunung Kanthan and small hills in the Pulau Kemari area. Total number of lineaments = 57. Inserts (b1) and (b2) are Rose Diagrams of frequency and length of negative lineaments in adjacent granite of the Main Range. Total number of lineaments = 322.

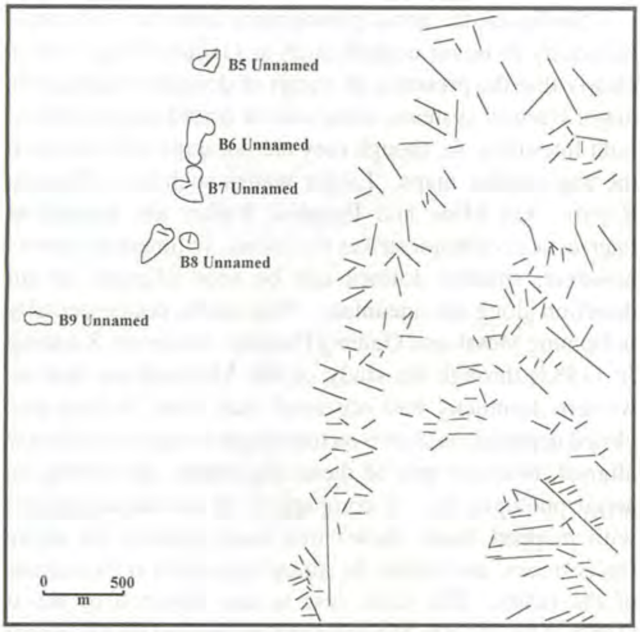

Figure 7. The lineaments from aerial photograph study and geomorphological features of small hills in the Pulau Kemiri areas. Please refer to Figure 3 for legend.

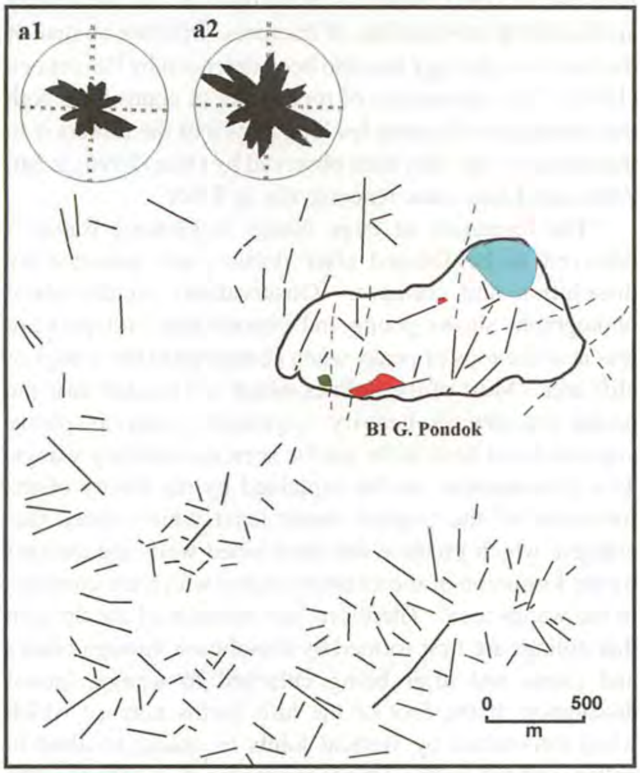

Figure 9. The lineaments from aerial photograph study and geomorphological features of Gunung Pondok and surrounding. Please refer to Figure 3 for legend. Inserts (a1) and (a2) are Rose Diagrams of frequency and length of negative lineaments in Gunung Pondok and nearby Bintang Range granite. Total number of lineaments = 152.

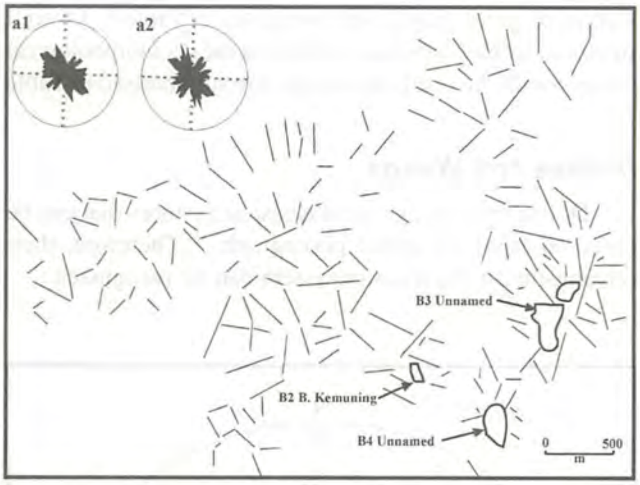

Figure 8. The lineaments from aerial photograph study and geomorphological features of Bukit Kemuning. Please refer to Figure 3 for legend.Inserts (a1) and (a2) are Rose Diagrams of frequency and length of negative lineaments in the area of Bukit Kemuning. Total number of lineaments = 166.

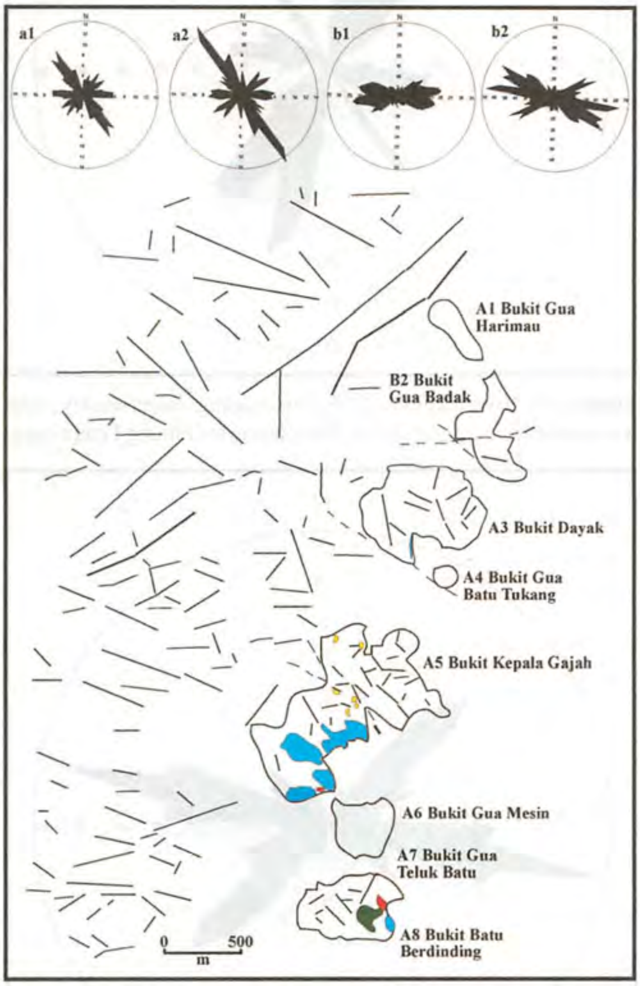

Figure 10. The lineaments from aerial photograph study and geomorphological features in Lenggong and surrounding. Please refer to Figure 3 for legend. Inserts (b1) and (b2) are Rose Diagrams of frequency and length of negative lineaments in adjacent Bintang Range granite in Lenggong area. Total number of lineaments = 113. Inserts (a1) and (a2) are Rose Diagrams of frequency and length of negative lineaments in Lenggong area. Total number of lineaments = 48.

seen from aerial photographs are given in Table 6. Overall structural features and their control on the geomorphological features with the resultant features are summarised in Table 7.

Dolines and Wangs

Dolines and wangs are the easiest features that can be observed from the aerial photographs. Therefore, their relationship to the fracture system can be recognized.

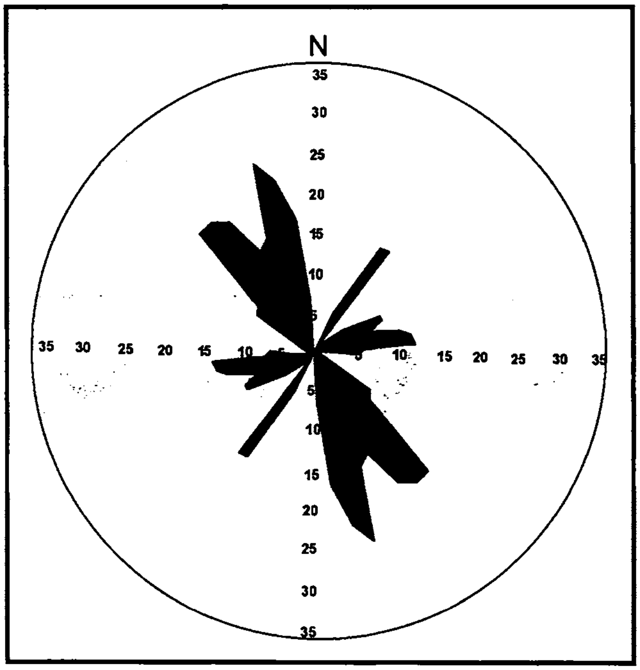

Figure 11. Rose diagram of 100 joint readings taken mainly in the western and middle part of Gua Tempurung in Gunung Tempurung.

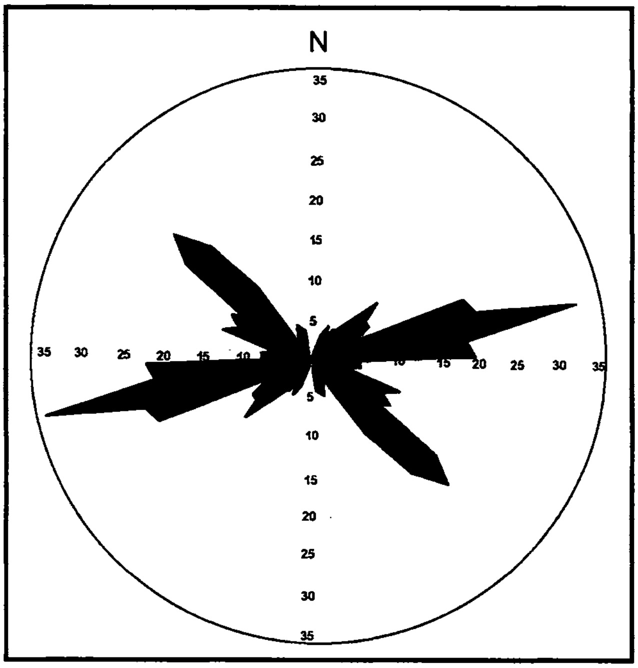

Figure 12. Rose diagram of 103 joint readings taken mainly in the western and part of Gunung Rapat.

Studies on the aerial photographs from the study area, especially in larger cockpit such as Gunung Rapat shows clearly that the presence of wangs or dolines lie along this major fracture systems, some can be traced along inferred fault lines (Fig. 4), though they are not quite obvious from the topographic maps. Larger wangs such as in Gunung Rapat: Tin Mine and Paradise Valley are located at intersections of major strikes directions. In limestone towers however, smaller dolines can be seen aligned certain direction along the lineament. This can be seen especially in Gunung Mesah and Gunung Panjang. However, Kastning Jr. (1983) through his study on the Mississipian Plateau, western Kentucky had observed that many dolines and closed depressions shown on topographic maps are strongly aligned, however few of these alignments are visible on aerial photographs. A comparison of doline alignments with mapped faults shows that many dolines lie along faults traces, and others lie along hypothetical extensions of the faults. The same case is also reported by Rossi (1989) in his study in Malagasi and recognised the alignment of dolines and kegels as results of the fractures and joints which allow high permeability of the rock mass, by facilitating water along preferred zones, and by increasing the karstifiable surface along these zones.

This is further supported by Tjia's (1969) observation on positive and negative lineaments in several karst region showing that they represent fracture directions which agree with Escher (1931) who was of the opinion that the dolines are located at intersections of fractures. Fracture control of the karst morphology has also been defended by Pannekoek (1941). The importance of rock strike in controlling both the orientation of pinnacles long axes and the direction to the pinnacles has also been observed by Dian (1996) in Mt. Zebri and Llasa area, respectively in Tibet.

The formation of large wangs in Gunung Rapat is believed to be formed after dolines are enlarged by dissolution and collapse. Observations on the aerial photographs shows young and intermediate collapses are less near the tops of peaks when compared to the wangs or cliff area. Most of the dolines which are located near the peaks are always heavily vegetated, whereas partly vegetated and bare walls can be seen surrounding wangs. This phenomenon can be explained by the theory of the formation of the tropical tower karst which stated that collapse which produce the steep-sided walls are assisted by the formation of the swamp notches which are common in the wangs area. Therefore, the writer is of the opinion that dolines are first formed by dissolution through cracks and joints and after being enlarged to wangs, lateral dissolution at the foot of the hills forms notches which when intersected by vertical joints or cracks resulted in collapse of the walls. This is the reason new collapses are more common near the enlarged wangs (or cliffs) compared to the dolines near the peaks.

Table 2. General comparisons between lineament frequency and length.

Figure	Frequency:	Length:
3(a1) and (a2)		ENE is short (less developed than other maxima)
3(b1) and (b2)		E is short
4(a1) and (a2)		NNW is long (relatively well developed)
4(b1) and (b2)		ENE long; other max comparable
4(c1) and (c2)	Similar F and L patterns	
5(a1) and (a2)		NE is short
5(b1) and (b2)		NNW is well developed/long
6(a1) and (a2)		NNW less developed/short
8(a1) and (a2)	Similar F and L patterns	
9(a1) and (a2)	Similar F and L patterns	
10(a1) and (a2)	Similar F and L patterns	
10(b1) and (b2)		ENE long/well developed

Table 3. The occurrences of joints and lineaments along Major Lineament Sets/Directions. Plots of joints are shown in Figure 11 and Figure 12. Plots of the lineaments are shown in Rose Diagrams as inserts in Figure 3 . Numbers in brackets represent the frequency of lineaments and total lineament length in kilometers.

Limestone Hill (number of joints/ lineaments	Set 1 030-210 LFZ	Set 2 040-220 LTZ	Set 3 050-230 UFZ	Set 4 060-240 UFZ	Set 5 070-250 UFZ	Set 6 120-300 LFZ	Set 7 130-310 RFZ	Set 8 140-320 RFZ	Set 9 150-330 UFZ	Set 10 160-340 RFZ	Set 11 170-350 LFZ
Gunung Tempurung (joints-100)	Major 11.6%	-	Minor 3.9%	Minor 4.9%	Moderate 9.6%	Moderate 7.7%	Major 14.4%	Moderate 8.7%	Major 15.4%	Major 11.5%	-
Gunung Rapat (joints-104)	Minor 4.0%	Moderate 5.9%	Minor 1.9%	Major 19.8%	Major 16.8%	Major 11.9%	Moderate 7.9%	Moderate 5.9%	Minor 3.0%	-	-
Gunung Tempurung (150)	Minor (4, 9)	Moderate (7, 10.5)	Major (14, 14)	Major (10, 13.5)	Major (10, 9.75)	Moderate (5,12.5)	Moderate (6, 16)	Major (18, 32.25)	Moderate (7, 13.75)	Major (14, 21.5)	Major (13, 22)
Gunung Rapat (123)	Minor (3, 3.25)	Major (13, 13.5)	Minor (5, 6.26)	Minor (3, 4)	Moderate (7, 6.5)	Minor (3, 5)	Moderate (7, 10.75)	Major (12, 23.25)	Moderate (7, 7.5)	Major (14, 19)	Minor (6, 7.75)
Gunung Lanno (138)	Moderate (8, 7.75)	Major (10, 10.25)	Moderate (7, 8.25)	Moderate (6, 8.5)	Minor (2, 2)	Moderate (6, 7)	Major (14, 17.5)	Moderate (9, 10)	Major (14, 11.75)	Major (11, 10.75)	Minor (3, 8)
Gunung Datok (216)	Major (20, 13.75)	Major (25, 20.25)	Major (11, 17.25)	Major (17, 16)	Minor (5, 5.75)	Moderate (8, 10.25)	Minor (4, 12.25)	Major (11, 21.75)	Major (12, 37.25)	Major (19, 17.75)	Major (17, 28.75)
Sungai Siput (147)	Moderate (6, 15)	Major (11, 18)	Minor (4, 5.25)	Moderate (8, 23.25)	Moderate (9, 12.5)	Major (10, 21.75)	Major (13, 26.5)	Minor (4, 12.75)	Major (13, 28.75)	Major (11, 27.75)	Moderate (8, 16)
Lenggong (48)	Minor (4, 5)	Minor (1, 1.5)	Minor (4, 4.75)	Minor (1, 0.5)	Minor (3, 3.5)	Minor (4, 3.2)	Moderate (7, 11.5)	Minor (4, 5)	Minor (2, 4.25)	-	Minor (2, 3.25)

Regional Fault Zone (RFZ): Lineaments which can be traced from the limestone and extended to the surrounding rocks. Localized Fault Zone (LFZ): Major lineaments which can be traced in the limestone only. Undefined Fault Zone (UFZ): Minor lineaments which can be traced in the limestone only.

Table 4. Relation of karstic features to the lineaments for Gunung Rapat. Additional important strike direction is given below the table.

Features	Set 1 030-210 LFZ	Set 2 040-220 LTZ	Set 3 050-230 UFZ	Set 4 060-240 UFZ	Set 5 070-250 UFZ	Set 6 120-300 LFZ	Set 7 130-310 RFZ	Set 8 140-320 RFZ	Set 9 150-330 UFZ	Set 10 160-340 RFZ	Set 11 170-350 LFZ
Alignment of the Peaks	yes	-	yes	-	yes	-	-	-	-	-	-
Alignment of the Wangs / Dolines	Yes (Sam Poh Tong)	Paradise valley Minex	Iron Mine – 050	Yes	Yes (Paradise Valley	-	-	Quarry -145	-	-	Yes (Minex)
Cliffs	-	-	-	yes	-	-	-	-	-	-	-
Valleys	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Caves formation/ direction									Yes (Paradise Valley)	Yes (Kek Look Tong)	
Undercut / Overhangs	-	-	-	-	-	-	-	-	-	-	-
090 (Paradise Valley)											

Table 5. Relation of karstic features to the lineaments for Gunung Tempurung and surrounding smaller hills. Additional important strike direction is given below the table.

Features	Set 1 030-210 LFZ	Set 2 040-220 LTZ	Set 3 050-230 UFZ	Set 4 060-240 UFZ	Set 5 070-250 UFZ	Set 6 120-300 LFZ	Set 7 130-310 RFZ	Set 8 140-320 RFZ	Set 9 150-330 UFZ	Set 10 160-340 RFZ	Set 11 170-350 LFZ
Alignment of the Peaks	yes	yes	yes		yes	-	-	-	yes	-	yes
Alignment of the Wangs / Dolines	-	-	-	-	-	-	-	-	-	-	yes
Cliffs	yes							yes		-	yes
Valleys	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Caves formation/ direction		Yes (G.Tempurung)	Yes (G.Tempurung)	Yes (G.Tempurung)		Yes (G.Tempurung)					yes (G.Tempurung)
Undercut / Overhangs	-	-	-	-	-	-	-	-	-	-	-
110 (G. Tempurung)											

Table 6. Relation of karstic features to the lineaments for other smaller limestone hills, mainly on the alignment of the dolines/wang (d), collapse plane (c) and major strike (y) seen from aerial photographs.

Mogote Hill	Set 1 030-210 LFZ	Set 2 040-220 LTZ	Set 3 050-230 UFZ	Set 4 060-240 UFZ	Set 5 070-250 UFZ	Set 6 120-300 LFZ	Set 7 130-310 RFZ	Set 8 140-320 RFZ	Set 9 150-330 UFZ	Set 10 160-340 RFZ	Set 11 170-350 LFZ
Gunung Terendum				y	y, d		y		y, c	y, c	
Gunung Lanno	y, c	y, d					y, c		y, d		
Gunung Kanthan	c			c			c	c		d	
Gunung Kuang	y							c			
Gunung Kandu				y	c		y		d		
Gunung Mesah					d					d	y, c
Gunung Panjang				c	y				y	d	y
Gunung Tunggal	y										
Gunung Datok			c		d		c		y	d	c
Gunung Panjang						d, y			c		

Caves

Besides dolines and wangs which are easily observed from the aerial photographs, caves which are studied in the field also show significant relationship with structure. Aerial photograph when combined with measurement in the field give meaningful results. The outline of Gua Tempurung is aligned along two lineaments: 060°-240° and 110°-270°. Although 060°-240° is marked as Unidentified Fault Zone and 110°-270° is not recognized as one of the major strikes, plot of the lineament clearly shown that the two directions control the direction of the cave (Fig. 3). Rasidah (1998) plotted a few rose diagrams along the cave and concluded that it is structurally controlled. The Kek Look Tong lies along a lineament which strike along 160° (Fig. 4). The formation of speleothem curtains along joints strikes which are parallel to the direction of Gua Gunung Runtuh is also evidence of the structure control. Besides caves formation which is always initiated at the major strike or fault zone, the enlargement of the caves are also occurred through joints and cracks. This is observed, for example in an unnamed cave Gunung Kuang and Perak Tong cave.

Further Analyses on the Cliff or Vertical Walls of the Mogote

Besides the lineaments, collapse of the walls of the tower hills which give rise to cliff surfaces are also recognized by the studies on aerial photographs. From the studies on the aerial photographs and then later in the field, where possible they are classified as young, intermediate and old collapse by judging the appearance of bare or vegetated surfaces on the wall.

Besides wangs and dolines, collapses of the walls are always formed along fracture systems, sometimes continuously from the alignment of the wangs and dolines. This can be observed especially in the Gunung Tempurung (Fig. 3) where two almost bare collapses which run across about 1.2 km long are controlled by a major fracture system. The lineament can be seen cutting through the nearby granite of the Main Range.

On some young and intermediate cliffs, aerial photographs often shows collapse planes. At Gunung Tempurung, 4 large collapse planes striking at 120° to 144° are observed along young collapses and two planes striking at 025° and 030° along two intermediate collapses.

From the writers' observation, the development of collapse along the strikes had also further separated and divided the larger limestone mass into a few smaller ones. Example for the division of the hill can be seen along Gunung Datok. Whereas Gunung Lanno and Gunung Rapat are advancing towards that. This is in the writers' opinion, is a stage of karstification that can be seen in the tropical karst.

Table 7. Summary of the overall structural elements (joints from measurement in the field and lineaments from aerial photographs) and their control on morphological features.

Strutural Elements	Details of the Structural Element	Morphological Features	Resultant Features
Joints	030-210 (LFZ)	peaks	cockpit towers
Lineaments	040-220 (LTZ)	dolines	cockpit towers
Lineaments	060-240 (UFZ)	Dolines, solution	wangs, cave
Lineaments	070-250 (UFZ)	Peaks, wangs, valleys	cockpit towers
Lineaments	120-300 (LFZ)	Valleys, solution	caves
Joints	130-310 (RFZ)	valleys	cockpit
Lineaments	140-320 (RFZ)	wangs, cliffs and valleys	cockpit
Joints	150-330 (UFZ)	valleys, peaks, solution	cockpit and caves
Joints	160-340 (RFZ)	valleys, solution	cockpit and caves
Lineaments	170-350 (LFZ)	peaks, wangs, valleys, cliffs, solution,	cockpit and caves
Lineaments	110-270	solution	cave direction
Lineaments	160-340 (RFZ)	solution	cave direction
Lineaments	025-205	collapse	steep wall
Lineaments	030-210 (LFZ)	collapse	steep wall
Lineaments	120-300 (LFZ)	collapse	steep wall
Lineaments	144-324 (RFZ)	collapse	steep wall

RELATIONSHIP BETWEEN LINEAMENTS IN THE LIMESTONE HILLS AND NEIGHBOURING GRANITE MASS

Limestone masses in the study area especially in the Kinta Valley has gone through extensive dissolution processes. This has erased some of the evidences of the structural features especially the lineaments observed from the aerial photographs. To obtain a clearer picture of the structure of this area, where possible, observations on the neighbouring rocks are also observed. Though most of the plain are covered by alluvium which prohibits lineament observation from the aerial photographs, some hills outcropping near the granite mass shows lineaments that can be traced into the surrounding rocks. In the Kinta Valley area, especially near Gunung Tempurung and a few other small hills on the northwest part (Fig. 3) observation were extended to the granite mass of the Main Range in the east and the south. For Gunung Rapat, Gunung Terendum, Gunung Lanno and other small hills (Fig. 4), observations on the lineaments were extended also to the Main Range in the east. Major lineaments can also be traced from the complex of G. Datuk (Fig. 5) and the surrounding hills into the granite of Main Range. Though the distance between Gunung Kuang, Gunung Kanthan and small hills in the area of Pulau Kemiri and the granite are quite distant, the lineaments are plotted to see if there is any structural relation (Fig. 6 and Fig. 7). Whereas in the Lenggong (Fig. 10) area, lineaments in the granite in the Bintang Range in the west of the limestone mass were observed. For these hills, lineaments from limestone and granite are separated, and plotted in separate Rose Diagrams (shown as inserts in Fig. 3). However, in Sungai Siput (Fig. 8), Gunung Pondok (Fig. 9) and Lenggong area, due to small exposure of the limestone measurement on the surrounding schist and granite area were done and plotted in the same rose diagram.

While many minor lineaments are localized in the limestone, observations from the aerial photographs show that major lineaments always extended into the granite area. In G. Tempurung, major lineaments which strike at about 140° and 144° which are also parallel to the plane of the large collapse along the southeast wall of the hill extends to the granite. Observation on Gunung Datok shows that a long lineament striking along 128° and 165° cut through the granite. Whereas in Lenggong, lineaments striking at about 080° and 120° are extended to the Bintang Range in the west. The rose diagrams do not show exact relationship in terms of lineament intensity between the two types of rocks. However, it is found that lineaments are most intense in the northwest direction which is from 310° to 350°. This agrees with the major northwest strike direction obtained by Gobbett (1971). The writer are of the opinion that both limestone and granite in the study area have gone through the same compressive stress directed 097°-277° (Gobbett, 1971).

DOMINANT STRIKES AND ITS RELATIONSHIP TO THE TECTONIC DEFORMATION

Lineaments are generally fractures (joints, fissures and/or faults), however major lineaments which is more than a kilometre in length can be associated with fault. In the study area, there are a few major lineaments that can be thought as faults and the rest as joints or fissures. The lineament naming as tension, extension, shear is indicating what their tendencies are if these are faults.

Overall, preferred orientations of lineaments frequencies in Kinta Valley are: 310°, 330°, 340°, 350°, 030°, 045°, 050°, 70°, 85°. Preferred orientations of lineament lengths in Kinta Valley are: 305°, 315°, 330°, 350°, 030°, 040°, 055°. Comparing these data, it is can be concluded that 310°, 330°, 350° and 045°-050° are the most dominant orientation when both frequency and length were taken into account. All of these directions are recognised to have controlled some of the karst features in the study area (Table 3).

Bradford and Ingham (1960, p. 83) stated that the tectonic axes run slightly west of north for the Main Range side of the Kinta Valley, while on the Kledang Range side the structural trends are slightly east of north. The dominant strikes of lineaments of the current study are 350°, 45-50°, 70°, 330°, and 310°. Most of these structural directions are in excellent agreement with the stress system on the Main Range side of the valley. In other words, 350°, 045°-050°, and 070° (the dominant frequencies/lengths) can be classified in structural terms as respectively: Tension direction, a first-order shear direction (with tendency of dextral slip), extension direction parallel to the maximum principal stress direction, and a second-order shear direction (also with tendency of dextral slip). The angular relations between compression direction, first-order and second-order shear, and extension fractures are discussed in most modern texts on structural geology (see e.g. Davis, 1984). Only the lineaments striking in 330° do not show obvious relation to the regional stress system on the east side of the Kinta Valley. This particular lineament direction could represent a regional, peninsula-wide, stress system, for instance.

CONCLUSION

Some conclusions based on the studies are:

1. Structural trends in the Kinta Valley and Lenggong karst area are largely in the direction of NNW and NE with main directions: 310°, 330°, 350°, 70°,85° and 45°-50°.
2. The formation of karst features such as dolines, caves and steep wall of the hills are controlled by these strikes.
3. Less extensive karstification in Lenggong karst had resulted in similar frequency and length pattern, whereas some anomalies were observed in the Kinta Valley karst.
4. The limestone and granite were deformed by the same tectonic stress.

ACKNOWLEDGEMENT

This study is part of the first author's PhD thesis which was funded by Universiti Malaya's Penyelidikan Jangka Pendek grant: F0200/2002A. The first author would like to thank the supervisors Dr. Yeap Ee Beng and Associate Professor Dr. Lee Chai Ping. The write-up stage of this paper was conducted while working as a research assistant for IRPA grant 02-02-02-0015 led by Prof Ibrahim Komoo of LESTARI, UKM.

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Manuscript received 28 February 2003