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Earthquake danger kept secret by China

By BRIAN POWER

STUDIES on earthquake dangers around the Daya Bay nuclear plant are being kept secret on orders from China despite new predictions of major tremors in Guangdong this decade.

A call from the chairman of the Hongkong Geological Society to release the data follows Chinese forecasts that a major earthquake in Guangdong province is due this decade. "Substantial" casualties and property damage are predicted.

Mr Ding Yuanzhang, director of the Guangdong Seismology Bureau, said yesterday the predictions had split scientists. He felt they were "too simplistic".

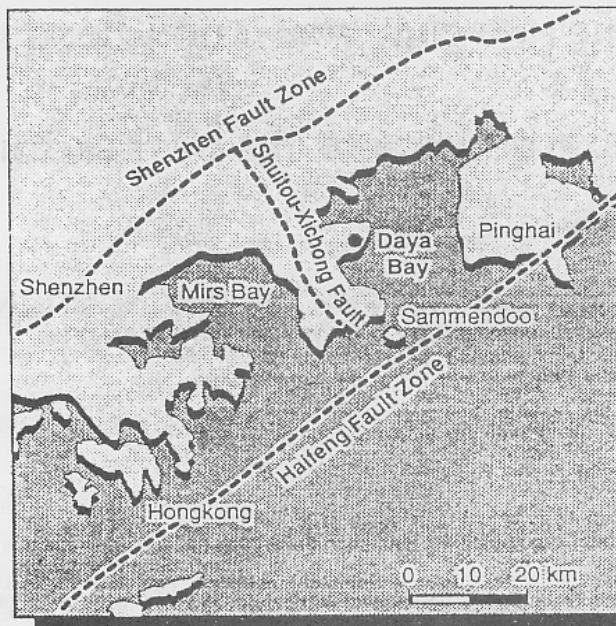
Hongkong relies on the forecasts since seismic data is supplied from China. It was secret until recent years.

Fault lines criss-cross southern Guangdong; one is seven kilometres from the nuclear reactor site. There have been 30 destructive tremors recorded in Guangdong since 288, averaging once every 60 years.

Daya Bay was jolted in 1918 by an earthquake measured VII on the modified Mercalli scale, knocking tiles off roofs in Shenzhen's Futian district. It devastated Swatow, 300 km east of Hongkong.

The seismic studies were part of a five-volume feasibility report commissioned by Guangdong Power Company and Hongkong's China Light and Power Co.

Two volumes were kept from release for "strategic" reasons in 1986 on orders of Mr Zhou Ping, now Deputy Minister in the State



Council's Science and Technology Commission. He could not be contacted in Beijing.

"If the Daya Bay plant is as safe as it is said to be, why is this information not being made public?" said Mr Maurice Atherton, the chairman of the Hongkong Geological Society.

A China Light and Power spokesman said China must be consulted before any seismic information was released. Guangdong Power in Guangzhou would not comment.

At present:

- There are disputes over how some Chinese scientists view earthquakes.
- A risk assessment study for Daya Bay found "the seismic hazard may be quite high".
- Experts dispute any threat

from the "weakly active" fault seven km from the power station.

● Concerns exist about "long period acting faults" south of the power station in the South China Sea.

Some Chinese research is controversial. For example, research on earthquake risks at Shenzhen concluded they have come in cycles of about 200 years.

At present, a moderate or strong earthquake "is not likely to occur", concluded Mr Yang Chaoqun, of China's Bureau of Geology and Mineral Resources.

Yet the new predictions for an earthquake in Guangdong province are being made because there has not been one for decades.

This cycle theory was criticised as misleading and out-

dated by a leading seismic expert, Mr N. N. Ambraseys, of Imperial College in London. "When you try and make these predictions you don't stand a chance of being effective," he said.

A UK Atomic Energy Authority risk assessment last year found that while Daya Bay was not highly seismic, distant earthquakes could be felt at the nuclear plant.

"The results indicate that the seismic hazard may be quite high," it stated.

The UKAEA's "pessimistic interpretation" found that every 600 years Daya Bay would experience an earthquake in the VIII range on the Mercalli scale. That would knock over chimneys and fissure masonry.

Daya Bay is designed to withstand earthquakes of that intensity. This means that during the 40-year life of the nuclear power station, statistically there is a one in 15 chance of possible damage.

In 1985, after Daya Bay was named the plant site, the Shuitou-Xichong fault was revealed in Hongkong. Only seven km from Daya Bay, it was classified as "weakly active" by Mr Liu Yixuan, of the South China Sea Institute of Oceanology in Guangzhou.

Mr Liu identified two small earthquakes, one in 1981, near the fault zone. He concluded "important structures" should not be built on weakly active faults.

To Mr Atherton, "this suggests that seismic activity is still going on" in the region.

Mr Atherton argued the many small earthquakes in southern Guangdong in recent years appear to roughly coincide with the active faults plotted by the Chinese.

STRATIGRAPHY OF THE PING CHAU FORMATION, HONG KONG

K W Lai

*Hong Kong Geological Survey
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Introduction

The Ping Chau Formation outcrops on Ping Chau, an island of low relief 600 m in length and 200 m in width, in the northeast of Tai Peng Wan (Mirs Bay). From offshore seismic data rocks of the Ping Chau Formation are clearly evident below the adjacent seabed forming part of an open synclinal basin (Figure 1). The Formation overlies gently dipping red coarse detrital rocks of the Port Island Formation (Figure 2).

The Ping Chau Formation was originally recognised by Williams (1943), and Peng (1978, 1983) endorsed the name Ping Chau Formation for these strata. Williams (1943) considered the Formation to be mainly Jurassic, suggesting a Lower Jurassic age, but Allen & Stephens (1971) assigned a Middle to Lower Jurassic age. With the recent discovery of numerous well preserved fossils and detailed studies of the Ping Chau strata, scientific opinion has focused the age on the Cretaceous to Lower Tertiary. These include Lower Cretaceous (Zhou 1990), late Early Cretaceous to early Late Cretaceous (Wu & Nau 1989; Nau *et al* 1990) and Upper Cretaceous (Peng 1983; Lee *et al* 1991a). Based on the most recent fossil evidence, lithology, structure and palaeoclimate, the age of the Formation is considered to be Lower Tertiary (Lai 1985; Lee *et al* 1991b).

Stratigraphy

The Ping Chau Formation has been divided into three informal members, and the Middle Member, which outcrops on Ping Chau Island, has been further subdivided, into three parts. The lithostratigraphy is illustrated in Figure 3, which also compares the Hong Kong stratigraphy with that of the nearby Sanshui Basin in Guangdong Province (Figures 4 & 5).

The Ping Chau Formation consists predominantly of dark grey, thinly bedded siltstone and dolomitic siltstone, together with mudstone and a layer of chert (Plate 1). All of these rocks are rich in dolomite, calcite and feldspar (mainly albite), with variable amounts of aegirine, zeolite, illite, quartz, pyrite, apatite, bitumen and carbonaceous matter (Peng 1967, 1971, 1978). The strata exhibit a variety of sedimentary structures such as ripple marks, subaqueous and subaerial shrinkage cracks, cross-bedding, loading and slump structures, and pyrite nodules.

Details

Seabed west of Ping Chau. From the offshore seismic profiles, rock outcrops can be seen exposed on the seabed within 300 m of the island. Further west, the Ping Chau Formation is overlain by marine mud. The seismic data indicate that the rock types beneath the seabed are mainly closely bedded rocks resembling the siltstones exposed onshore. Most rocks

would therefore belong to the Lower Member of Ping Chau Formation and directly overlie the red detrital rocks of the Port Island Formation, but the contact relationship between these formations are unknown. The Lower Member is approximately 150 m thick (Figure 3).



Plate 1 Thin bedded aegirine-bearing siltstone (as) with a layer of chert (CS) forming a synclinal basin, at Hok Ngam Teng beach (86230E 84430N)

Ping Chau. The strata on Ping Chau comprise the Middle Member of the Formation and consist of dark grey zeolite- and aegirine-bearing siltstone with calcareous siltstone (Figure 3). All the siltstones contain varying amounts of carbonate minerals (dolomite and calcite). The aegirine-bearing siltstone is well developed in the lower part of the sequence, whereas the zeolite-bearing siltstone occurs mainly in the upper part of the Middle Member. The Formation is characterised by thinly bedded strata. In general, each of the beds are only 2 to 6 cm thick but can be traced laterally for a distance of several hundred metres. Most beds are composed of very thin planar laminae less than 1 mm thick, interlaminated with detrital and chemical sediments (Plate 2).

The Middle Member can be divided into three parts. The lower part consists of dark grey, thinly bedded aegirine-bearing siltstone with dolomitic siltstone and a layer of chert. The thickness of the lower part exceeds 60 m. Intercalated pale yellowish brown dolomitic siltstones are well exposed at Cham Keng Chau (8617E 8454N) and Chau Bei (8625E 8444N). There are also several thin layers containing coarse calcite crystal aggregates outcropping at Hok Ngam Teng beach (86230E 84430N). Calcite veinlets averaging 5 to 10 mm in thickness fill the minor faults at Cham Keng Chau (86180E 84540N).

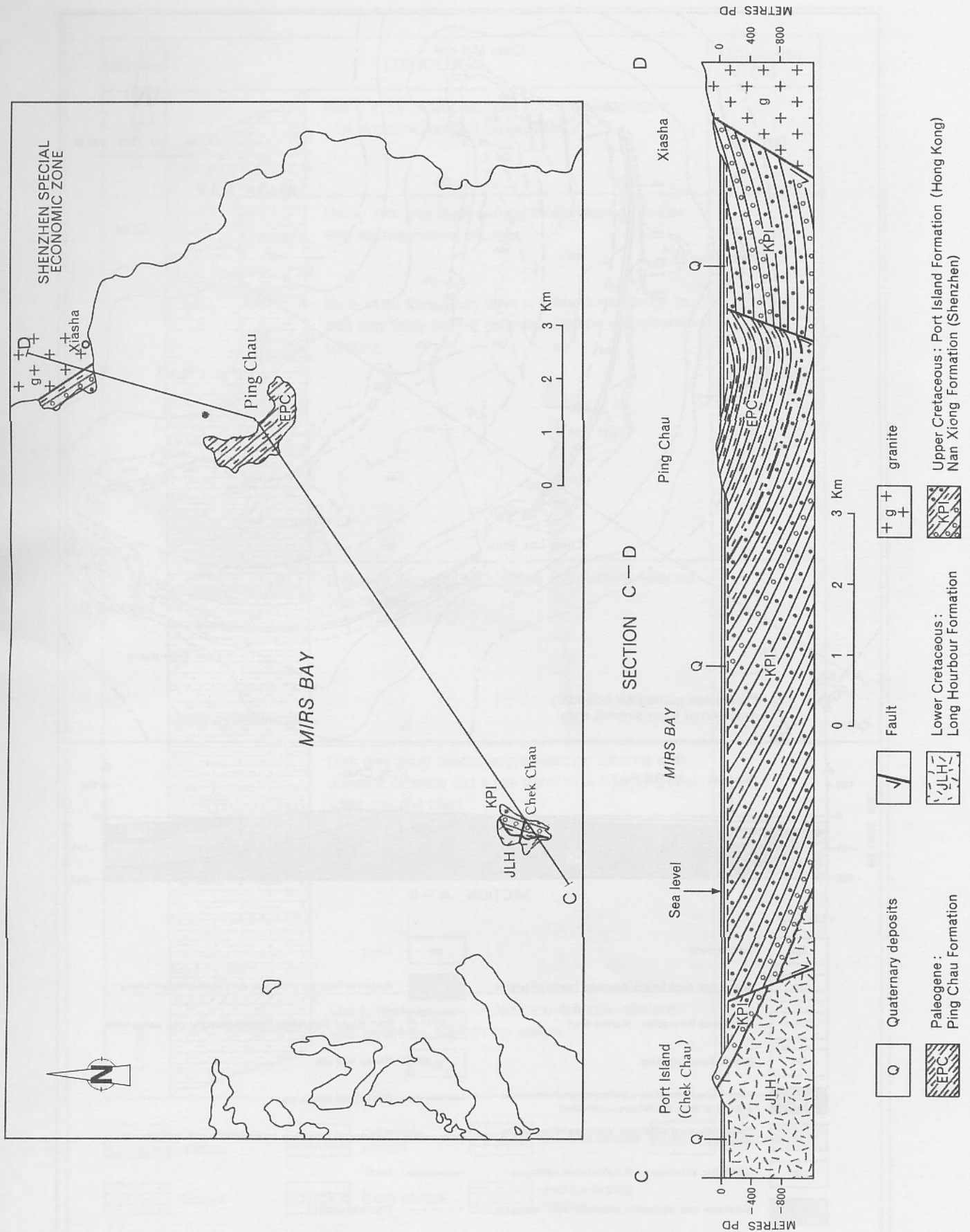


Figure 1 Geological section of Ping Chau and Mirs Bay

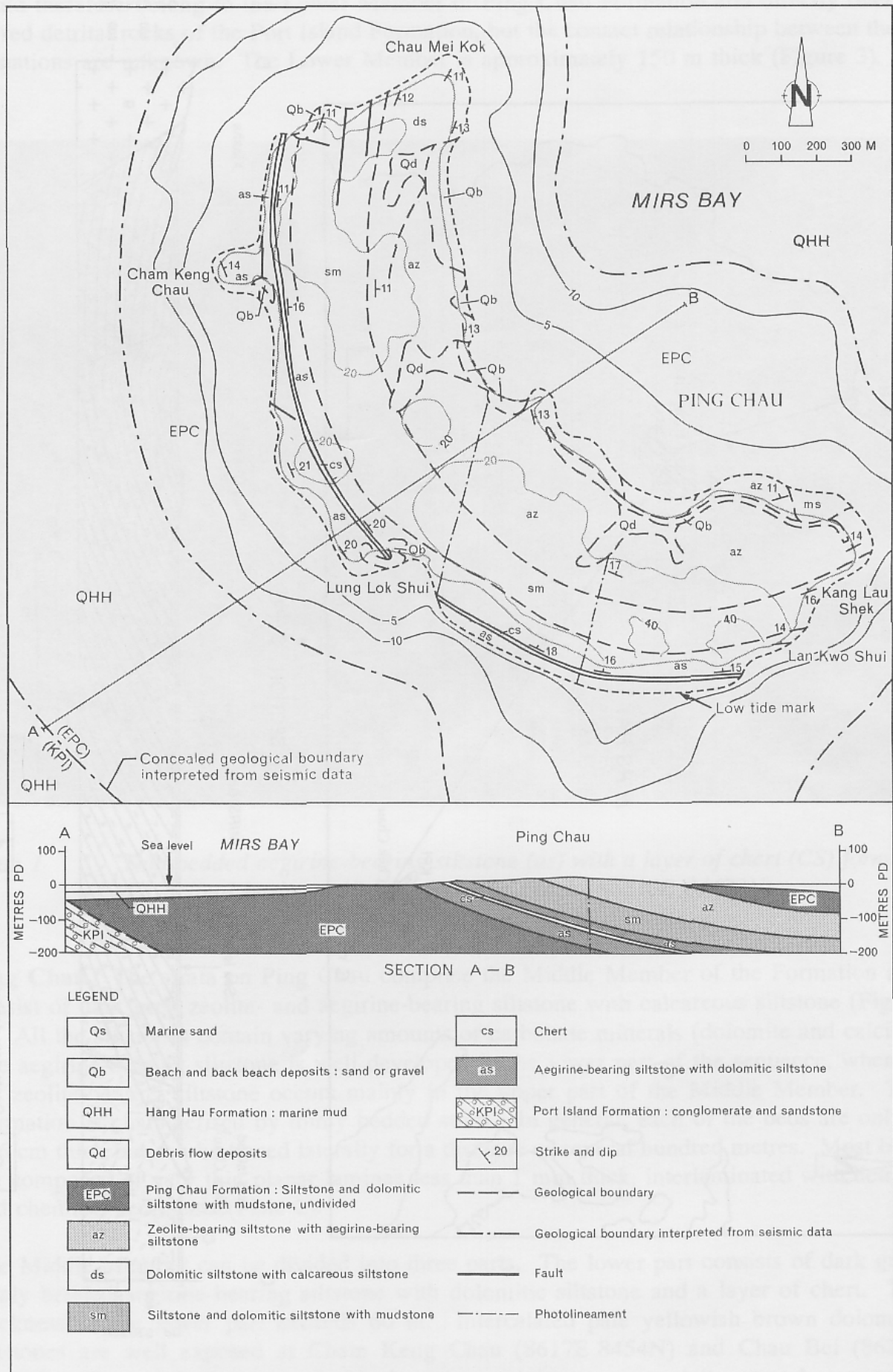


Figure 2 Geological map of Ping Chau

Stratigraphy of the Ping Chau Formation, Hong Kong

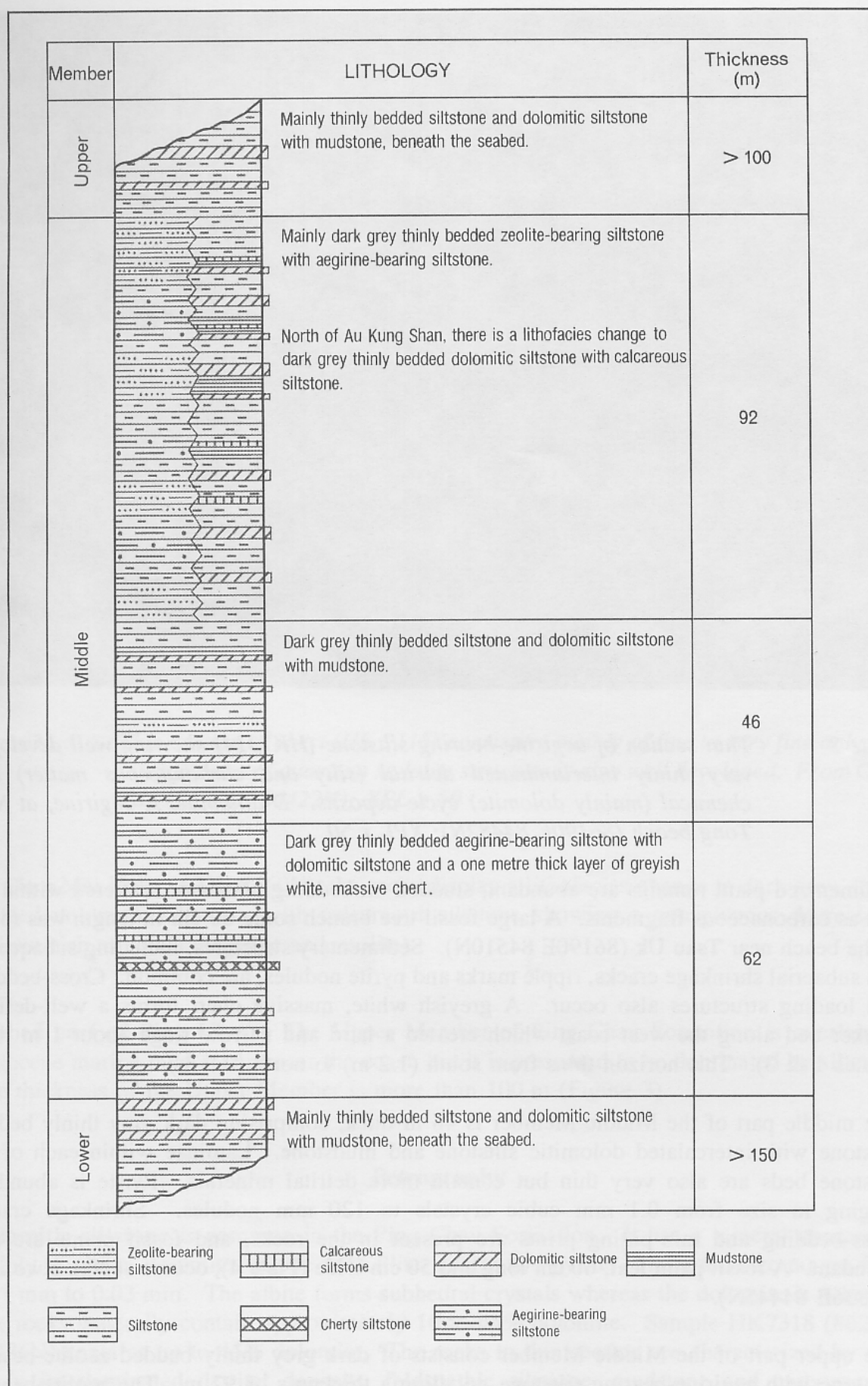


Figure 3 Lithostratigraphy of the Ping Chau Formation

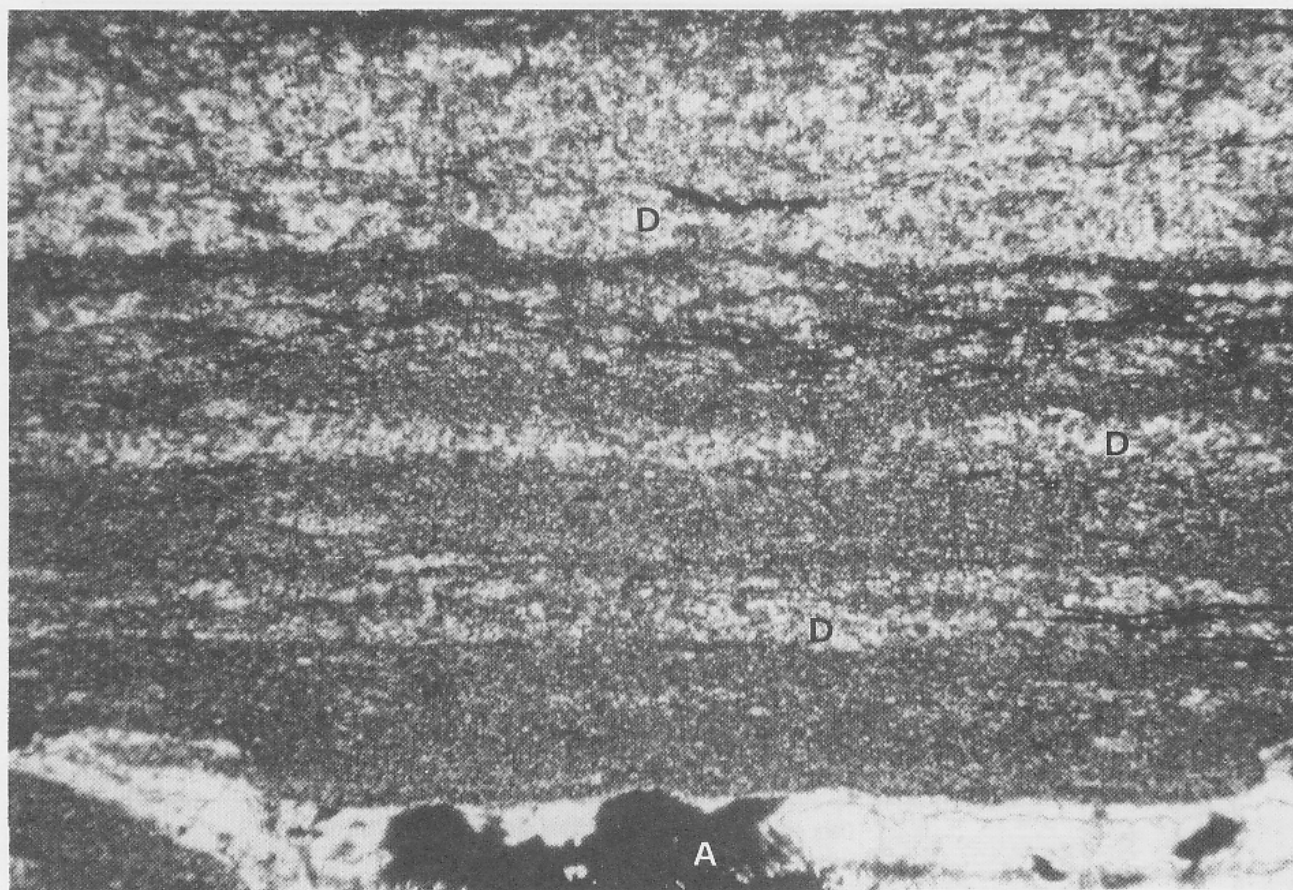


Plate 2 Thin section of aegirine-bearing siltstone (HK7314) showing well developed very thinly interlaminated detrital (silty and carbonaceous matter) and chemical (mainly dolomite) cycle deposits. D-dolomite, A-aegirine, at Nam Tong beach (86190E 84482N); XPL x 50

Bitumenized plant remains are abundant, studded on bedding planes or scattered within the bed as carbonaceous fragments. A large fossil tree branch some 60 cm in length was found at the beach near Tsau Uk (86190E 84510N). Sedimentary structures, including subaqueous and subaerial shrinkage cracks, ripple marks and pyrite nodules, are common. Cross-bedding and loading structures also occur. A greyish white, massive chert forms a well-defined marker bed along the west coast which created a hard and narrow ridge about 1 m thick (Plates 1 & 3). This horizon thins from south (1.2 m) to north (0.6 m).

The middle part of the Middle Member is 46 m thick, comprising dark grey thinly bedded siltstone with intercalated dolomitic siltstone and mudstone. Laminae within each of the siltstone beds are also very thin but contain more detrital minerals. Pyrite is abundant, ranging in size from 0.1 mm cubic crystals to 120 mm nodules. Shrinkage cracks, cross-bedding and rain-pitting prints are present in the rocks, and fossil plants are also abundant. A fossil palm leaf, 60 cm long and 50 cm wide (Plate 4), occurs at Nan Kwo Shui (86336E 84445N).

The upper part of the Middle Member consists of dark grey thinly bedded zeolite-bearing siltstone with aegirine-bearing siltstone, totalling a thickness of 92 m. The zeolite-bearing siltstone is well developed along the east coast from Wong Ye Kok (86255E 84500N) to Lam Uk (86290E 84465N). Pyrite is present as nodules, laminae or subspherical bodies; cross-bedding is common at Wong Ye Kok (8627E 8449N).



Plate 3 *Thin section of chert (HK 9115) consisting mainly of fine to very fine anhedral intergrowths of quartz; a stylolite structure is also well developed. From Chau Tau (86276E 84422N); XPL x 50*

At Chau Mei Kok (8623E 8460N), the rocks display a lithofacies change to dark grey, thinly bedded dolomitic siltstone, with calcareous siltstone showing a conspicuous decrease of sodium-rich minerals (aegirine and zeolite).

Seabed east of Ping Chau. The Upper Member of Ping Chau Formation is overlain by Holocene marine mud except near the coast, but it is presumed to be dominated by siltstone. The thickness of the Upper Member is more than 100 m (Figure 3).

Petrography

Dolomitic siltstone is common in the Ping Chau Formation. It has a mineral component mainly of albite, dolomite, calcite with illite, quartz and pyrite. The grain size ranges from 0.01 mm to 0.03 mm. The albite forms subhedral crystals whereas the dolomite is euhedral. The rocks generally contain approximately 10 to 45% dolomite. Sample HK7318 (86271E 84486N) contains up to 45% dolomite. The rocks in thin section are characterized by very thinly interlaminated detrital deposits, feldspathic siltstone, mudstone and carbonaceous matter, and chemical sediments, mainly clayey dolomite. The laminae vary from 0.05-0.35 mm thick.

The **aegirine-bearing siltstone** is dark grey and thinly bedded. In thin section it contains mainly subhedral albite and euhedral dolomite associated with accessory calcite, illite, quartz, pyrite and carbonaceous matter. The rock often contains 10 to 20% dolomite, and the grain size varies from 0.05 to 0.02 mm. The most distinctive feature is the presence of 2 to 8% of aegirine. This occurs as sheaves or radiating aggregates of green to bluish green needles less than 1 mm in length, along with calcite, dolomite and albite filled shrinkage cracks and "birds eye" fabrics, or is densely scattered along bedding planes (HK9107, 86183E 84561N; HK7314, 86190E 84482N). Rock sample HK7316 contains 6.14% Na₂O and 8.27% MgO + CaO (Table 1).

The **zeolite-bearing siltstone** is dark grey and thinly bedded. Each bed is composed of 0.1 to 0.35 mm thick laminae (HK7318, 86270E 84485N). In thin section the main minerals are albite, dolomite (5 to 25%) with calcite, illite quartz, pyrite, asphalt and carbonaceous matter. Rock sample HK9679 contains 5.53% Na₂O and 10.04% MgO + CaO (Table 1). The grain size varies from 0.005 to 0.02 mm. A distinctive feature is the presence of zeolite (5 to 10%) including natrolite and analcime. It is abundant as rosette-shaped crystal aggregates lying on the bedding planes or forming prismatic and granular crystal aggregates up to 4 mm long filling cracks, cavities and "birds eye" fabrics.



Plate 4 A fossil palm leaf Amesoneuron sp at Nan Kwo Shui (6336 4445); specimen size 500 x 600 mm

The **chert** is greyish white, massive, and very hard with stylolite structures. In thin section (HK9108, 86188E 84576N; HK7313, 86212E 84460N; HK9115, 86276E 84422N) it consists mainly of anhedral intergrowths of quartz (75 to 84%). Most quartz grains are fine to very

fine (0.01 mm), and were probably recrystallized from opal. Rhombs of dolomite and ankerite (5-9.5%) also occur, and are a secondary development of late diagenetic origin. Scattered clastic grains of albite (0.015 mm), quartz and accessory zircon form 3 to 5% of the rock. Rare occurrences of zeolite and aegirine of authigenic minerals are dispersed throughout in dolomitic crystalline patches. Rock sample HK7313 contains 78.54% SiO₂ and 5.90% Na₂O (Table 1).

Table 1 Major element analyses of Ping Chau Formation sedimentary rocks

Element	Aegirine-bearing siltstone	Zeolite-bearing siltstone	Chert
	HK7316 Tsau Uk 86190E 84510N	HK9679 Wong Ye Kok 86270E 84490N	HK7313 Lung Lok Shui 86220E 84460N
SiO ₂	50.80	47.05	78.54
Al ₂ O ₃	16.19	14.41	11.04
TiO ₂	0.47	0.35	0.03
Fe ₂ O ₃	4.88	3.76	0.68
MgO	2.32	2.34	0.23
CaO	5.95	7.70	0.94
Na ₂ O	6.14	5.53	5.90
K ₂ O	3.54	3.76	0.63
MnO	0.11	0.10	0.07
P ₂ O ₅	0.07	0.12	0.01
LOI	9.38	14.69	1.58
Total	99.85	99.81	99.65

Notes: 1 LOI mainly includes CO₂ and H₂O

2 Samples HK7316, HK9679 & HK7313 were analyzed by the University of Nottingham using the fused bead method

Palaeontology

Numerous fossils are found in the rocks of the Ping Chau Formation. They include specimens of some 200 fossil plants (Lee *et al* 1991b) and 39 fossil insects. Photographs of 36 fossil insect specimens (Lee *et al* 1991b) together with one insect fossil were sent to Nanjing Institute of Geology and Palaeontology, Academia Sinica, and identified by Q B Lin. The fossil insect collected by P S Nau was identified as *Tettigarctidae* gen et sp cf *Liutaiprosbole* sp (Plate 5), and from the insect photographs the following were identified; *Gyrinidae* gen et sp, *Cicadellidae* gen et sp, *Coleoptera* sp, *Bibiorridae* gen et sp and *Cupididae* gen et sp. Lin reported that the age of these insects was Cretaceous to Tertiary. These identifications agreed with Cockerell's original opinion, suggesting the age of the insect fossil *Otiorynchites williamsi* Cockerell from Ping Chau was Cretaceous, Eocene or later.

Otiorhynchid weevils are, however, very numerous and widespread in the Eocene (Williams 1943).

There were 35 determinable or indeterminable genera recognized from the fossil plants (Table 2, Plate 5), in which 17 genera (48.6%) belong to the Angiospermae, 15 genera (42.8%) to the Gymnospermae and 3 genera (8.6%) to the Pteridophyta (Lee *et al* 1991b). Eight spore-pollen samples were studied by the Guangdong Institute of Geological Sciences and Nanjing Institute of Geology and Palaeontology, Academia Sinica. Among the total of 114 genera (Table 3, Plates 6 & 7) 48.3% belong to the Angiospermae, 17.5% to the Gymnospermae and 34.2% to the Pteridophyta. Angiosperms have been more dominant since the Late Cretaceous, and are especially common in the Cenozoic. Moreover, some of the macroplants such as *Cercis* sp and *Ocotea sinensis*, and spore-pollen such as *Quercordites microhenrici*, *Engelhardtoidites punctatus* and *Ulmoideipites granulatus* are restricted to the Tertiary.

The spore-pollen assemblage from the Ping Chau Formation comprise *Pterisisporites*, *Verrutetraspora*, *Inaperturopollenites*, *Ulmipollenites*, *Ulmoideipites* and *Subtriporopollenites*. Palynological comparison of the Ping Chau Formation with those strata of the Sanshui Basin, Guangdong, (Table 4) indicates that the Ping Chau Formation is equivalent to the Palaeogene Buxin Group. Furthermore, it is quite different from those in the Cretaceous Dalang Shan Formation, dominated by *Pterisisporites*, *Schizaeoisporites*, *Gabonisoris*, *Exesipollenites*, *Classopollis* and *Sporopollis* (Table 4).

Sedimentary environment

The Ping Chau Formation consists mainly of dolomitic siltstone and possesses a high sodium-rich zeolite and aegirine content. The composition of these rocks indicates that they have been deposited in a tropical to subtropical brackish water lake under semi-arid conditions. The Formation is characterised by well-developed very thinly interlaminated detrital and chemical cycle deposits. In the detrital cycles, the presence of carbonaceous matter and feldspathic siltstone layers reflects a relatively humid period. In the chemical depositional cycles, the carbonate layers indicate dry periods. The interlaminated layers are interpreted as reflecting seasonal fluctuations of lacustrine water level and salinity.

Ripple marks and cross-bedding indicate a shallow water environment, whereas the rain pitting and subaerial desiccation polygons show the sediments had at times been subaerially exposed. The presence of pyrite reflects a reducing environment in the sediments. Zeolite and aegirine are of syngenetic origin. No relict gypsum and salt minerals, or red detrital sediment can be found in the rocks exposed on Ping Chau. The abundant flora present in the strata, however, indicates that a relatively warm and humid climate must have existed, contrasting with the hot and arid climate predominating in the Upper Cretaceous.

Lithostratigraphic comparison with strata of the Sanshui Basin

Ping Chau and the Sanshui Basin have similar rock types and are situated between the same latitudes (22 to 23°N) only 110 km apart. Therefore, they should reflect the same palaeoclimate in their sediments. In the Sanshui Basin, the red coarse clastic rock of Upper Cretaceous point to a hot and dry palaeoclimate, and also indicate that the crust was rapidly

uplifted. However, the dark grey fine clastic sediments of the Lower Tertiary reflect a relatively warm and humid climate, and the crust is stable. The nearby Dongguan and Xinhui Basins also contain the same Upper Cretaceous and Lower Tertiary sediments (Figure 4). The Ping Chau Formation is characterised by dark grey siltstone of greater than 400 m thickness overlying red coarse clastic rocks. A lithostratigraphic comparison of the Ping Chau Formation with strata of the Sanshui Basin (Figure 5) indicates that the Ping Chau Formation is equivalent to the Palaeogene Buxin Group. In particular, the Middle Member can be compared to the Eocene age Second Formation of the Buxin Group.

Table 2 Fossil plants of Ping Chau, Mirs Bay

PTERIDOPHYTA

Equisetum? sp
Salvina? sp
Adiantopteris ? sp

GYMNOSPERMAE

Otozamites sp (?sp nova)
Otozamites ? sp (?sp nova)
Otozamites ? sp
Otozamites sp
Dictyozamites ? sp
Brachyphyllum sp (sp nova)
Brachyphyllum sp
Brachyphyllum ? sp
Glyptostrobus cf *europaeus* (Brongn) Heer
Glyptostrobus ? sp
Sphenolepis ? *densifolis* Cao
Sphenolepis cf *kurrians* (Dunker) Schenk
Schizolepis sp
Pityolepis sp
Pityolepis ? sp

ANGIOSPERMAE

Cinnamomum sp
Nectandra quangxiensis Guo
Ocotea cf *sinensis* Guo
Cercis ? sp
Trapa ? sp
Leguminosites ? sp
Juglandaceae
Dicotylophyllum spp
Dicotylophyllum ? sp
Sabalites sp
Cyperacites sp
Cyperacites ? spp
Monocotylophyllum spp
Monocotylophyllum ? sp
Antholithes ? sp
Antholithes ? (*Carpites* ? sp)
Carpites spp
Carpites ? spp

Collected by the Palaeontology Specialist Research Group (Lee *et al* 1991a)
Identified by S Q Wu

Table 3 Sporo-pollen of Ping Chau, Mirs Bay

HK Number	9497	9498	9499	9500	9661	8336	9106	9110
Sporo-pollen	A	A	A	A	A			
PTERIDOPHYTA								
<i>Pterisporites</i> sp	*	*	*	*	*	*	*	*
<i>P undulatus</i> Sung & Zheng	*	*	*	*	*			
<i>P granulatus</i> Sung & Zheng	*	*	*	*	*			
<i>P trizonatus</i> Sung et al	*	*	*	*	*			
<i>P bellus</i> Sung et al	*							
<i>P tuberosus</i> Sung et al	*	*						
<i>P cretaciatus</i> Sung et al		*	*		*			
<i>P fatangularis</i> Liu		*		*				
<i>Verrutetraspora elegans</i> Sung & Zheng	*	*			*			
<i>V verrucosa</i> Ke & Shi	*				*			
<i>V</i> sp	*		*			*	*	*
<i>Zlivisporis</i> sp	*	*	*	*	*			
<i>Z novamexicanum</i> (Anderson) Leffingwell				*				
<i>Echinatisporis</i> sp	*							
<i>Klukisporites</i> sp	*							
<i>Multinodisporites</i> sp	*		*	*				
<i>Cicatricosisporites</i> sp	*							
<i>Deltoidospora</i> sp	*	*	*					
<i>D regularis</i> (Pflug) Sung & Zheng				*				
<i>D microlepioides</i> (Kretzsch) Wang	*	*	*	*	*			
<i>D apheles</i> Huger				*				
<i>Lygodiumsporites</i> sp						*		
<i>Lygodioisporites</i> sp		*				*		
<i>Lophotriletes</i> cf <i>obscurus</i> Bolch		*						
<i>Rouseisporites reticulatus</i> Bolch		*					*	
<i>Schizaeisporites palaeocenious</i> (Selling) Potonie		*						
<i>S</i> sp			*		*			
<i>S minor</i> Wan & Li			*		*			
<i>Leptolepidites verrucatus</i> Couper			*	*	*			
<i>L</i> sp				*	*			
<i>Toroisporis</i> sp			*	*	*	*	*	
<i>T (T) lusaticu</i> Krutzsch				*	*			
<i>T (D) brevidivisus</i> Sung et al				*	*			
<i>Osmundacidites micanicus</i> (Verb) Zheng			*					
<i>Angiopteris</i> sp			*					
<i>Divisisporites</i> sp					*			
<i>Sphagnumsporites</i> sp					*			
<i>Polypodiaceoisporites volubilis</i> po Sung & Zheng					*			
<i>Undulatisporites</i> sp						*		
GYMNOSPERMAE								
<i>Classopollis annulatus</i> (Ver) Li	*		*	*	*			
<i>C</i> sp				*		*		
<i>Ephedripites</i> sp	*	*		*		*	*	
<i>E (E) viesensis</i> Krutzsch					*			
<i>E (D) cf scabratus</i> Sung & Zheng	*				*			*
<i>E (D) fusiformis</i> Krutzsch		*			*			
<i>Pinuspollenites</i> sp	*		*		*	*	*	*
<i>P banksianaeformis</i> (Zakl) Ke & Shi	*		*		*			
<i>P minutus</i> (Zakl) Sung & Zheng		*		*	*			
<i>Araucariacites</i> sp		*		*	*			
<i>Inaperturopollenites</i> sp		*	*	*	*	*		
<i>Sciadopityspollenites</i> sp			*					
<i>Parcisporites parvisaccus</i> Sung & Zheng					*			
<i>Podocarpidites nageiaformis</i> (Zakl) Krutzsch					*			
<i>P</i> sp						*		*
<i>Keteleeria</i> ? sp					*	*		
<i>Rugubivesiculites</i> sp						*	*	*
<i>Taxodiaceapollenites</i> sp						*	*	*
<i>Abietinaepollenites</i> sp							*	*
<i>Exesipollenites</i> sp								*

Stratigraphy of the Ping Chau Formation, Hong Kong

HK Number	9497 A	9498 A	9499 A	9500 A	9661 A	8336	9106	9110
Sporo-pollen								
ANGIOSPERMAE								
<i>Retitricolporites</i> sp	*		*	*				
<i>R oblongatus</i> Sung et al	*							
<i>Tricolporopollenites</i> sp	*		*					
<i>T satzveyensis</i> Thomas & Pflug			*					
<i>Pentapollenites minor</i> Sung et al	*		*	*				
<i>P pentangulus</i> Krutzsch	*			*	*			
<i>P laevigatus</i> Krutzsch	*		*	*				
<i>P dungtaiensis</i> Zhou	*		*		*			
<i>Jiangsupollis striatus</i> subsp <i>striatus</i> Sung	*							
<i>J striatus</i> subsp <i>medius</i> Sung			*					
<i>J ?</i> sp					*			
<i>Symplocospollenites</i> sp	*							
<i>Plicapollis granulatus</i> Sung & Lee	*	*	*	*	*	*		
<i>Subtriporopollenites granulatus</i> Sung & Lee	*	*	*	*				
<i>S</i> sp						*		*
<i>Ulmipollenites minor</i> J Groot & R Groot	*	*	*		*			
<i>U</i> sp		*		*		*	*	
<i>U scabratus</i> Sung et al	*	*	*					
<i>U granulatus</i> Stone		*						
<i>Ulmoideipites granulatus</i> Sung et al	*	*	*	*	*			
<i>U Krempii</i> Anderson					*			
<i>U</i> sp						*		
<i>Myrtaceidites cajupitiformis</i> (Zakl) Zhou	*							
<i>Nuxpollenites bellatus</i> Sung et al	*							
<i>N corrugis</i> Sung et al	*							
<i>Chenopodipollis multiporatus</i> (Pflug & Thomson) Zhou	*	*	*	*				
<i>Loniceraipollis</i> sp		*			*			
<i>L simplex</i> Sung & Zheng		*				*		
<i>Quercoidites</i> sp		*	*	*				
<i>Q hanrici</i> (Pot) Pot, Thoms & Thier			*	*	*			
<i>Extratropipollenites perlucidus</i> Skavby			*		*			
<i>Cupuliferoipollenites pusillus</i> (Pot) Potonie				*				
<i>C pusillus</i> Krutzsch			*	*	*			
<i>Gothanipollis rutungensis</i> Liu			*	*				
<i>Caprifoliipites microratus</i> Sung & Lee			*					
<i>Sporopollis singularis</i> Zaklinskaja			*		*			
<i>Paranyssapollenites striatus</i> Sung et al	*		*					
<i>Beaupreaoidites proteaformis</i> Sung et al			*					
<i>Proteacidites adenathoides</i> Gouper			*					
<i>Celtispollenites</i> sp				*	*			
<i>Triporopollenites</i> sp				*		*		
<i>Magnolipollis grandus</i> Sung & Zheng				*				
<i>Triorites sublyeoatus</i> Couper					*			
<i>Tiliaepollenites indubitililis</i> R Potonie					*			
<i>Peltandripites davisii</i> Wodehouse					*			
<i>Sapotaceoidaepollenites granulatus</i> Sung et al					*			
<i>Engelhardtoidites quietus</i> Potonie					*			
<i>E punctatus</i> Potonie					*			
<i>E</i> sp						*		
<i>Tricolpites sanshuiensis</i> Sung et al				*			*	
<i>Rhoipites</i> sp								
<i>Jianghanpollis</i> sp							*	
<i>Exesipollenites</i> sp			*					*
<i>Callistopollenites</i> sp			*				*	
<i>C radiatus</i> Zhou			*					

- Notes: 1 Samples HK9497A, HK9498A, HK9499A, HK9500A & HK9661A were identified by Guangdong Institute of Geological Sciences
- 2 Samples HK8336, HK9106 & HK9110 were identified by Nanjing Institute of Geology and Palaeontology, Academia Sinica
- 3 Sample locations: HK9497A, Kan Lau Shek (86342E 84450N); HK9498A, Kan Lau Shek (86348E 84452N); 9499A, Chau Mei (86236E 84583N) HK9500A, Chau Mei (86237E 84591N); HK9661A, Cham Keng Chau (86179E 84540N); HK8336, Nan Kwo Shui (86336E 84445N); HK9106, Cham Keng Chau (86183E 84548N) & HK9110, Chau Mei (86234E 84576N)

Table 4 Palynological comparison of the Ping Chau Formation with those strata of the Sanshui Basin, Guangdong

Sporo-pollen	Ping Chau ¹	Sanshui Basin ²			
	Palaeogene	Upper Cretaceous	Palaeogene Buxin Group		
	Ping Chau Formation	Dalang Shan Formation	First Formation	Second Formation	Third Formation
PTERIDOPHYTA					
<i>Pterisporites</i>	29.1	2.4 - 26.0	0 - 1	4 - 50	+ - 7
<i>Verrutetraspora</i>	7.3	0 - 3.5	0 - +	0 - 12	0 - 2
<i>Lygodiumsporites</i>	1.5	0 - 1.6	0 - +	0 - 2	0 - 3
<i>Schizaeoisporites</i>	---	0.8 - 14.0	0 - +	---	0 - +
<i>Gabonisporis</i>	---	0 - 5.8	---	---	0 - +
GYMNOSPERMAE					
<i>Inaperturopollenites</i>	4.5	---	3 - 11	1 - 20	2 - 9
<i>Taxodiaceapollenites</i>	5.3	0 - 1.6	---	---	0 - 2
<i>Ephedripites</i>	4.0	0 - 1.6	0 - +	0 - 2	0 - 3
<i>Classopollis</i>	2.1	0 - 52.6	0 - +	---	---
<i>Exesipollenites</i>	---	4.3 - 52.9	0 - 5	---	---
<i>Rugubivesiculites</i>	4.5	1.4 - 13.2	---	---	---
ANGIOSPERMAE					
<i>Ulmipollenites</i>	6.8	0 - 8.2	} 17 - 19	} 6 - 17	} 0 - 11
<i>Ulmoideipites</i>	2.1	---			
<i>Subtriporopollenites</i>	4.5	0 - 2.5	1 - 20	0 - 4	0 - 2
<i>Plicapollis</i>	1.5	1.6 - 4.3	16 - 26	5 - 16	0 - 4
<i>Triporopollenites</i>	0.7	0 - 1.4	1 - 2	1 - 11	0 - 6
<i>Engelhardtoidites</i>	0.7	---	---	0 - +	0 - +
<i>Quercoidites</i>	0.7	0 - +	+ - 3	1 - 12	2 - 38
<i>Sporopollis</i>	---	4.9 - 8.8	---	---	---

Notes: + sparse

1 sample HK8336

2 from Song *et al* (1986)

Conclusion

The floral assemblage of the Ping Chau Formation contains older members such as *Otozamites* and *Brachyphyllum*, which are common in the Jurassic and Cretaceous. However, since there is no evidence of transgression in the Ping Chau area between the Middle Jurassic and Lower Tertiary, and it is believed that the Ping Chau area was in a continuous terrestrial environment for that time, some older members of the flora might survive. The key point is that the angiosperms dominate the floral assemblage, and some of these are known to be limited to the Tertiary. Together with evidence based on the lithology, palaeoclimate, palaeoenvironment, geological structure and stratigraphic correlation, the Ping Chau Formation is therefore suggested as belonging to the Lower Tertiary.

Acknowledgements

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References

- ALLEN P M & STEPHENS E A (1971). *Report on the Geological Survey of Hong Kong 1967-1969*. Hong Kong Government Press, 116 p plus 2 maps
- HUANG Z G, LI P Y, CHANG C Y, LI K H & QIAO P N (1982). *The formation, development and evolution of the Pearl River Delta*. Gaungzhou Institute of Geography Scientific Results. Science Press, Guangzhou (in Chinese)
- LAI K W (1985). A review of the Late Cretaceous-Palaeogene fault basins around Hong Kong. In: WHITESIDE P G D & ARTHURTON R S (Eds). *Marine geology of Hong Kong and the Pearl River Mouth*. Geological Society of Hong Kong, Hong Kong, p 39-45
- LEE C M, ATHERTON M J, WU S Q, HE G X, CHEN J H & NAU P S (1991a). Discovery of angiosperm fossils from Hong Kong - with discussion on the age of the Ping Chau Formation. *Geological Society of Hong Kong Newsletter* Vol 9 No 1 p 50-60
- LEE C M, CHEN J H, HE G X, ATHERTON M J & LAI K W (1991b). On the age of the Ping Chau Formation. *Geological Society of Hong Kong Newsletter* Vol 9 No 1 p 34-49
- NAU P S (1979). Geological notes on the sedimentary rocks of Ping Chau Island, Mirs Bay, Hong Kong. *Annals of the Geographical, Geological and Archaeological Society, University of Hong Kong* No 7 p 33-41 plus 2 figures & 2 plates
- NAU P S, JIANG Q Q & WU Q J (1990). Sporepollen flora from Ping Chau island Mirs Bay, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 8 Pt 2 p 25-29
- PENG C J (1967). Occurrence of zeolites in Upper Jurassic rocks of Hong Kong. *Abstracts: International Mineral Association Meeting, Tokyo* p 225-226
- PENG C J (1971). Acmite and zeolite-bearing beds of Hong Kong: a new and unusual occurrence (abstract). *Eighth International Sedimentology Congress, Heidelberg* p 76-77
- PENG C J (1978). *Hong Kong minerals*. Hong Kong Government Printer, 81 p (English version and Chinese version)
- PENG C J (1983). Geology. In: CHIU T N & SO C L (Eds). *A Geography of Hong Kong*. Oxford University Press, Oxford, p 1-21
- SONG Z C, LI M Y & ZHONG L (1986). *Cretaceous and Early Tertiary spore-pollen assemblages from the Sanshui Basin, Guangdong Province*. Science Press, Beijing, 204 p
- WANG J K, LI G F & WANG J S (1981). *The Early Tertiary fossil fish from Shanshui and its adjacent basin, Guangdong*. Science Press, Beijing, 100 p
- WILLIAMS M Y (1943). The stratigraphy and palaeontology of Hong Kong and the New Territories. *Transactions of the Royal Society of Canada Third Series* Vol 37 Sect IV p 93-117
- WU Q J & NAU P S (1989). The characteristics of fossil plants and age of the strata of Ping Chau Island, Mirs Bay, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 7 Pt 4 p 2-11
- ZHOU Z Y, LI H M, CAO Z Y & NAU P S (1990). Some Cretaceous plants from Pingzhou (Ping Chau) island, Hong Kong. *Acta Palaeontologica Sinica* Vol 29 No 4 p 415-430 plus 4 plates (in Chinese with English summary)

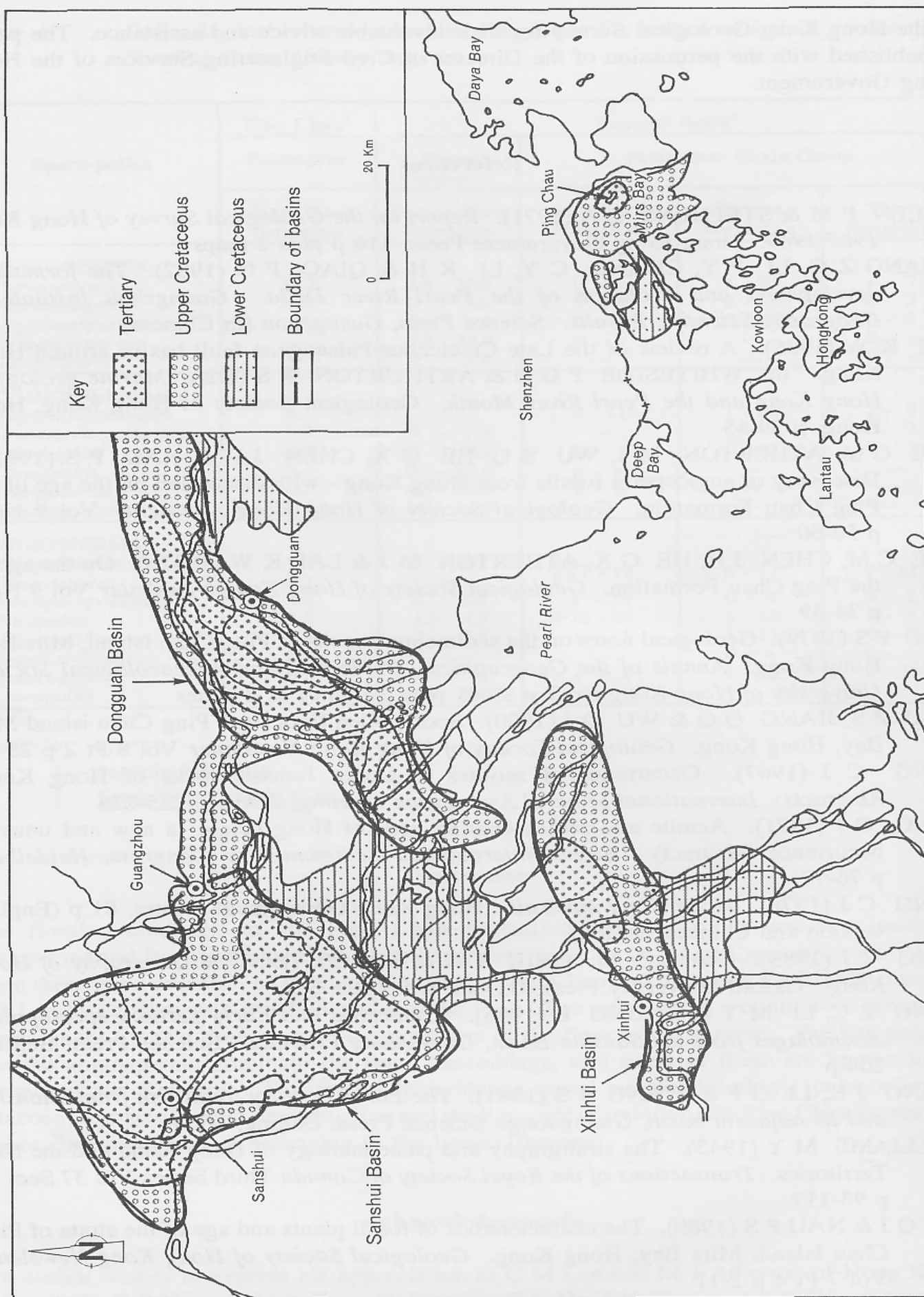


Figure 4 Cretaceous - Tertiary basins in the Pearl River estuary area and Mirs Bay. Modified from Huang et al (1982), Figure 4-2 p 40

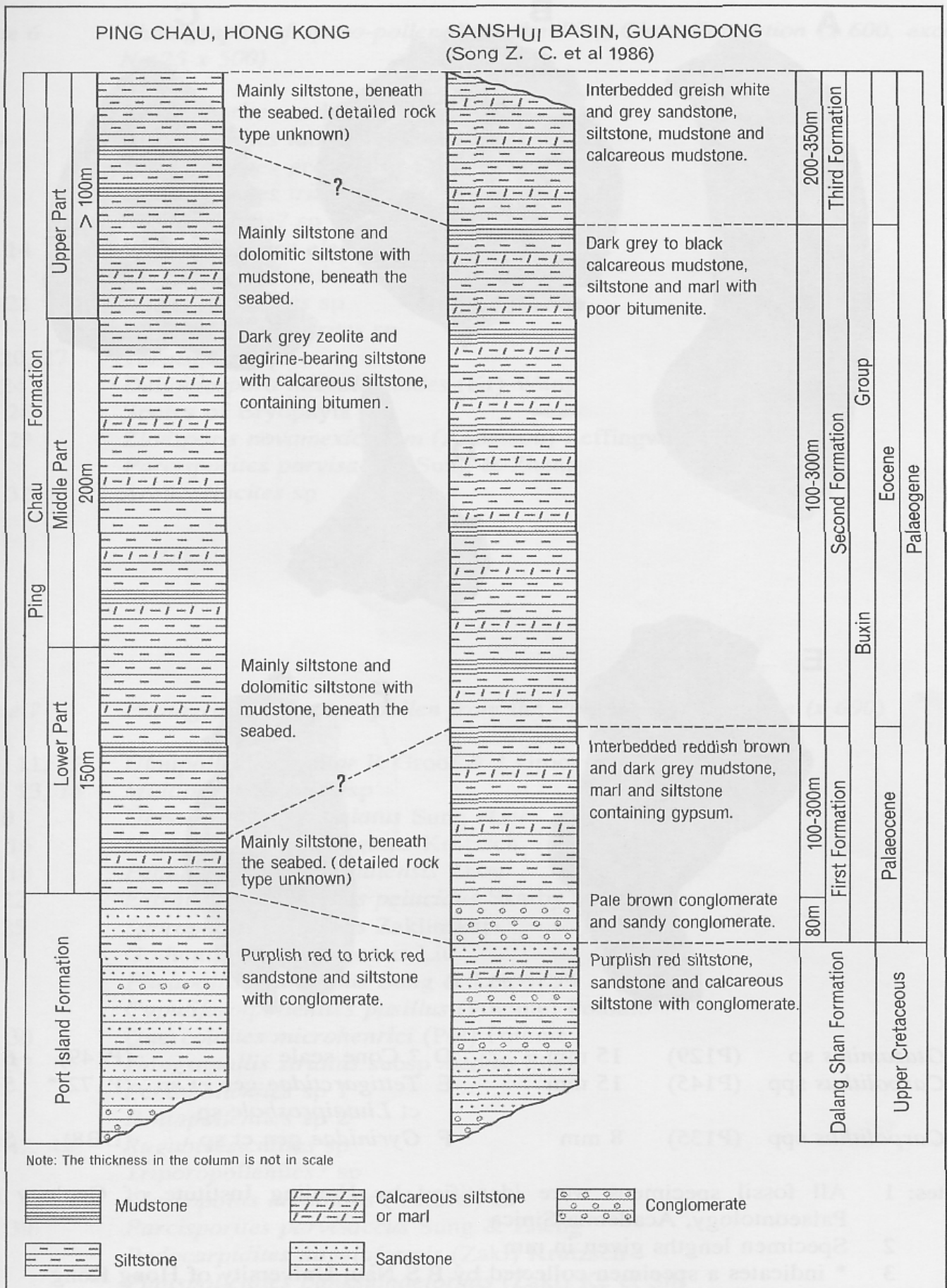
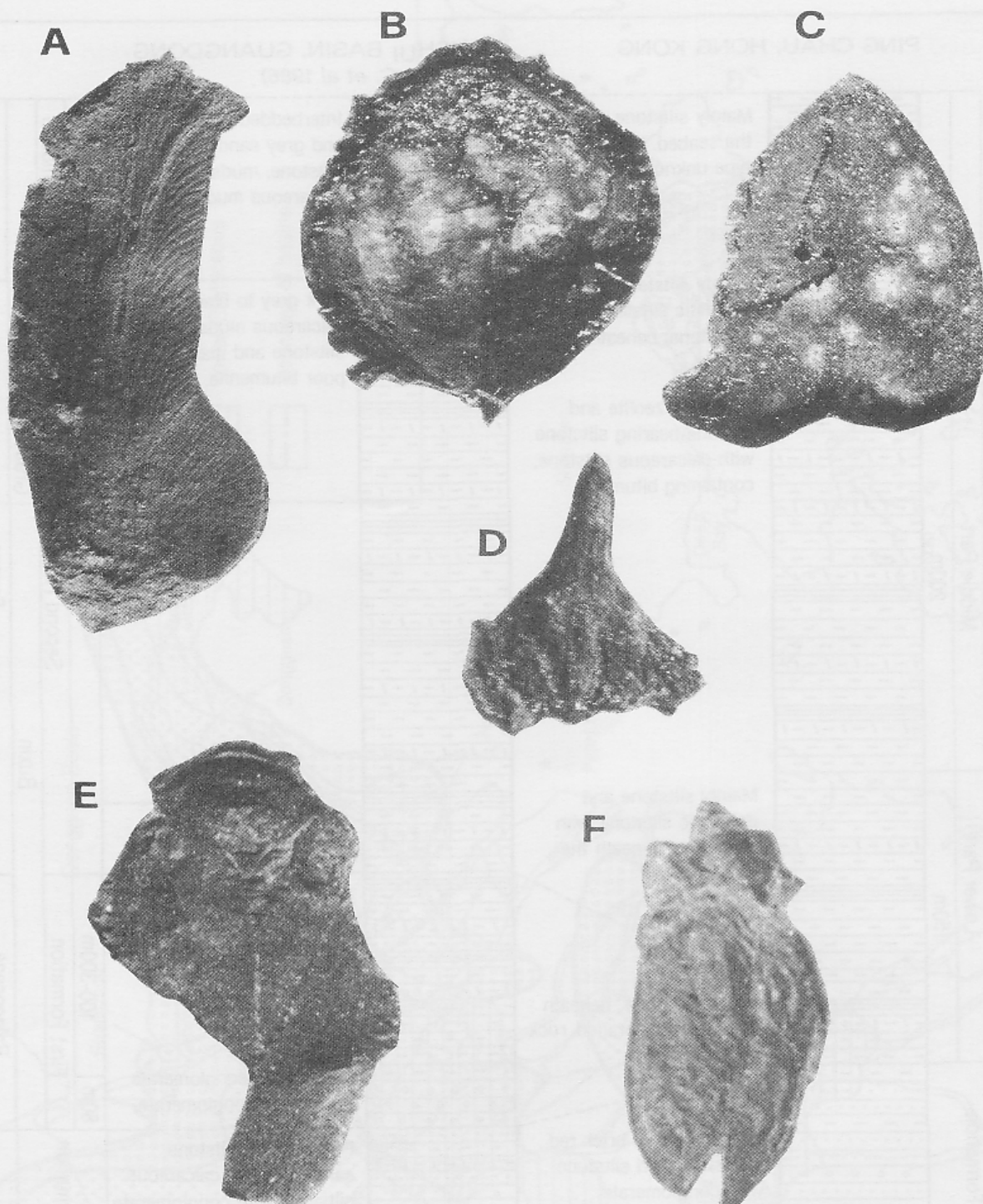


Figure 5 Lithostratigraphic comparison of the Ping Chau Formation with the Buxin Group of the Sanshui Basin, Guangdong



A *Otazamites* sp (P129) 15 mm
 B *Carpolithus* spp (P145) 15 mm
 C *Carpolithus* spp (P135) 8 mm

D ? Cone scale (P149) 6 mm
 E *Tettigarctidae* gen et sp (P172)* 5 mm
 cf *Liutaiprosbole* sp
 F *Gyrinidae* gen et sp (DB8) 5 mm

- Notes: 1 All fossil specimens were identified by Nanjing Institute of Geology and Palaeontology, Academia Sinica
 2 Specimen lengths given in mm
 3 * indicates a specimen collected by P S Nau, University of Hong Kong

Plate 6 Photographs of sporo-pollen from the Ping Chau Formation (x 600, except No 25 x 500)

- 1-7 *Pterisisporites undulatus* Sung & Zheng
- 8, 9 *Pterisisporites tuberus* Sung et al
- 10 *Pterisisporites granulatus* Sung et al
- 11 *Pterisisporites trizonatus* Sung et al
- 12 *Leptolepidites?* sp
- 13, 14 *Verrutetraspora elegans* Sung & Zheng
- 15 *Schizaeoisporites minor* Wan et Li
- 16, 21 *Schizaeoisporites* sp
- 17 *Polypodiaceoisporites* sp
- 18-20, 27 *Toroisporis* sp
- 22-24 *Deltoidospora microlepioides* (Kr) Wang
- 25, 26 Spores of Bryophyta
- 28, 29 *Zlivisporis novamexicanum* (Anderson) Leffingwell
- 30 *Parcisporites parvisaccus* Sung & Zheng
- 31, 32 *Araucariacites* sp

Plate 7 Photographs of sporo-pollen from the Ping Chau Formation (x 600)

- 1-4, 11, 12 *Ulmipollenites minor* R Groot & J Groot
- 5-7, 13, 14 *Multiporopollenites* sp
- 8-10 *Ulmoideipites granulatus* Sung et al
- 15, 16 *Pentapollenites laevigatus* Krutzsch
- 17, 18 *Pentapollenites dungtaiensis* Zhou
- 19-22 *Extratripoporopollenites pelucidus* Skarby
- 23-25 *Sporopollis singularis* Zaklinskaja
- 26 *Gothanipollis rutungensis* Liu
- 27 *Plicapollis granulatus* Sung & Lee
- 28 *Cupuliferoipollenites pusillus* (Potonie) Potonie
- 29, 30 *Quercoidites microhenrici* (Pot) Potonie
- 31, 32 *Jiangsupollis striatus* subsp *medius* Sung
- 33 *Pentapollenites* sp 1
- 34 *Pentapollenites* sp 2
- 35, 42, 46 *Rugubivesiculites* sp
- 36 *Tripoporopollenites?* sp
- 37 *Classopollis annulatus* (Verbits) Li
- 38, 39 *Parcisporites parvisaccus* Sung & Zheng
- 40 *Podocarpidites nageiaformis* (Zakl) Krutzsch
- 41 *Pinuspollenites banksianaeformis* (Zakl) Ke et Shi
- 43 *Ephedripites* (D) *fusiformis* Krutzsch
- 44 *Ephedripites* (E) *viesensis* Krutzsch
- 45 *Cedripites microsaccoides* Sung & Zheng

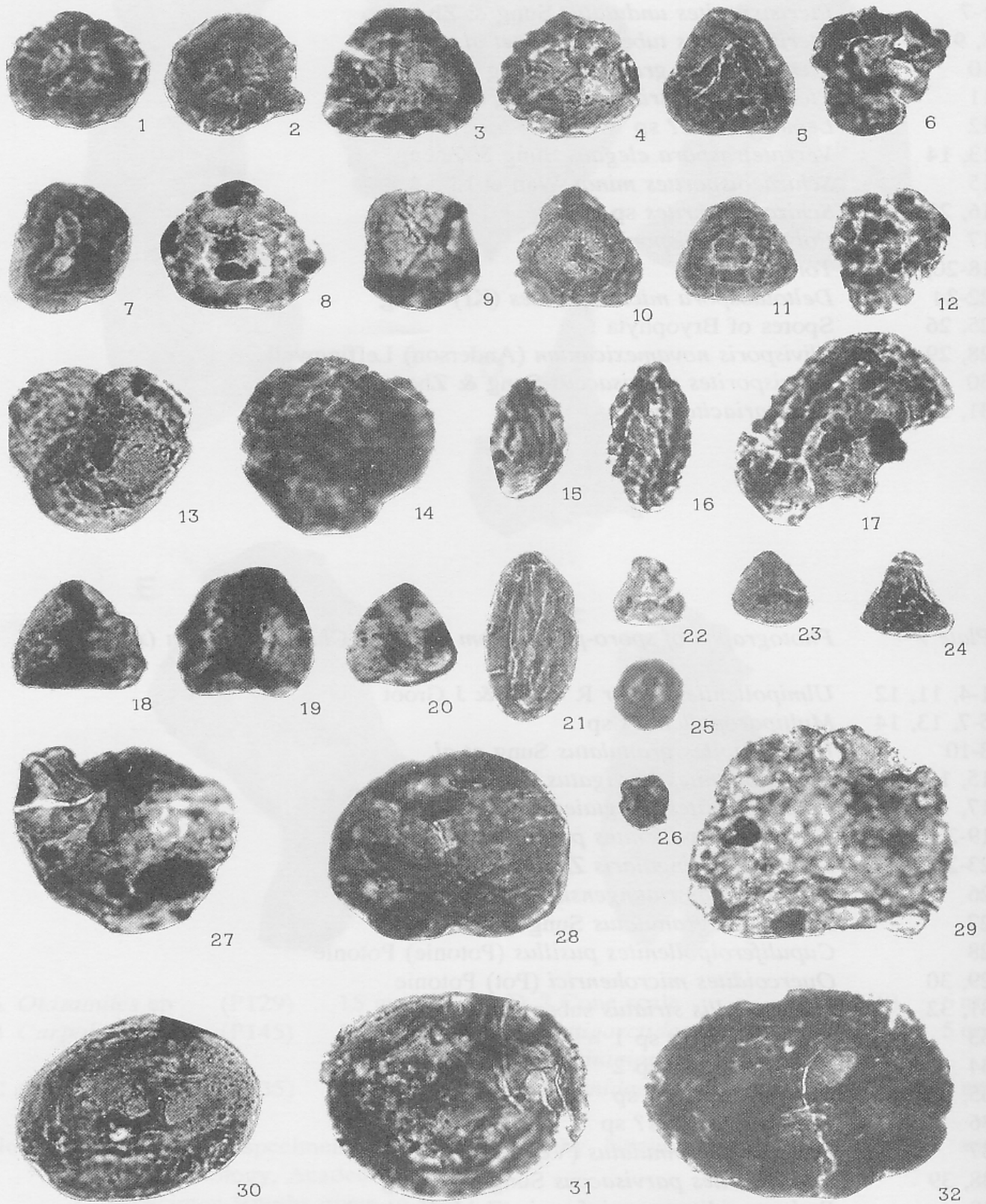


Plate 6 Photographs of spore-pollen from the Ping Chau Formation (x 600, except No 25 x 500)

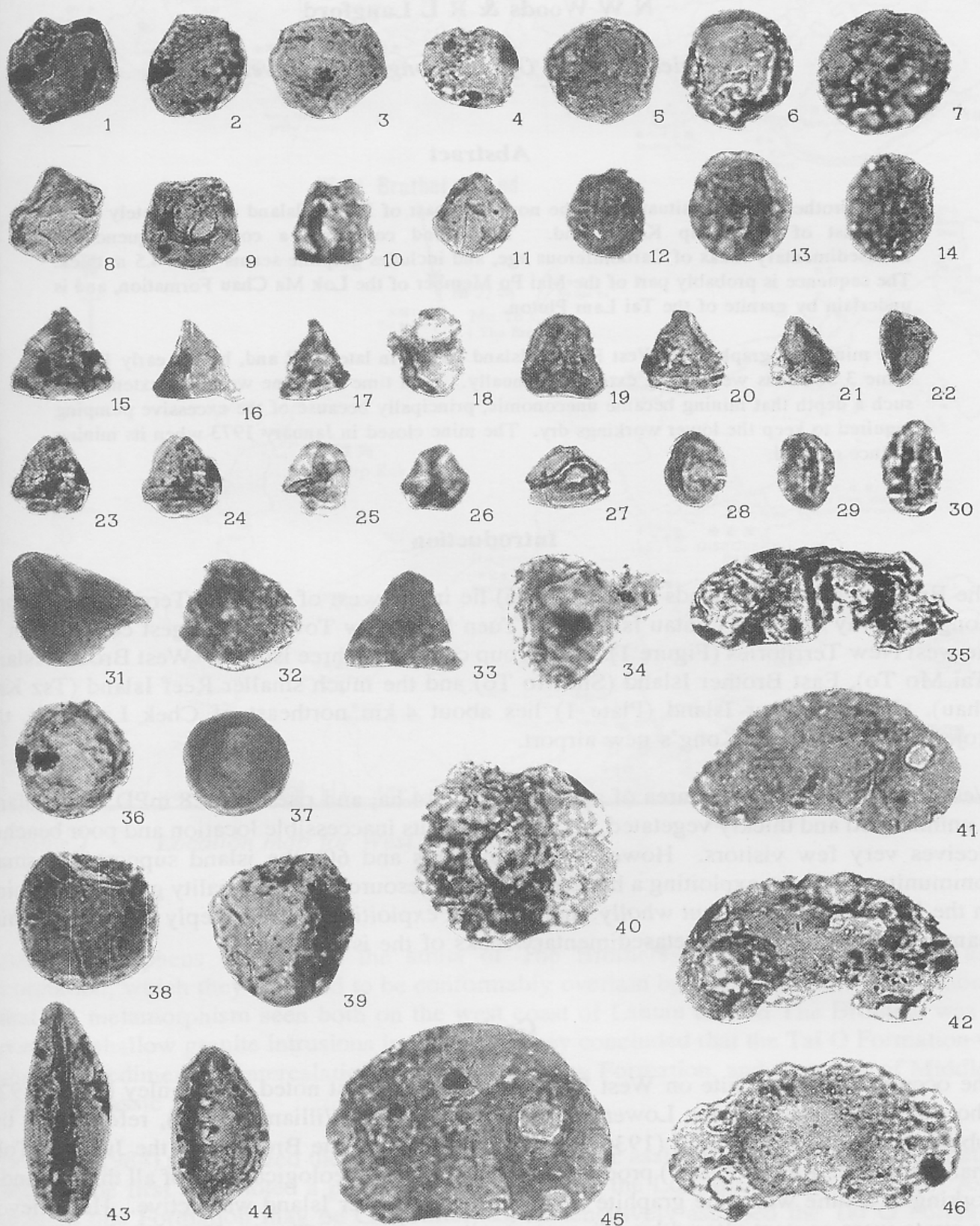


Plate 7 Photographs of spore-pollen from the Ping Chau Formation (x 600)

THE GEOLOGY AND EXPLOITATION OF THE WEST BROTHER ISLAND GRAPHITE DEPOSIT

N W Woods & R L Langford

Geotechnical Control Office, Hong Kong Government

Abstract

West Brother Island is situated off the northern coast of Lantau Island approximately 4 km northeast of Chek Lap Kok Island. The island comprises a complex sequence of metasedimentary rocks of Carboniferous age, and includes graphite seams up to 4.5 m thick. The sequence is probably part of the Mai Po Member of the Lok Ma Chau Formation, and is underlain by granite of the Tai Lam Pluton.

The mining of graphite on West Brother Island started in late 1952 and, by the early 1960s, some 3 500 tons were being extracted annually. With time the mine workings extended to such a depth that mining became uneconomic, principally because of the excessive pumping required to keep the lower workings dry. The mine closed in January 1973 when its mining licence expired.

Introduction

The Brothers group of islands (Mo To Chau) lie in the west of the New Territories of Hong Kong, midway between Lantau Island and Tuen Mun New Town, the largest conurbation in the west New Territories (Figure 1). The group comprises three islands: West Brother Island (Tai Mo To), East Brother Island (Siu Mo To) and the much smaller Reef Island (Tsz Kan Chau). West Brother Island (Plate 1) lies about 4 km northeast of Chek Lap Kok, the projected site of Hong Kong's new airport.

West Brother Island has an area of approximately 14 ha, and rises to 67.8 mPD. The island is uninhabited and thickly vegetated, and because of its inaccessible location and poor beaches receives very few visitors. However, in the 1950s and 60s the island supported a small community of miners exploiting a hitherto untapped resource of high quality graphite. Mining on the island was carried out wholly underground, exploiting a thin, steeply dipping graphite seam which occurs in the metasedimentary rocks of the island.

Geology

The occurrence of graphite on West Brother Island was first noted by Heanley (1923 p 92), who placed the strata in the Lower Jurassic or Triassic. Williams (1943), referring to the published map of Brock *et al* (1936), placed the rocks of The Brothers in the Jurassic Tolo Channel Series. Ruxton (1957) produced the only detailed geological map of all three islands, working at a time when the graphite mine on West Brother Island was active. He believed the strata were contact altered by adjacent granite such as on Chu Lu Kok (Chek Lap Kok), and he kept the assignation to Tolo Channel Series.

*The geology and exploitation of the
West Brother Island graphite deposit*

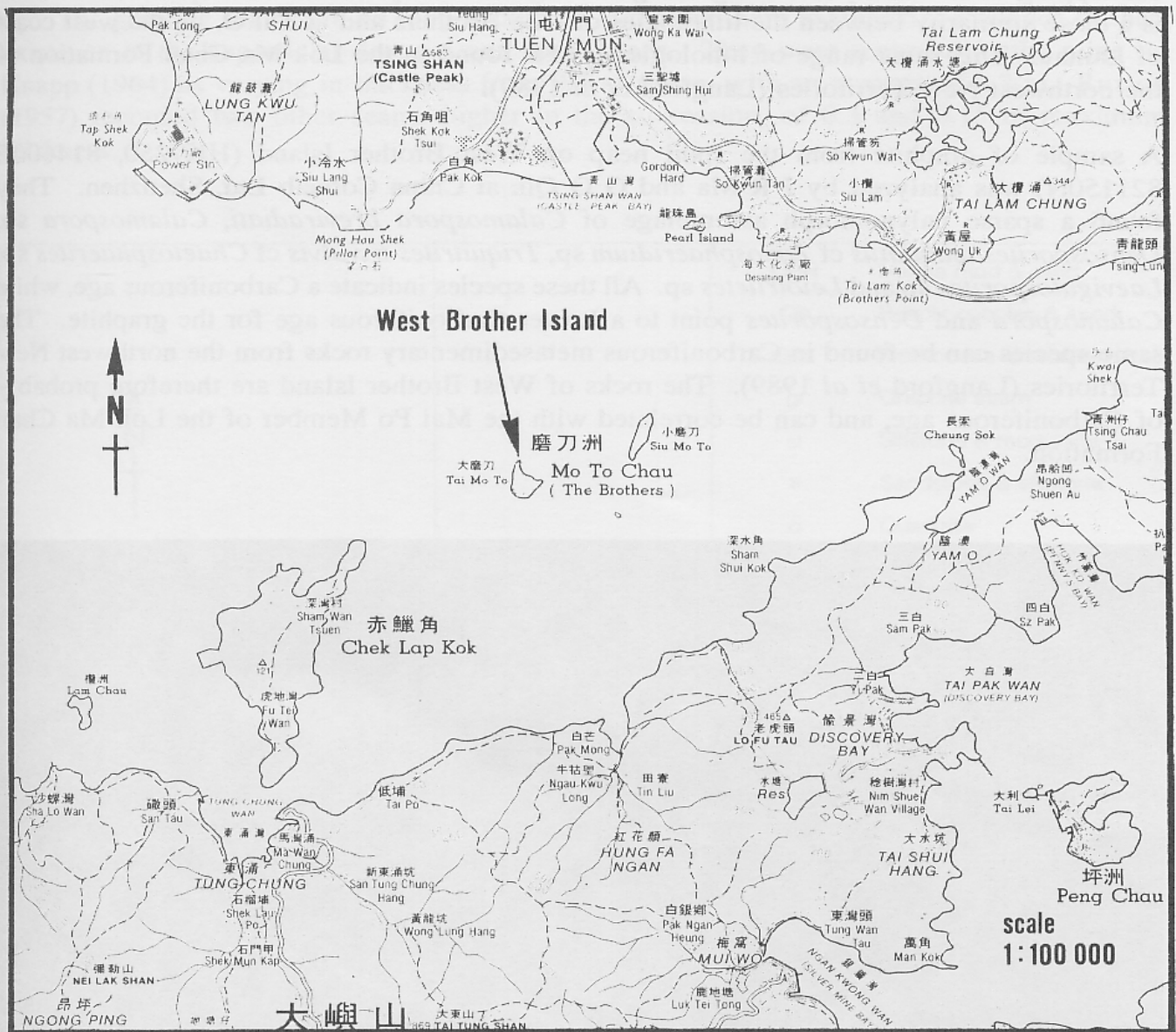


Figure 1 Location map for West Brother Island

Allen & Stephens (1971) put the strata of The Brothers into a newly defined Tai O Formation, which they believed to be conformably overlain by tuff on Lantau. They thought that the metamorphism seen both on the west coast of Lantau and on The Brothers was the result of shallow granite intrusions in the area. They concluded that the Tai O Formation was simply a sedimentary intercalation in the Repulse Bay Formation, and therefore of Middle or Lower Jurassic age.

Bennett (1984) summarized the problems of stratigraphic assignation of the Tai O Formation, and for the first time noted a possible correlation with the Lok Ma Chau Formation. As he thought this Formation may be Carboniferous, he tentatively ascribed the Tai O Formation to the Carboniferous. However, Bennett carefully reviewed all the options and left the conclusion to the present mapping programme.

Remapping of Lantau by the Hong Kong Geological Survey has been completed, and there is a close similarity between the lithologies on The Brothers and at Tai O, on the west coast of Lantau. This same range of lithologies is also found in the Lok Ma Chau Formation of the northwest New Territories (Langford *et al* 1989).

A sample of graphite from the spoil heap on West Brother Island (HK7250, 814600E 821150N) was analyzed by J R Ma and G Q Qin at China Corelab Ltd, Shenzhen. They found a sparse palynomorph assemblage of *Calamospora breviradiati*, *Calamospora* sp, *Densosporites annulatus* cf *Zonosphaeridium* sp, *Triquitrites trivalvis* cf *Chaetosphaerites* sp, *Laevigatosporites* sp and *Leiotriletes* sp. All these species indicate a Carboniferous age, while *Calamospora* and *Densosporites* point to a Lower Carboniferous age for the graphite. The same species can be found in Carboniferous metasedimentary rocks from the northwest New Territories (Langford *et al* 1989). The rocks of West Brother Island are therefore probably of Carboniferous age, and can be correlated with the Mai Po Member of the Lok Ma Chau Formation.



Plate 1 Aerial view of West Brother Island from the south, taken in 1988

The Carboniferous metasedimentary sequence of The Brothers, together with proven subcrop in the offshore areas, forms a local roof capping to the underlying granite of the Tai Lam Pluton. This pluton also produced the thermal metamorphism which gave rise to the high quality graphite ore extracted on West Brother Island. The lithologies found on West Brother Island include quartzite, sandstone, siltstone, mudstone and graphite (Figure 2). The lithologies are often finely interbedded, and contain features such as load structures indicating that they have not been inverted. The north and east of the island are dominated by pale sandstone and siltstone, while the darker, graphitic rocks are exposed around the southwest

*The geology and exploitation of the
West Brother Island graphite deposit*

tip. The graphite seams are no longer exposed, although there is abundant evidence of their existence in the superficial deposits and spoil heaps. They were recorded in the mine by Knapp (1964) as varying in thickness from 0.3 to 4.5 m, with an average of 1.2 m. Ruxton (1957) recorded two other seams higher in the succession, of 0.3 and 0.15 m maximum thickness.

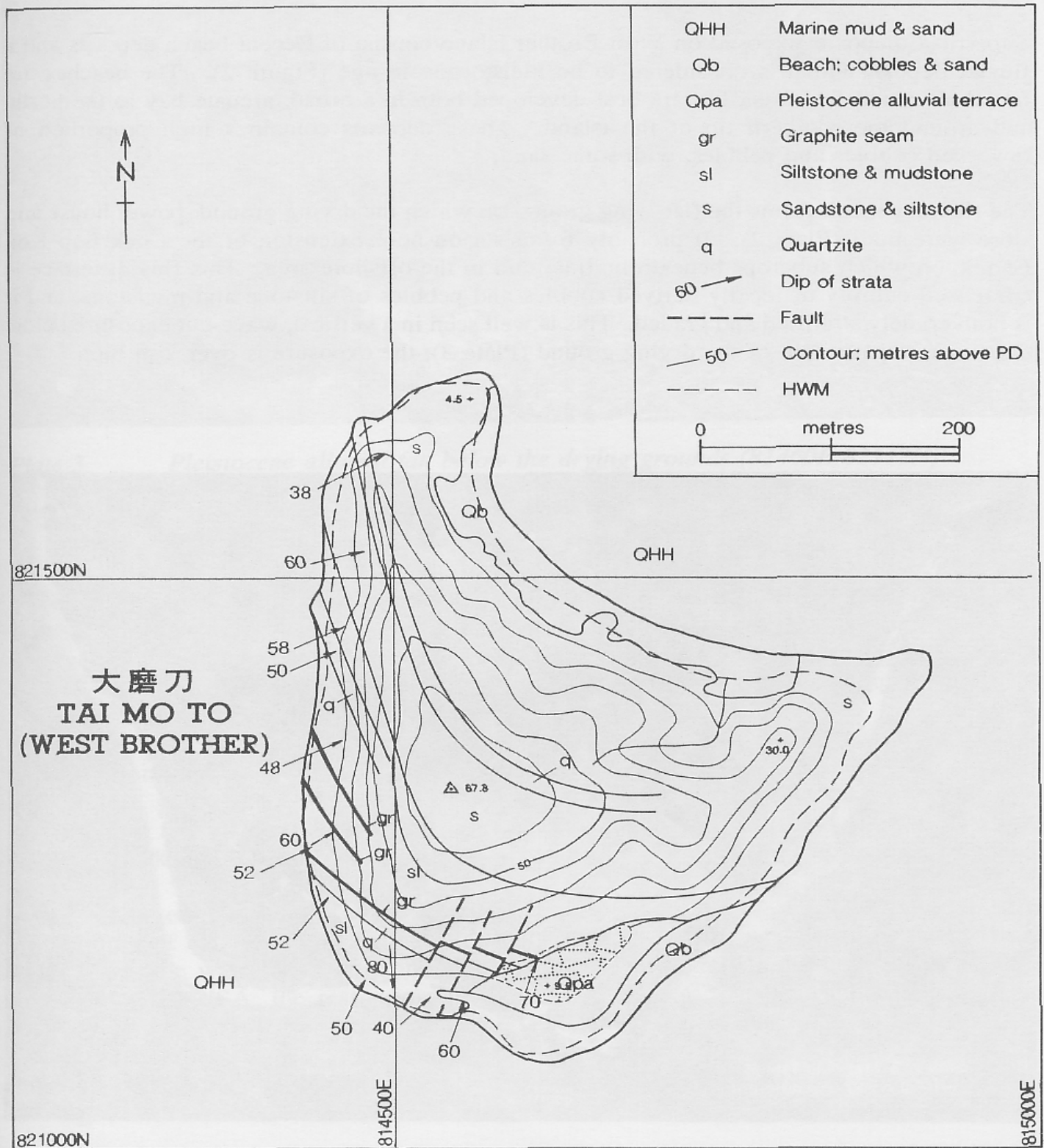


Figure 2 Geological map of West Brother Island (modified from Ruxton 1957)

The geological structure of the island, which has almost certainly been influenced by the emplacement of the Tai Lam granite pluton, consists of a northeast-trending, steeply plunging syncline. The strata on the west coast strike southsoutheast and dip 38 to 58° east (Figure 2). However, on the southwestern tip of the island (Frontispiece) the strike trend swings rapidly towards the east, with dips locally up to 80°. This point marks the exposure of the northeast-trending axial trace of the syncline. Although on the east coast the more siliceous rocks have poorly displayed or absent bedding, the strike trend appears to remain slightly north of east.

Superficial deposits exposed on West Brother Island consist of Recent beach deposits and a fluvial deposit which is considered to be Pleistocene in age (Figure 2). The beaches are found all round the coast, but are best developed both in a broad, arcuate bay to the north, and around the southern tip of the island. These deposits contain a high proportion of reworked cobbles and pebbles, with some sand.

The fluvial deposit forms the flat-lying ground on which the drying ground, power house and store were built (Plate 2). It probably forms an onshore extension of the Chek Lap Kok Formation which subcrops beneath marine mud in the offshore area. This fluvial terrace is composed entirely of locally derived cobbles and pebbles of siltstone and mudstone, and it is both crudely stratified and graded. This is well seen in a vertical, wave-cut exposure below the concrete pavement of the drying ground (Plate 3); the exposure is over 2 m high.

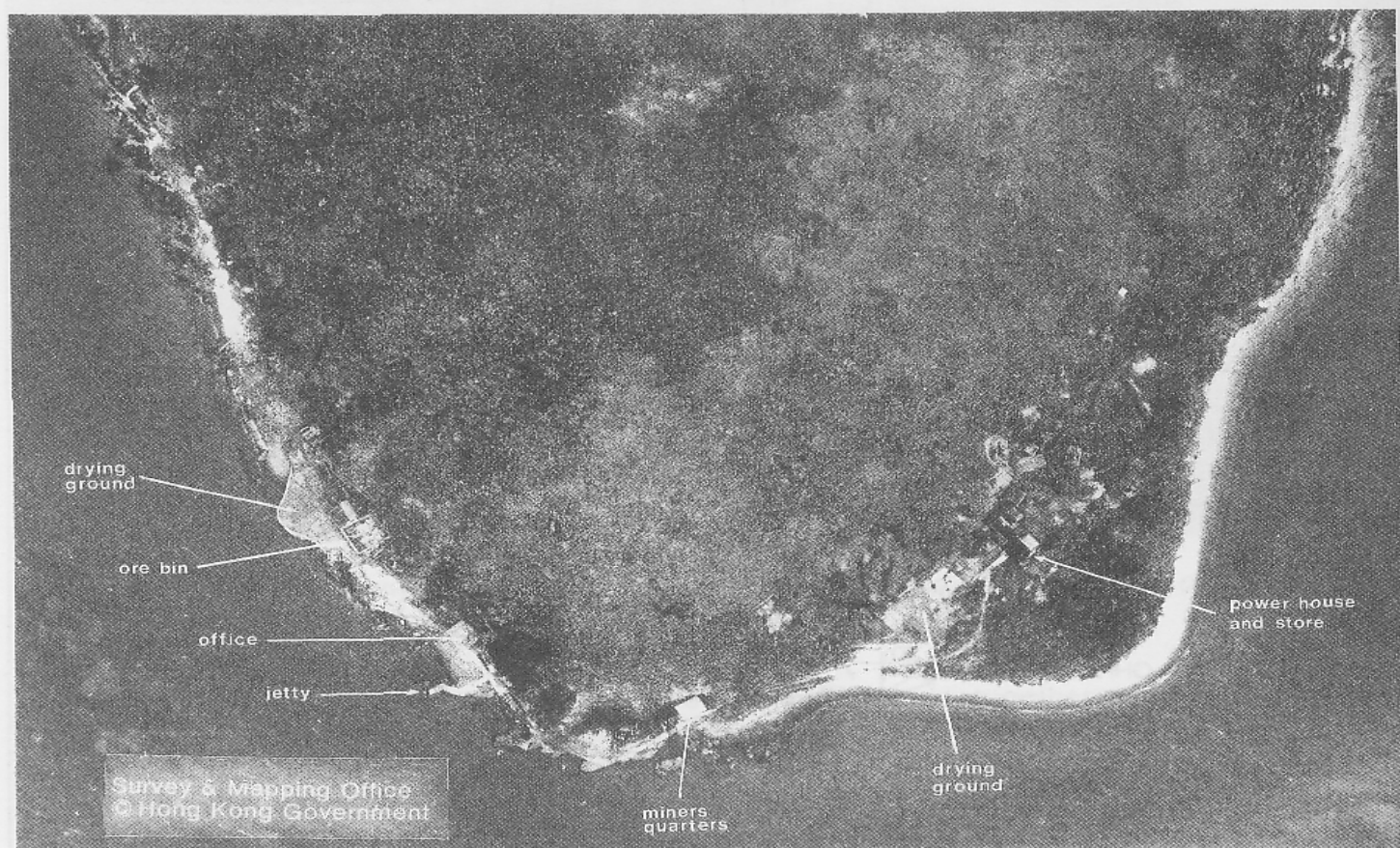


Plate 2 1967 aerial photograph of part of the island. Copyright © Hong Kong Government



Plate 3 Pleistocene alluvial fan below the drying grounds (81460E 82112N)

Development of the mine

An article (Anon 1956) in the 5 August 1956 edition of the *South China Morning Post*, concerning a visit to the island by the UK Trade Commissioner, records that graphite was first discovered there by fishermen who were in search of "sandstone" for making grinding stones. Instead, they found a black material which they mistook for coal. Subsequent analyses showed that it was graphite.

Mining operations were commenced in late 1952 by the Tin Bo Mining Development Corporation. However, it is assumed that shortly afterwards there was either a change in ownership or the name of the company was changed, as all subsequent records give the name of the Ng Fuk Black Lead Mining Company Limited as the operator of the mine.

Initially, all ore produced was exported to the UK. However, this soon changed, and by 1955 the majority of the graphite was being sent to the USA. In that year, approximately 1 500 tons of graphite were extracted from the mine and, of that amount, some 1 200 tons were exported to the USA; the rest was sent to the UK or used locally. It is likely that the majority of the graphite exported to both the UK and USA would have been used in control rods for nuclear power plants. The extent of the mine workings in 1955 is shown in Figure 3. Both this plan and Figure 4 are based on old mine plans now held by the Hong Kong Geological Survey.

By the late 1950s, annual production had grown to between 3 000 and 3 500 tons, and this production rate continued into the early 1960s. By 1964 the extent of the mine workings had

increased considerably, as shown in Figure 4. The workings were not only extensive laterally, but also reached a considerable depth. Knapp (1964) records that the workings had reached a depth of about 90 m below sea level by this time. At this depth, continuous pumping was required to keep the lower workings dry, and flooding had become a hazard. In addition, air compressors were required to maintain adequate ventilation in certain sections of the workings. The need for these expensive measures seriously affected the profitability of the operation and, by 1971, mining had been terminated. The mine closed in January 1973 when its mining licence expired.

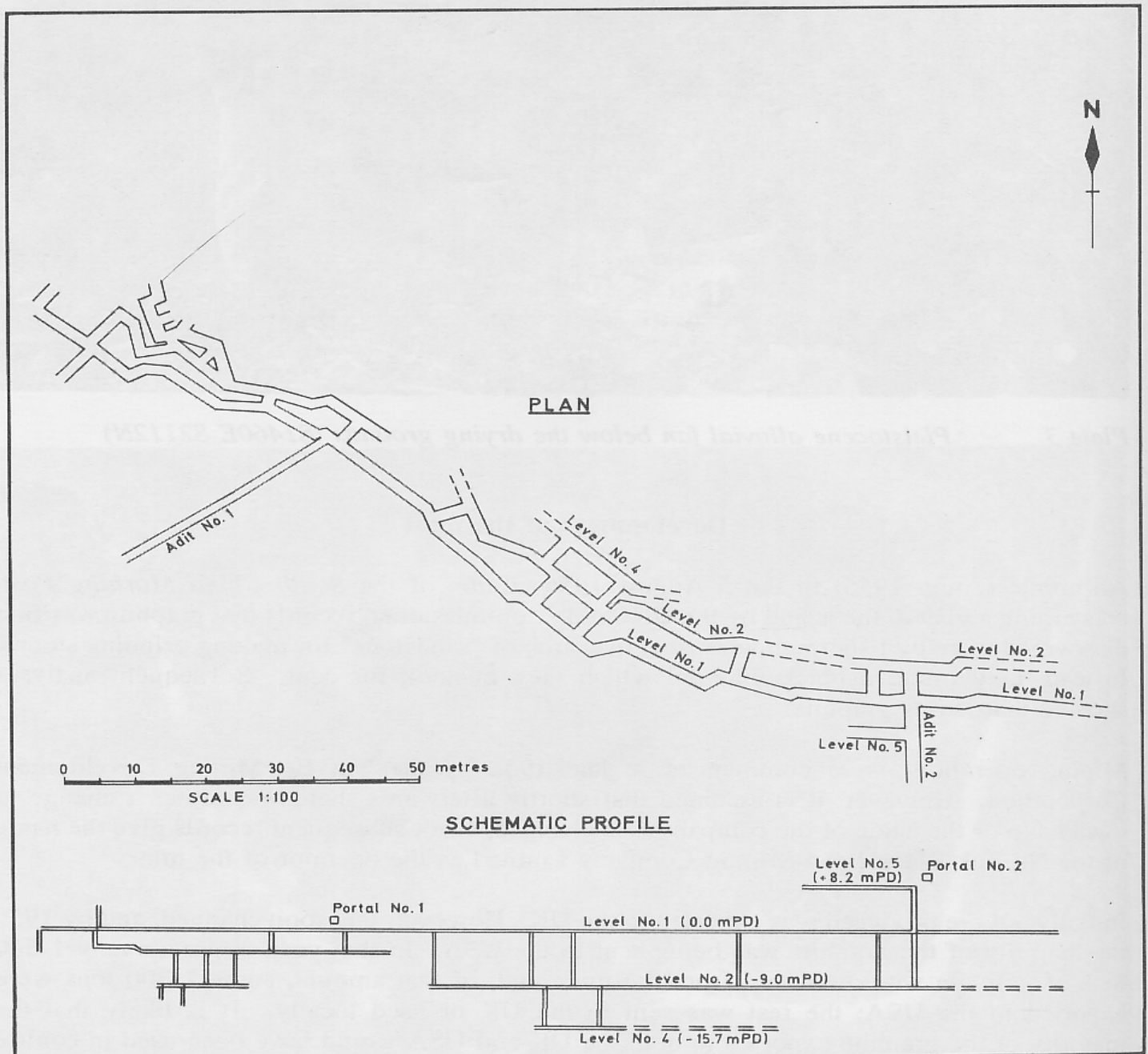


Figure 3 The extent of the mine workings in 1955 (from a plan in the Hong Kong Geological Survey archives)

*The geology and exploitation of the
West Brother Island graphite deposit*

All mining on West Brother Island was carried out underground, the workings being accessed by a number of adits situated around the southwestern corner of the island. The location of these is indicated in Figure 4. Mining was carried out by a technique called underhand stoping. This is a form of open stoping where the ore is mined from below the level which is being used to access the ore. Excavation of the graphite was carried out by labourers using picks and chisels. This would have been quite an appropriate means of excavation as the rock in the graphite seams is very weak. Blasting was only required for the excavation of development tunnels where stronger rock was encountered. After stoping had been completed in a particular section it was then backfilled with tailings. This was primarily to prevent collapses which could jeopardise the stability of workings above. Timber shoring was apparently provided in all sections of the mine workings.

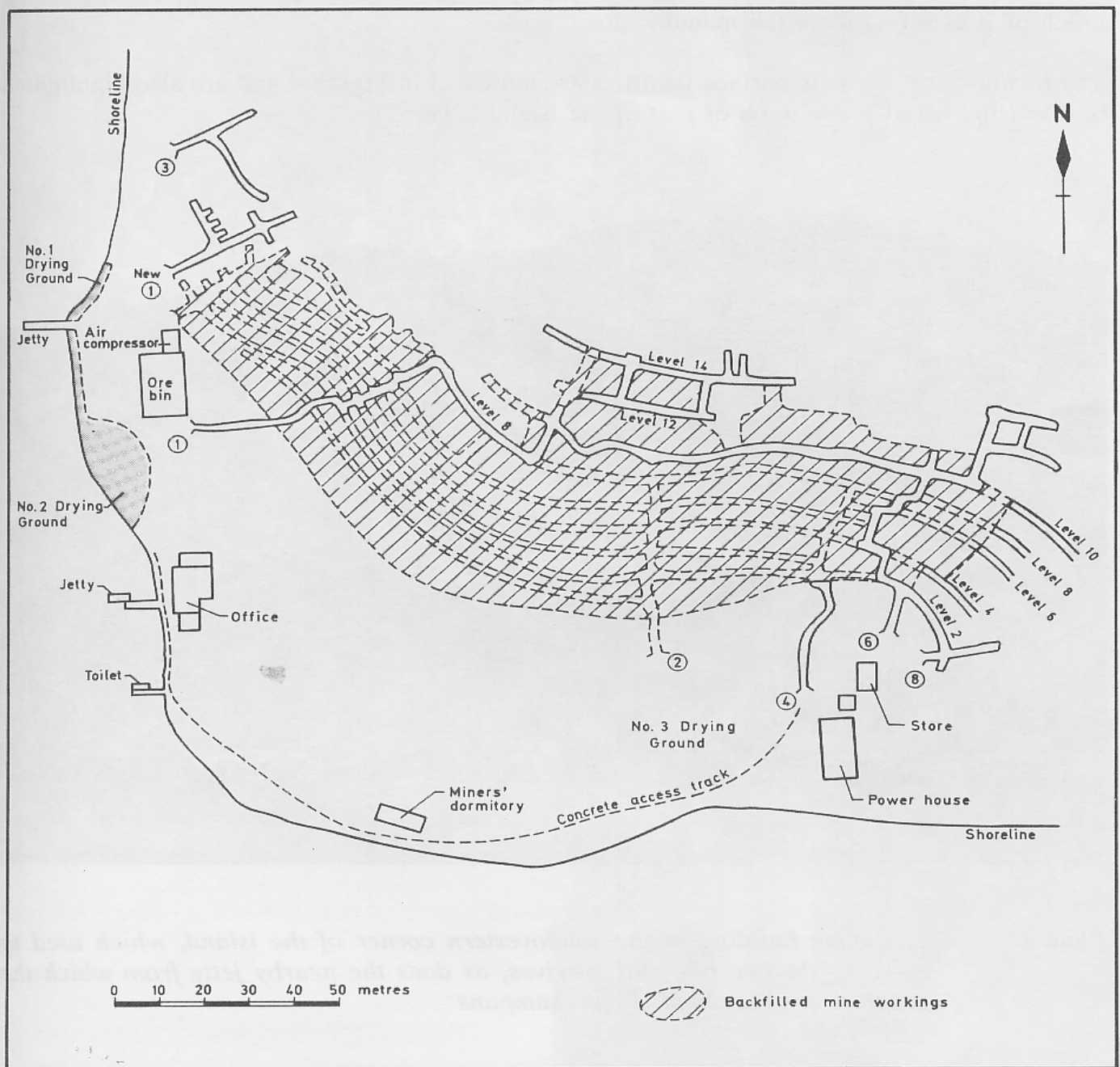


Figure 4 The extent of the mine workings in 1964 (from a plan in the Hong Kong Geological Survey archives)

Ruxton (1957) records that ventilation in the mine was good due to the numerous tunnels and shafts interconnecting the various levels. However, as mentioned previously, ventilation became a problem in later years as the mine workings became deeper. Initially, only rudimentary lighting was provided, consisting of candles spaced at frequent intervals along the tunnels. Later, as the extent of the workings increased, electric lighting was provided. Electricity was also required for operating pumps to dewater the lower workings, for hoisting and for running the air compressor.

The excavated ore was hoisted up from the lower levels and then carried out of the mine in baskets. It was then laid out to dry before being hand-sorted according to quality. After being bagged in sacks it was moved to an ore bin near the jetty at the western end of the island (Figure 4) to await shipment. All of the ore with a fixed carbon content of more than 80% was suitable for export. The poorer quality graphite was used locally in Hong Kong, much of it as a fuel for brick manufacture.

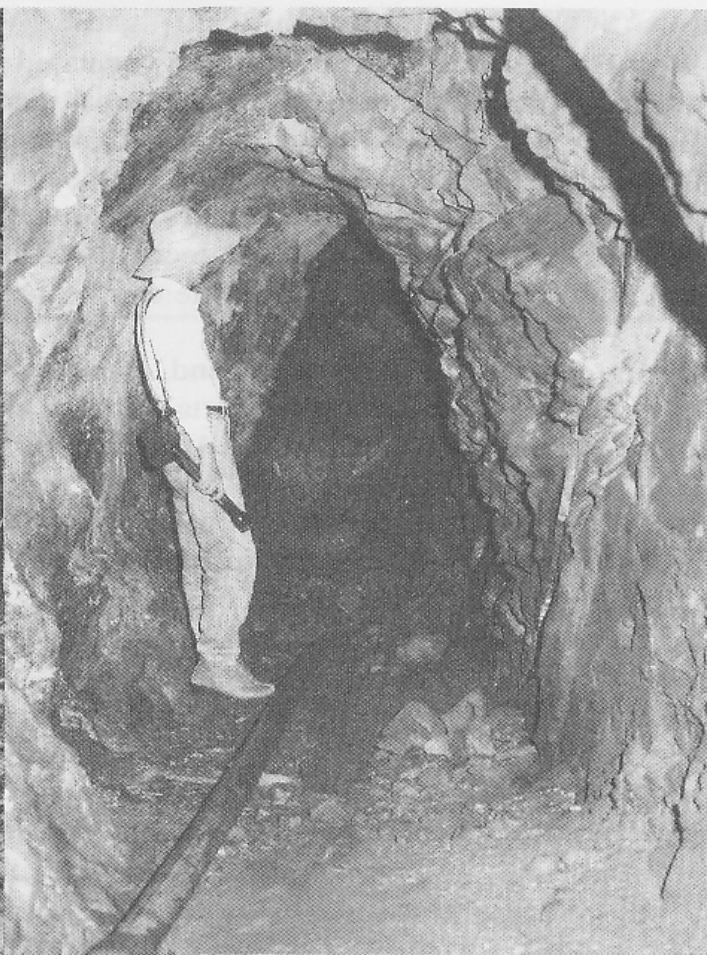
The locations of the main surface facilities are indicated in Figure 4 and are also highlighted on the 1967 aerial photograph of part of the island (Plate 2).



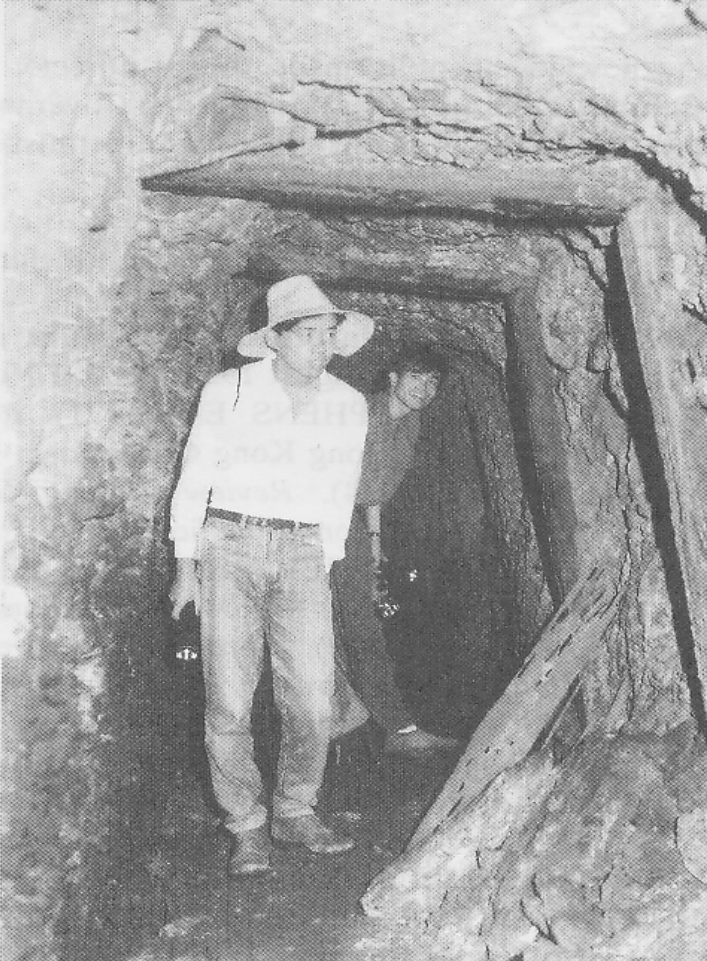
Plate 4 The stone building in the southwestern corner of the island, which used to serve as the ore bin, still survives, as does the nearby jetty from which the graphite ore was loaded onto sampans



*Plate 5 (Top left)
Portal No 1 behind the derelict ore bin*



*Plate 6 (Top right)
Tunnel beyond Portal No 1*



*Plate 7 (Bottom right)
Rotten timber props in adit beyond
Portal No 1*

The mine today

West Brother Island is now thickly vegetated (Plate 4), and the areas previously occupied by the mine buildings, the ore drying areas and the access paths are all heavily overgrown. However, the stone building in the southwestern corner of the island, which used to serve as the ore bin, still survives (Plate 4), as does the nearby jetty from which the graphite ore was loaded onto sampans. The ore drying area on the southern side of the island, a large, flat, concrete-paved area, can still be recognised, and directly uphill of it is a large spoil heap from which good specimens of graphite can be obtained.

During a recent visit to the island, three of the mine adits were found. One of them was blocked by a collapse at the portal, and in another the adit was blocked by a roof collapse about 9 m in from the portal. A third portal (Plate 5) was found just behind the stone ore bin. This adit, which is about 2 m high and 1.2 m wide, goes in about 30 m but is blocked at the end by a roof collapse. There is a steel pipe running along the tunnel floor, which was probably a water discharge pipe (Plate 6). The reader is cautioned that it would be unwise to enter this adit as there have been collapses in places and the timbers, which were intended for support, are rotten and no longer serve their purpose (Plate 7).

Although the stopes in the mine may have been backfilled, the thoroughness with which this was done is not certain. Also, it is quite likely that many of the main tunnels in the mine are still open. The condition of the underground workings would clearly need to be investigated carefully should there be any development on the island in the future.

Acknowledgements

Acknowledgement is made to the Director of Civil Engineering Services, who is also Commissioner of Mines, Hong Kong Government for permission to publish this paper. The aerial photograph is reproduced with permission of the Director of Building and Lands.

References

- ANON (1956). Trade official down mine in pongee coat. *South China Morning Post, Hongkong*, 5 August 1956 Vol XII No 218 p 5
- ALLEN P M & STEPHENS E A (1971). *Report on the Geological Survey of Hong Kong 1967-1969*. Hong Kong Government Press, 116 p plus 2 maps
- BENNETT J D (1984). *Review of Hong Kong stratigraphy*. GCO Publication No 5/84. Geotechnical Control Office, Hong Kong, 86 p
- BROCK R W, SCHOFIELD S J, WILLIAMS M Y & UGLOW W L (1936). *Geological map of Hong Kong, 1:84 480*. Ordnance Survey, Southampton
- HEANLEY C M (1923). Some geological excursions around Hong Kong. *The Caduceus (Hong Kong University Medical Society)* Vol 2 p 85-94 (plus 1 map)
- KNAPP J H (1964). Mining in Hong Kong. In: DAVIS S G (Ed). *Economic Geology of Hong Kong*. Hong Kong University Press, p 3-10
- LANGFORD R L, LAI K W, ARTHURTON R S & SHAW R (1989). *Geology of the Western New Territories*. Hong Kong Geological Survey Memoir No 3. Geotechnical Control Office, Hong Kong, 140 p
- RUXTON B P (1955). Graphite in Hong Kong. *Far Eastern Economic Review* Vol 18 No 4 p 98-100

- RUXTON B P (1957). Graphite seams in Hong Kong. In: *Colonial Geology and Mineral Resources* Vol 6 No 4 p 429-441
- WILLIAMS M Y (1943). The stratigraphy and palaeontology of Hong Kong and the New Territories. *Transactions of the Royal Society of Canada* Third Series Vol 37 Sect IV p 93-117

PLANT FOSSILS OF SOME SEDIMENTARY INTERCALATIONS WITHIN THE REPULSE BAY VOLCANIC GROUP IN HONG KONG

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Introduction

The Repulse Bay Volcanic Group (formerly Repulse Bay Formation) in Hong Kong, being part of the southeastern maritime Mesozoic volcanic belt of China, consists of a succession of tuffs, agglomerates, lavas and sedimentary rocks, and is dominated by tuffs. According to the geological mapping (1:20 000 scale) undertaken by the Geological Survey Section of the Planning Division of the Geotechnical Control Office (Addison 1986; Strange & Shaw 1986; Langford *et al* 1989; Strange *et al* 1990), it is found to comprise at least 12 formations as listed below (from young to old):

Long Harbour	coarse ash crystal tuff
Lai Chi Chong	rhyolite lava, tuff, tuffite, mudstone and conglomerate
High Island	fine ash vitric tuff
Clear Water Bay	mainly trachydacite-rhyolite lavas, some tuff and tuffite
Mong Kung Uk	tuff, tuffite and sandstone
Silverstrand	eutaxite
Tai Mo Shan	coarse ash crystal tuff
Ap Lei Chau	fine ash vitric tuff with eutaxite
Shing Mun	lithic and crystal tuffs, tuff-breccia and tuffite
Yim Tin Tsai	coarse and crystal tuff
Tuen Mun	meta-andesite lava
Tsing Shan	sandstone and conglomerate

The sedimentary intercalation within the Lai Chi Chong Formation in the east New Territories has long been known to yield plant fossils which had been reported previously (Williams 1943; Dale & Nash 1984; Nau 1986; Wai 1986). On Lantau Island, certain sedimentary intercalations within the Volcanic Group also yield plant fossils (Davis 1952). Commonly, the black and grey shale, mudstone and siliceous rock (chert) are fossil-bearing strata. The present report is the result of fossil investigations at Cheung Sheung (east New Territories), Ngong Ping and Lung Tsai (both west Lantau Island) in July 1987.

Characteristics of strata at Cheung Sheung, Ngong Ping and Lung Tsai

The locations of Cheung Sheung, Ngong Ping and Lung Tsai are given in Figure 1. The sedimentary intercalation at Cheung Sheung is now included in the Lai Chi Chong Formation (Strange *et al* 1990), but the sedimentary intercalations of Ngong Ping and Lung Tsai are not included in any of the above 12 Formations at the moment. The sedimentary rocks of the three areas include sandstone, siltstone, mudstone and conglomerate, with siliceous rock. The rocks are usually tuffaceous, and those exposed at Cheung Sheung are somewhat softer than those of the other two areas. Only the sedimentary intercalation exposed at Cheung Sheung has a complete stratigraphic record.

*Plant fossils of some sedimentary intercalations within
the Repulse Bay Volcanic Group in Hong Kong*

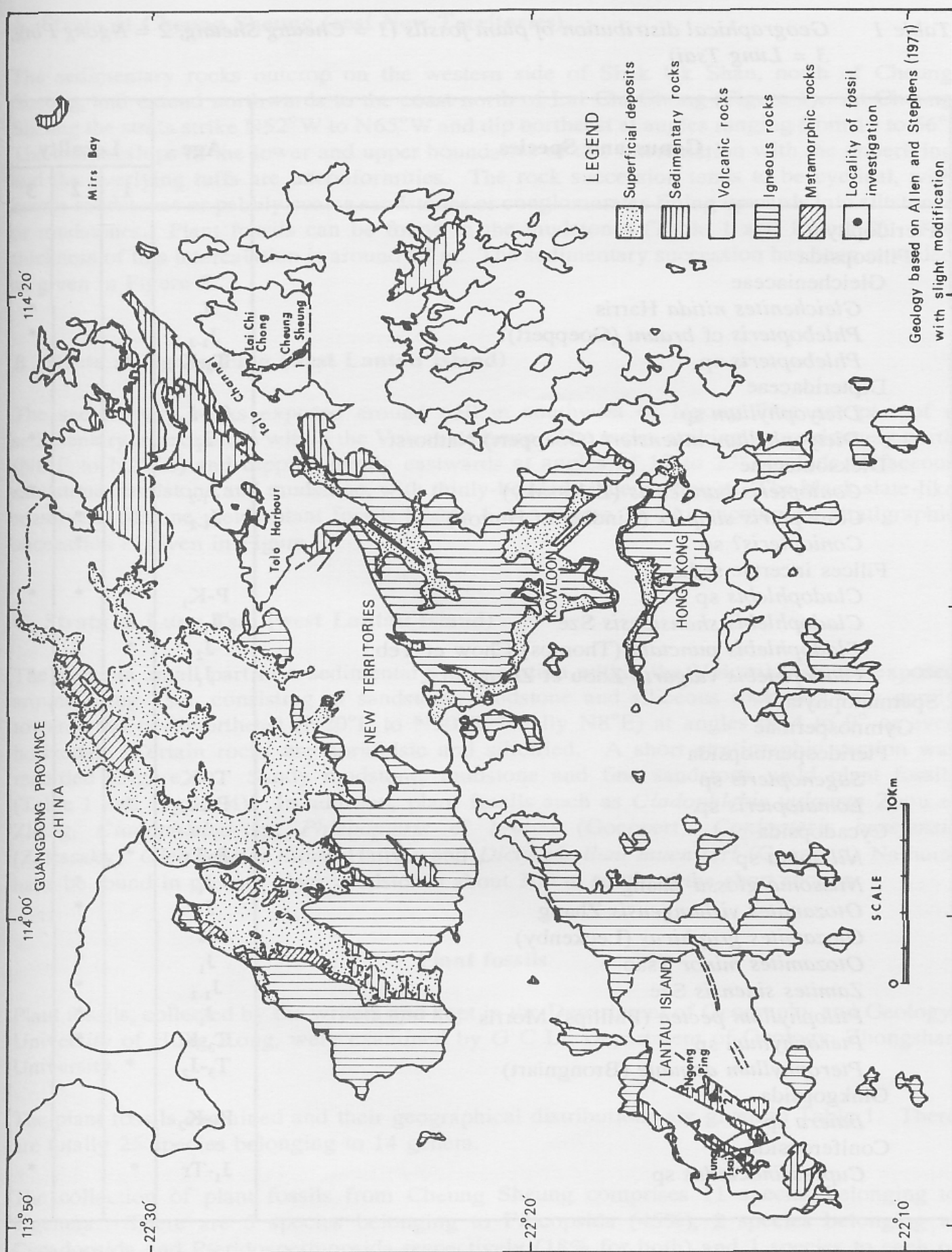


Figure 1 *Simplified geological map showing localities of fossil investigation*

Table 1 Geographical distribution of plant fossils (1 = Cheung Sheung, 2 = Ngong Ping, 3 = Lung Tsai)

Genus and Species	Age	Locality		
		1	2	3
Pteridophyta				
Filicopsida				
Gleicheniaceae				
<i>Gleichenites nitida</i> Harris	J ₁			*
<i>Phlebopteris</i> cf <i>brauni</i> (Goeppert)?	J ₁₋₂			*
<i>Phlebopteris</i> sp	T ₃ -K	*		
Dipteridaceae				
<i>Dictyophyllum</i> sp	T ₃ -J ₂	*		
<i>Dictyophyllum muensteri</i> (Goeppert) Nathorst	J ₁			*
Dicksoniaceae				
<i>Coniopteris burejensis</i> (Zalessaky)	J ₁₋₂		*	*
<i>Coniopteris simplex</i> (Lindley et Hutton)	J ₁₋₂		*	
<i>Coniopteris?</i> sp			*	
Filices incertae sedis				
<i>Cladophlebis</i> sp	P-K ₁	*	*	*
<i>Cladophlebis shansiensis</i> Sze	J ₁₋₂	*		
<i>Cladophlebis punctata</i> (Thomos) Chow et Yeb	J ₂	*		
<i>Cladophlebis vulgata</i> Zhou et Zhang	J ₁			*
Spermatophyta				
Gymnospermae				
Pteridospermopsida				
<i>Sagenopteris</i> sp	T ₃ -K	*		
<i>Lomatopteris</i> sp	P-K ₁	*		
Cycadopsida				
<i>Nilssonia</i> sp	P-Tr	*		
<i>Nilssonia glossa</i> Zhang	J ₁		*	
<i>Otozamites yizhangensis</i> Zhang	J ₁		*	
<i>Otozamites graphicus</i> (Leckenby)	J ₁		*	
<i>Otozamites minor</i> Tsao	J ₁		*	
<i>Zamites sinensis</i> Sze	J ₁₋₂		*	
<i>Ptilophyllum pecten</i> (Phillips) Morris	J ₁		*	
<i>Pterophyllum</i> sp	C ₃ -K		*	
<i>Pterophyllum aequale</i> (Brongniart)	T ₃ -J ₂	*		
Ginkgopsida				
<i>Baiera</i> sp	P ₂ -K ₂	*		
Coniferopsida				
<i>Cupressinocladus</i> sp	J ₁ -Tr	*		*

A Strata at Cheung Sheung (east New Territories)

The sedimentary rocks outcrop on the western side of Shek Uk Shan, north of Cheung Sheung, and extend northwards to the coast north of Lai Chi Chong (Figure 1). At Cheung Sheung the strata strike N52°W to N65°W and dip northeast at angles ranging from 19 to 56°. The relationships of the lower and upper boundaries of this intercalation with the underlying and the overlying tuffs are unconformities. The rock succession tends to be cyclical, with coarse sandstones or pebbly coarse sandstones or conglomerates fining upwards into siltstones or mudstones. Plant fossils can be found in the mudstones (Table 1 and Figure 2). The thickness of this intercalation is around 97 m. The sedimentary succession has been recorded as given in Figure 2.

B Strata at Ngong Ping (west Lantau Island)

The sedimentary rocks exposed around 650 m southwest of Ngong Ping are part of a sedimentary intercalation within the Volcanic Group. The rocks, striking approximately north (N8°E to N25°E) and dipping gently eastwards at angles of 17 to 23°, include tuffaceous sandstone, sandstone and mudstone, with thinly-bedded siliceous layers. The black slate-like massive mudstone yields plant fossils (Table 1 and Figure 3). An incomplete stratigraphic succession is given in Figure 3.

C Strata at Lung Tsai (west Lantau Island)

The rocks (a small part of a sedimentary intercalation within the Volcanic Group) exposed around Lung Tsai, consisting of sandstone, mudstone and siliceous rock, dip very gently towards the northnortheast (N20°E to N30°E, locally N8°E) at angles of 4 to 9° or even horizontal. Certain rocks are hornfelsic and silicified. A short stratigraphic section was recorded (Figure 4). Sandy mudstone, mudstone and fine sandstone yield plant fossils (Table 1 and Figure 4). In addition, plant fossils such as *Cladophlebis vulgata* Zhou et Zhang, *Cladophlebis* sp, *Phlebopteris* cf *brauni* (Goeppert), *Coniopteris burejensis* (Zalessaky), *Gleichenites nitida* Haiivis and *Dictyophyllum muensteri* (Goeppert) Nathorst have been found in greyish black mudstones about 300 m south of the short section.

Plant fossils

Plant fossils, collected by the writers and kept in the Department of Geography and Geology, University of Hong Kong, were examined by G C Li, Department of Geology, Zhongshan University.

The plant fossils examined and their geographical distributions are given in Table 1. There are totally 25 species belonging to 14 genera.

The collection of plant fossils from Cheung Sheung comprises 11 species belonging to 9 genera. There are 5 species belonging to Filicopsida (45%), 2 species belonging to Cycadopsida and Pteridospermopsida respectively (18% for both) and 1 species to each of Ginkgopsida and Coniferopsida (9% each).

The fossil collection from Ngong Ping includes 11 species belonging to 7 genera. Of these, 3 species belong to *Coniopteris* (27%), 1 species belongs to *Filices incertae sedis* (9%) and 7 species belong to *Cycadopsida* (64%).

The plant fossils from Lung Tsai include 7 species belonging to 6 genera. Of the total specimens, 93% belong to *Filicopsida* (including 4 species of 4 genera) and *Filices incertae sedis* (including 2 species of 1 genera). There is only 1 species belonging to *Coniferopsida*.

Discussion of ages of the sedimentary intercalations

A Cheung Sheung

Among the plant fossils as shown in Table 1, *Cupressinocladus*, *Sagenopteris*, *Baiera*, *Nilssonina* and *Cladophlebis* have been known to occur in the Nanyuan Formation (Upper Jurassic) in Fujian. *Pterophyllum aequale* is an older element of the Jurassic flora in Southern China, which has been reported from the Xiangxi Group (Lower Jurassic) in Sichuan, Songling Group (Lower Jurassic) in Guangdong and Ziliujing Group (Middle Jurassic) in Sichuan. *Cladophlebis shansiensis* is mainly found in strata of Middle Jurassic or late Early Jurassic age in Northern China. *Phlebopteris* can usually be found in strata of Triassic-Jurassic age. According to this fossil collection, the age of the sedimentary strata is supposed to be Upper Jurassic, and the volcanic series containing this sedimentary intercalation corresponds to the Gaojiping Group (Upper Jurassic) in Guangdong.

On the age of the sedimentary strata concerned, the earliest published opinion is that of Williams (1943), who offered a Jurassic (probably Liassic) age according to the plant fossils (*Cladophlebis*, ?*Equisetites*, ?*Nilssonina*, ?*Brachyphyllum* or ?*Thuites*, ?*Phoenicopsis* and *Pterophyllum kingianum* Feistm) collected from the rock exposures to the north of Lai Chi Chong by Heanley, Brock and Williams. Nau (1986), from an examination of plant fossils (*Cladophlebis todiodes* Yang and *Cladophlebis* sp) collected from mudstone on the coast north of Lai Chi Chong, suggested a late Early Jurassic age. Recently, based on the fossil plants, listed as *Equisetites* sp, *Cladophlebis exiliformis* (Geyler) Oishi, *Cladophlebis* cf *browniana* (Dunker) Seward, *Cladophlebis lhoronensis* Li, *Cladophlebis* sp, ?*Coniopteris* sp, *Gleichenites* cf *giesekiana* Heer, *Gleichenites gladiatus* Li, *Gleichenites* sp, *Nilssonina* cf *cultrata* Li, *Nilssonina* sp, *Ptilophyllum* cf *borealis* (Heer) Seward, cf *Zamiophyllum buchianum* (Ett.), *Cupressinocladus* sp, *Brachyphyllum* sp, *Carnolithus* sp, collected from the same sedimentary intercalation at Cheung Sheung and Lai Chi Chong by a Joint Survey Team, the age of the sedimentary strata is regarded as Early Cretaceous (Lee *et al* 1990). According to the Rb/Sr age of 135 ± 8 Ma on the volcanic rocks from the High Island (Strange *et al* 1990), which is overlain by the Lai Chi Chong Formation, the above mentioned sedimentary layer is assigned to the Lower Cretaceous.

B Ngong Ping

Among the fossils given in Table 1, *Coniopteris* and *Ptilophyllum* are the important elements in the Jurassic flora as they are known to occur in Yorkshire (Middle Jurassic) in Great Britain. *Coniopteris* appeared first in the Early Jurassic and flourished in the Middle Jurassic. *Coniopteris burejensis* has only been found in strata of Middle Jurassic or later in Europe.

*Plant fossils of some sedimentary intercalations within
the Repulse Bay Volcanic Group in Hong Kong*

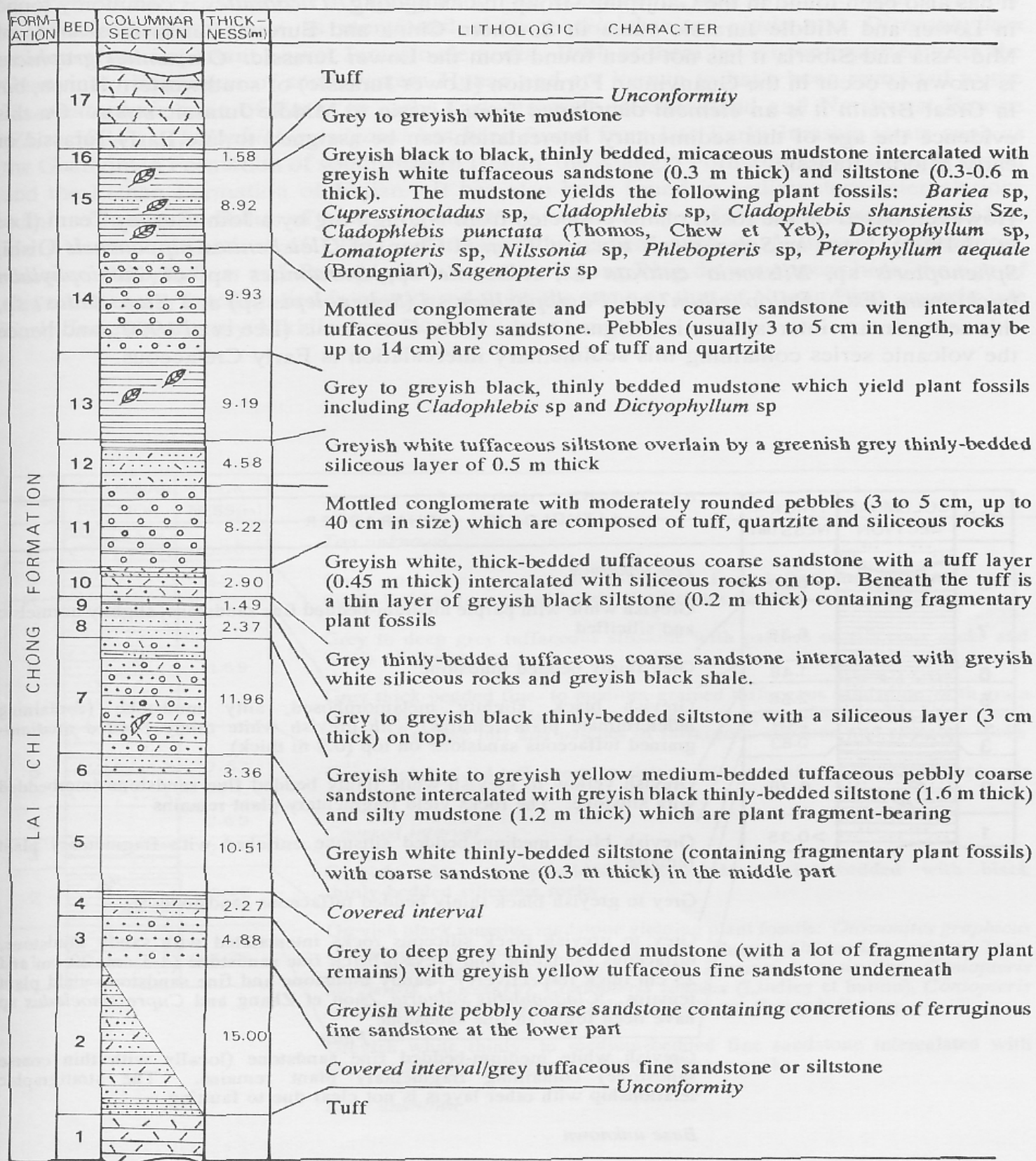


Figure 2 Columnar section at Cheung Sheung

Ptilophyllum is a major element of the Lower and Middle Jurassic flora not only found in Southern China but also in Europe and Mid-Asia. *Ptilophyllum pecten* is a common element found in late Early Jurassic strata, but it can also be found in Yorkshire. However, in China it has also been found in the Gaojiping Group in Guangdong. *Otozamites* is commonly found in Lower and Middle Jurassic strata in Southern China and Europe, but in most areas of Mid-Asia and Siberia it has not been found from the Lower Jurassic. *Otozamites graphicus* is known to occur in the Guanyintan Formation (Lower Jurassic) of southwestern Hunan, but in Great Britain it is an element distributed from Liassic to Middle Jurassic strata. On this evidence the age of this sedimentary intercalation can be assigned to late Early Jurassic or early Middle Jurassic.

However, based on the fossil plants collected from Ngong Ping by a Joint Survey Team (Lee *et al* 1990), listed as *Scleropteris tibetica* Tuan et Chen, cf *Gleichenites nipponensis* Oishi, *Sphenopteris* sp, *Nilssonia cultrata* Li, *Nilssonia* sp, *Otozamites* sp, cf *Zamiophyllum buchianum* (Ett.), *Ptilophyllum?* sp, *Pagiophyllum* sp (*Sphenolepis* sp) and *Elatocladus?* sp, this sedimentary intercalation is assigned to the Early Cretaceous (Lee *et al* 1990), and hence the volcanic series containing this sedimentary intercalation is Early Cretaceous.

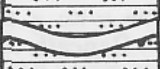
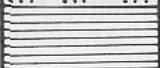
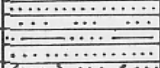
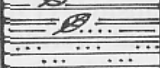
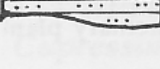
BED	COLUMNAR SECTION	THICKNESS (m)	LITHOLOGIC CHARACTER
8		> 0.20	Top unknown
7		6.36	Greyish white with purple medium-bedded fine sandstone, slightly hornfelsic and silicified
6		1.48	Grey thinly bedded mudstone
5		2.58	Greyish black, slightly metamorphosed, silty mudstone (containing indeterminate plant remains) with greyish white thinly bedded medium-grained tuffaceous sandstone on top (0.9 m thick)
4		2.01	
3		0.83	
2		6.76	Greyish yellow to greyish white thinly bedded fine sandstone interbedded with siltstone. The rocks yield fragmentary plant remains
1		> 0.35	Greyish black medium-bedded siltstone enriched with fragmentary plant remains
			Grey to greyish black thinly bedded tuffaceous sandstone
			Grey to greyish black siliceous rocks intercalated with sandy mudstone, tuffaceous sandstone and greyish-black fine sandstone (4-5 cm, 20 cm and 25 cm thick respectively). Sandy mudstone and fine sandstone yield plant remains. <i>Cladophlebis vulgata</i> Zhou et Zhang and <i>Cupressinocladus</i> sp have been found in fine sandstone
			Fault
			Greyish white medium-bedded fine sandstone (locally with thin coarse sandstone) containing fragmentary plant remains. The stratigraphic relationship with other layers is not clear due to faulting
			Base unknown

Figure 3 Columnar section at Ngong Ping

C Lung Tsai

Coniopteris burejensis found at Ngong Ping also occurs here, and its distribution is mainly in Middle Jurassic strata as mentioned above. *Gleichenites nitida* and *Dictyophyllum muensteri* are important Lower Jurassic elements. Both of them have been reported from the Guanyintan Formation of southwestern Hunan and are known to have been restricted to the *Thaumatopteris* zone of Early or early Early Jurassic in Greenland and Northwest Europe (Zhou 1984). *Cladophlebis vulgata* has been found from late Early Jurassic strata such as the Guanyintan Formation of southwestern Hunan, the Xiangxi Formation in of western Hubei and the Lishan Formation of Fujian. It has also been found in sedimentary intercalations within volcanics in Boluo of eastern Guangdong, with the age of the rock considered as late Early Jurassic (Chen *et al* 1984). Although the genera such as *Nilssonia*, *Otozamites*, *Zamites*, *Ptilophyllum* and *Pterophyllum* found at Ngong Ping do not appear here, the age of this sedimentary intercalation is considered to be the same as that of Ngong Ping, namely late Early Jurassic or early Middle Jurassic.

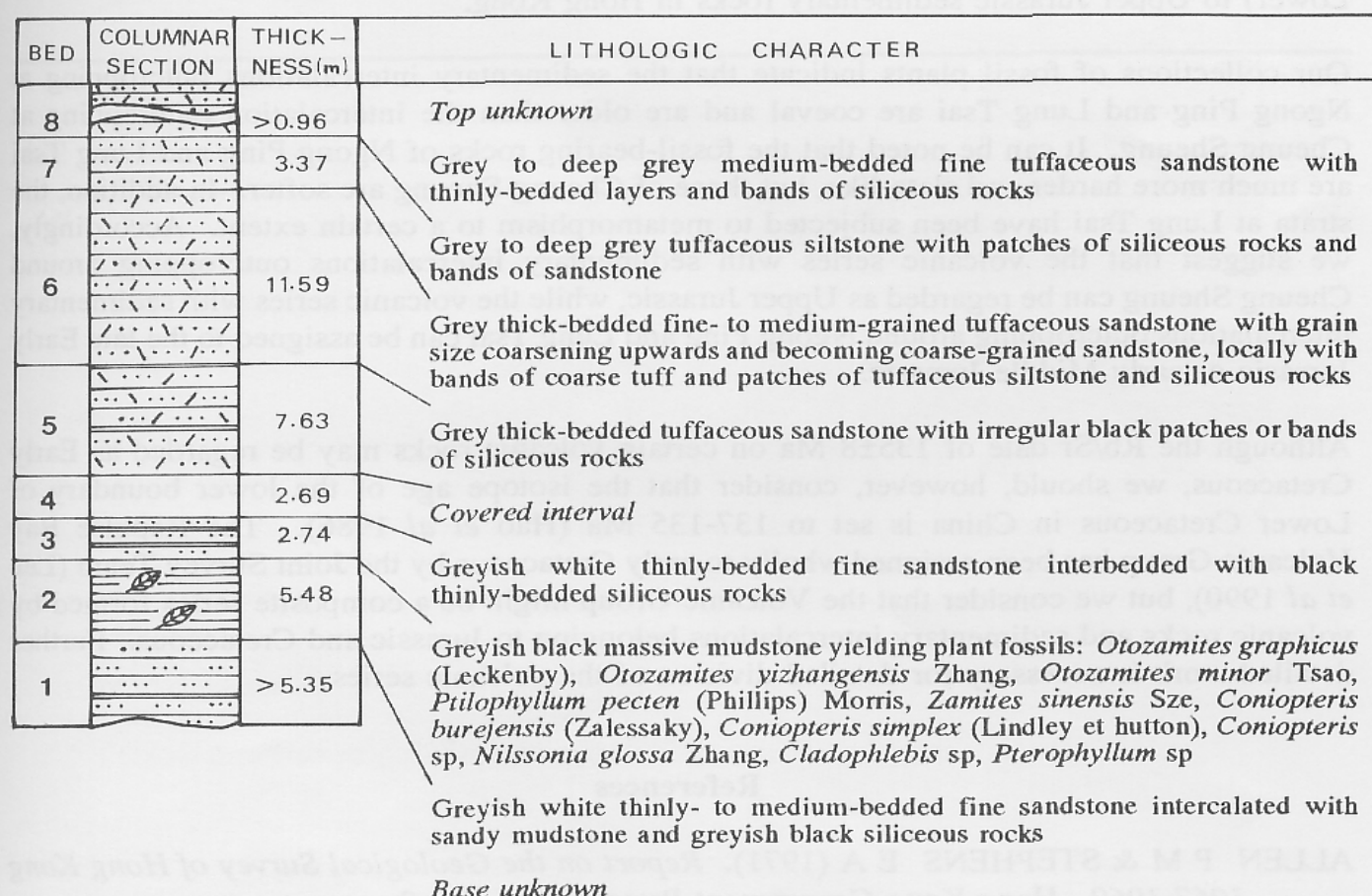


Figure 4 Columnar section of Lung Tsai

Conclusion

As mentioned above, our fossil plant collections from the three areas includes many older species of Jurassic flora, while the fossil plants collected from Cheung Sheung and Ngong Ping by the Joint Survey Team (Lee *et al* 1990) include certain younger species. It is evident that we will have different views on the ages of the sedimentary intercalations within the Repulse Bay Volcanic Group.

Judging from the Geological Map of Shenzhen (1:50 000) compiled in 1988 by the Regional Geological Surveying Party, Bureau of Geology and Mineral Resources of Guangdong Province, there are strata belonging to Middle and Upper Jurassic in the Shenzhen area. The Middle Jurassic sequence (mainly sedimentary rocks with volcanic intercalations, which may probably include Lower Jurassic strata) are grouped as the Tangxia Group. The Upper Jurassic volcanic series are grouped as the Gaojiping Group (probably including Early Cretaceous volcanics) which extends into the New Territories of Hong Kong. However, volcanic series of late Early Jurassic have been found to outcrop at Gongzhuang, Boluo and eastern Guangdong (Chen *et al* 1984). The Songling Group coal series of Lower Jurassic in eastern Guangdong also contains volcanic layers. In Hong Kong, sedimentary intercalations are present at many levels as sedimentation was still taking place during volcanic activity (Allen & Stephens 1971). It is reasonable to assume that there will be Middle (or even Lower) to Upper Jurassic sedimentary rocks in Hong Kong.

Our collections of fossil plants indicate that the sedimentary intercalations outcropping at Ngong Ping and Lung Tsai are coeval and are older than the intercalation outcropping at Cheung Sheung. It can be noted that the fossil-bearing rocks of Ngong Ping and Lung Tsai are much more harder and slate-like, but those of Cheung Sheung are softer. In addition, the strata at Lung Tsai have been subjected to metamorphism to a certain extent. Accordingly, we suggest that the volcanic series with sedimentary intercalations outcropping around Cheung Sheung can be regarded as Upper Jurassic, while the volcanic series with sedimentary intercalations outcropping around Ngong Ping and Lung Tsai can be assigned to the late Early Jurassic or early Middle Jurassic.

Although the Rb/Sr date of 135 ± 8 Ma on certain volcanic rocks may be regarded as Early Cretaceous, we should, however, consider that the isotope age of the lower boundary of Lower Cretaceous in China is set to 137-135 Ma (Hao *et al* 1986). The Repulse Bay Volcanic Group has been assigned wholly to early Cretaceous by the Joint Survey Team (Lee *et al* 1990), but we consider that the Volcanic Group might be a composite series formed by volcanic rocks and sedimentary intercalations belonging to Jurassic and Cretaceous. Further detailed work is necessary for detailed division of the volcanic series.

References

- ALLEN P M & STEPHENS E A (1971). *Report on the Geological Survey of Hong Kong 1967-1969*. Hong Kong Government Press, 116 p plus 2 maps
- CHEN P J & WU S Q (1984). The plant fossils and Phyllopora in the sedimentary intercalations within the Early Jurassic volcanics in Eastern Guangdong. *Professional Papers of Guangdong Geological Society* No 2 (Whole Number 10) p 18 (in Chinese)
- DALE M J & NASH J M (1984). The occurrence of silicified wood in the Repulse Bay Formation sediments at Lai Chi Chong, New Territories, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 2 No 3 p 1-4

- DAVIS S G (1952). *The geology of Hong Kong*. Government Printer, Hong Kong, 231 p plus 14 plates & 3 maps
- HAO Y C, SU D Y *et al* (1986). The Cretaceous System of China. *Stratigraphy of China*. No 12. Geological Publishing House (In Chinese)
- LEE C M, ATHERTON M J, WU S Q, HE G X & CHEN J H (1990). On the geological age of the Repulse Bay Formation, Hong Kong. In: ATHERTON M J, LEE C M, CHEN J H, HE G X & WU S Q. (*Supplement*) *Report on the stratigraphy of Hong Kong*. Department of Civil and Structural Engineering, Hong Kong Polytechnic, p G1-9
- NAU P S (1986). Discussion on the age of the rock sequence on the coast north of Lai Chi Chong, New Territories, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 4 No 3 p 1-4 plus 1 plate & 2 maps
- STRANGE P J, SHAW R & ADDISON R (1990). *Geology of Sai Kung and Clear Water Bay*. *Hong Kong Geological Survey Memoir No 4*. Geotechnical Control Office, Hong Kong Government, 111 p
- WAI C C (1986). A note on the discovery of fossil wood found in the Repulse Bay Formation sediments at Cheung Sheung, Sai Kung, New Territories, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 4 No 3 p 5-7
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ON THE GEOLOGICAL AGE OF THE REPULSE BAY FORMATION, HONG KONG

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Introduction

The Repulse Bay Formation is extensively distributed on Hong Kong Island, Lantau Island, the Kowloon peninsula and New Territories, and is represented by continental strata dominated by volcanic rocks and containing intercalations of sedimentary rocks, with a total thickness of more than 2 000 m. It is composed of tuff, agglomerate, welded tuff (ignimbrite) and acid lava intercalated with a few layers of sedimentary rocks, forming folds and displaying slight metamorphism, with intrusions of various kinds of granites.

The term "Repulse Bay volcanics" was first used by Uglow (1926) and Brock & Schofield (1926) for these volcanoclastic strata. Later, Williams *et al* (1945) distinguished four units of volcanics in ascending order as Repulse Bay volcanics, Rocky Harbour volcanics, Shelter volcanics and Tai Mo Shan porphyry. Allen & Stephens (1971 p 30) adopted the name "Repulse Bay Formation", but they broadened it into a large stratigraphic unit covering all of the volcanics of Hong Kong. During recent years, Addison (1986), Strange & Shaw (1986), Langford *et al* (1989) and Strange *et al* (1990) have done detailed research on the volcanic lithostratigraphy of the newly defined Repulse Bay Volcanic Group, divided into a number of formations.

Lee (1987) gave the division of the Repulse Bay Formation into five lithological units in descending order as:

Rocky Harbour volcanics, containing porphyritic rhyolite, rhyolite, volcanic breccia and tuff

Tai Mo Shan volcanics, containing dacite porphyry, rhyolite and tuff

Ap Lei Chau volcanics, containing multi-striped taxite and hyaline tuff

Shing Mun volcanics, containing volcanic breccia, and volcanic conglomeratic tuff

Yim Tin Tsai volcanics, containing tuffaceous breccia, coarse tuff and welded tuff (ignimbrite)

Within the volcanic rocks of the Repulse Bay Formation there are two types of sedimentary intercalations, the thinner and the thicker. The former vary from several to about 100 m in thickness, mainly comprising regular interbeds of black or grey thin-bedded siltstone and green fine-grained sandstone, but also containing fossil-bearing black shale and massive chert, of which some might belong to a lacustrine facies, while others more likely belong to a fluvial facies. The latter are all composed of shale, siltstone and sandstone with a thickness of several hundred metres; some geologists wondered if they were of the marine origin (Allen & Stephens 1971 p 33), but without any reliable evidence.

Previous work on the age of the Formation

The Repulse Bay Formation has been regarded by Allen & Stephens (1971) as corresponding to the Gaojiping (Kaochiping) Formation of Guangdong Province. In the past, the Gaojiping Formation was considered as Late Jurassic in age. However, considering the age (130 ± 3 to 134 ± 2 Ma) of the granite which intrudes into the Repulse Bay Formation, they proposed the age of the Group as the Middle Jurassic.

In addition, Lai (1976) also considered the Repulse Bay Formation as corresponding to the Gaojiping (Kaochiping) Formation, which is dominated by volcanic rocks and is of late Middle Jurassic to Late Jurassic age. Lee (1987 p 31-33) placed the Repulse Bay Formation in the Upper Jurassic, and also correlated it with the Gaojiping (Kaochiping) Formation of eastern Guangdong. It appears that there are not very great divergences in the stratigraphic correlation of the Repulse Bay Formation; the problem mainly lies in the different opinions on its geological age.

In the Repulse Bay Formation, the sedimentary intercalations yield fossil plants. Davis (1952 p 77) recorded the fossil plants discovered by Heanley from the south bank of Tolo Channel, which were identified and listed by Seward as *Pterophyllum kingianum* Feistm, *Cladophlebis* sp, *Equisetites* sp, *Nilssonina?* sp, a cycad frond, *Brachyphyllum* or *Thuites*, and *Phoenicosis?* sp. Among them, one of the specimens is closely similar to *Pterophyllum kingianum* Feistm from the Rajmahal Group (Liassic), except for the greater number of the veins. He determined the age of these plant fossils as Jurassic.

On the west shore of Lai Chi Chong Pier, Nau (1986) had collected fossil plants from the grey and white mudstone intercalations in the volcanics of the Repulse Bay Formation, which were identified by Q J Wu as *Cladophlebis todiodes* Yang and *Cladophlebis* sp, with their age determined as Early Jurassic.

Around the southern slope of Sunset Peak on Lantau Island, Davis (1952 p 21) had discovered fossil plants from the shale intercalations of the volcanics of the Repulse Bay Formation, including *Brachyphyllum*; some other materials were studied by W N Edwards, who said in his personal communication that the age of these fossils ranged from Middle Jurassic to the Wealden Stage of Early Cretaceous.

To sum up, previous scholars held different views on the age of the fossil plants from the sedimentary intercalations of the Repulse Bay Formation, including Jurassic, Early-Middle Jurassic, and up to the Early Cretaceous.

New palaeontological evidence on the age of the Formation

In recent years, fossil plants have been collected by P S Nau and C M Lee from a number of localities such as Lantau Island, Cheung Sheung, Sai Kung and Lai Chi Chong on the south bank of Tolo Channel, giving additional material for determining the age of the Repulse Bay Formation. During the period from the Winter of 1988 to the Autumn of 1989, our research group made a further investigation into these localities and collected a considerable number of fossil plants. The present paper makes a positive contribution to the problem of the age of the Repulse Bay Formation based on the materials currently obtained and with reference to the achievements of previous scholars.

The fossil plants listed according to their occurrence are as follows:

Lai Chi Chong, south bank of Tolo Channel

Equisetites sp
Cladophlebis exiliformis (Geyler) Oishi
Cladophlebis spp
 cf *Gleichenites gladiatus* Li
Nilssonina? sp
Carnolithus sp

Cheung Sheung, Sai Kung

Equisetites sp
Cladophlebis cf *browniana* (Dunker) Seward
Cladophlebis cf *exiliformis* (Geyler)
Cladophlebis lhoronensis Li
Cladophlebis sp
Conionteris? sp
Gleichenites cf *giesekiana* Heer
Gleichenites sp
Nilssonina cf *cultrata* Li
Nilssonina sp
Ptilophyllum cf *borealis* (Heer) Seward
 cf *Zamiophyllum buchianum* (Ett)
Cupressinocladus sp
Brachyphyllum sp

Ngong Ping, Lantau Island

cf *Gleichenites nipponensis* Oishi
Scleropteris tibetica Tuan & Chen
Sphenopteris sp
Nilssonina cultrata Li
Nilssonina sp
Otozamites sp
 cf *Zamiophyllum buchianum* (Ett)
Ptilophyllum? sp
Pagiophyllum sp (*Sphenolepis*? sp)
Pagiophyllum sp
Elatocladus? sp

Somewhere between Man Cheung Po and Tai O, Lantau Island

Articulatae?
Raphaelia? sp
Phlebopteris? sp
Cladophlebis sp
Desmiophyllum sp

Comparisons with fauna from other areas

The sedimentary intercalations in the volcanics of the Repulse Bay Formation contain important plant elements characteristic of the early Early Cretaceous in the world, such as *Zamiophyllum buchianum*. This species is extensively distributed in West Europe, North America and East Asia, for example, the Wealden series of the Early Cretaceous in Germany and Britain, the Potomac Group in North America, the Ryoseki and Tetori groups in Japan,

and the Albian strata in Syria and Gruzinskaya, USSR. In China, this species has been previously found from the Liupanshan Group in eastern Gansu, the Guantou Formation in Taishun, Zhejiang, and the Lhasa Coal Series and the Duoni Formation in Xizang (Tibet).

Ptilophyllum borealis has been found from the Bantou Formation of Fujian, and the Yantang Formation of Anhui; similar specimens also have been found from the Duoni Formation in eastern Xizang.

Cladophlebis browniana is widespread in West Europe, North America, the Far East and Japan, and is also an indicator plant for the Wealden of the Early Cretaceous. In China, this species appears in the Lhasa Coal Series and the Duoni Formation of eastern Xizang, the Shouchang Formation of Zhejiang and the Bantou Formation of Fujian; similar species can also be found from the Dalazi Formation in eastern Jilin and the Muleng Formation in Dongning, Heilongjiang.

The species *Gleichenites nipponensis* was originally found in the Ryoseki and Tetori Groups of Japan; similar specimens can also be found from the Lower Cretaceous of Korea. In China, this species is found in the upper part of the Dalazi Formation at Luozigou, Wangqing, Jilin, and the lower part of the Lower Cretaceous in Zhejiang.

The two species *Cladophlebis exiliformis* and *Gleichenites giesekiana* have been found in the Duoni Formation in eastern Xizang, while *Scleropteris tibetica*, *Gleichenites gladius*, *Cladophlebis lhorongensis* and *Nilssonina cultrata* were all first discovered and named from the Lhasa Coal Series in northern Lhasa and the Duoni Formation in eastern Xizang. In these localities no angiosperm fossils have ever been discovered. It seems unquestionable that the age of this flora belongs to the early Early Cretaceous.

Summary

In the Repulse Bay Formation of Hong Kong, the plant fossils are very close to the flora of the Lhasa Coal Series (Duan 1977) and the Duoni Formation (Li 1981) in Xizang, and also to the early Early Cretaceous flora in the Shouchang Formation of Zhejiang and the Bantou Formation of Fujian. All the flora mentioned above are very similar in general features to those of the Wealden in Europe. Within this flora, the pteridophytes belong to the microphyll type, while the conifers belong to the scale-leaf type, with their leaves closely attached to the branches; all this reflects the morphological characteristics of a hot dry southern climate.

As to the correlation of the Repulse Bay Formation with the related strata in neighbouring Guangdong Province, the writers are in favour of the opinions proposed by Allen & Stephens (1971), Lai (1976) and Lee (1987), ie, it can be correlated with the Gaojiping (Kaochiping) Formation. With regard to the age of the Gaojiping (Kaochiping) Formation, in the past it was conventionally placed in the Middle Jurassic, Middle to Upper Jurassic or Upper Jurassic by most geologists in Guangdong and Hong Kong. However, judging from the list of fossil plants from the Gaojiping (Kaochiping) Formation in eastern Guangdong published by Feng *et al* (1981), there is no doubt that its age belongs to the early Early Cretaceous. These are *Onychiopsis elongata* (Geyler), *Onychiopsis psilotoides* (Stockes & Webb) Ward, *Gleichenites nipponensis* Oishi, *Zamiophyllum angustiolium* (Schimper), *Cupressinocladus gracilis* (Sze), *Cupressinocladus elegans* (Chow), *Cupressinocladus haifengensis* Feng and *Frenelopsis ramosissima* Fontaine.

These fossil plants have also been listed by Cao *et al* (1982 p 279) as *Onychiopsis elongata*, *Gleichenites* sp, *Ptilophyllum cf boreale*, *Zamites* sp, *Nilssonia* sp, *Cupressinocladus elegans*, *Cupressinocladus gracilis*, *Brachyphyllum obesum*, *Elatocladus* sp, etc. They also attributed the Gaojiping (Kaochiping) Formation to the early Early Cretaceous. At the same time they pointed out that the Early Cretaceous volcanic series in southeast China (including eastern Guangdong, Fujian, Jiangxi, Zhejiang, southern Anhui, etc) in general unconformably overlies the Middle Jurassic or even still older strata, without Late Jurassic deposits. Volcanic activity shows a tendency towards a gradual increase in frequency and scale, with the volcanic eruptions becoming younger and younger in age from west to east along the coast of the Pacific Ocean. These viewpoints have been mentioned many times by Chinese palaeobiologists (eg, Chen *et al* 1979, 1982; Hao *et al* 1986).

Overall, the Repulse Bay Formation may be correlated with the Gaojiping (Kaochiping) Formation of eastern Guangdong and the corresponding volcanic-sedimentary rocks along the southeastern coastal areas of China, all of which belong to the early Early Cretaceous (Table 1).

Table 1 Classification and correlation of the Early Cretaceous volcanic and sedimentary rocks in the southeastern coastal areas of China and east Tibet

Area		Hong Kong	Guangdong	Fujian	Zhejiang	East Tibet
Age						
Lower Cretaceous	Aptian-Albian	Pat Sin Lin Fm	Guancaochu Fm	Xiaoxi Fm	Kuantou Fm	?
	Neocomian	Repulse Bay Fm	Gaojiping Fm	Bantou Fm	Shouchang Fm	Duoni Fm
				Nanyuan Fm	Huangjian Fm	
				Changlin Fm	Laocun Fm	

References

- ADDISON R (1986). *Geology of Sha Tin. Hong Kong Geological Survey Memoir No 1*. Geotechnical Control Office, Hong Kong, 85 p
- ALLEN P M & STEPHENS E A (1971). *Report on the Geological Survey of Hong Kong 1967-1969*. Hong Kong Government Press, 116 p plus 2 maps
- BROCK R W & SCHOFIELD S J (1926). The geological history and metallogenic epochs of Hong Kong. *Proceedings of the third Pan-Pacific Science Congress, Tokyo* Vol 1 p 576-581
- CAO Z Y, LI B X & GUO S X (1982). The Cretaceous plant-bearing strata in China, *Stratigraphic correlation chart in China with explanatory text*. Science Press, Beijing, p 270-282 (in Chinese)
- CHEN P J (1985). Migration of Mesozoic vulcanism in the Circum Pacific region of Eastern China. *the palaeontology and stratigraphy of Shandong*. Ocean Press, Beijing, p 1-10 (in Chinese with English abstract)

- CHEN P J & SHEN Y B (1979). Mesozoic and Cenozoic conchostracan faunas and their distribution in the red beds of Southern China. *Mesozoic and Cenozoic Red Beds in South China*. Science Press, Beijing, p 79-97 (in Chinese)
- DAVIS S G (1952). *The geology of Hong Kong*. Government Printer, Hong Kong, 231 p plus 14 plates & 3 maps
- FENG S N & MA G G (1981). On the age of the Gaojiping and Lingxiang Groups. *Journal of Stratigraphy* Vol 5 No 4 p 294-298 (in Chinese)
- HAO Y C, SU D Y, YU J X, LI P X, LI Y G, WANG N W, QI H, GUAN S Z, HU H G, LIU X, YANG W D, YE L S, SHOU Z X & ZHANG Q B (1986). *The Cretaceous System of China*. Geological Publishing House, Beijing, 301 p plus 16 plates (in Chinese)
- LAI K W (1976). Research on the geological structure and Mesozoic stratigraphy of Hong Kong. *Geographical Journal*. Geography Society, The Chinese University of Hong Kong No 1 p 3-12 (in Chinese)
- LEE C M (1987). A summarized introduction on Hong Kong geology. *Geology of Guangdong* Vol 2 No 1 p 29-48 plus 3 maps & 6 tables
- LI P J (1981). Early Cretaceous plants from the Duoni Formation of Eastern Xizang. In: *Stratigraphy and Palaeontology of West Sichuan and East Xizang, tas 2*. Sichuan People's Press, p 71-115 plus plates 1-14 (in Chinese with English abstract)
- NAU P S (1986). Discussion on the age of the rock sequence on the coast north of Lai Chi Chong, New Territories, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 4 No 3 p 1-4 plus 1 plate & 2 maps
- STRANGE P J & SHAW R (1986). *Geology of Hong Kong Island and Kowloon*. Hong Kong Geological Survey Memoir No 2. Geotechnical Control Office, Hong Kong, 134 p
- UGLOW W L (1926). Geology and mineral resources of the Colony of Hong Kong. *Government of Hong Kong, Legislative Council Sessional Papers* No 7/1926 p 73-77
- WILLIAMS M Y, BROCK R W, SCHOFIELD S J & PHEMISTER T C (1945). The physiography and igneous geology of Hong Kong and the New Territories. *Transactions of the Royal Society of Canada Third Series* Vol 39 Sect V p 91-119
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DISCUSSION ON MARBLE CLASTS IN COARSE ASH CRYSTAL TUFF AT AU TAU, NEW TERRITORIES, HONG KONG

Newsletter Vol 9 No 1 p 16-19, 1991

R L Langford writes: In his article, K M Wong uses the presence of marble clasts in the tuff at Au Tau to correlate the sequence with either the Shing Mun or Yim Tin Tsai formations. Noting that marble is found in Yim Tin Tsai Formation tuff at Tai Po, he favours this correlation.

Detailed mapping by the Hong Kong Geological Survey of the sequence in the northwest New Territories resulted in the new classification of the Repulse Bay Volcanic Group into Yim Tin Tsai, Shing Mun and Tai Mo Shan formations. The hillside exposures, exposures in the Water Supplies Department Western Aqueduct and numerous boreholes in the tuff between Au Tau and the Yuen Long marble, all point to the tuff of the area being part of the Tai Mo Shan Formation. Samples collected recently from the site described by K M Wong also have the characteristics of the Tai Mo Shan Formation.

The Tai Mo Shan Formation is typically a lithic-bearing crystal tuff. The grain size is lapilli-ash, with prominent white feldspar pyroclasts up to 4 mm across (it was this feature that led to the misnomer of Tai Mo Shan porphyry by the pre-war Canadian geologists). The lithic clasts can be tens of centimetres across, but also form part of the ash component of the rock. Most of the lithic clasts are volcanic glass, sandstone or mudstone of indeterminate source.

It is therefore interesting to note that the clasts of marble can be found. Marble or limestone appear in the Devonian, Carboniferous and to a lesser extent in the Permian of south Guangdong, but are not commonly found. With Carboniferous marble known to occur between San Tin and Yuen Long, and now being confirmed east of The Brothers Islands, this unit is likely to be widespread in the Palaeozoic basement. The marble at Ma On Shan and Tai Po is probably Devonian, but opinions vary.

Unfortunately, the proximity of the Carboniferous marble subcrop at Yuen Long does not mean that this is the source. These strata have been overthrust onto the Jurassic volcanic sequence, with *intense metamorphism* and mylonitization in the tuff.

It is unwise to attach too much significance to rare occurrences in pyroclastic rocks of exotic clasts such as marble. The source of most clasts in the tuff will be older, consolidated basement, and in Hong Kong this means anything from Lower Jurassic to Devonian. Detailed mapping of distinctive lithological characters is a better guide to stratigraphic assignment. On this basis the tuff at Au Tau clearly belongs to the Tai Mo Shan Formation; we now know that this Formation can be marble-bearing.

Acknowledgment is made to the Director of Civil Engineering Services for permission to publish this discussion. I would also like to thank Keith Nicholls of the Geotechnical Control Office for collecting samples from the new cut slopes.

R L Langford, Hong Kong Geological Survey, Geotechnical Control Office

DISCUSSION ON EARTHQUAKE WARNING FOR NUCLEAR PLANT SITE

South China Morning Post, Hongkong Vol XLVII No 87 p 4, 1991

Reprinted in Newsletter Vol 9 No 1 p 2, 1991

M J Atherton writes: I refer to the article reprinted from the *South China Morning Post*, which states in column three, paragraph three, "The Daya Bay nuclear plant is designed to withstand earthquakes of magnitude eight on the Richter scale". This is incorrect, as an earthquake of magnitude eight on the Richter scale occurring near the plant would wreck both it and Hong Kong.

What P Y Wong presumably meant was that the Daya Bay plant is designed to withstand an intensity on eight on the Modified Mercalli scale. But even this is incorrect, as the plant is only designed to withstand an earthquake part way through grade eight on the Modified Mercalli scale.

According to our Royal Observatory the Daya Bay site has already been jolted by an earthquake measuring seven on the Modified Mercalli scale, on 13 February 1918, which devastated the town of Swatow, 300 km east of Hong Kong.

May I remind your readers that the Richter scale (magnitude) is a scale of energy released by an earthquake at its source, and the Modified Mercalli scale (intensity) shows the effect of an earthquake at a distance from the source. The two scales mean something quite different and are not related to each other.

M J Atherton, Hong Kong Polytechnic

REPORT ON A FIELD TRIP TO TOLO CHANNEL

Sunday 12 May 1991

M J Atherton

Hong Kong Polytechnic

A full boat load of members and friends led by M J Atherton and D R Workman set off by junk from Chinese University on a warm but humid day to explore Centre Island and some of the shorelines of Tolo Channel. The following localities were visited:

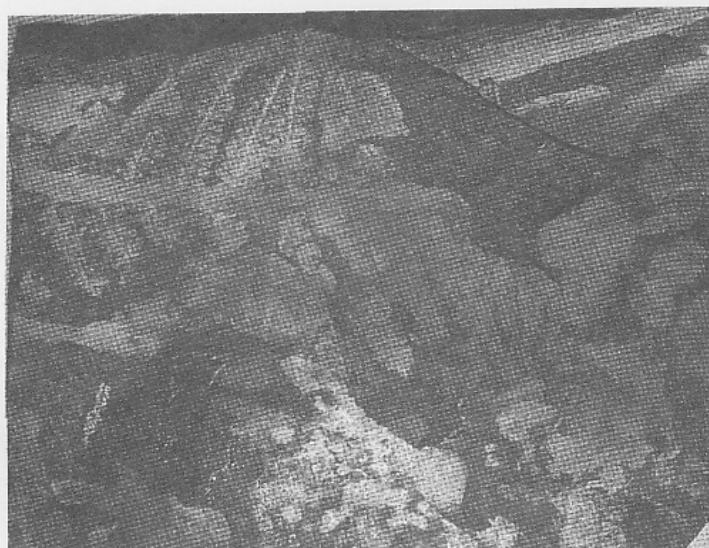
Centre Island. The island consists of faulted and contorted strata of the Permian Tolo Harbour Formation. Quartzitic sandstones are interbedded with dark siltstones and black shales. The rocks show thermal metamorphism possibly associated with an intrusion of porphyritic granodiorite seen on the east coast of the island. Fossil plants have been found in the argillaceous siltstones (Plate 1).

Fung Wong Wat. This is the famous site of the discovery of the first ammonite in Hong Kong by Heanley in 1924. A thin sliver of black shales of the Lower Jurassic Tolo Channel Formation containing ammonites is separated from the Devonian Bluff Head Formation to the north by a major fault along which is intruded a porphyritic dyke showing hydrothermal alteration.

Pak Kok Tsai. Here there is a new discovery by K W Lai of the Hong Kong Geological Survey of the Lower Jurassic Tolo Channel Formation. Shales containing brachiopods, ostracods and scaphapods are separated from the Devonian Bluff Head Formation to the north by a major fault. On the south side of the shales another fault and hydrothermally altered rocks separate them from tuff.

Lai Chi Chong/Sham Chung. The party landed at a shingle beach halfway between these two localities to walk the section to Sham Chung where our junk awaited. The first part of the walk crossed a sequence of well-bedded black shales, volcanic mudstones, cherty mudstones and sandstones of the Repulse Bay Volcanic Group (Jurassic-Cretaceous), while the latter part of the walk crossed black shales of the Lower Jurassic Tolo Channel Formation rich in ammonites and bivalves.

Plate 1 *Pecopteris (Asterotheca)*
norinii Halle from
Centre Island. Courtesy
of C M Lee



REPORT OF 1990-91 ANNUAL GENERAL MEETING

The Annual General Meeting was held on 7 June 1991 in the Geology Laboratory of Hong Kong Polytechnic; some 20 members attended. After tea the Chairman and Treasurer gave their reports, and the new committee was elected. M J Atherton and R Shaw gave slide presentations of geological trips they had made to China and the USA before some 8 members retired to the new Staff Club Bar and Sportsview Restaurant for a slap up dinner.

Chairman's Report

The year has been another busy one for the Society. Local field trips were made to Au Tau, San Yin, Tsing Shan, Bride's Pool, Port Island, Kat O and Tolo Channel. The Christmas trip to Shantou and Nan Ao was attended by 26 members and friends, and was a great success favoured by exceptionally good weather.

A series of 5 lectures by local geologists was held at the Mariner's Club. Three visiting geologists from the Geological Society of Guangdong Province gave a talk on the structural geology of Guangdong, and three geologists from the Geological Institute of Zhejiang Province gave a talk on Cathaysia.

The Newsletter is much improved, and the Society is grateful for the efforts of Dr Langford in upgrading the publication, which has even won approval from Dr Brand. Publication sales have been good, with some publications of the Society being sold out. Bulletin No 4 on the karst of Hong Kong has just been published, and will go on sale shortly from our store at the Polytechnic.

Treasurer's Report

Statement of income and expenditure for the year ended 31 December 1990.

	Income HK\$	Expenditure HK\$
Subscriptions	19 631.00	-
Publications	2 741.71	-
Bank Interest	10 255.91	-
Conferences	6 711.60	-
Local Trips	9 200.00	7 520.00
China Trips	56 310.00	59 350.00
Newsletter & Printing	-	28 079.20
Stamps & General Expenses	-	11 921.28
TOTAL	104 850.22	106 870.48
Excess of Expenditure Over Income		-2 020.26

Accumulated Funds HK\$			
31.12.89		31.12.90	Income 1990
124 265.32	Bank Deposit Account	134 521.23	10 255.91
91 638.59	Bank Current Account	84 617.50	-7 021.09
6 063.80	Petty Cash	808.72	-5 255.08
*221 967.71		*219 947.45	-2 020.26

* Includes HK\$20 958 for GBGP and HK\$26 675 for GSGP

ANNOUNCEMENTS

From the Editor

The second issue of the 1991 Newsletter follows the first in upgrading the appearance and content. All articles are being printed as carefully as possible, although mistakes will inevitably creep in. There is no policy on reviewing articles, and all members are most welcome to submit contributions for publication. At present we have some articles presented or in preparation for the next issue, but we are always looking for more material or photographs.

West Guangdong field trip

A trip to the west of Guangdong Province has been provisionally booked for 20-29 December, following our tradition of organizing Christmas excursions. Please contact C M Lee on 766-6039 for details.

Fossil collecting licences

The Chairman of the Archaeological and Palaeontological Committee of the Antiquities Advisory Board requests members of the Society who are qualified professionals and who are interested in collecting fossils in Hong Kong, to give their names to M J Atherton, Hong Kong Polytechnic, for consideration of *en bloc* approval by the Board for their fossil collecting.

Publication costs

The cost of printing has been steadily increasing over the years, and the Society has also been doing its best to increase the size, frequency and quality of publications. The Newsletter now costs about \$25 an issue to print, plus the cost of reproducing photographs. The latest Bulletin cost about \$150 to print, and the Society feels that these costs should be covered as best as possible. Of course, we also hold a stock of these publications and may never cover our entire printing costs. We feel that the price increases listed on the inside back cover are reasonable, and hope you agree that the only regular geological publication in Hong Kong is worth paying a little more for.

Publications out of stock

Over the years the Society has been steadily selling its publications. While there are large stocks of some, others have sold out. The Society is currently reviewing the need to reprint some publications, depending on cost and demand. At present we have no stock of the following:

Bulletin No 2; *Abstracts* Nos 1, 2 & 3; *Newsletters* Vol 1 Nos 1 & 4, Vol 2 No 4, Vol 7 No 1

In addition, we have less than ten copies of each of 10 Newsletter issues; if you do not have a complete set we would advise you to put in your order quickly as we will only be able to supply photocopies of issues out of stock.

Subscription increase

Inflation takes its toll, and although we have kept the subscription to \$100 for many years, we now feel that an increase is justified. The new subscription will be \$150; the half-yearly subscription will be dropped, and new members joining after 1 January will be entitled to back issues of the Newsletter for the whole year.

Karst geology in Hong Kong

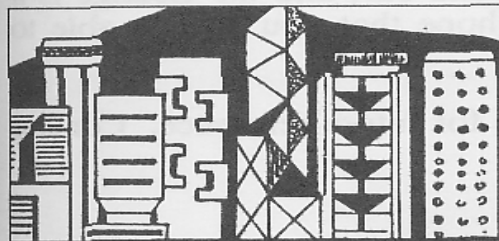
Bulletin No 4, "Karst geology in Hong Kong", is now available and is being distributed to conference participants. Because of an increase in printing costs the Bulletin will now be sold at \$150 to Members and \$180 to non-Members. Any orders for copies should be sent, with a draft or cheque (payable to *The Geological Society of Hong Kong*), to the Chief Editor, *Dr R L Langford*, Hong Kong Geological Survey, Geotechnical Control Office, 6/F Empire Centre, 68 Mody Road, Tsim Sha Tsui East, Kowloon, HONG KONG. Enquiries are welcome for both the Bulletin and Abstracts (published last year) on 366-7916 or FAX 369-0007.

Seismicity in Eastern Asia, Hong Kong, 23-26 October 1991

The conference is organized by *The Geological Society of Hong Kong* with the support and cooperation of *Guangdong Seismological Society*. It includes 3½ days of oral presentation, and post-conference field visits to the nuclear power station at Daya Bay and to the New Territories. It will be held at the Studio Theatre in Hong Kong Polytechnic, and registration costs US\$80 (HK\$624). The conference will encompass the following topics:

- Seismic activity
- Earthquake precursors and prediction
- Seismic tectonics
- Seismic zonation
- Seismic risk and counter-measures
- Seismic engineering

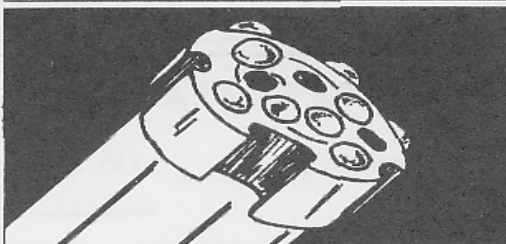
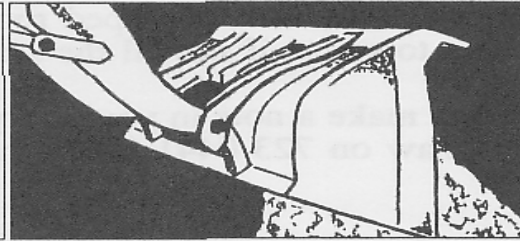
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- | | |
|-------------------------|---|
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| 15 November 1991 | PRECAMBRIAN TECTONICS IN THE NORTHWEST HIGHLANDS OF SCOTLAND
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Alan Brimicombe (<i>Hong Kong Polytechnic</i>) |
-
- | | |
|-------------------------|---|
| 17 January 1992 | RIFT VALLEY TECTONICS AND SEDIMENTATION IN MALAWI
Bernie Owen (<i>Hong Kong Baptist College</i>) |
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Phil Kirk (<i>Hong Kong Geological Survey</i>) |
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All the talks will be held in the Seven Seas Lounge, Mariner's Club, Tsim Sha Tsui, from 6 pm to 7.30 pm. The Mariner's Club has a good restaurant and bar, and the Lounge is a comfortable, well equipped room for the lecture series. We hope that you will be able to come to some, if not all the series.

Please make a note in your diary and keep a copy of this notice for future reference. Contact Dr Shaw on 723-0441 for further details.

BOAT TRIP TO PING CHAU (MIRS BAY)

Sunday 15 September 1991

Ping Chau, always a popular destination, needs no introduction for most of our members. It is geologically and scenically unique in Hong Kong, with an atmosphere all its own. Delightful walks over the easy terrain, intriguing geology, pleasant beaches and outstanding views. Food and drink are available at shops opened specially at weekends in the two more or less abandoned hamlets near the pier, but business is usually brisk at these establishments and many prefer to bring picnics.

The boat will depart from Ma Liu Shui ferry pier, near the KCR University Station, at 9.30 am. Allow at least 10 minutes for the walk from the station. We will get back at about 5 pm.

Cost per person:	Members and spouses	\$ 60
	Student Members	\$ 30
	Member's children under 18	\$ 30
	Guests	\$ 80

BOOK NOW: FIRST COME, FIRST SERVED. MEMBERS AND FAMILIES WILL HAVE PRIORITY OVER GUESTS. YOU WILL BE CONTACTED ONLY IF THERE ARE NOT ENOUGH PLACES TO ACCEPT YOUR BOOKING.

Booking slip: PING CHAU (MIRS BAY), 15 SEPTEMBER 1991

I wish to book _____ places at \$ 60, _____ places at \$ 30 and _____ places at \$ 80. I enclose the total payment of \$ _____

NAME: _____

CONTACT TELEPHONE: _____ (OFFICE) _____ (HOME)

NAMES OF OTHERS (state if Member, Student Member, spouse, child or guest):

Cheques should be payable to *The Geological Society of Hong Kong* and crossed. Send completed slips, with payment, to P S Nau, Department of Geography and Geology, University of Hong Kong, Pokfulam Road, HONG KONG.

BOAT TRIP TO WONG WAN CHAU (DOUBLE ISLAND)

Saturday 26 October 1991
(postponed from 20 July)

This large island just north of Bluff Head, uninhabited except for an Outward Bound cabin on the beach at Wong Wan, offers a variety of pursuits: walking (superb views, interesting geology), swimming (shark hunting possibly) or just lying on the very pleasant beach at Tung Wan. The water is clear and marine life varied, with plentiful coral along both sides of Tung Wan close to the beach. This is one of the best places in Hong Kong for easy and rewarding snorkelling. Along the south and west coast of the island there are excellent exposures of the Port Island Formation (KPI). Contrasting fault contacts between the KPI and the overlying volcanics can be seen at the eastern extremity of the island (near Tung Wan) and the western extremity. Destinations (landing points) will be Tung Wan and others by arrangement on the day. All landings will be by sampan.

The boat will depart from Ma Liu Shui ferry pier, near the KCR University Station, at 9.30 am. Allow at least 10 minutes for the walk from the station. We will get back at about 5 pm. Bring food and drink.

Cost per person:	Members and spouses	\$ 60
	Student Members	\$ 30
	Member's children under 18	\$ 30
	Guests	\$ 80

BOOK NOW: FIRST COME, FIRST SERVED. MEMBERS AND FAMILIES WILL HAVE PRIORITY OVER GUESTS. YOU WILL BE CONTACTED ONLY IF THERE ARE NOT ENOUGH PLACES TO ACCEPT YOUR BOOKING.

ALL THOSE WHO BOOKED AND PAYED FOR THE CANCELLED TRIP WILL HAVE PRIORITY. IF YOU BOOKED BUT CANNOT GO, PLEASE CONTACT P S NAU FOR A REFUND.

Booking slip: WONG WAN CHAU (DOUBLE ISLAND), 26 OCTOBER 1991

I wish to book _____ places at \$ 60, _____ places at \$ 30 and _____ places at \$ 80. I enclose the total payment of \$ _____

NAME: _____

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Cover photograph: Steeply inclined, interbedded grey siltstone and graphitic black mudstone on the coast west of the old Miner's Quarters on West Brother Island (Tai Mo To) (814470E 821140N). Photograph courtesy of R L Langford, Hong Kong Geological Survey

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