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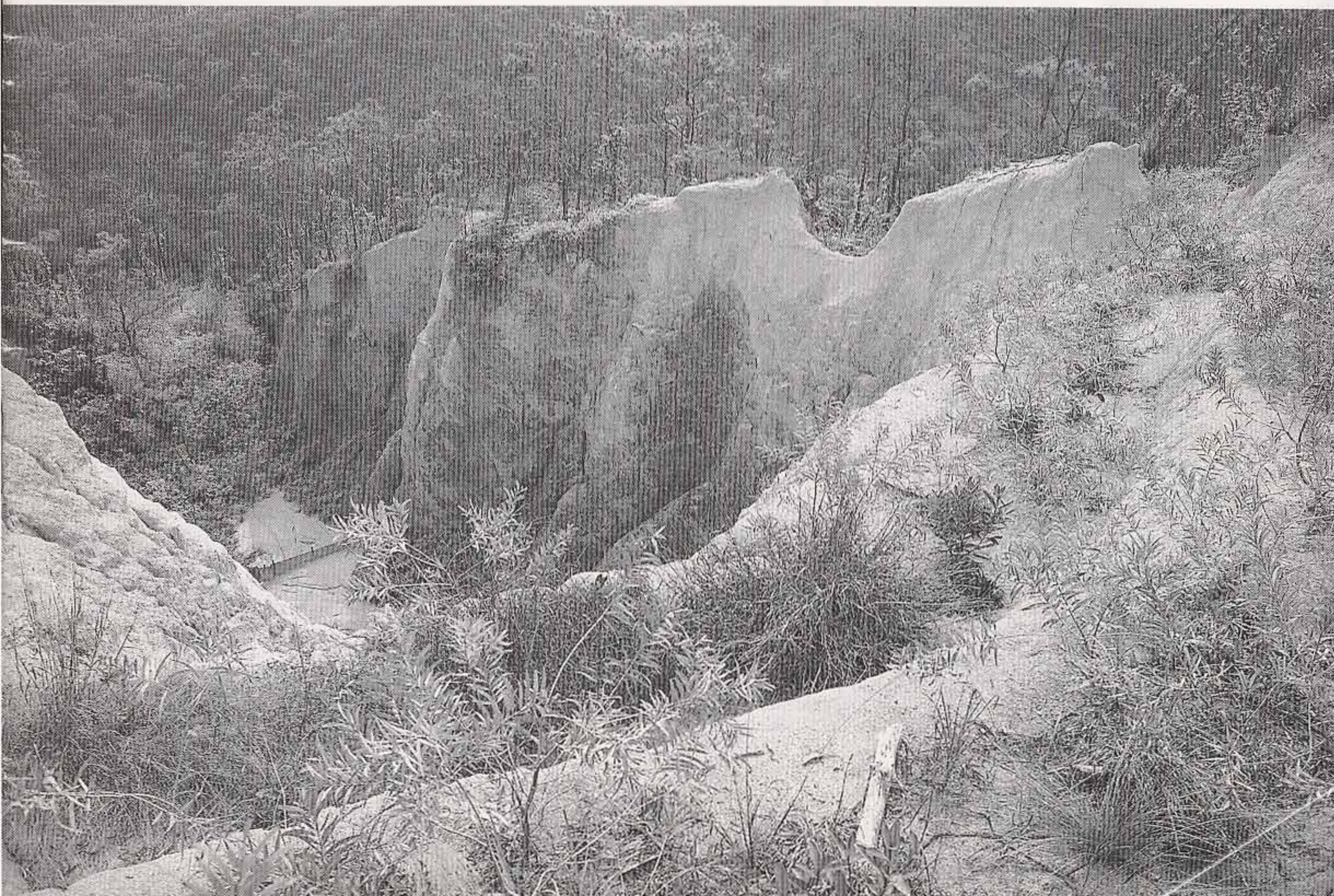

GEOLOGICAL SOCIETY OF HONG KONG

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POLYGONAL HILL RIDGES ON WEATHERED GRANITE IN HONG KONG

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Abstract

Near circular and near polygonal upstanding ridge crests occur at three localities in deeply weathered granite in Hong Kong. At Tai Lam Chung a group of broken polygons occur in a dissected basin. When reconstructed they form an orthogonal-polygonal network. The polygons are about 100 metres across with a local relief of 30 to 40 metres. The ridge crest pattern bears no relation to the structural lineaments of the granite. The centres of the polygonal network, however, shown preferred directions at 40° and 135° which are the major structural trends in the region. Joint spacing of 100 to 120 m, and extra weathering at the intersection of joints, would provide centres of swelling. The impinging of pressure circles would cause a polygonal framework of stiffness in the weathered granite on the undissected surface which would etch out on erosion.

Introduction

Discovery of polygonal hill ridges in Papua New Guinea (Ruxton 1978) and in New South Wales, Australia (Ruxton 1979) prompted a search for similar features elsewhere. The Hong Kong examples, all on weathered granite, were discovered from the air in 1980. Polygon means a closed, roughly equidimensional, figure bounded by several sides some of which may be curved (Lachenbruch 1963). Hill ridges are upstanding and the normal processes of erosion break through one side of the polygons. Nests of polygonal hill ridges occur and intergrade laterally into orthogonal ridge patterns and then rectangular ridge patterns of normal erosional development. The polygonal hill ridges are best developed on formerly gently sloping surfaces. This terrain differs from the alveolate patterns of Hurault (1967) in that centres are depressed not raised. The pattern is similar to grain growth in thin films (Frost *et al* 1986).

Hong Kong is a mountainous terrain formerly under rain forest with an average annual rainfall of 2130 mm. The annual average temperature is 21.6° C. and the climate causes deep weathering. A two cycle landscape occurs on the granite. The polygonal hill ridges occur where subjacent gently sloping surfaces are deeply weathered and then dissected (Ruxton & Berry, 1957). After deforestation some 800 years ago annual burning of the grass has led to gullying and the formation of local badlands with erosion up to 17 m/1000 years (Lam 1977). In the areas studied the general form of the ridges is still the same as that prior to deforestation. Occurrences of polygonal hills in Hong Kong range from 110 to 300 m altitude and are shown in Figure 1. The best polygonal ridge development is in the Tai Lam Chung catchment and this will be described first.

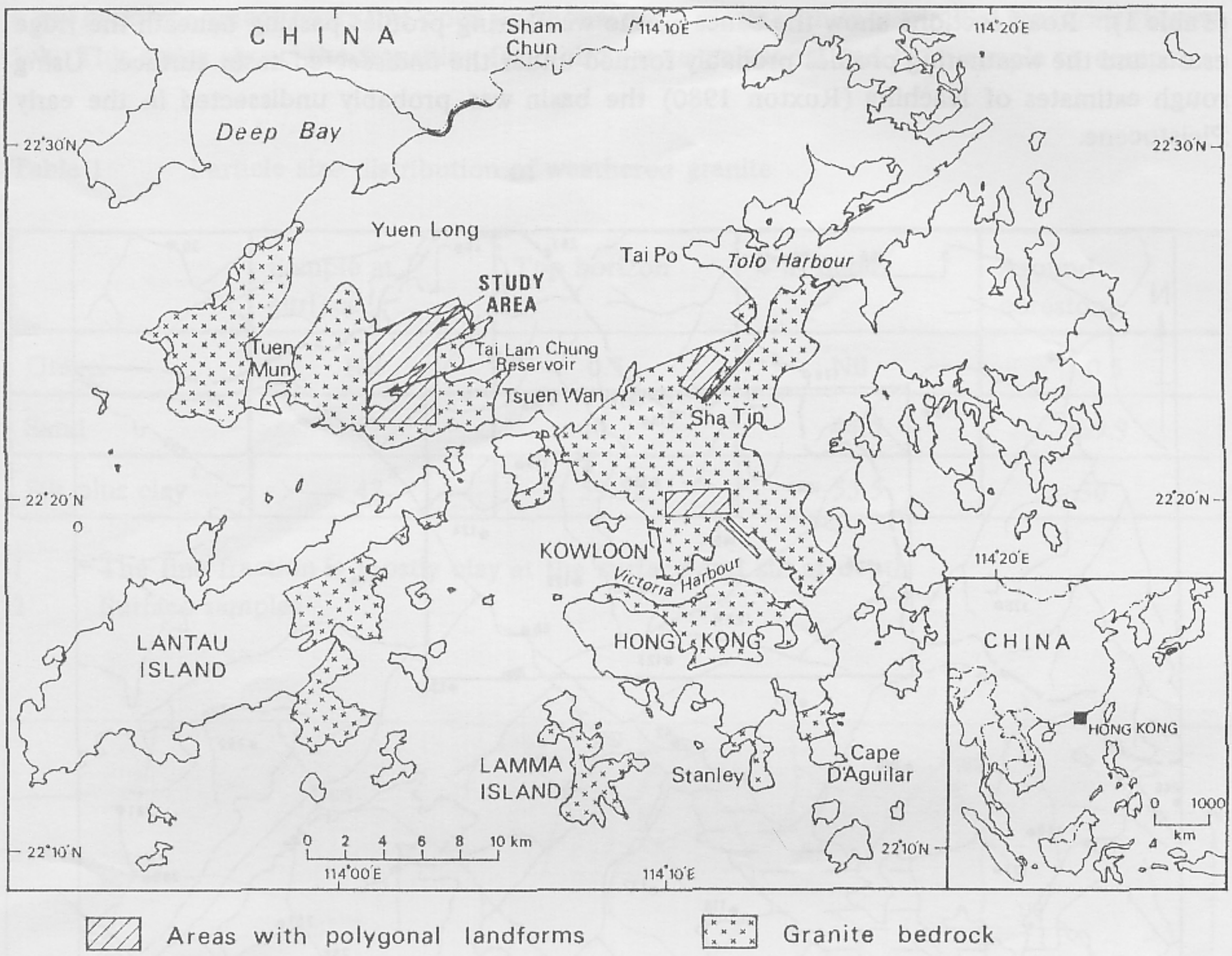

Figure 1 Location map of occurrences of polygonal hill ridges in Hong Kong

Tai Lam Chung

The catchment of the Tai Lam Chung reservoir is underlain by porphyritic leucogranite (Allen & Stephens 1971). Fine-grained granite occurs in the higher hills and the remainder is medium-grained granite. Patches of greisen occur and the area is traversed by many faults and thrusts with associated shear zones (Peng 1986). The drainage shows preferred lineaments at 145°, 82° and 40° (Figure 2). The hill ridges show directions in all points of the compass and are often curved so there is no apparent relation between hill ridge patterns and bedrock structure. The northern part of the catchment is basin-like in form (Figure 3) with accordant ridge crests at 112 to 123 m which are within the range of Berry's (1986) 130 m erosional level. The basin is surrounded by high hills frequently over 200 m in height. The dissected basin has high drainage density with close adjustment to the lineaments in the granite (So 1983). Some major streamlets, however, are partly centripetal, superimposed on the underlying structure (Figure 2). The relief is 30 to 40 metres and the stream spacing is about 200 m. Ridge crests are rounded and narrow and slopes are straight or concave (Figure 4). Headwall slumping is common.

The weathering profiles are 20 to 30 m in thickness with few corestones. In general the profile passes down into grus. Material near the top of the profile consists of approximately equal parts of sand and silt/clay with some selective loss of fines by erosion. This is also the case for material near the base of the grus which may be indicative of a high degree of decomposition

(Table 1). Road sections show the zones of the weathering profiles passing beneath the ridge crests and the weathering profiles probably formed under the undissected basin surface. Using rough estimates of leaching (Ruxton 1980) the basin was probably undissected in the early Pleistocene.

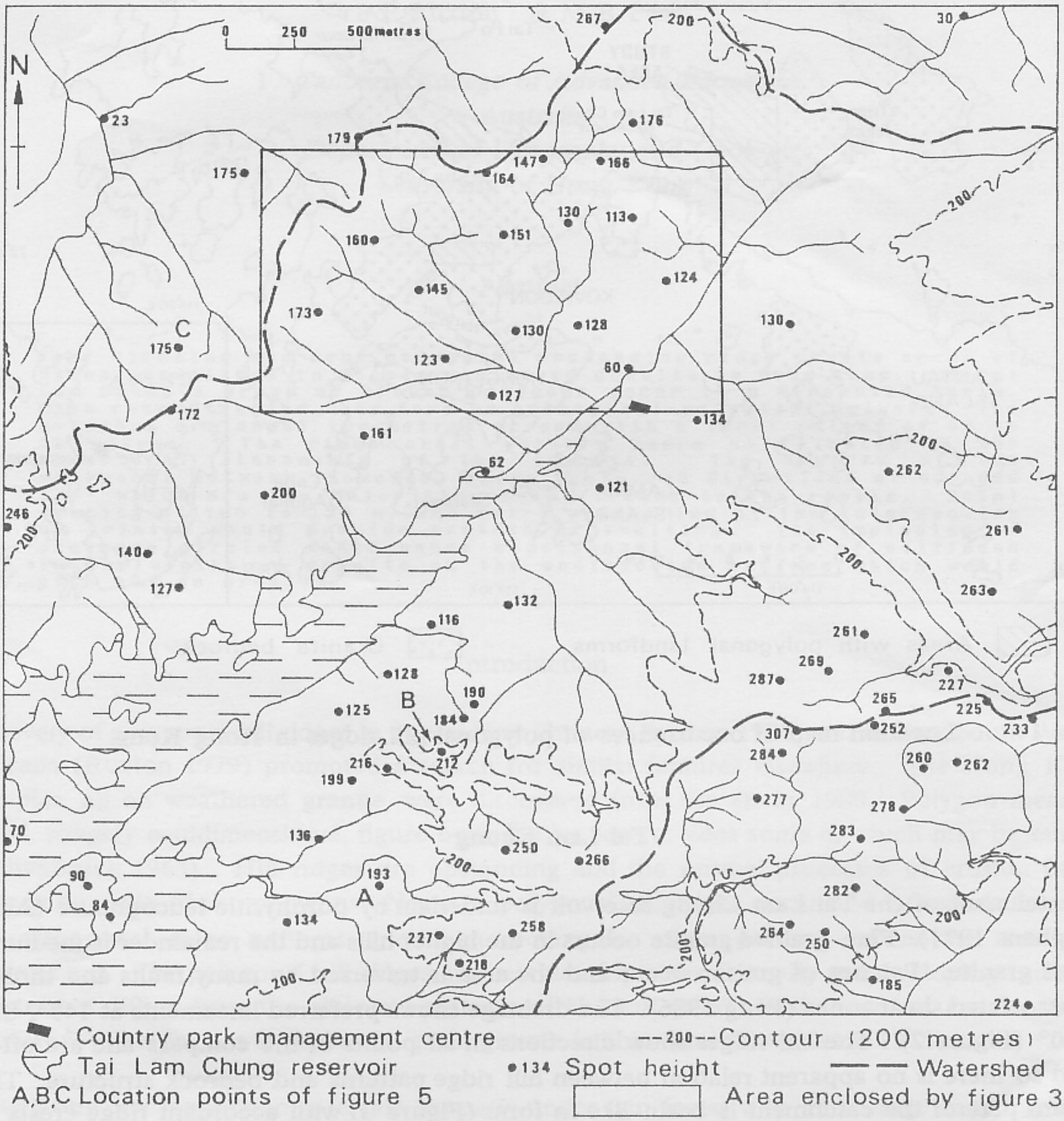

Figure 2 Tai Lam Chung catchment showing ridge crest heights in metres

The polygonal hill ridges

Compartments of granite bounded by joints or shear zones may be only 150 m across. One such compartment (Figure 5a) bears at its centre a nearly complete circular ridge crest. Three of these occur (Figure 6). The next stage, with a 300 m compartment (Figure 5b), bears both a curved ridge crest and two open polygonal ridge crests with one triradial junction (120°). Finally a 350 m compartment bears five open polygonal ridge crests with four triradial junctions (Figure 5c). This series shows the transition from circular to polygonal and from simple to complex.

Table 1 Particle size distribution of weathered granite

	Sample at surface	Top horizon	4 m depth	Around corestone
Gravel	Nil	0.5	Nil	0.5
Sand	57	40	44.5	69.9
Silt plus clay [1]	43 [2]	59.52	55.5	30

1 The fine fraction is mostly clay at the surface and silt at depth
2 Surface samples

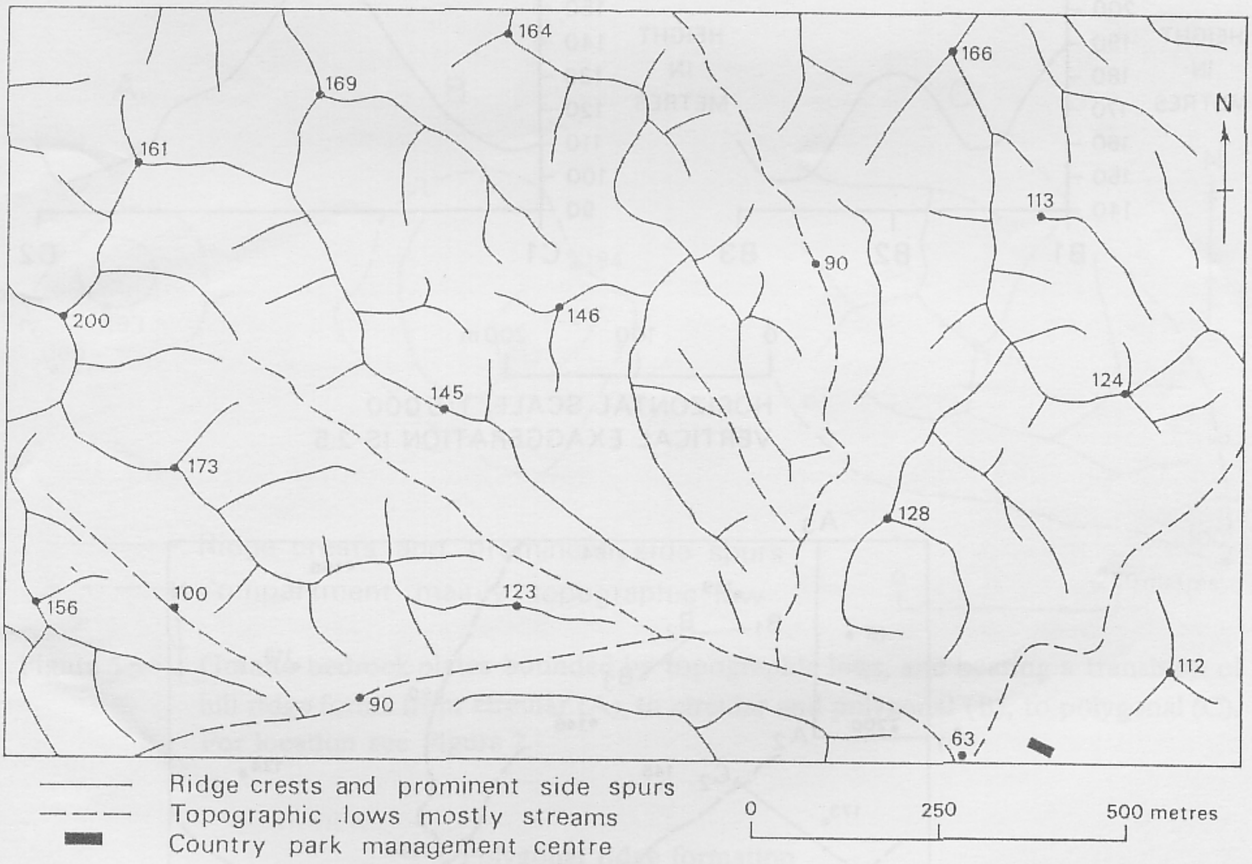

Figure 3 Ridge crest pattern in northern Tai Lam Chung Basin (location Figure 2)

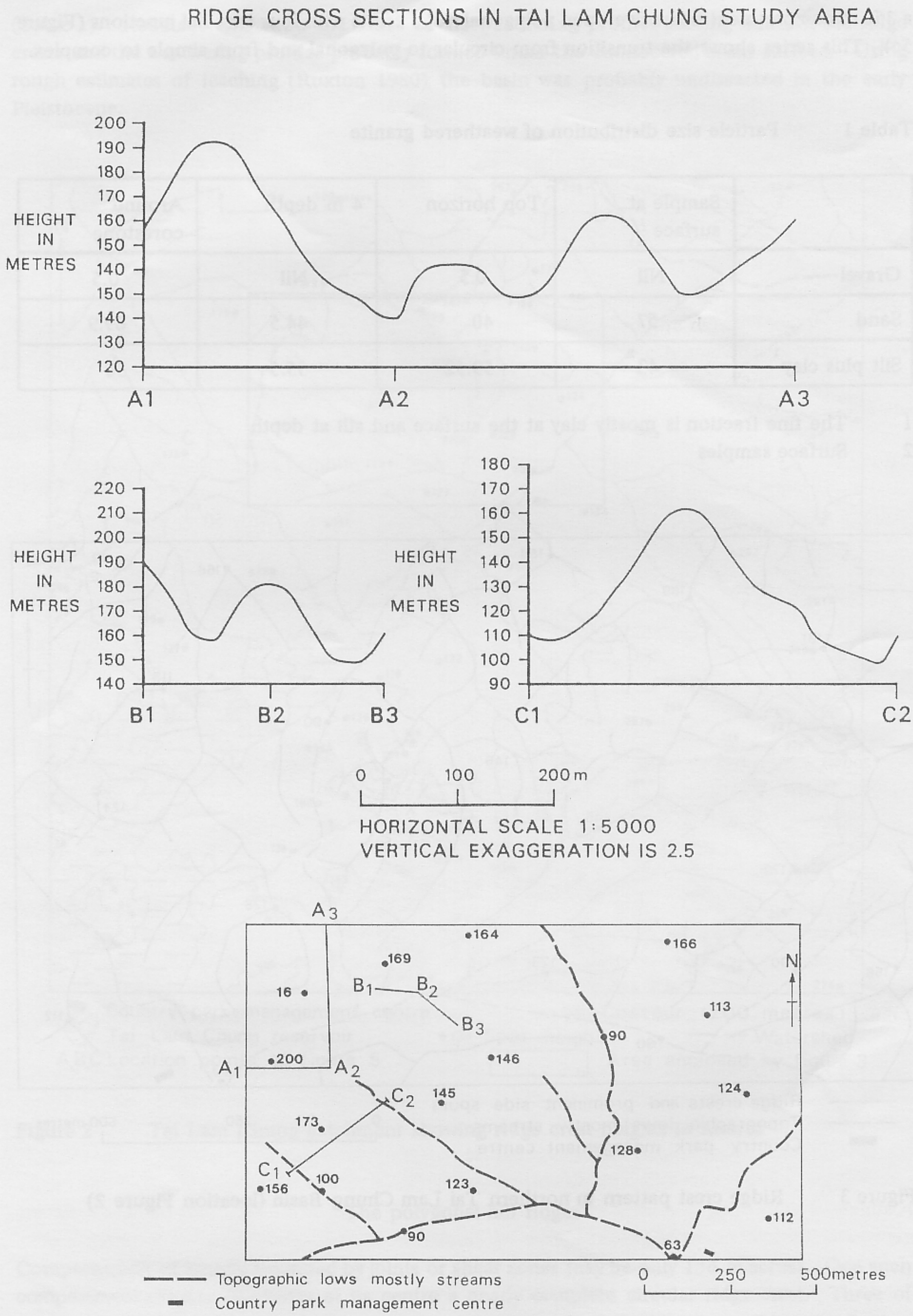

Figure 4 **Sections across hill ridges (section lines in inset, area covered is same as Figure 3)**

Figure 6 shows the reconstructed hill ridge pattern believed to have been dormant prior to the dissection of the basin drawn from the aerial photograph. The incomplete ridge pattern was completed by extending ridge crests, joining ridges pointing towards each other, and when three or more sides were present completing the final side. The fact that a completed network emerged, which can be envisaged under the stereoscope, suggests that the undissected basin form had this pattern. The network shows clearly a polygonal nest in the east and rectangular patterns from normal erosion in the north. Larger polygons are more irregular than small ones and may be partitioned by a bridge which is as method of subdivision to average size and demonstrates the principle of homogeneity (Conrad 1964).

The dispersion pattern of the centres of the centres of the polygons (Figure 7) shows alignments of 135° and 40° which are the major structural directions in Hong Kong. Intersection joints 100 to 120 m apart would give much of the pattern observed. In limestone country sinkholes form at these intersections (Williams 1972) and perhaps in granite country deeper weathering occurs in the broken rock at these points (Thomas 1974).

The polygonal hill ridges at Sha Tin and Kowloon are sometimes perfect broken hexagons on dissected, gently sloping, deeply weathered surfaces on medium-grained granite (Addison, 1986, Strange & Shaw, 1986). Some of these polygons are 200 m across with 50 m relief.

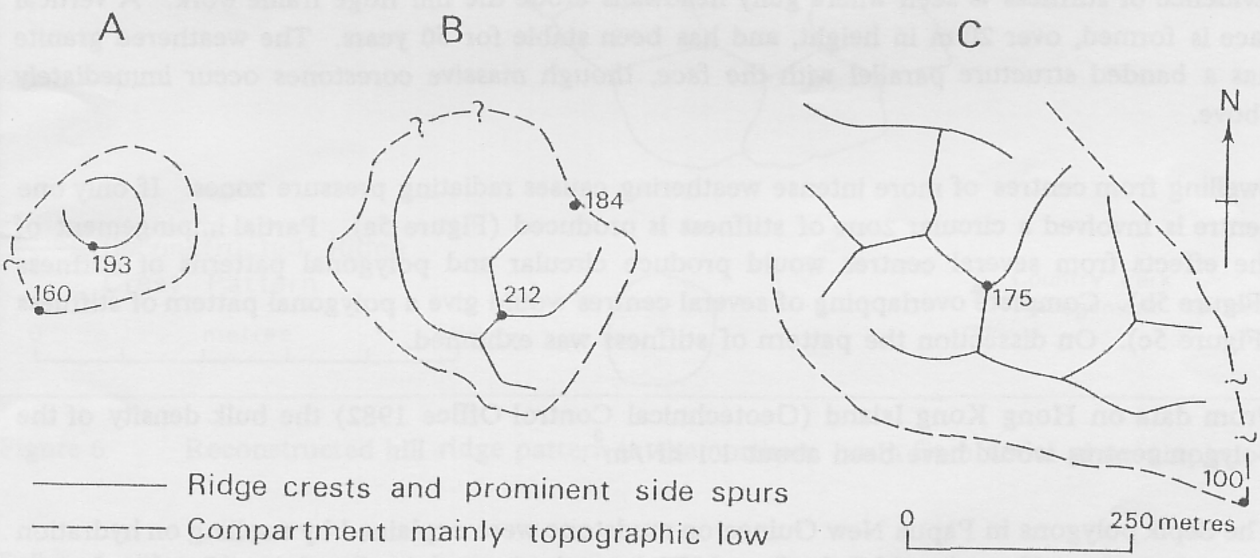

Figure 5 Granite bedrock plates bounded by topographic lows, and bearing a transition of hill ridge forms from circular (A), to circular and polygonal (B), to polygonal (C). For location see Figure 2

Polygonal ridge formation

A suggested sequence of events for polygonal ridge formation is; the formation of less resistant centres at the intersection of joints; the swelling from these centres; and the formation of a resistant framework of hill ridges. This sequence may involve weathering, swelling, stiffness, cementation and compaction.

1 Weathering. Solution is the cause of polygonal karst (Williams 1972) which is very similar in form to the Hong Kong polygons. Solution depressions of similar diameter are also known in

diorite (Le Grand 1952) and a range of depressions are known in granite (Twidale 1982). At joint intersections it is expected that the deeper and more thoroughly weathered material, with an angle of friction of the debris at about 37°, would be eroded preferentially to the grus on the ridge crests with an angle of friction of about 44° (Geotechnical Control Office 1982).

2 **Swelling.** Claims that granite expands on weathering were made by Merrill (1895), Branner (1896) and Folk & Patton (1982). In the early stages of weathering the production of clay products may outstrip the leaching (Blackwelder 1925; Kiersch & Treasher 1955; Twidale 1982). The platelets of Figure 5 are reminiscent of the unloading plates of Hack (1966) in North Carolina. Maybe expansion on unloading is succeeded by expansion during rock hydration and early weathering (Nishioka & Harada 1958; Thomas 1974). Grus can swell on hydration (McLean & Gribble 1979) and some weathered granite swells (Gordon *et al* 1958; Duncan *et al* 1968). The sequence of clay mineral changes on weathering of granite in Hong Kong (Lumb & Chack-Fan 1975) is allophane, fully hydrated halloysite, halloysite and kaolin. The fully hydrated halloysite phase would probably cause the swelling of the weathered debris (cf Kazda 1961). In grus the content of fully hydrated halloysite may increase with depth (Wolff 1967). Only very slight expansion occurs. Pressure builds up around centres causing tightening of the fabric where pressure waves meet and produces a polygonal pattern of stiffened saprolite.

3 **Stiffness.** Stiffness is a tightened interlocking of the grains of the weathered granite. Evidence of stiffness is seen where gully headwalls erode the hill ridge frame work. A vertical face is formed, over 20 m in height, and has been stable for 50 years. The weathered granite has a banded structure parallel with the face, though massive corestones occur immediately above.

Swelling from centres of more intense weathering causes radiating pressure zones. If only one centre is involved a circular zone of stiffness is produced (Figure 5a). Partial impingement of the effects from several centres would produce circular and polygonal patterns of stiffness (Figure 5b). Complete overlapping of several centres would give a polygonal pattern of stiffness (Figure 5c). On dissection the pattern of stiffness was exhumed.

From data on Hong Kong Island (Geotechnical Control Office 1982) the bulk density of the polygon centres would have been about 1.1 kN/m^3.

The Sepik polygons in Papua New Guinea on mudstone were explained by swelling on hydration beneath a cover of pervious fanglomerate. The weathering would then be confined and great pressures could be built up perhaps even forming thrust planes along which reverse mass movement could take place afterwards. The claim of constant volume alteration (Ollier 1967) may not then be universal. The best polygons at Tai Lam Chung are in the lowest areas of the basin where a previous colluvial cover is most likely to have occurred.

Alternate hypotheses

1 **Compaction.** Earthquake vibrations may cause settling and compaction in patterns (Corbel 1954). Earthquakes were probably common in the Pleistocene in Hong Kong when the basin was undissected as is shown by the abundance of large debris flows at that time (Ruxton 1985). A similar polygonal pattern on a large scale was shown for fault blocks caused by the Tokyo earthquake (Miyabe 1935).

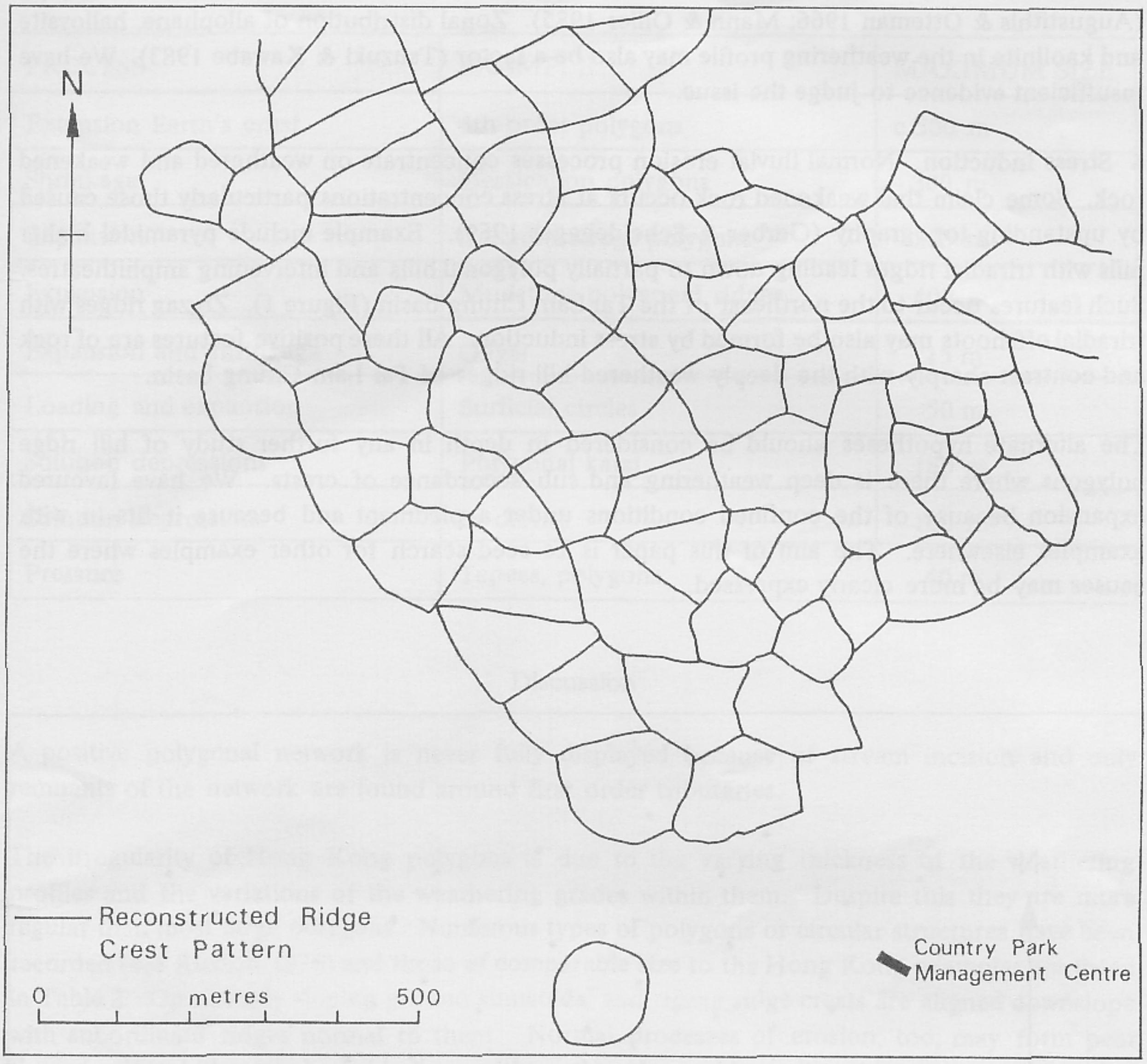

Figure 6 Reconstructed hill ridge pattern in the northern basin from aerial photographs

Ball and pillow structures is coal measures up to 500 m from faults are explained as due to shock waves emanating from the fault lines (Weaver 1976). If two crossing faults are activated at the same time (at 135° and 40° Figure 7) compaction of saprolite in polygonal patterns is a strong possibility due to seismic wave interference effects.

2 Cementation. The reconstructed pattern of hill ridges (Figure 6) is very similar to giant dessication fissures in the great playas (Neal *et al* 1968) and may thus be partly a contraction phenomena. Contraction could not be by open fissures or negative polygons would forms. Many cracks and loosened zones heal when wet and provide pathways for vigorous water circulation. Cementation of these zones by iron and clay may follow and cause overall strengthening of them. Weathered granite is strongly cemented elsewhere in Hong Kong (Ruxton 1987). Cementation, causing polygons, is also reported for calcrete wedge development (Goudie 1973) and tepee formation in lagoons. The patterns of groundwater circulation beneath the piedmont surface may have assisted cementation in some places and solution in others.

3 Diffusion. Diffusion from centres may be involved with precipitation of clay, silica or iron (Augustithis & Otteman 1966; Mann & Ollier 1985). Zonal distribution of allophane, halloysite and kaolinite in the weathering profile may also be a factor (Tsuzuki & Kawabe 1983). We have insufficient evidence to judge the issue.

4 Stress induction. Normal fluvial erosion processes concentrate on weathered and weakened rock. Some claim that weakened rock occurs at stress concentrations particularly those caused by upstanding topography (Gerber & Scheideggger 1969). Example include pyramidal higher hills with triradial ridges leading down to partially polygonal hills and intervening amphitheatres. Such features occur to the northeast of the Tai Lam Chung basin (Figure 1). Zigzag ridges with triradial offshoots may also be formed by stress induction. All these positive features are of rock and contrast sharply with the deeply weathered hill ridges of Tai Lam Chung basin.

The alternate hypotheses should be considered in depth in any further study of hill ridge polygons where there is deep weathering and sub-accordance of crests. We have favoured expansion because of the confined conditions under a piedment and because it fits in with examples elsewhere. The aim of this paper is to seed search for other examples where the causes may be more clearly expressed.

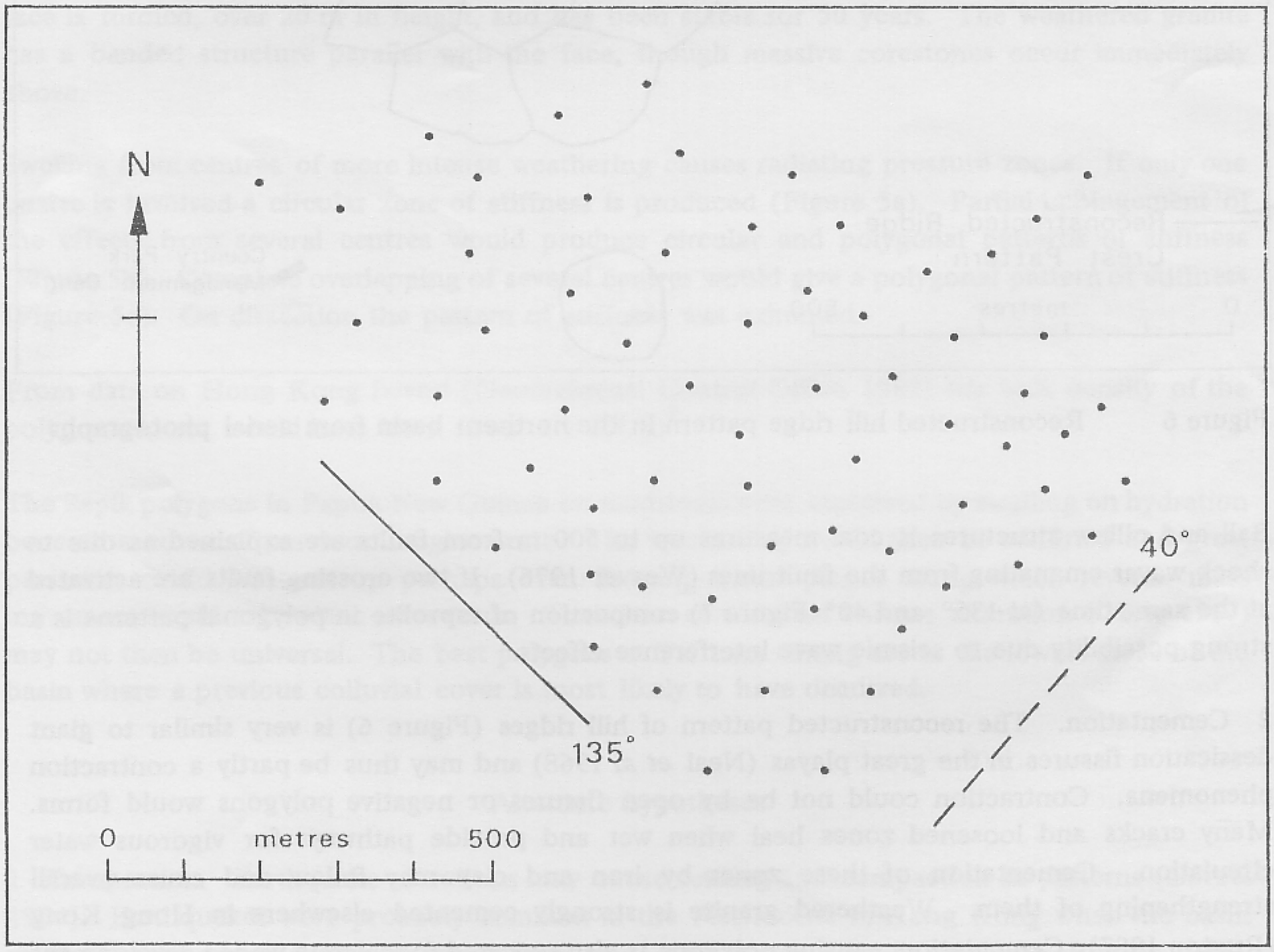

Figure 7 Dispersion of polygonal centres from Figure 6 showing dominant trends at 135° and 40°

Table 2 Origin of comparable polygons and circles

PROCESS	EXAMPLE	MAXIMUM SIZE
Extension Earth's crust	5th order polygons	c 500 m
Shrinkage	Dessication polygons	300 m
Expansion	Calcrete wedge polygons	200 m
Expansion	Mudstone polygonal ridges	400 m
Expansion and shrinkage	Gilgai	15 m
Loading and expansion	Surficial circles	50 m
Solution depressions	Polygonal karst	180 m
Solution depressions	In diorite	100 m
Pressure	Tepees, polygons	40 m

Discussion

A positive polygonal network is never fully displayed because of stream incision and only remnants of the network are found around first order tributaries.

The irregularity of Hong Kong polygons is due to the varying thickness of the weathering profiles and the variations of the weathering grades within them. Despite this they are more regular than most large polygons. Numerous types of polygons or circular structures have been recorded (see Ruxton 1978) and those of comparable size to the Hong Kong examples are listed in Table 2. On strongly sloping ground sinusoidal and zigzag ridge crests are aligned downslope with subordinate ridges normal to them. Normal processes of erosion, too, may form pear shaped or amphitheatre shaped hollows with partly polygonal bounding ridge crests and triradial junctions but they seldom form a tessellation.

The Tai Lam Chung rectangular ridges can form without the need for pressure swelling because the zones of the weathering profile, going upwards, are increasingly less resistant towards the surface (Ruxton & Berry 1957). On exhumation of the basin surface the soft centres would be most eroded leaving a framework of hill ridges at the divides.

All three types of polygonal hill ridges in Papua New Guinea, New South Wales (Australia) and Hong Kong, could be controlled by regularly spaced intersecting joint systems and weathering induced swelling confined beneath a previous piedmont colluvial or alluvial cover. In Hong Kong the former colluvial cover was probably thin and patchy.

There is a relationship between the radius of the circle or polygon (50 m) and the depth of weathering (20 to 30 m). In Papua New Guinea and Hong Kong this ratio is about 2:1. Each polygon or circle has its own tablet of weathered debris albeit in Hong Kong joined to the neighbouring ones. The swelling of the tablet causes both weakness at the surface in the centre and strength on impingement with neighbours.

Table 3 Suggested geomorphic history of the hill ridges

6	Deforestation, drying out, regolith contraction, cracks on ridges	800 years
5	Ridge network reduced by fluvial erosion and slumping under rain forest	Upper Pleistocene
4	Piedmont is exhumed and dissected into polygonal hill ridges	Middle Pleistocene
3	Confined weathering profile swells from centres forming stiff framework	Early
2	Deep weathering of piedmont, deeper at joint intersections	Pleistocene
1	*Parallel slope retreat forms piedmont with cover of pervious colluvium*	*?Pliocene*

The history of the Tai Lam Chung dissected basin is given in Table 3. Parallel slope retreat was suggested by Ruxton & Berry (1957) but other forms of basin formation are possible. Continuous downwearing is not favoured because the weathering profiles would be expected to be much more variable laterally. The age of the weathering profiles is taken as roughly half a million years (Ruxton 1980). Low permeating pressures of 2 kg/cm² (Kazda 1961) over long time periods would be sufficient to cause patterned stiffness. Since exhumation the polygonal pattern has been much eaten into by normal fluvial erosion and no perfect polygons are found. Perfect polygons are extremely rare in Papua New Guinea despite 2000 km² of patterns. Of interest is the change from slumping under rain forest to ridge cracking by dessication under grass. Contraction, therefore, has only occurred in the last 800 years since deforestation. Compaction and cementation could have accompanied other changes anytime in the history.

Conclusion

Uniformly spaced joint intersections in granite caused centres of initial weathering under a small, colluvium covered, piedmont. As weathering spread a pressure front due to swelling of fully hydrated halloysite radiated outwards. Circles of pressure, seen as circular ridges, impinged and became orthogonal or polygonal. Most of the polygonal frameworks are five sided as in polygonal karst. Later, lateral variations developed in the weathering profiles from the centre to the rim of the compartments. Bulk densities probably varied from 1.1 to 1.7 kN/m³ and shear strength probably from friction angles of 37° to 44°. Material at the rim of the polygons has stood for over 50 years as 20 m vertical faces. Cementation may also be a factor and cracks due to contraction and swelling may have been healed and reinforced. These processes caused an orthogonal-polygonal framework. On dissection the framework pattern was exhumed as negative centres and positive surrounding hill ridges.

The generation of a compressional planar stress system from a centre depends on there being homogeneous elastic weathered debris of generally uniform thickness with few corestones to dampen the pressure wave. Uniformity is essential as there is no buckling or flowage visible. Some buried slump shear surfaces could have been thrusts but this has not yet been confirmed.

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SUPPLEMENTARY REPORT ON THE DISCOVERY OF LOWER AND MIDDLE DEVONIAN FOSSILS IN HONG KONG

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Localities

After the report with the title "A Report on the Discovery of Lower Devonian Fossils in Hong Kong" (C M Lee *et al* 1990) was completed in August 1989, the cooperative team further found abundant fossils of Devonian age in the Plover Cove area, New Territories, Hong Kong. The new collection includes about 300 specimens classified into five kinds of fossil; plants, ostracods, bivalves, conchostracans and fishes obtained from 18 new localities in addition to the previously reported 5 localities. The localities are demonstrated in Figure 1, and the new finds with the principal description of lithological characteristics at the 18 localities are summarized as follows:

- Locality 4′ – Plants from the purple-red siltstone
- Locality 6 – Plants, ostracods, bivalves and conchostracans from the brown-red mudstone
- Locality 7 – Ostracods from the brown-yellow siltstone
- Locality 8 – Ostracods, bivalves and conchostracans from the red mudstone and brown-yellow siltstone
- Locality 9 – Ostracods and fishes from the red mudstone and siltstone
- Locality 10 – Plants from the brown-yellow siltstone
- Locality 11 – Plants from the brown-red siltstone
- Locality 12 – Ostracods and fishes from the purple-red siltstone and brown-yellow mudstone
- Locality 13 – Ostracods from the purple-red siltstone
- Locality 14 – Plants, bivalves and conchostracans from the brown-red mudstone
- Locality 15 – Plants and fishes from the brown-yellow mudstone
- Locality 16 – Fishes from the purple-red siltstone and mudstone
- Locality 17 – Plants from the brown-yellow siltstone
- Locality 18 – Bivalves, plants, conchostracans and fishes from the brown-yellow mudstone and siltstone
- Locality 19 – Bivalves and conchostracans from the purple-red and brown-yellow mudstone and siltstone
- Locality 20 – Plants, conchostracans and bivalves from the purple-red mudstone and siltstone
- Locality 21 – Fishes from the brown-red mudstone
- Locality 22 – Conchostracans and ostracods from the purple-red mudstone and brown-yellow siltstone
- Locality 23 – Plants from the purple-red siltstone and mudstone

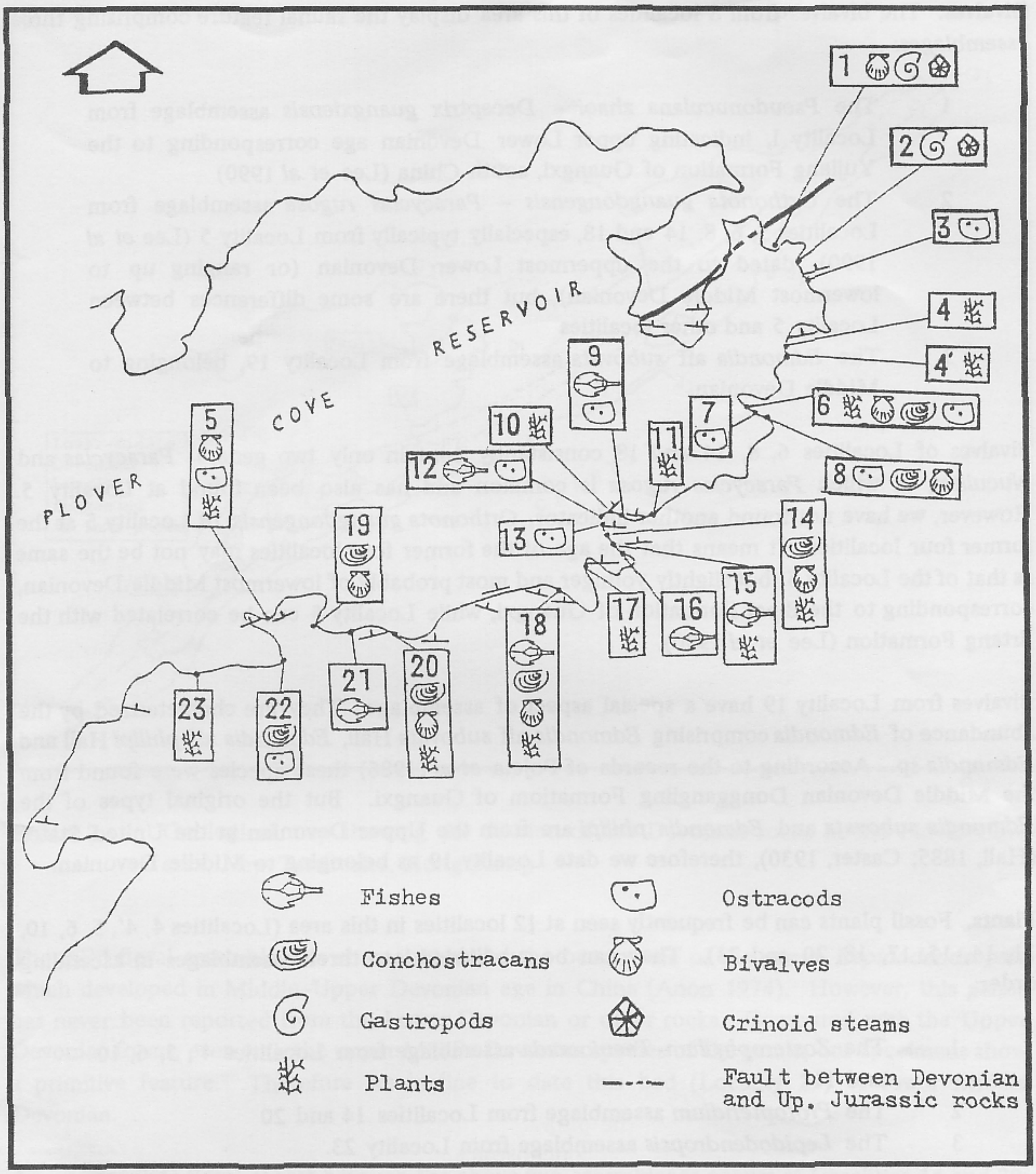

Figure 1 Devonian fossil localities in the Plover Cove area, New Territories, Hong Kong

Age

This paper gives the results of identification of fossil bivalves and plants from the new localities and discusses the geological age, taking account of the former study, although further study of other fossil kinds will be made in the near future.

Bivalves. The bivalves from 8 localities of this area display the faunal feature comprising three assemblages:

1 The *Pseudonuculana zhaoi* - *Deceptrix guangxiensis* assemblage from Locality 1, indicating upper Lower Devonian age corresponding to the Yujiang Formation of Guangxi, south China (Lee *et al* 1990)

2 The *Orthonota guangdongensis* - *Paracyclas rugosa* assemblage from Localities 5, 6, 8, 14 and 18, especially typically from Locality 5 (Lee *et al* 1990), dated to the uppermost Lower Devonian (or ranging up to lowermost Middle Devonian), but there are some differences between Locality 5 and other localities

3 The *Edmondia* aff *subovata* assemblage from Locality 19, belonging to Middle Devonian.

Bivalves of Localities 6, 8, 14 and 18 consistently contain only two genera, *Paracyclas* and *Nuculites*, of which *Paracyclas rugosa* is common and has also been found at Locality 5. However, we have not found another indicator, *Orthonota guangdongensis*, of Locality 5 at the former four localities. It means that the age of the former four localities may not be the same as that of the Locality 5, but slightly younger and most probably of lowermost Middle Devonian, corresponding to the Sipai Formation of Guangxi, while Locality 5 can be correlated with the Ertang Formation (Lee *et al* 1990).

Bivalves from Locality 19 have a special aspect of assemblage. They are characterized by the abundance of *Edmondia* comprising *Edmondia* aff *subovata* Hall, *Edmondia* aff *philipi* Hall and *Edmondia* sp. According to the records of Pojeta *et al* (1986) these species were found from the Middle Devonian Donggangling Formatiom of Guangxi. But the original types of the *Edmondia subovata* and *Edmondia philipi* are from the Upper Devonian in the United States (Hall, 1885; Caster, 1930), therefore we date Locality 19 as belonging to Middle Devonian.

Plants. Fossil plants can be frequently seen at 12 localities in this area (Localities 4, 4′, 5, 6, 10, 11, 14, 15, 17, 18, 20 and 23). They can be subdivided into three assemblages in ascending order:

1 The *Zosterophyllum*- *Taeniocrada* assemblage from Localities 4′, 5, 6, 10 and 11

2 The *Protopteridium* assemblage from Localities 14 and 20

3 The *Lepidodendropsis* assemblage from Locality 23.

The remainder from Localities 4, 15, 17 and 18 are indeterminable.

The first assemblage contains *Zosterophyllum*, *Taeniocrada*, *Psilophytopsida*? and *Psilophytites*?. The genus *Zosterophyllum* is an indicator of the Lower Devonian age in south China; it is also regarded as an indicator of that age widely throughout the world (Li & Cai 1977, 1978, 1979; Hang 1979; Cai & Li 1982; Fang *et al* 1985). So it is undoubtedly true that this assemblage belongs to the Lower Devonian age. This is very important for the biostratigraphical correlation of the Hong Kong strata with other places in southeast China because this genus was formerly also found in similar horizons to the present assemblage such as the Lower Devonian of Hueiji county of northwest Guangdong and of Jiangyong county of southwest Hunan.

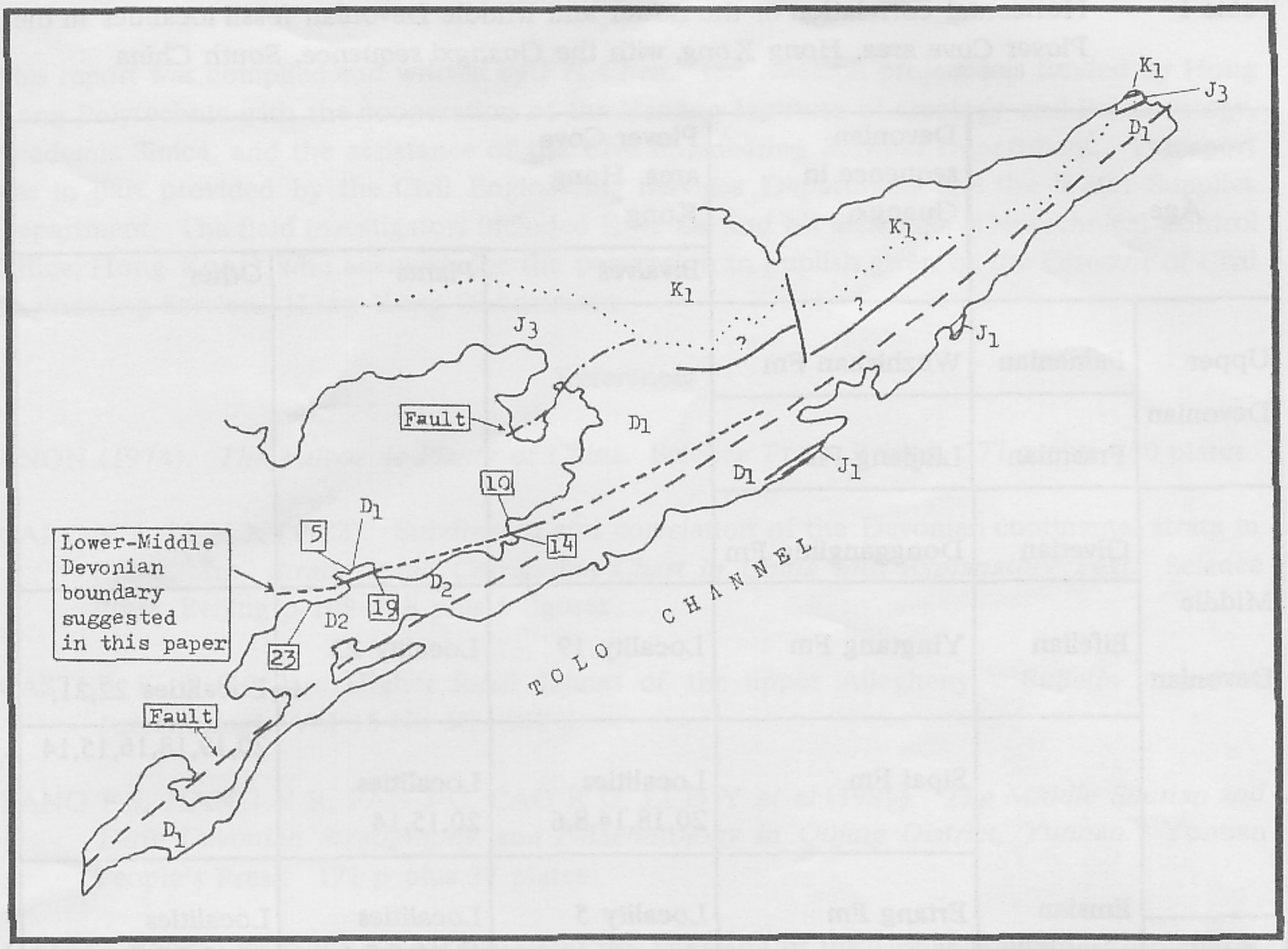

Figure 2 Geological map showing the division of the Devonian rocks in the Plover Cove area, New Territories, Hong Kong

The third floral assemblage is characterized by the occurrence of the genus *Lepidodendropsis*, which developed in Middle–Upper Devonian age in China (Anon 1974). However, this genus has never been reported from the Lower Devonian or older rocks. Compared with the Upper Devonian forms, even with the upper Middle Devonian species of the genus, our specimens show a primitive feature. Therefore we incline to date this bed (Locality 23) to lower Middle Devonian.

An intermediate floral aspect between the above two assemblages occurs at Localities 14 and 20; it is represented by cf *Protopteridium minutum* Halle and *Protopteridium*? sp of the second assemblage. However, this assemblage has no advanced elements such as Protolepidodendrales which occur in the third assemblage, although the genus *Protopteridium* is restricted to the Middle Devonian in age in China. We correlate this assemblage to the uppermost Lower Devonian or lowermost Middle Devonian due to its close location with the *Zosterophyllum* bearing-bed (Locality 10).

The geological ages of these localities are synthetically shown in Table 1, determined by J H Chen and S Q Wu.

Table 1 Horizontal correlation of the Lower and Middle Devonian fossil localities in the Plover Cove area, Hong Kong, with the Guangxi sequence, South China

Age		Devonian sequence in Guangxi	Plover Cove area, Hong Kong		
			Bivalves	Plants	Other
Upper Devonian	Famenian	Wuzhishan Fm			
	Frasmian	Liujiang Fm			
Middle Devonian	Givetian	Donggangling Fm			
	Eifelian	Yingtang Fm	Locality 19	Locality 23	Localities 22,21, 20,19,18,16,15,14
		Sipai Fm	Localities 20,18,14,8,6	Localities 20,15,14	
Lower Devonian	Emsian	Ertang Fm	Locality 5	Localities 11,10,6,5,4	Localities 13,12,9,8,7,6,5,3
		Yujiang Fm	Locality 1		Locality 1
	Siegenian	Nagaoling Fm			
	Gedinian	Lianhuashan Fm			

Conclusion

The Devonian rocks to the east Plover Cove can be divided into two; Lower Devonian in the north and Middle Devonian in the south. Between them the lithological boundary is not clear because of the gradual change. However, an age boundary of the Lower–Middle Devonian is inserted between Locality 5 and Locality 19 on the basis of bivalves, and between Locality 10 and 14 based on plants (Figure 3).

Acknowledgments

This report was compiled and written by J H Chen. The research project was funded by Hong Kong Polytechnic with the cooperation of the Nanjing Institute of Geology and Paleontology, Academia Sinica, and the assistance of the Civil Engineering Services Department. Transport was in part provided by the Civil Engineering Services Department and the Water Supplies Department. The field investigators included K W Lai and his assistants (Geotechnical Control Office, Hong Kong), who acknowledge the permission to publish given by the Director of Civil Engineering Services, Hong Kong Government.

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Explanation for Plates

Plate I

(All fossils in this plate are enlarged)

1 & 2	Ostracods from Locality 9
3	Bivalve from Locality 8
4 – 10	Fishes
4 & 5	From Locality 21; 6 from Locality 18; 7 & 8 from Locality 16; 9 from Locality 9; 10 from Locality 18

Plate II

(All plant fossils in this plate are enlarged)

1 & 2	*Protopteridium*? sp, from Locality 20
3	*Psilophylites*? sp, from Locality 11
4 & 8	*Zosterophyllum* sp, from Locality 10
5 & 6	cf *Protopteridium minutum* Halle, from Locality 14
7	*Taeniocrada* sp, from Locality 4′

Plate I

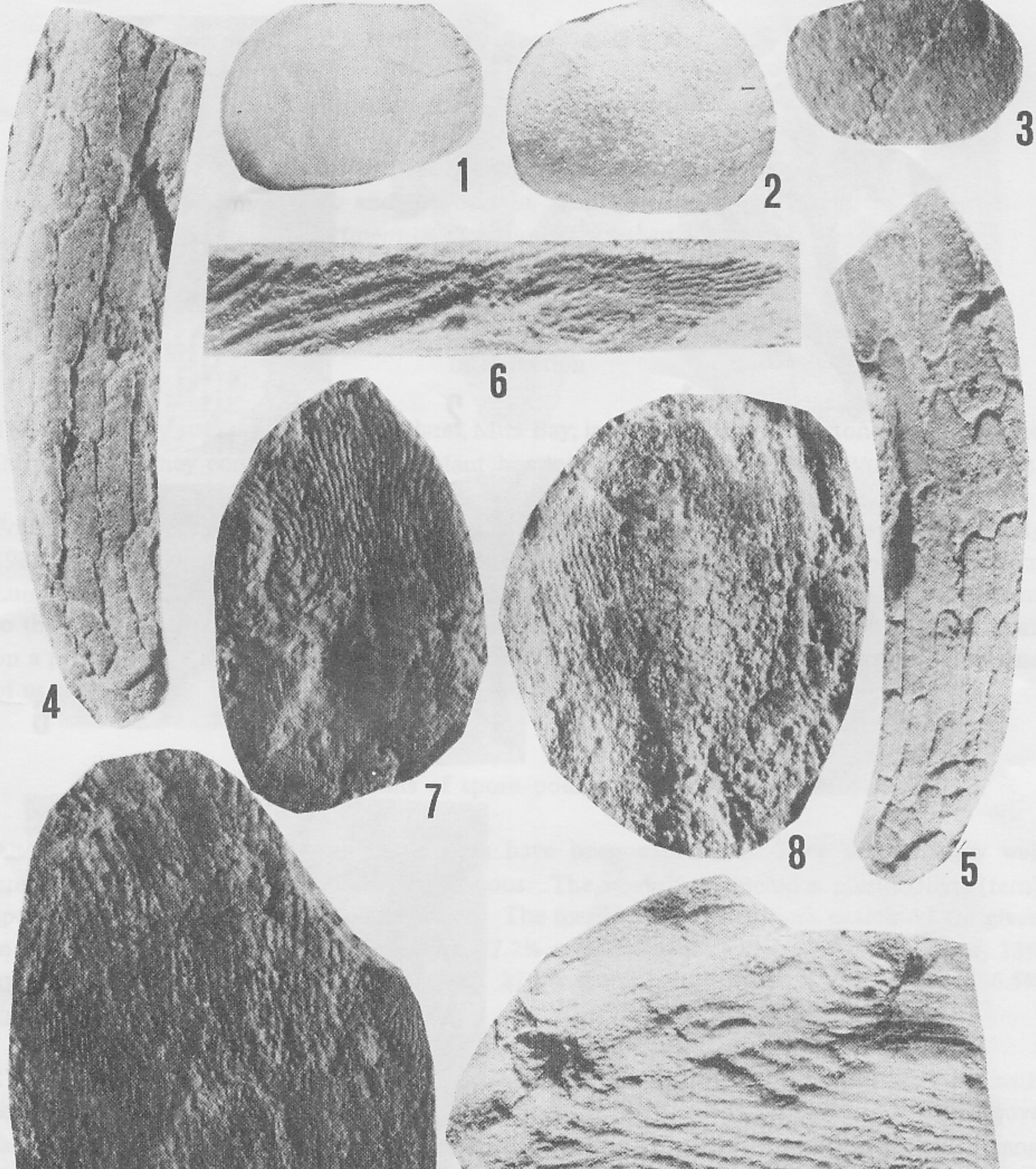
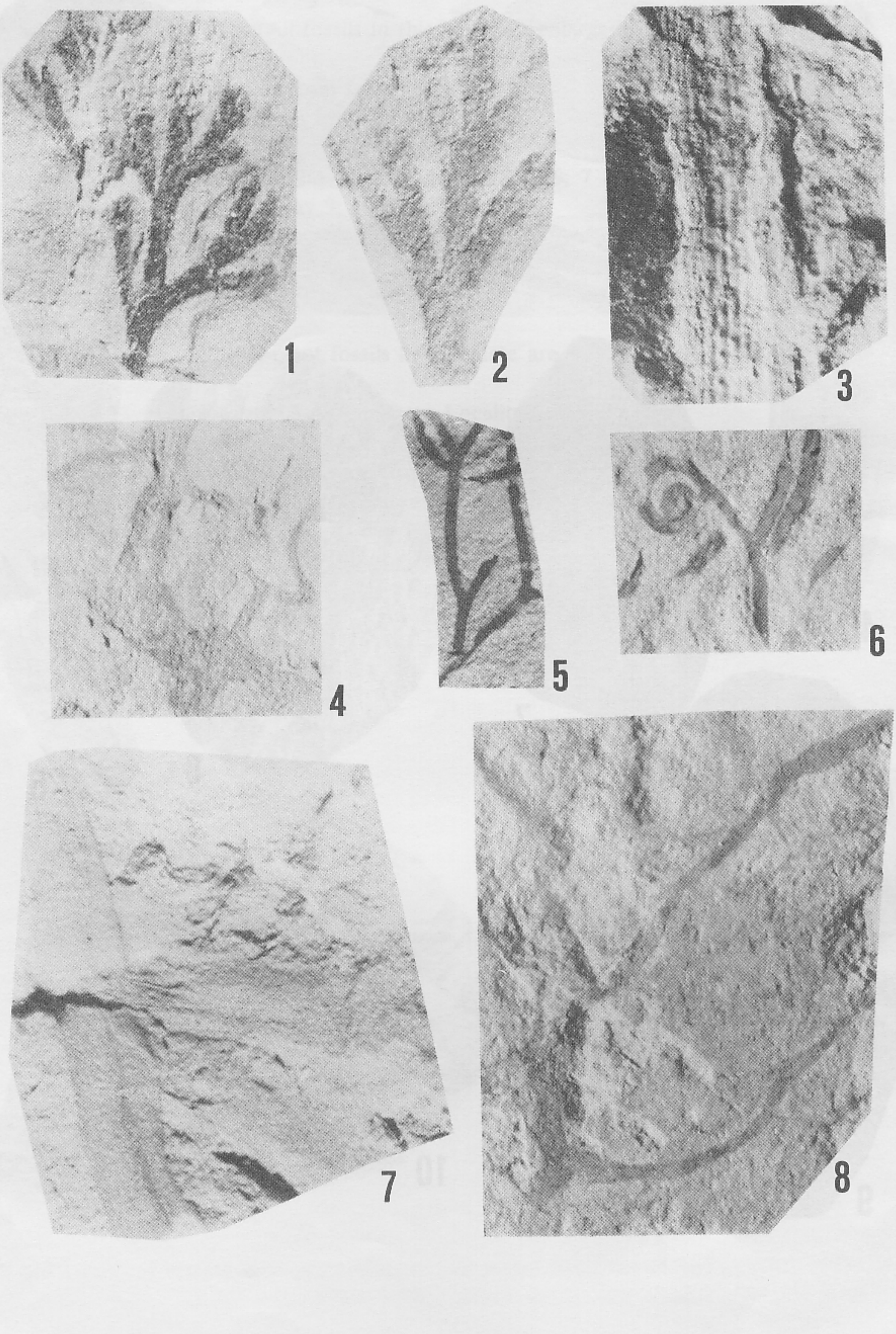


Plate II



Geological Society of Hong Kong Newsletter Vol 8 Pt 2 p 25-29

SPORE-POLLEN FLORA FROM PING CHAU ISLAND MIRS BAY, HONG KONG

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Introduction

The sedimentary rocks of Ping Chau Island, Mirs Bay, include mudstone, siltstone and marlstone (Nau 1979). They contain insect- and plant-bearing layers (Williams 1943; Wu & Nau 1989).

Four samples were collected from the island by two of the authors (Wu and Nau) early in July 1987 for palynological analyses. Of these, two were collected from Lan Guo Shui and two from Lung Lok Tsui (Figure 1). The purpose of the present work is to seek more evidence pertinent to the dating of the rock sequence concerned, and this article presents the first result of work on a palynological assemblage from Ping Chau. Palynological analyses were carried out by one of us (Jiang).

Results of spore-pollen analysis

Altogether 123 grains of spore-pollen flora have been examined. They are not very well preserved and taxonomically rather monotonous. The assemblage includes pteridophyte (fern) spores, gymnosperm and angiosperm pollen. The fossil spore-pollen flora examined are given in Table 1. Of the total spore-pollen flora, 77.2% came from Lung Lok Tsui (61% spores, 13% gymnosperms and 3.3% angiosperms), and 22.8% from Lan Guo Shui (13% spores, 6.5% gymnosperms and 3.3% angiosperms).

The assemblage is dominated by pteridophyte spores (74% of the total spore-pollen flora), with those referable to the family Pteridaceae as the most abundant at 81% of this type. Of the above family, *Pterisisporites* sp (39.8%) is the most preponderant. *Pterisisporites distaverrucosus* Jiang also occurs in significant amount at 11%. Less abundant ones include *Pterisisporites undulatus* (5%), *Pterisisporites fantanguluris* (2.4%), *Leptolepidites* sp (0.8%) and *Verrutetraspora elegans* (0.8%).

Gymnosperm pollen (19.5% of the total flora) include *Psophosphaera* sp (7.3%), *Classopollis annulatus* (4.9%) and *Pinus pollenites* sp (4%). There are also *Ephedripites* sp and *Exesioporites* sp occurring in small amounts (1.6% each). Angiosperm pollen, including ?*Plicapollis granulatus* (2.4%), *Ulmipollenites* cf *minor* (1.6%), ?*Plicapollis* sp (0.8%) and *Moideipites* sp (0.8%), etc, are only 6.5% of the total flora.

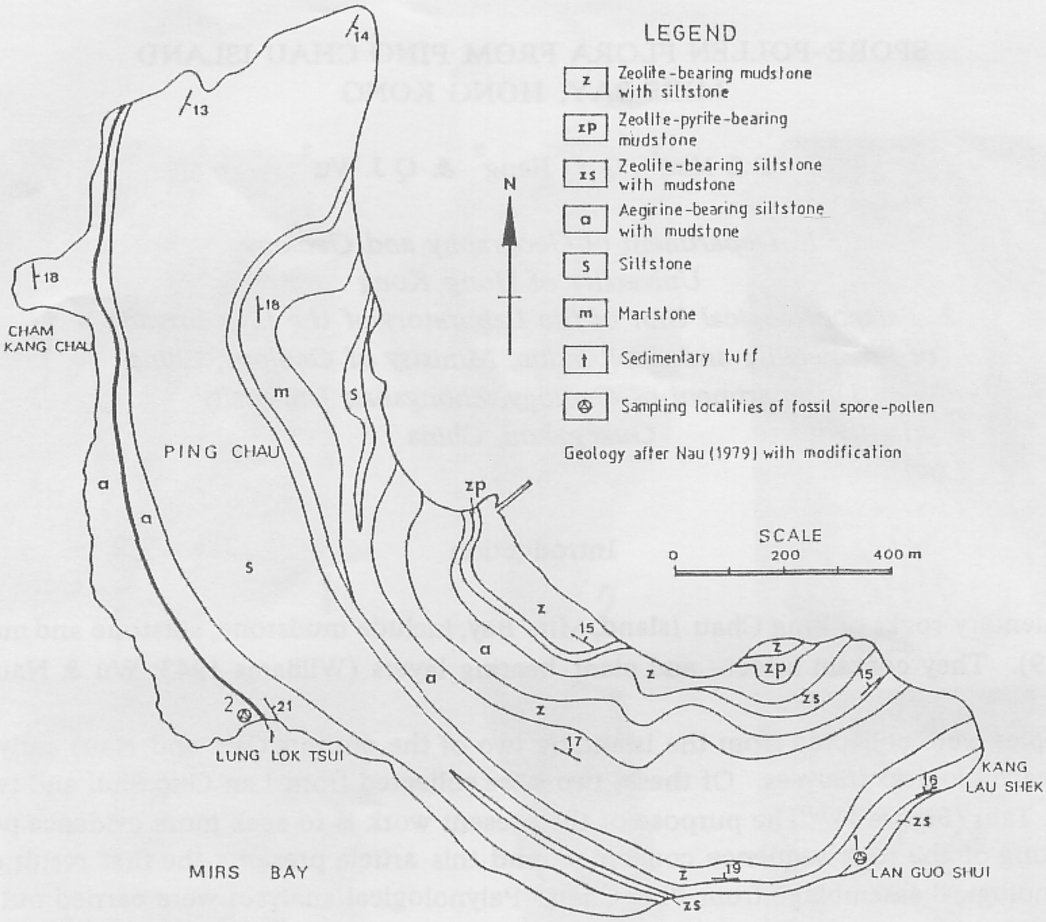

Figure 1 Geological map of Ping Chau Island

Discussion of the palynological flora and age

The fern spores of the family Pteridaceae represented by *Pterisisporites distaverrucosus*, *P fatanguluris*, *P undulatus* and *P* sp, etc, are common in Early and Late Cretaceous, or from Late Cretaceous to Early Tertiary sediments in Jiangsu, Jiangxi and Yunnan Provinces of China. Jiang points out that *Pterisisporites distaverrucosus* is a new species known from the Lengshuiwu Formation (Early Cretaceous) in the Xinjiang basin of Jiangxi Province, and *Pterisisporites fatanguluris* is a new species known from the Taizhou Formation (Late Cretaceous) in Jiangsu Province. Although *Pterisisporites* sp has the greatest abundance (up to 39.8%, Table 1), it is not considered to have biostratigraphic utility due to its wide time span from Cretaceous to Tertiary. *Schizaeoisporites* is known from Late Cretaceous deposits in the Jianghan basin (oilfield) in China (Chengdu Institute of Geology 1982), but in Siberia, fern spores referable to the family Schizaeaceae occur in great amount in sediments considered as middle Early - Cretaceous (Markova 1966). *Verrutetraspora* is generally regarded as Early Tertiary or Late Cretaceous in age, and the species *Verrutetraspora elegans* is known to be quite well developed in Early Tertiary sediments in South China, but its occurrence here is less than 1%. As *Pterisisporites distaverrucosus* occurs in significant amount (despite the high percentage of *Pterisisporites* sp) it can be considered that spores of Early Cretaceous age are relatively abundant.

Table 1 The abundance of spore-pollen flora from Ping Chau Island, Mirs Bay, Hong Kong (1 Lan Guo Shui, 2 Lung Kok Tsui)

Spores and pollen	1	2	%
Pteridophyte spores			
Selaginellaceae			
Neoraistrickis sp		●	1.6
Lycopodiaceae			
Lycopodiacidites sp	●		0.8
Lygodiaceae			
Toroisporis sp		●	0.8
Pteridaceae			
Pterisisporites undulatus Sung et Zheng		●	5.6
Pterisisporites fantanguluris Liu		●	2.4
Pterisisporites distaverrucosus Jiang	●	●	11.3
Pterisisporites sp	●	●	39.8
Leptolepidites sp		●	0.8
Verrutetraspora elegans Sung et Zheng		●	0.8
Schizaeaceae			
Schizaeoisporites kulandyensis (Bolkhovitina) Sung et Zheng		●	2.4
Taxonomic position unknown			
Undulatisporites pannuceus (Brenner) Singh		●	0.8
Divisisporites sp	●		0.8
Deltoidospora sp	●	●	4.0
Verrucosisporites sp		●	1.6
Gymnosperm pollen			
Cheirolepidiaceae			
Classopollis annulatus (Verbitskaja) Li	●	●	4.9
Dinaceae			
Pinuspollenites sp	●	●	4.0
Ephedraceae			
Ephedripites (E) sp		●	1.6
Cupressaceae and Taxodiaceae			
Exesipollenites sp	●		1.6
Taxonomic position unknown			
Psophosphaera sp	●	●	7.3
Angiosperm pollen			
Ulmaceae			
?*Ulmoideipites* sp		●	0.8
Ulmipollenites cf *minor* J Groot et R Groot		●	1.6
Betulaceae			
? *Plicapollis granulatus* Sung et Lee	●		2.4
? *Plicapollis* sp	●		0.8
Unknown affinity			
Tricolpites sp		●	0.8

Table 2 Estimated number of seed-plant and pteridophyte species taxa existing at certain times in the Jurassic and Cretaceous (from N F Hughes 1976)

	Ma	Gymnosperm	Pteridophyte	Angiosperm
End Cretaceous	65	500	2 000	20 000
Beginning Cretaceous	135	1 500	1 500	0
Middle Jurassic	170	1 500	1 000	0

Among the gymnosperm pollen found, *Psophosphaera* accounts for 7.3% of the total flora, and it is known to dominate the Early Cretaceous spore-pollen flora of the North Jiangsu Oilfield in China (Beijing University 1977). *Classopollis* (which is widespread in the world) is about 5% of the total flora. Geohistorically, it reached two peaks of abundance, in latest Triassic-early Jurassic (Rhaeto-Liassic) and Late Jurassic. However, it has also been recorded in Cretaceous strata in great amount. For example, the Shenhuangshan Formation (middle Lower Cretaceous) in Hunan Province, the Zhoutian Formation (early Upper Cretaceous) in Jiangxi Province, and the Dalangshan Formation (late Upper Cretaceous) in Guangdong Province, have all been reported as having *Classopollis* over 50% (Yu *et al* 1983). *Pinuspollenites* and *Ephedripites* (4% and 1.6% respectively) have been reported from Quantou Formation (late Early Cretaceous) and Quingshankou Formation (early Late Cretaceous) south of the Songhua River (Yu et al 1983). It seems that gymnosperms of Early Cretaceous are relatively prevalent.

Angiosperm components are greatly subordinate to the pteridophytic and gymnosperm elements. *Ulmoideipites*, *Ulmipollenites* and *Plicapollis* are widespread and occur in considerable amounts in the Late Cretaceous and Paleogene in North America and Asia. However, they occur in small amounts (from less than 1% to 2%) in this study.

Summary

From the above data it is evident that the palynological flora is composed of predominantly pteridophytes in company with relatively abundant gymnosperms. Palaeobotanical studies have shown that Jurassic-Cretaceous palynofloras are dominated by ferns and gymnosperms, and those of the Late Cretaceous by angiosperms (Table 2). As there are some Late Cretaceous to Paleogene elements, we consider that the age of the Ping Chau rocks is late Early Cretaceous (Albian) to early Late Cretaceous (Cenomanian), and is in concordance with the age proposed earlier based on macroflora (Wu & Nau 1989).

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BOAT TRIPS, SEPTEMBER-OCTOBER 1990

Sunday 2 September. WONG WAN CHAU (DOUBLE ISLAND). Stop 1: Tung Wan (East Beach, for the geology of the eastern end of the island; sandy beach; swimming and snorkelling (coral in the bay). Stop 2: Wong Wan (optional), for geology and walking around the west end of the island, with excellent shoreline exposures of the Port Island Formation

Sunday 9 September. CHEK LAP KOK. Joint trip with the Hong Kong Archaeological Society and the Hong Kong Historical Society. Three archaeological sites, including Tang Dynasty lime kilns and Tin Hau Temple c 1820; old kaolin mine; granite freestone workings; quartz veins (once worked); variety of dykes; current borrow area and trial embankment; sandy beaches for swimming.

Sunday 30 September. CHEK CHAU (PORT ISLAND). Exploration of the island; swimming at the anchorage in a small bay near the northeastern tip; exposures of Port Island Formation along the eastern coast; unconformable contact with the Repulse Bay Volcanic Group exposed near the southwestern tip.

Sunday 21 October. KAT O CHAU (CROOKED ISLAND) and AP CHAU (ROBINSON ISLAND). Kat O Formation exposures on the north coast of Kat O and on Ap Chau; coastal geomorphology; no good swimming.

All the trips, except Chek Lap Kok, start from Ma Liu Shui ferry pier at 9:30 am, return at about 5:00 pm. The Chek Lap Kok trip starts from Blake pier at 9:00 am, return about 5:00 pm. Contact Mr P S Nau at Hong Kong University on 859-2825 to see if places are available. Future trips include TAI O (11 November), SHARP PEAK (9 December) and EAST GUANGDONG (23-31 December)

Geological Society of Hong Kong Newsletter Vol 8 Pt 2 p 30-31

18 MONTHS WITH THE GEOLOGICAL SURVEY UNIT (1967-68)

S C Lee

Building and Lands Department
Hong Kong Government

At the instigation of my Class I superior and Section Head, saying that I should have a temporary change of working environment, and suggesting that I join the Geological Survey Unit to work as a field assistant, I applied, little knowing that the new mission would take me 18 months. At the selection interview by AS of Survey (later known as GLS) I was told the exact nature of work and the duration. Since I was supposed to have applied with full knowledge, although I didn't have that knowledge beforehand, I had to accept the challenge if selected, for at that moment I could not retreat from it.

At last I was told to join the Unit in January 1967, with Dr E A Stephens, Senior Geologist from IGS of UK, heading the Unit within the CLSO and having a survey labourer and a driver to staff the Unit. Acting as an assistant to Dr Stephens and his liaison officer, I had to organise all sorts of things for him such as field trip planning and the necessary information prior to each field trip, equipment and air photos, and keeping an office register of rock specimens at the end of each trip and recording the information on the office record copies of maps. In any field trip I had to instruct the driver where to go to for the start of each trip and where to pick the team up at the finish of each trip. When making field trips the Senior Geologist with me and the survey labourer would walk over the area under survey to examine the rock types and collect specimens and, when required, take dip and strike for field note writing.

In addition to the geological survey task I had to carry out a mineral survey; that is, collecting sand samples at tributaries of water courses, recording their positions and soil conditions and taking the pH of the water at each location. This was mainly done with the help of air photos for easy identification and transfer of position when coming back to the office.

Later in the year another geologist, Dr P M Allen, came from the UK and another team was formed when Dr Allen selected Henry Lai as his field assistant, recruiting one survey labourer and one driver for the task. So Dr Allen was mainly responsible for the mapping of the Hong Kong Island and Lantau, while Dr Stephens covered the mainland, particularly the New Territories.

It was beyond my expectation that the job would be so demanding, doing a lot of walking and climbing for long hours in isolated mountains and looking for contacts of different rock types as verification of office photogeology study. Indeed, it was very interesting and remarkable to note the outcome of photogeology matching with field findings. Throughout the period with the Unit I had opportunities to visit the graphite mining site at the Brother Islands, Needle Hill for iron ores, study the geology along the proposed water tunnel from Tai Lam Chung to Tuen Mun looking for a possible fault which might cause leakage, and study the Airport runway rock

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aggregate degeneration. Other than the normal duties as a field geologist, Dr Stephens also acted as a consultant to the Director of Engineering Development, so I had to obtain all necessary information for him prior to meeting these government officials requiring his expertise/advice.

In the office, between field trips, I had to transfer all field data, such as rock specimen position, dip and strike, onto the office working sheets, keeping a library of these specimens, and make silt preparation from sand samples, to be labelled and sent to the UK for chemical analysis regarding element content in parts per million, this data to be represented on separate map sheets. Some chosen rock specimens had to be despatched to UK for further study and age determination, while most of them had thin sections made locally in the University of Hong Kong (Department of Geography) for study under the microscope. Visits made to spots like Lai Chi Chong and Ping Chau for plant fossils were very interesting, and it was almost like an archaeologist's job digging with great care; the search was a fruitful one, but the effort made on Ma Sze Chau looking for animal fossils was not a success. In the latter case, we had to grind the sedimentary rock collected from Ma Sze Chau to very fine particles for examination under the microscope.

After I had spent about 1 year on this type of work, Dr Stephens had to return to UK to take up a higher position in the Directorate grade of IGS, and so I had to spend the remaining 6 months or so on a different job which had been started earlier. It was the retrieval of information from site investigation reports submitted by authorised architects describing borehole information, such as the position, log of the core and penetration information, in connection with final recommendations on piling depth. Indeed, after having received a short period of training I had to carry on the job on my own, with assistance from Dr Allen only when there was any difficulty arising. The final end product was a subsurface map using the large scale survey sheets as the data base for recording this information. The conclusion I had come to after this exercise was to drill boreholes at desirable locations at government expense to confirm the depth to bedrock, and if sufficiently dense enough, some sort of contour map could be derived for reference for any future engineering work or foundation design.

There were some unforgettable events that happened to me during my period with the Geological Survey Unit. To name a few, the torrential flow down stream from Bride's Pool to the Plover Cove Reservoir, after a downpour of rain, almost took away my life had it not been for a prompt rescue by Mr Chow Yiu-pong, who was quick enough to grasp my hammer stretching to him for help. To Mr Chow I owe my life, and not many realise the danger encountered by field staff unless one really experiences that kind of happening.

Another event was my trip sand sampling along the border for the mineral survey, which was indeed one full of excitement. I had to get military escort throughout the mission as the situation was still tense soon after the Sha Tau Kok incident, and we had to be extremely cautious and keep silent so as not to create any sign that would cause irritation across the border.

All in all, an interesting period in my career, and despite the hardships endured it gave me a great deal of job satisfaction and increased my knowledge of geology and geological studies considerably.

EPHEMERA

South China Morning Post, Wednesday 27 June 1990, *Environment Watch* by Jamie Allen

"Never let it be said that geologists do not have a sense of the dramatic. On Sunday the Geological Society of Hongkong is going on a 'farewell trip to the doomed island of Chek Lap Kok, which will be swallowed up in the near future by the new airport development', according to a flyer. The Society hopes to 'salvage some of the remaining rock crystal for which the island is well known'. The trip starts from the Tuen Mun (Castle Peak Bay) kaido pier at 10:30 am."

REPORT ON FIELD TRIP TO TSING SHAN
SUNDAY 1 JULY 1990
(ABORTED TRIP TO CHEK LAP KOK)

M J Atherton & R L Langford

Some 30 members turned up at Tuen Mun Ferry Pier, Butterfly Estate, at 10:15 am for the kaido to Chek Lap Kok, and a day's field excursion led by Dr Langford of the Hong Kong Geological Survey. However, in spite of assurances from the HK Tourist Association that the boat would depart from there at 10:30 am, it could not be found. At 10:20 am, following searching enquiries, it was discovered that the kaido departed from Castle Peak Bay on the other side of Tuen Mun. A frantic dash by taxis enabled members to view the kaido sailing away on the horizon.

Fruitless attempts were made to find another boat, so while 10 members retired for a nearby restaurant, 20 members decided to look along the flanks of Tsing Shan. To add insult to injury, while some members returned to the car park at Butterfly Estate, a tremendous downpour made those waiting think twice about the wisdom of fieldwork. However, up at Tsing Shan monastery, where some enjoyed a vegetarian lunch, the day started to look much better.

Following the monastery visit we were taken by Dr Langford on an illustrated walk along the recently constructed panoramic path which runs along the slopes of Tsing Shan (Castle Peak). The walk proved extraordinarily interesting as it follows exposures of the Tsing Shan Formation (conglomerates, sandstones, siltstones), and crosses the mylonite zone on the intrusive contact between the granite of Castle Peak and the Tsing Shan Formation. Unfortunately, many of the best exposures of the sedimentary strata are temporary, so excellent cleavage/bedding intersections will be lost beneath the concrete. However, the path now makes accessible an area that was notoriously difficult to get into, but in which the relationship between the pluton and older sedimentary strata is perhaps the best of any in the Territory. Below the Tsing Shan Formation could be seen the notorious Area 19, where lobate debris flows occur on the deeply weathered andesite of the Tuen Mun Formation.

Some members returned to the monastery and their cars, while others scrambled down a steep track to return by LRT to the ferry pier for a hoverferry to Hong Kong. Three vehicles with weary, and in some cases sunburnt travellers were forced to make an unscheduled stop at a goose restaurant in Sham Tseng, where the quality of Hong Kong's beverage industry was sampled. All in all a successful day rescued from potential disaster. Anyone wishing to look at the geology of Tsing Shan would be well advised to follow our route as soon as possible.

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Cover Photograph: Gully in deeply weathered granite near the northeastern end of Tai Lam Chung Reservoir (82235E 82855N). Courtesy of R Shaw (see article by Ruxton & Peart in this issue)

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