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香港地質學會

NEWSLETTER
通　訊

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NOTES FOR THE GUIDANCE OF CONTRIBUTORS TO THE NEWSLETTER

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Vol 9 No 1 (March 1991)

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ERRATA

31. 5. 1991

WORKMAN D R (1990). Vol 8 Pt 4 p 40-45

p 41 **Plate 1** in the plate caption should be **Plate 5**

p 44 **Plates 2-5** in the plate captions should be **Plates 1-4**

p 41 **Plate 5** in paragraph 3, line 8 should be **Plate 4**

The bibliographic reference should be:

WORKMAN D R (1990). The recent Castle Peak landslide - was rock sliding involved?. *Geological Society of Hong Kong Newsletter* Vol 8 Pt 4 p 40-45 plus errata

Enclosed with this issue of the Newsletter is an errata slip which we recommend that you stick into Vol 8 Pt 4 at the bottom of page 1, page 42 or page 44.

Reprinted from *South China Morning Post, Hongkong*, Saturday 30 March 1991
Vol XLVII No 87 p 4

Earthquake warning for nuclear plant site

By DANIEL KWAN

EARTHQUAKES measuring more than six on the Richter scale may hit Guangdong later in the decade, Chinese seismologists have predicted.

The warning came from experts attending a seismology conference in the provincial capital Guangzhou this week and coincides with plans to build a second nuclear plant, possibly near Daya Bay where the current $28.8 billion Sino-Hongkong joint nuclear project is being built.

Mr Ding Yuanzhang, director of the Guangdong Seismology Bureau, said that should a serious earthquake occur, casualties and damage would be "substantial".

"While it is unlikely to see earthquakes measuring above seven on the Richter scale to hit Guangdong in this decade, earthquakes measuring from five to six are possible," Mr Ding said.

The seismologists at the conference predicted that in the 1990s, China would enter a new "seismological active period" and even witness earthquakes measuring above eight on the scale.

Guangdong, the seismologists said, falls within the areas of frequent earthquakes.

"It is possible that earthquakes measuring above six grade on the Richter Scale will hit the economic affluent Guangdong which has a past record of earthquakes," the seismologists said.

The last major earthquake that hit Guangdong was in 1969 in Yangjiang, 228 kilometres west of Hongkong.

Yangjiang is one of the three possible sites named by Chinese energy officials where Guangdong might build its second nuclear plant. The two other options are Daya Bay and Taishan.

After the Yangjiang disaster, Guangdong set up 38 earthquake monitoring stations throughout the province to predict possible tremors.

Earlier this week, China's Minister of Energy Resources, Mr Huang Yicheng, said in Beijing that Hongkong people's worries about nuclear safety would be considered when Guangdong builds its second atomic facility.

A former Hongkong legislator Mr Wong Po-yan, who heads the Sino-Hongkong Nuclear Safety Consultative Committee on the Daya Bay scheme, said yesterday Hongkong people should not be alarmed by the reports.

"The Daya Bay nuclear plant is designed to withstand earthquakes measuring up to eight on the Richter scale. This means that it is at least one or two grades above the predictions," he said.

But Mr Wong said he would raise the issue in a meeting with mainland officials in May.

The Reverend Fung Chiwood, spokesman of the Hongkong-based Joint Conference for the Shelving of the Daya Bay Nuclear Plant, said the report highlighted the risk of the Daya Bay station.

"We have always suspected that the Daya Bay is close to a fault line and the report has reinforced our belief," Mr Fung said.

Geological Society of Hong Kong Newsletter Vol 9 No 1 p 3-15 (1991)

THE GEOLOGY AND EXPLOITATION OF THE MA ON SHAN MAGNETITE DEPOSIT

P J Strange & N W Woods

Geotechnical Control Office
Hong Kong Government

Abstract

The abandoned Ma On Shan Iron Mine is situated on the western slopes of Ma On Shan, approximately 5 km northeast of Sha Tin. The principal iron mineral extracted from the mine, was magnetite, which is intimately associated with a major skarn or tactite body. The ore deposit is approximately 100 m in width and 500 m in length at surface outcrop and dips towards the northwest. The skarn mineralisation has resulted from contact metasomatism between granitic fluids and calcareous sedimentary rocks.

Opencast mining at Ma On Shan commenced in 1906, but it was not until 1949 that serious exploitation of the deposit began. By 1959, all mining was being carried out underground and by the mid-1970s in excess of 400 000 tons was being mined annually. When mining operations were suspended in 1976, it was estimated that some 4 million tons of iron ore remained unexploited.

Geology

The abandoned Ma On Shan Mine is situated on the western slopes of Ma On Shan, approximately 5 km northeast of Sha Tin (Figure 1). The existence of a significant iron ore body at this location was known as early as 1906, and the geology of the deposit was first described by Weld (1915), who also noted that other similar skarn deposits existed around Tai Mo Shan and south of Tai Po Hui. Tegengren (1923) also briefly described the Ma On Shan deposit. Addison (1986) noted the ore deposit as a skarn or tactite body formed by contact metasomatism between Devonian sedimentary rocks and a granitic intrusion (Figure 2).

The ore body consists of a lenticular shaped mass of magnetite surrounded by a calc-silicate skarn or tactite halo. In the centre of the ore body, and only exposed in underground workings is a large core of marble up to 220 m across. The ore body is exposed over some 500 m, trending eastsoutheast at the surface (in the old opencast workings) and averages 100 m in width (Figure 3). The deposit dips northwards between 35 and 55° and thins at depth with no significant economic ore found at the 110 m level in the mine.

The magnetite occurs as finely disseminated crystals scattered throughout a groundmass within the range of granite-granodiorite (Davis 1952). During a recent visit to the mine, the authors noted considerable amounts of greisen in the footwall of the main ore body between the 192 m and 144 m levels. This greisen closely resembles the late stage emanations mapped in the granites of east Kowloon (Strange & Shaw 1986).

Surrounding the magnetite body, calc-silicate skarn rock is abundant (Figures 4 & 5). The rock contains a complex and varied mineralogy, including tremolite, actinolite, diopside and garnet, all of which are common (Peng 1978). The skarn at Ma On Shan has in fact produced the most varied mineral assemblage recorded in Hong Kong. Peng also notes the occurrence of fluorite, rhodonite, stilpnomelane, serpentine, palygorskite, galena, malachite, azurite, pyrrhotite, calcite, apatite, topaz, andradite, vesuvianite and epidote. He describes all these minerals in detail and also notes their mode of occurrence within the skarn deposit.

Addison (1986) mapped the granites in the vicinity of the Ma On Shan mine as intruding sedimentary rocks of the Devonian Bluff Head Formation. The ore body occurs immediately below this contact (Figure 2), and the presence of the apparently northward dipping marble in the workings implies this calcareous rock lies stratigraphically below the sandstones. This therefore suggests that the marble is of Devonian age or older. Frost (in press) has however suggested that the marble, as studied on the Ma On Shan reclamation sites, appears very similar to the Carboniferous marble of the Yuen Long District (Langford *et al* 1989).

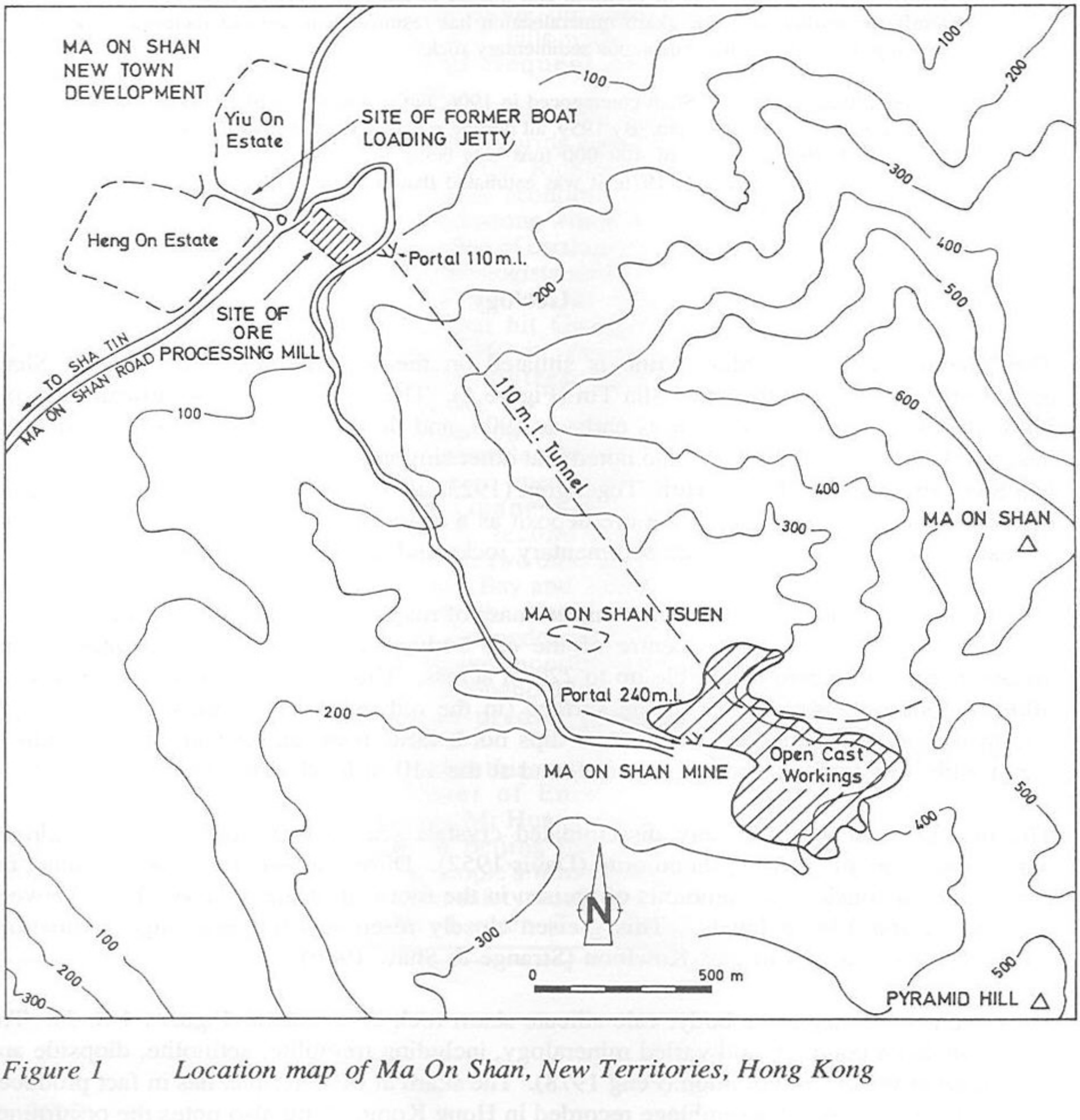

Figure 1 Location map of Ma On Shan, New Territories, Hong Kong

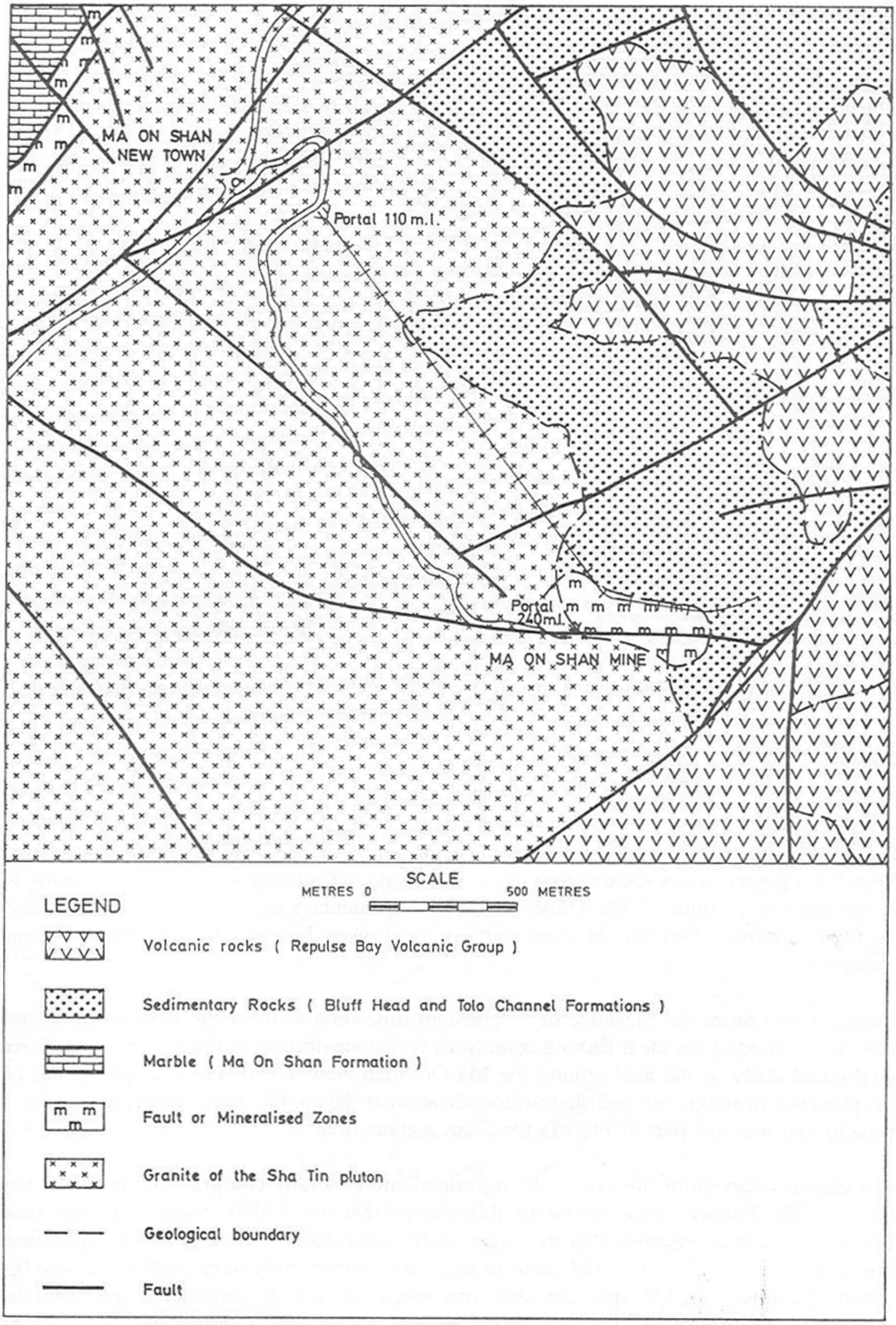

Figure 2 *Generalized solid geology of the Ma On Shan district after Addison (1986), modified by Frost (in press)*

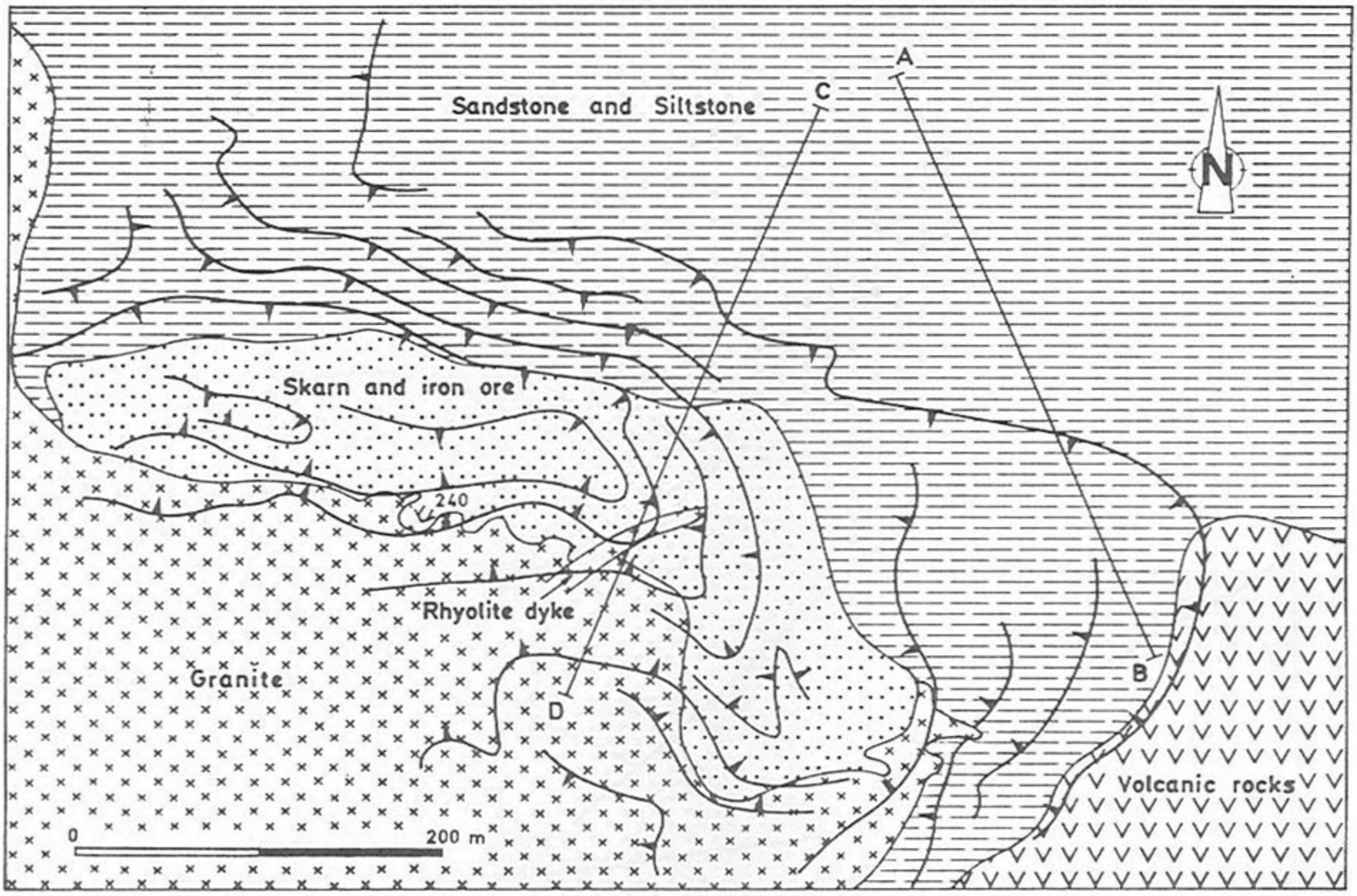

Figure 3 *Surface geology of the Ma On Shan opencast mine workings, taken from 1968 mine geology records. For the legend see Figure 5*

Palaeontological or isotope age-dating has not yet been conclusive. Frost (in press) and Sewell (in press) have indicated that since there is no definite age data available for the Bluff Head Formation south of The Hunchbacks, the sedimentary strata in this area could indeed be Carboniferous, Permian or even part of the Lower Jurassic Tolo Channel Formation sequence.

Davis (1961) notes the presence of magnesium limestone in the mine workings, suggesting this rock provided the ideal fluxing conditions for concentration of the iron oxides. A recent geological study of the area around the Ma On Shan New Town (Frost, in press) has noted the presence of magnetite and skarn mineralisation at the contact between granite and marble beneath the western part of the Ma On Shan reclamation.

The granites vary from fine- to medium-grained, are generally equigranular and form part of the Sha Tin Pluton. Age dating of this pluton (Strange 1990) gives a cooling date of 148 ± 9 Ma. It is assumed that the skarn body mineralisation took place at approximately this date. Whereas the silica-rich sandstones of the country rock were readily digested by the intruding molten granitic rock, the limestone lens could not be assimilated and acted as the flux to concentrate the mineralisation present within the granite and the late stage hydrothermal fluids emanating from the cooling pluton.

Development of the mine

The first license to prospect and later mine the deposit was issued to the Hong Kong Iron Mining Company in 1906 and in 1931 a 50 year Crown Lease was issued to the New Territories Iron Mining Company. However, up to 1947, ore production averaged less than 1 000 tons annually (Davis 1952). Major ore extraction by opencast mining commenced in 1949, and by 1950 annual production had increased dramatically to 169 374 tons.

In 1953 the Mutual Trust Company Ltd, who were then operating the mine on behalf of the lessee, the New Territories Mining Company Ltd, entered into an agreement with the Nittetsu Mining Company Ltd of Japan to help operate the mine. In the same year, underground operations commenced. By 1959, the opencast workings had been abandoned and all ore was being extracted underground. However, by the early 1960s the reserves in the upper levels of the underground workings had been virtually exhausted and exploratory drilling was carried out to assess the extent of the ore body below and to determine the available reserves. It was estimated that some 10 million tons of ore were available for extraction down to a level of 110 m. In order to more efficiently exploit these reserves, a new 2 200 m long haulage drive was constructed at the 110 m level out to a portal near the processing plant, which was at that time situated only about 200 m away from the coastline (Figure 1). This drive, which was completed in 1963, for the sum of $3.5 million, considerably reduced the cost of hauling the ore from the workings to the processing plant. Previously, the ore had to be transported by truck from Ma On Shan Tsuen down the narrow winding access road to the coast.

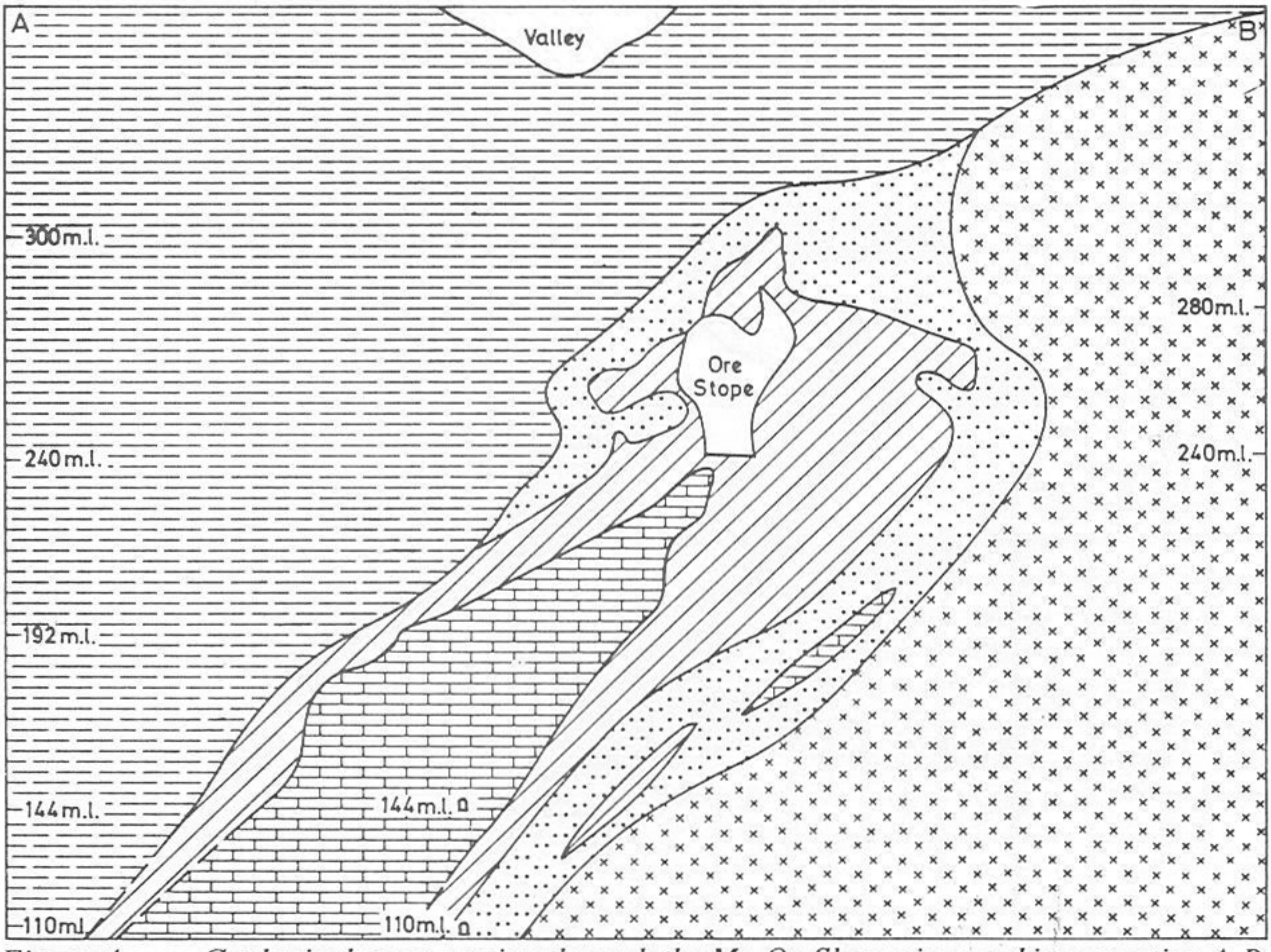

Figure 4 *Geological cross-section through the Ma On Shan mine workings; section A-B on Figure 3 (see Figure 5 for the legend). Taken from 1968 mine geology records*

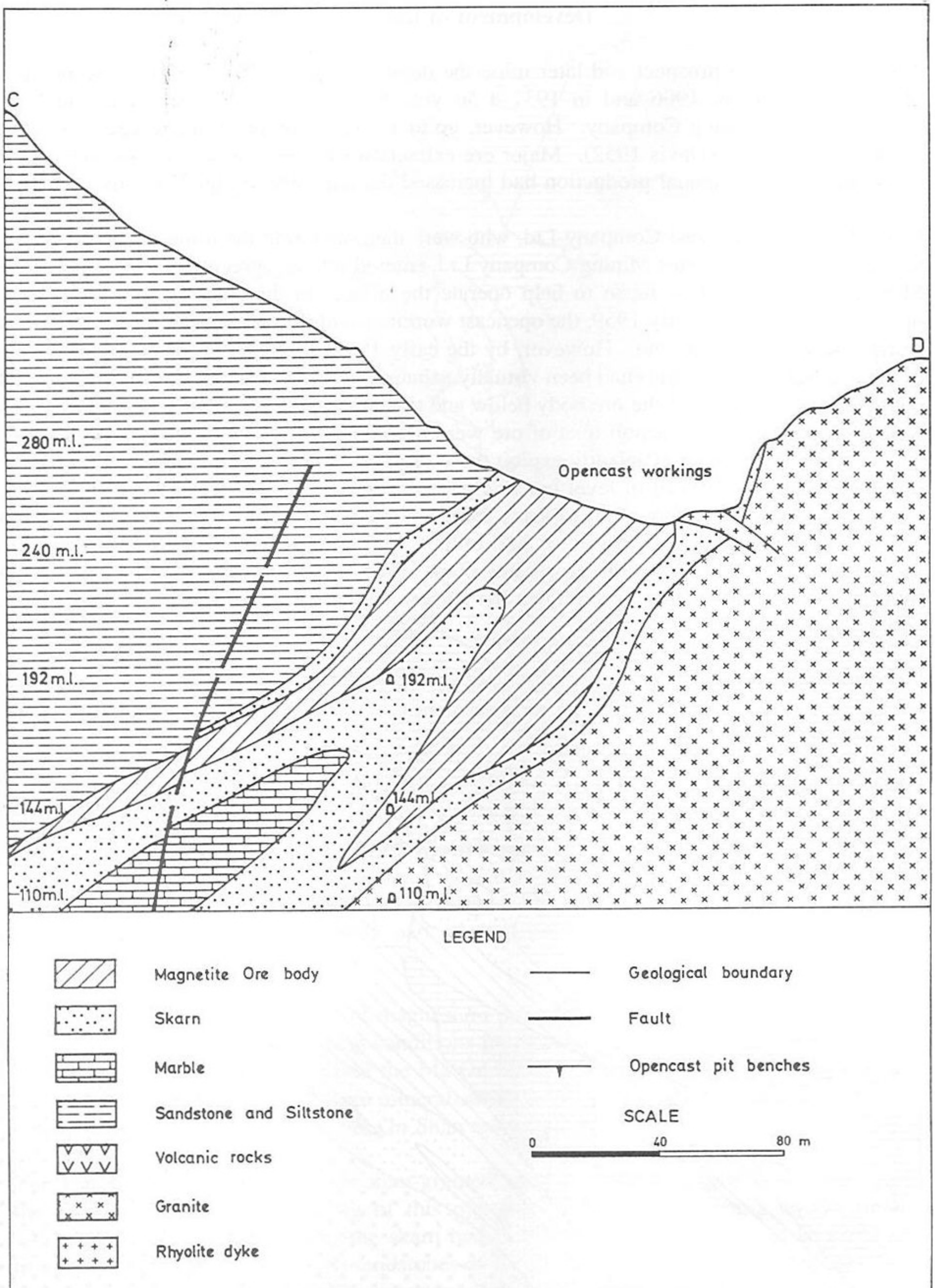

Figure 5 *Geological cross-section through the Ma On Shan mine workings; section C-D on Figure 3. Taken from 1968 mine geology records*

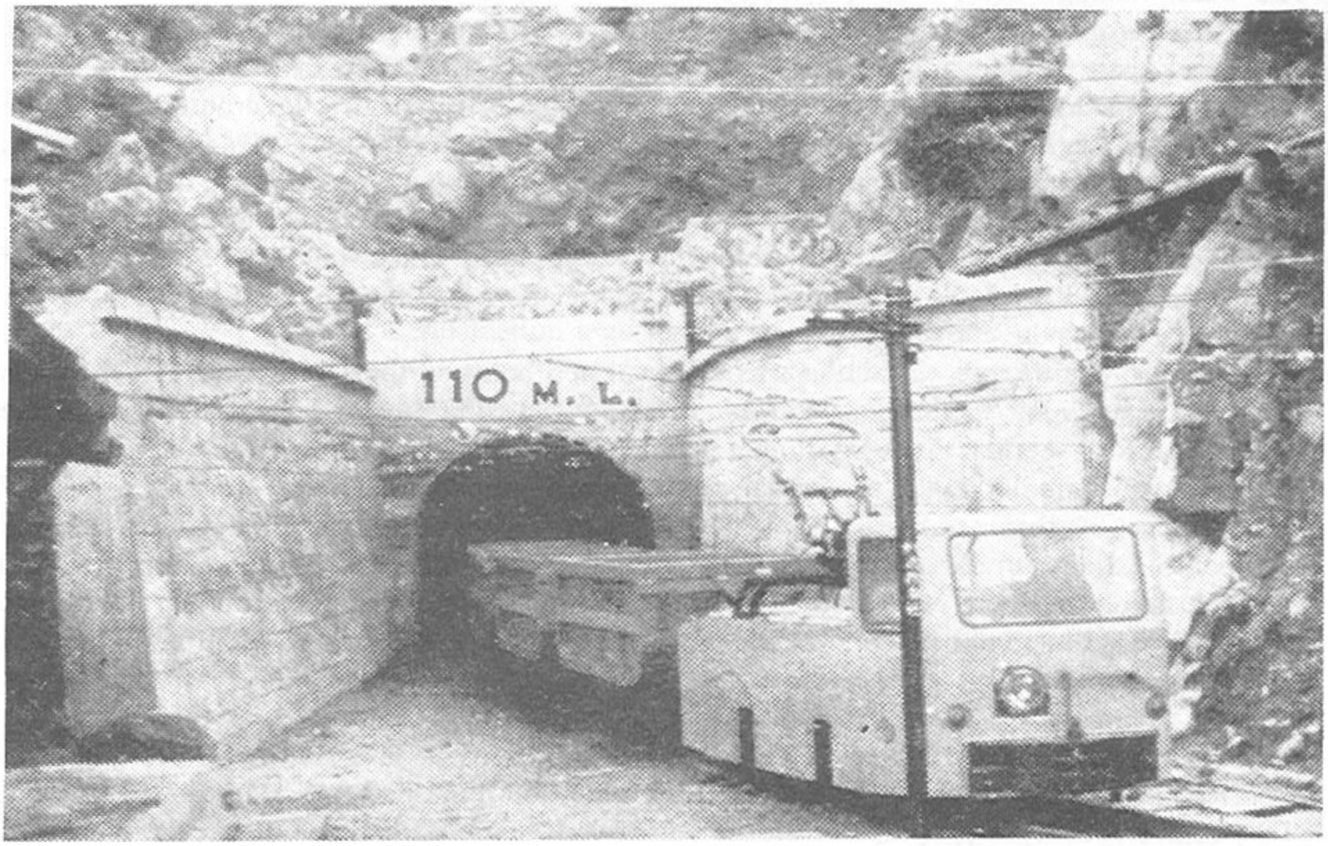

Plate 1 Photograph taken in 1963 showing the 110 m level portal

Plate 2 Landslip scars in the hillslopes in the vicinity of the opencast workings

The main haulage drive was connected to the workings above by a 30° incline which extended up to the main working levels at 144 m, 192 m and 240 m. In addition, five main ore passes were constructed up to 144 m level. Mechanical chutes at the base of each of these discharged the ore into mine tubs which were hauled by electric locomotive out to the processing plant (Plate 1). Another 26° incline was constructed from the 144 m level up to a new portal at Ma On Shan Tsuen (at the 240 m level). This incline provided access for the miners and equipment and also assisted ventilation throughout the new development areas. Shibata (1961) provides details of these development plans, which include some 3 000 m of sub levels as well as 5458 m of main tunnels and shafts to be excavated.

From 1963 onwards, ore extraction was concentrated between the 240 m and 192 m levels and, by the early 1970s, stoping had extended down to the 144 m level, as shown in the schematic cross-section given in Figure 6. By this time, the output from the mine had increased substantially, with an annual production of mined ore in one year in excess of 400 000 tons. Unfortunately, in the mid-1970s, there was a world-wide decline in the demand for steel,together with the commencement of mining vast iron ore deposits in Australia, and the mine failed to secure further supply contracts from Japan. As a result, mining operations were suspended in March 1976. The mining lease expired in March 1981 and the mine was finally abandoned.

During the period from 1949 to 1976, some 3 million tons of processed iron ore had been exported, principally to Japan, and during this time, the mine had provided work for about 400 people, both underground and on the surface. It has been estimated that there are still about 4 million tons of iron ore in the mine which remain unexploited.

The mine today

The scars of the opencast workings, which consist of a series of benches extending up to the 300 m level, are still clearly visible on the hillsides in the vicinity of Ma On Shan Tsuen. Natural revegetation has been largely unsuccessful in masking the workings. Also, the opencast mining operations gave rise to considerable instability of the hillslopes; Plate 2 shows the landslip scars on the hillside on the northern side of the small valley in which the main mine buildings were situated. Many of these buildings still survive although, except for the miners' houses, which are still in use, most are derelict and overgrown. The abandoned processing plant buildings can still be clearly seen on the hillside directly southeast of the roundabout at Heng On Estate.

The underground mine workings are still accessible through a portal at the 240 m level at Ma On Shan Tsuen and through the 110 m portal near the derelict processing plant. However, the reader would be advised not to attempt to enter the workings which are both extensive and complex and one could easily get lost without detailed mine plans which are not available to the general public. Also, and more importantly, the workings are in places in a dangerous state; roof collapses have occurred, particularly in older sections of the mine at the higher levels, and even where these were subsequently supported, the supports may be rotten or corroded and may be easily dislodged. In addition, there are many deep vertical shafts (ore passes), many of which are not adequately protected. Plate 3 shows the top of one ore pass which extends from the 144 m level vertically downwards more than 30 m to the 110 m level main haulage drive.

All of the machinery in the mine, including ventilation fans and winches, as well as other items of value, including most of the railway tracks, were removed after mining was suspended in 1976. However, there are many reminders of past mining activity. On the 144 m level, the level on which most mining activity took place immediately prior to its closure, a *Marie Celeste* atmosphere pervades (Plate 4). The layout of workings on the 144 m-level are shown in Figure 7. The office and canteen on this level must be much as they were when the mine was abandoned some 15 years ago. Betting slips were found on the table in the office, as well as a blackboard showing the work roster for the last day of operations and a set of identification tags for the miners. In the canteen, where rice bowls lay scattered on the ground, a set of mine plans were found lying open on the table. The plans were recovered, and although they have suffered from the humidity, they are still readable.

Ventilation in the underground workings examined is generally good, because of the many inclines and ore passes interconnecting the various levels in the mine. Along the mine haulage drives and down the inclines there is a steady draft of air. However, in some places, where there is no interconnection, the air temperature and humidity are noticeably higher and it can be quite uncomfortable.

Drainage in the underground workings is good, also because of the many interconnections between different levels. The 30° incline, which extends from the 240 m level down to the main haulage drive at 110 m, functions as the main drainage path for the workings. There is a substantial flow of water down this incline and this has resulted in undermining of the railway tracks by eroding away the underlying ballast. The water exits the mine at the 110 m adit portal (Plate 5) via the 110 m level main haulage drive. Originally, the water was carried along the drive in channels each side of the railway tracks. However, as a result of a number of roof collapses along the length of the tunnel, fallen blocks of rock have dammed the water and, in places, the water is knee deep (Plate 6).

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.

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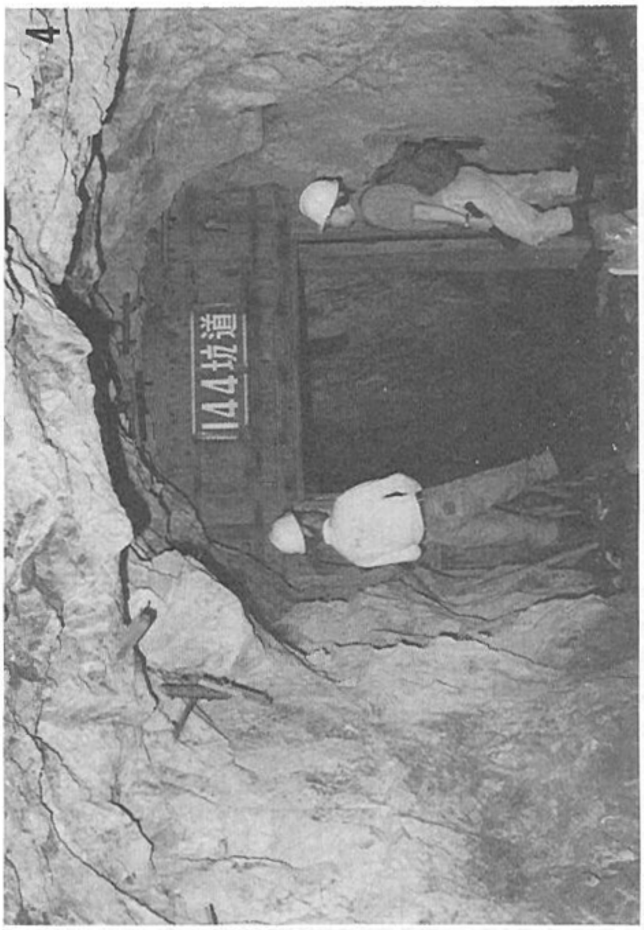
Explanation of plates on facing page

Plate 3	*Top of the No 1 ore pass on the 144 m level; this shaft extends vertically down to the 110 m level*
Plate 4	*Entrance to the 144 m level workings at the base of the 26° incline*
Plate 5	*The 110 m level portal*
Plate 6	*Flooding in the 110 m level main haulage drive caused by a roof collapse*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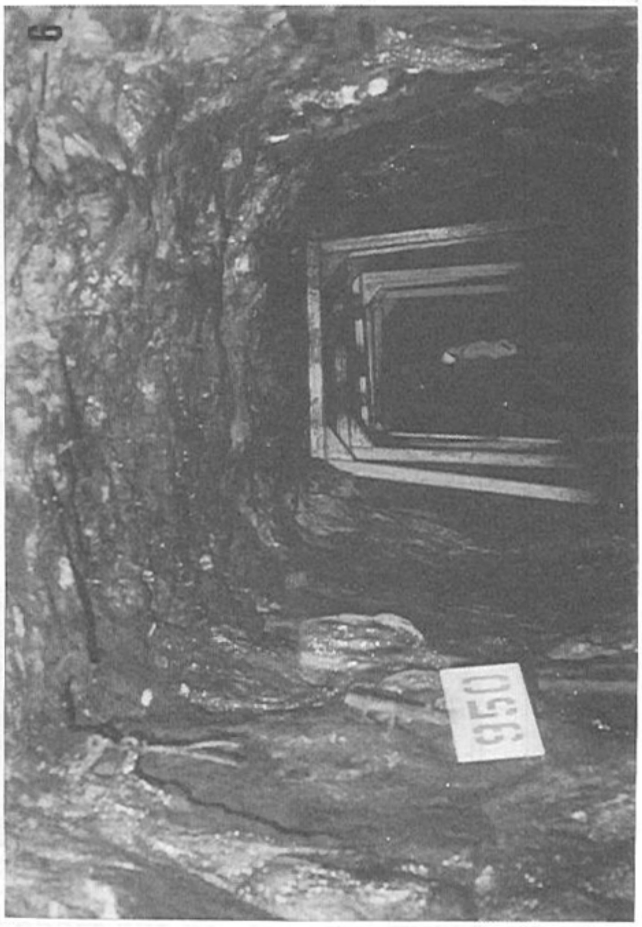
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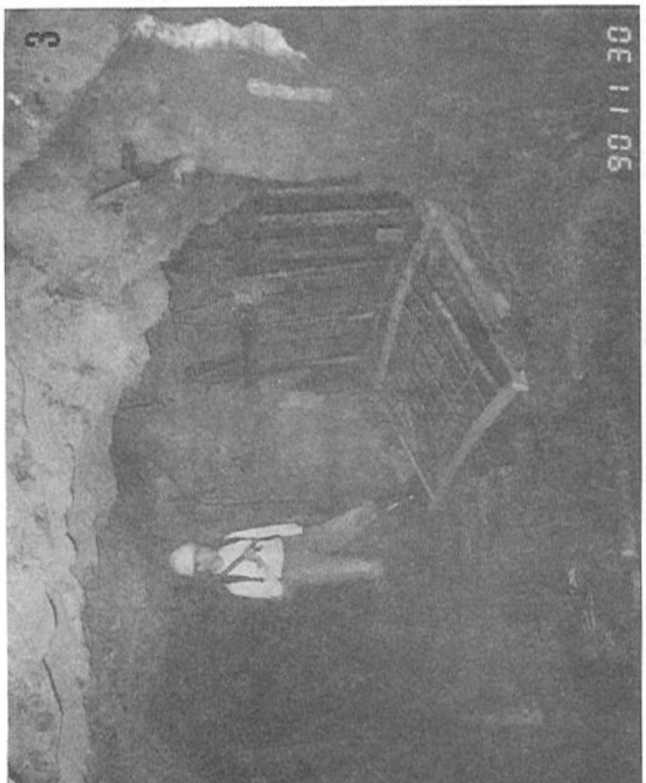
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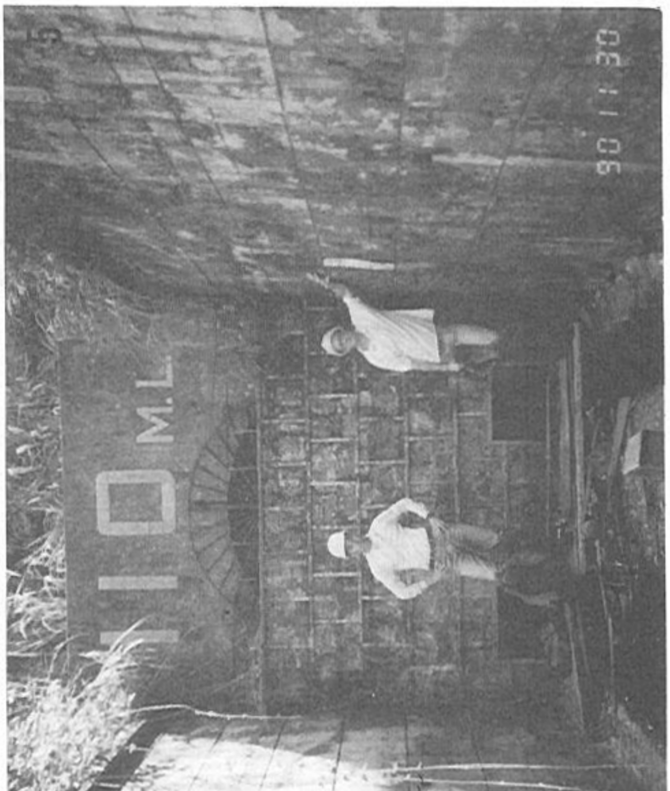
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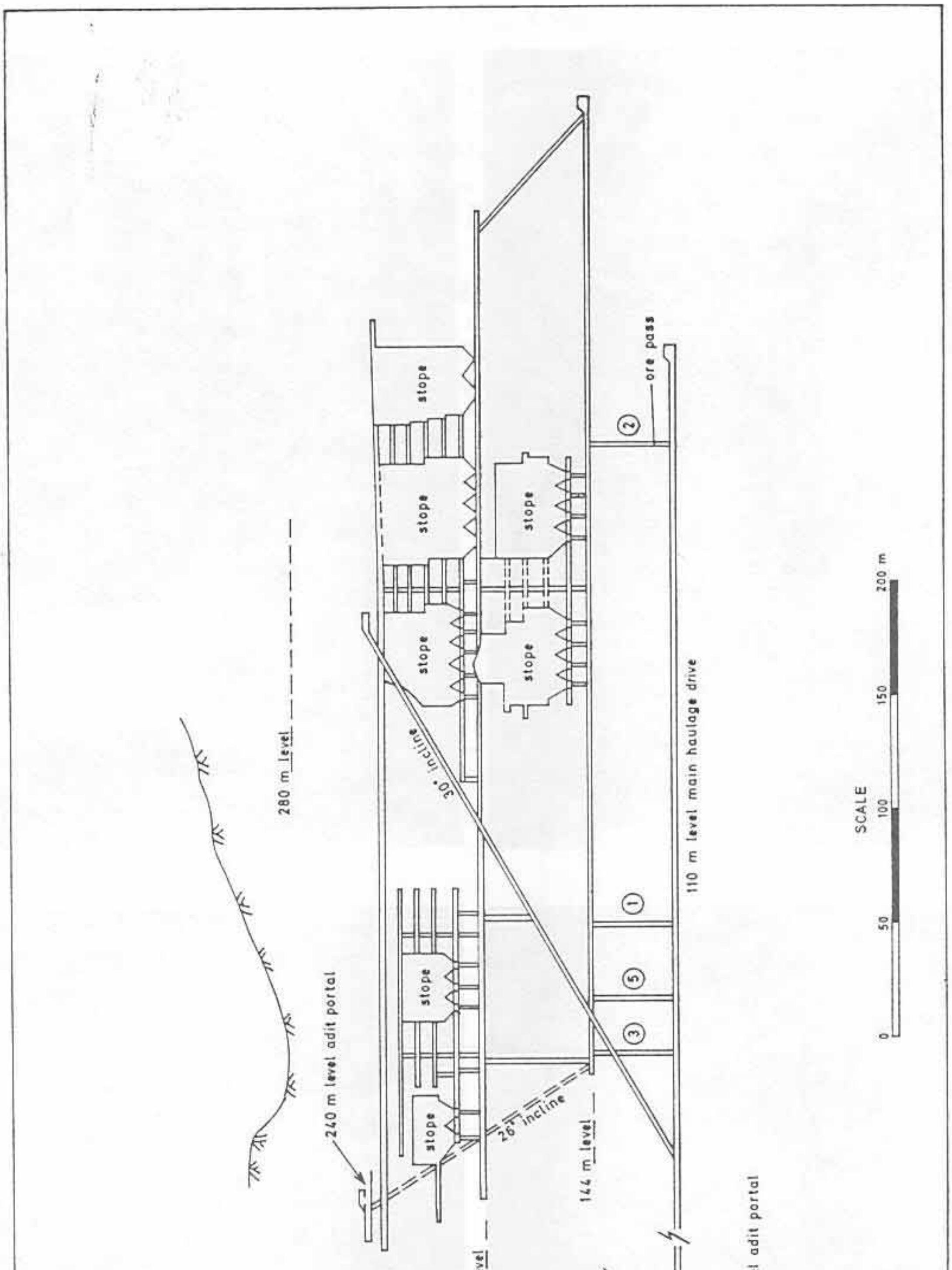

Figure 6 *Schematic cross-section of Ma On Shan mine showing the layout of the workings*

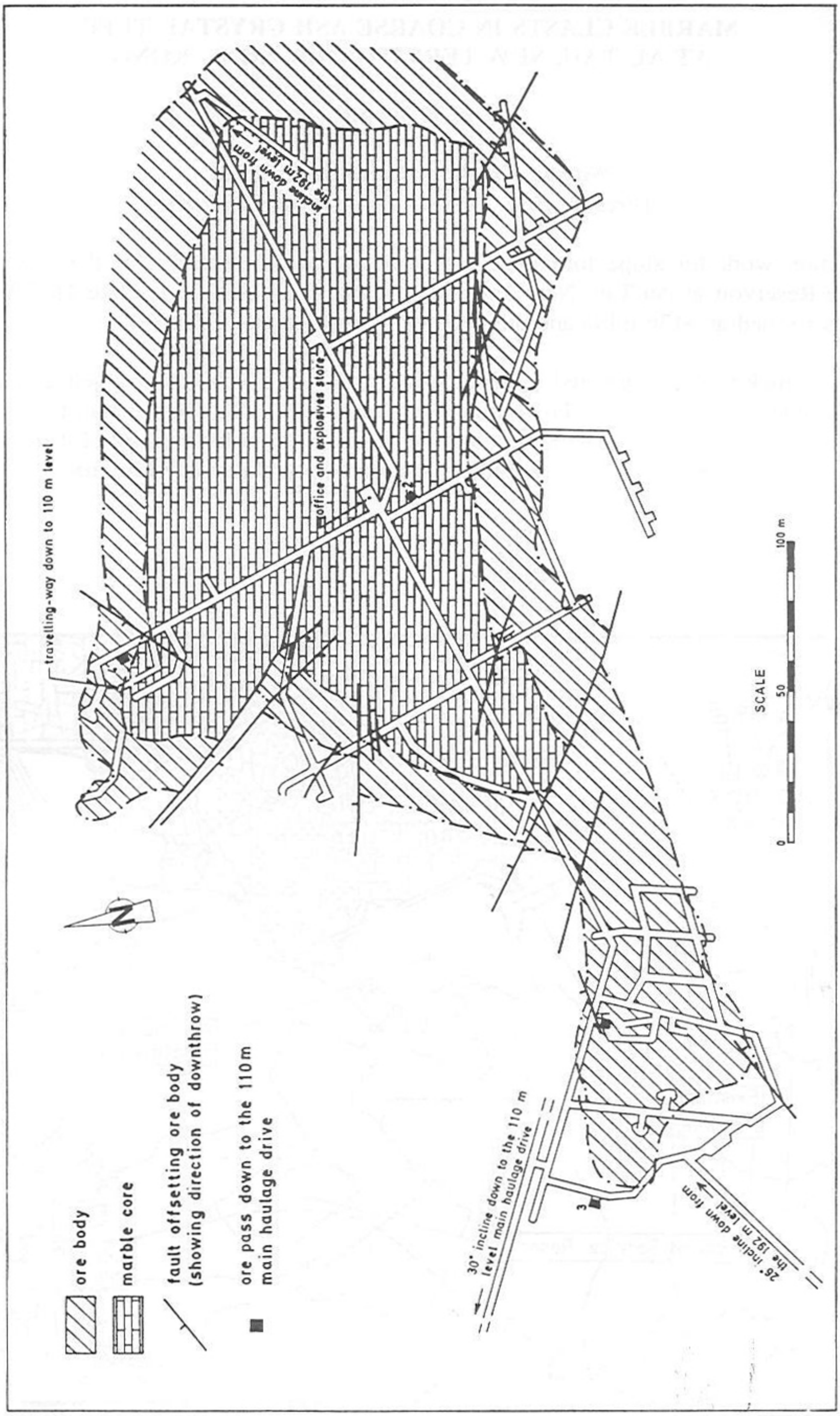

Figure 7 *Geology and layout of mine workings on the 144 m level*

Geological Society of Hong Kong Newsletter Vol 9 No 1 p 16-19 (1991)

MARBLE CLASTS IN COARSE ASH CRYSTAL TUFF AT AU TAU, NEW TERRITORIES, HONG KONG

K M Wong

Watson Hawksley Earth Science Ltd
(Present firm: Binnie Hong Kong Limited)

Excavation work for slope formation has been carried out recently for the new Primary Service Reservoir at Au Tau, New Territories, Hong Kong (Figure 1, Plate 1). The top of slope is formed at +136 mPD and the bedrock is exposed at +105 mPD.

The main rock type encountered is coarse ash crystal tuff which was mapped as part of the metamorphosed Tai Mo Shan Formation (Langford *et al* 1988). In general, the rock mass consists of coarse ash crystalloclastic quartz and feldspar, and lithic clasts of dark grey, fine sandstone, siltstone and white quartzite set in a dark grey glassy or vitric matrix.

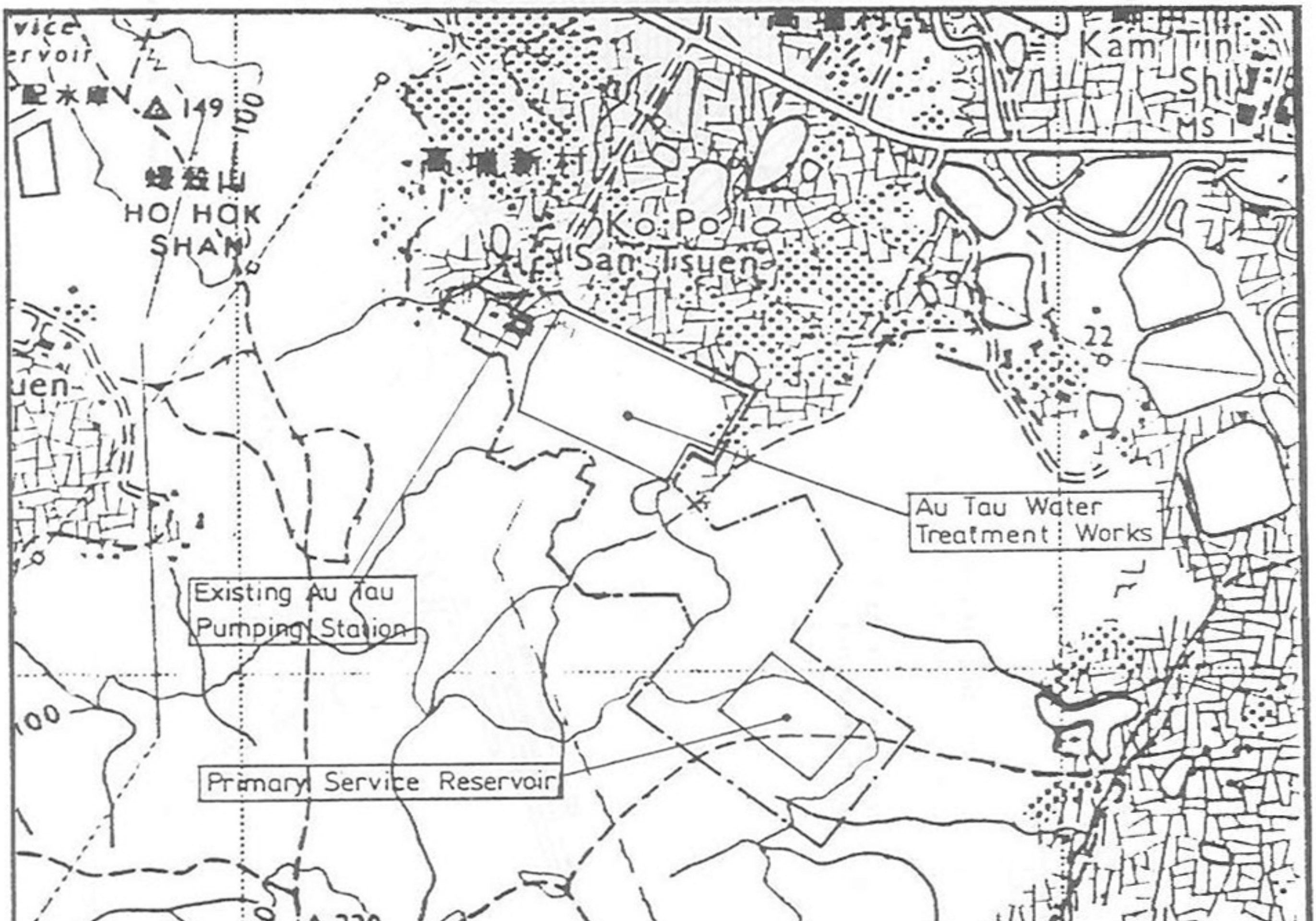

Figure 1 *Location plan*

In February 1990, heavy rain washed out and cleaned off the surface of the rock face formed on the site. As a result, marble clasts up to 70 mm x 230 mm were exposed on the rock face at the southern end of slope at about +95 mPD (Plate 2). The marble clasts were found in the fresh, massive coarse ash crystal tuff immediately above a prominent joint plane dipping 20° towards 115°. This joint plane was infilled with a quartz vein 20 mm or more thick. Visual inspection indicated the joint surface was striated, but this appearance may have been due to the presence of black tourmaline aggregate (Plates 3 & 4).

The discovery of marble clasts in the coarse ash crystal tuff suggests sedimentary carbonate rock may occur in the vicinity; marble of the Yuen Long Formation is located 3 000 m to the west.

Discussion

This is the first that time marble clasts have been discovered in coarse ash crystal tuff of the metamorphosed Tai Mo Shan Formation (Langford *et al* 1989). The general sequence of this volcanic group with marble clasts could also be correlated either to the Shing Mun Formation or even to the older Yim Tin Tsai Formation.

The Au Tau site is situated some 3 000 m east of Yuen Long, where the main marble formation of the territory is found, and it is possible that the marble clasts originated from the Carboniferous Yuen Long Formation. It is also possible that the marble clasts in Au Tau may be comparable to the volcanic group in Tai Po, Tolo Harbour, where similar marble-bearing volcanics had been encountered beneath the Tai Po Industrial Estate during a site investigation carried out several years ago. These marble-bearing volcanics could be in the sequence of Yim Tin Tsai Formation of Repulse Bay Volcanic Group.

Acknowledgements

The author wishes to thank the Water Supply Department, Hong Kong Government, for permission to publish this article.

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Plate 1 *Rock slope formation in coarse ash crystal tuff located at the southeastern end of flight 6; March 1990*

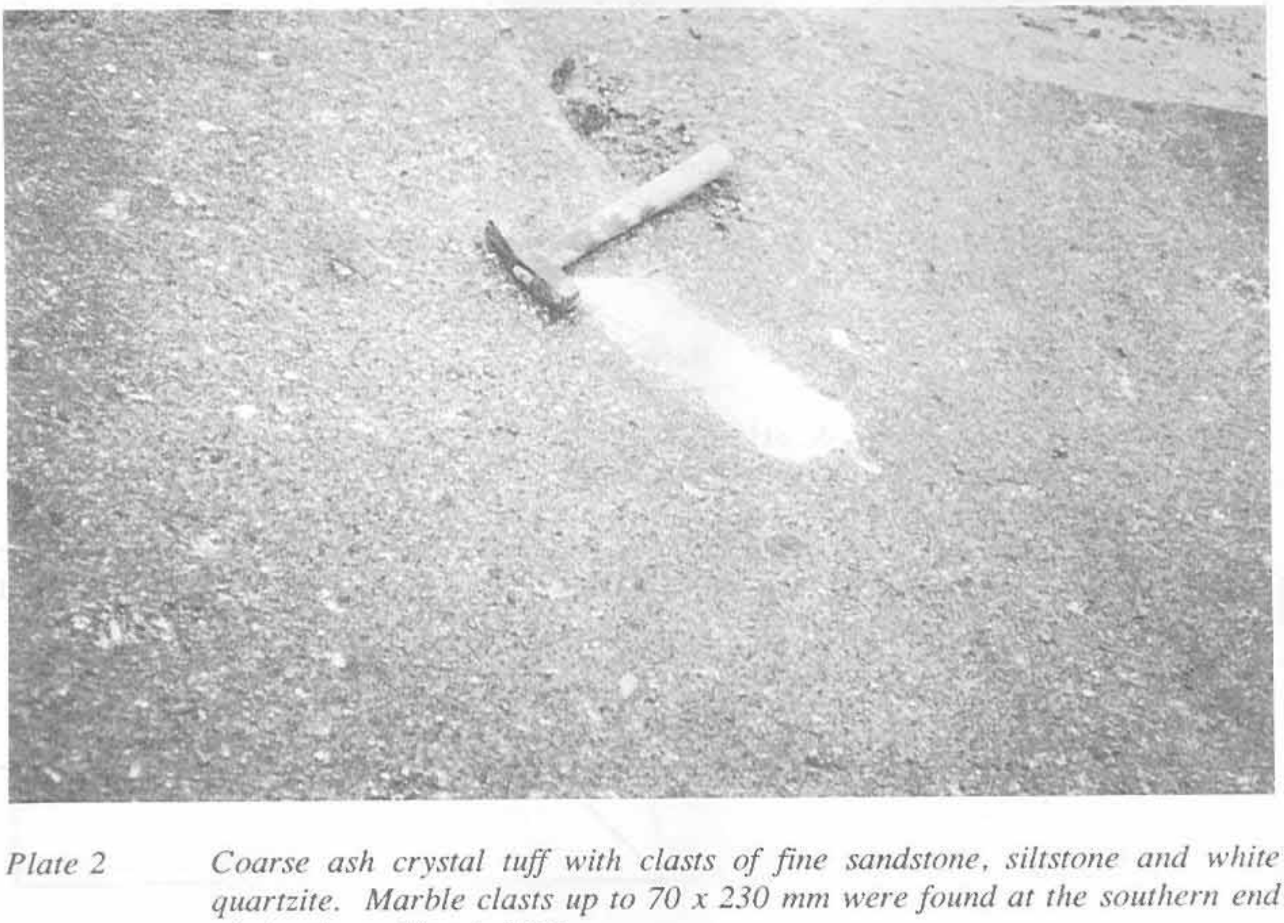


Plate 2 *Coarse ash crystal tuff with clasts of fine sandstone, siltstone and white quartzite. Marble clasts up to 70 x 230 mm were found at the southern end of the slope; March 1990*

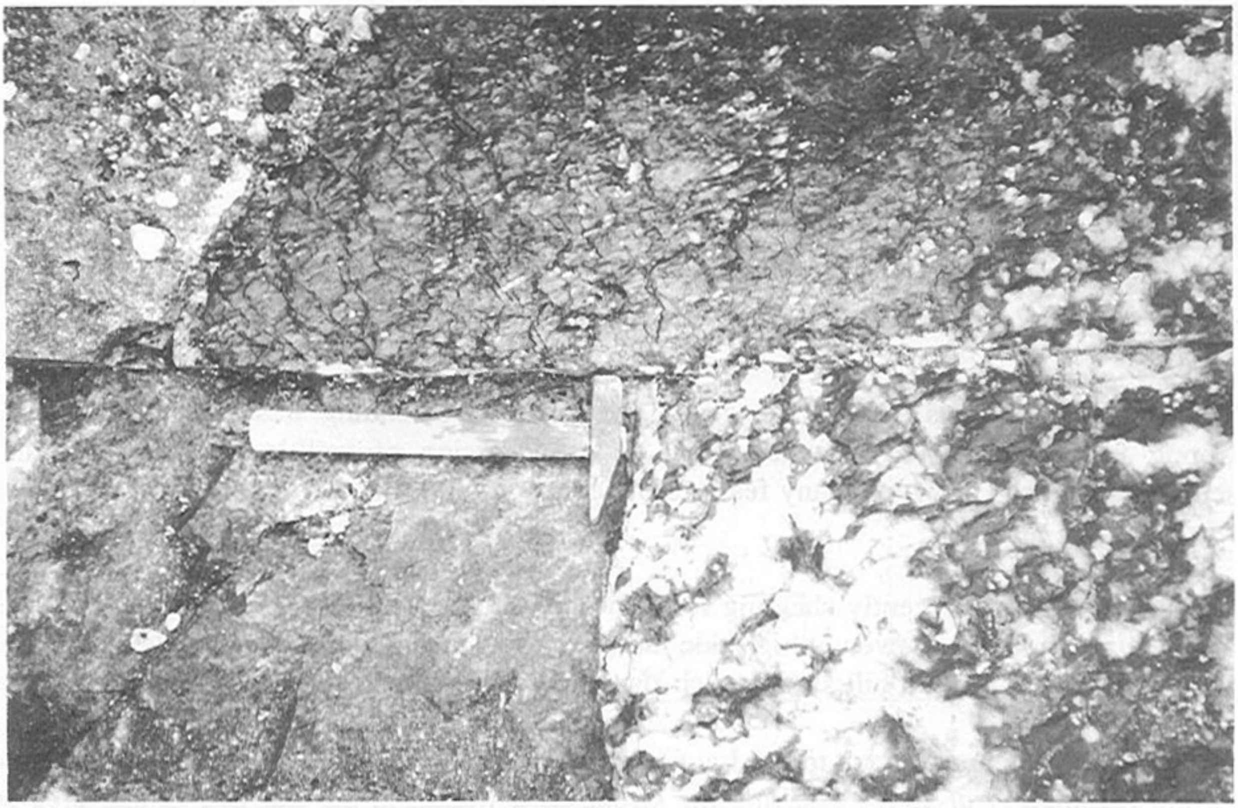


Plate 3 *Quartz vein dipping at 12-25°. The striated appearance is possibly due to the presence of black tourmaline; March 1990*

Plate 4 *Quartz vein with a striated appearance, possibly due to the presence of black tourmaline, along a joint dipping 12-25° towards 086-130°; March 1990*

Geological Society of Hong Kong Newsletter Vol 9 No 1 p 20-33 (1991)

FIELD GUIDE TO THE GEOLOGY OF THE SHORELINE WEST OF LAI CHI CHONG PIER, TOLO CHANNEL

D R Workman

University of Hong Kong

Introduction

The area of interest is a 500 m length of the shoreline extending west from the Lai Chi Chong ferry pier (Plate 1), where there is a succession of well-bedded volcanic and sedimentary rocks in which many features of sedimentological and structural interest can be seen.

The exposures on the gently shelving rocky beach are excellent. At low tide, the beach is about 30 m wide, while even at high tide there are exposures along the water line and at the foot of the bush-covered hill slope which rises steeply from near the high water mark.

The rocks of this area belong to the Lai Chi Chong Formation of the Repulse Bay Volcanic Group (Strange *et al* 1990). Taking the Group as a whole, in the Lai Chi Chong area as elsewhere, the overwhelmingly predominant rocks are tuffs of various kinds, usually massive, crystalline rocks of strictly "igneous" appearance. In the section in question, however, the rocks are in bedded units of differing composition.

Plate 1 General view looking east along the beach from a point about 400 m west of the pier (visible in the distance)

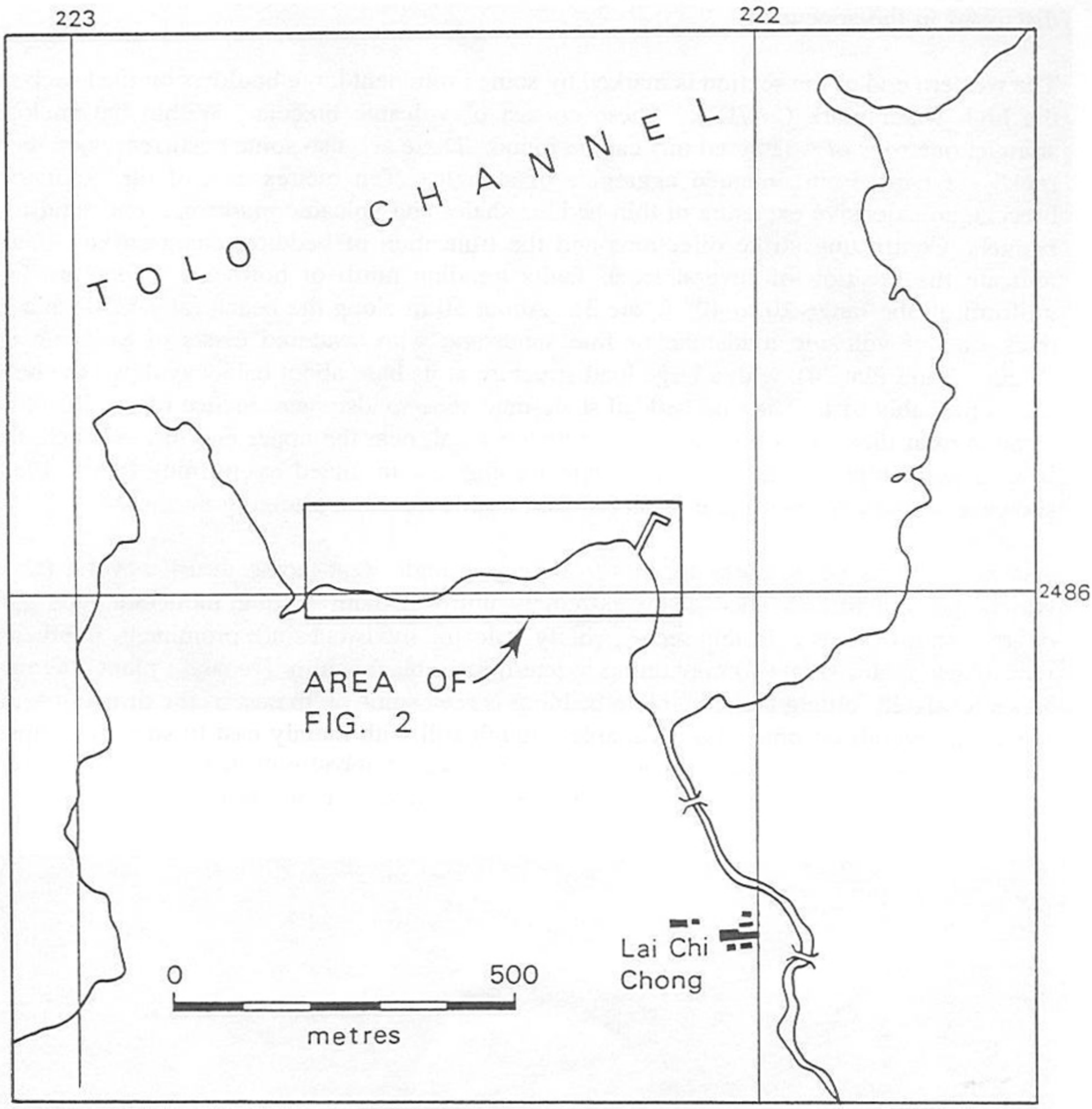


Figure 1 *Location map*

Access. Lai Chi Chong is an almost abandoned village overlooking a small inlet on the south side of the Tolo Channel (Figure 1). Its only transport link with the outside world is the HYF ferry which sails between Ma Liu Shui, Tap Mun and Wong Shek, calling at Lai Chi Chong pier once daily in each direction and allowing a six-hour stopover.

Description of the exposures

For convenience of location in the description which follows, the geological sketch map of the area (Figure 2) is covered by a 50 m grid, the squares numbered 1 to 10 from west to east and lettered A to C from south to north. The grid is tied to the 100 m grid of the 1:1 000 base map; all distances are approximate. The reasons behind the choice of rock names are discussed in the appendix.

The western end of the section is marked by some prominent large boulders on the beach near the high water mark (1A/1B). These consist of volcanic breccia. Within the enclosing shingle, outcrops of weathered tuff can be found. There are also some occurrences of "beach rock" - a hard, iron-cemented aggregate of shingle. Ten metres east of the boulders of breccia, an extensive exposure of thin-bedded shales and volcanic mudstones and sandstones begins. Contrasting strike directions and the truncation of bedding along strike (Plate 2) indicate the position of several small faults trending north or northeast. Dips are fairly uniform, in the range 20 to 40° (Plate 3). About 50 m along the beach (at 2A/2B) is a 2 m thick bed of volcanic mudstone or fine sandstone with scattered clasts of volcanic rock (Figure 2 and Plate 4), with a large load structure at its base about half-way down the beach; this is probably tuff. The thin-bedded shale-mudstone-sandstone sequence resumes, with the same regular dips, for a further 30 m, at which point, near the upper end of the beach, there is an area of highly contorted strata with folding and localized overturning (3A). Plate 5 shows a prominent overturned synclinal fold at this location, plunging northeast.

Just beyond this point, there appears to be a low-angle west-facing thrust, beyond (above) which the structure is once again extremely uniform, with regular moderate dips a few degrees south of east. In this sector, cherty volcanic mudstones are prominent, interbedded with black shales (Plate 6) containing indeterminate black, shiny ("coaly") plant fragments. More localized folding and convolute bedding is seen some 50 m east of the thrust (4A), and the strike overall becomes more variable, though still with mainly east to southeast dips.

Plate 2 Shales with discordance of strike directions across a fault (location 1B)

Plate 3 *Typical thin-bedded sequence of black shales and volcanic mudstones, cherty mudstones and sandstones, area 2A/B*

Plate 4 *The prominent tuff at 2A/B, looking northeast along the strike*

Plate 5 *Folded beds at location 3A. An overturned syncline plunging away from the viewer occupies the centre of the picture*

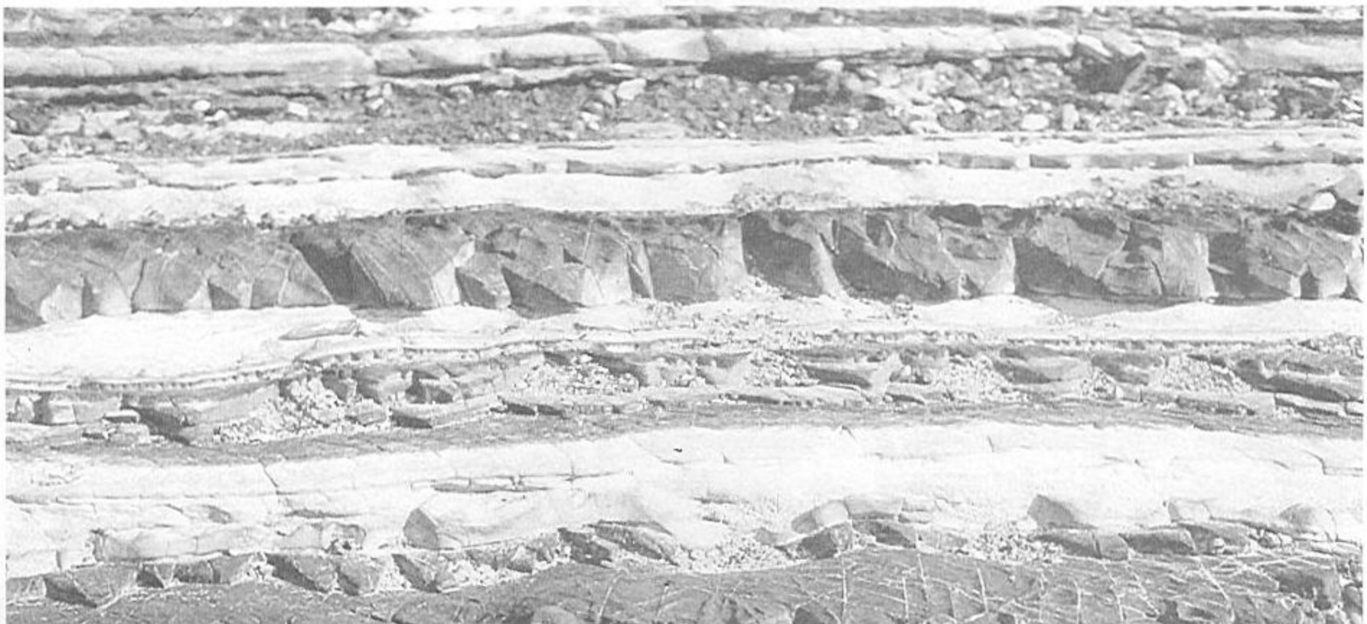


Plate 6 *Detail of very regular bedding of volcanic sandstones and mudstones (light) and cherty mudstones (dark). Note the close-spaced regular joints in the hard cherty mudstones (area 3A, west)*

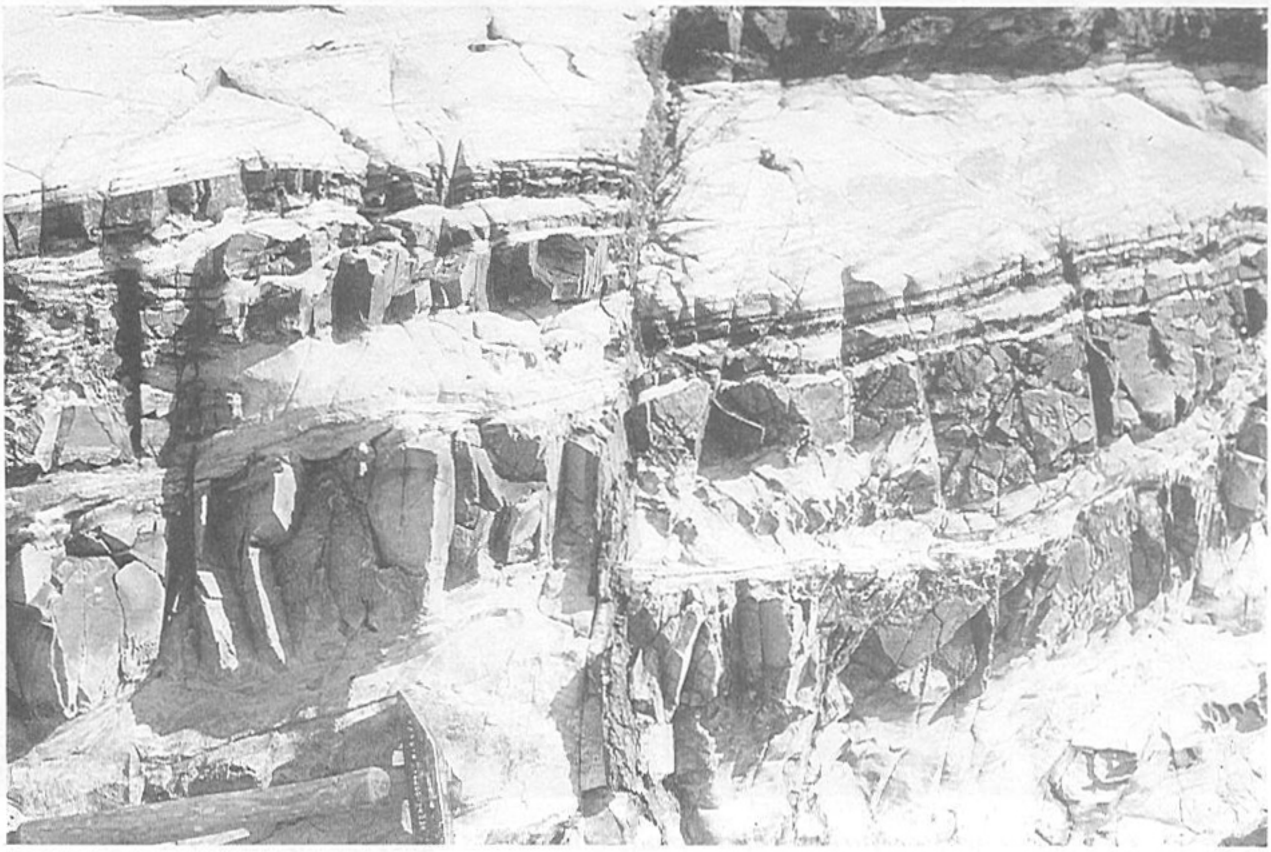


Plate 7 *A fault cutting a sequence of volcanic sandstones and (dark) cherty mudstones (area 5A)*

Plate 8 *Pebbly volcanic sandstone (tuff); location 6A*

Plate 9 *Flame structure - cherty mudstone layers squeezed up into the base of an overlying layer of tuff (6A/B)*

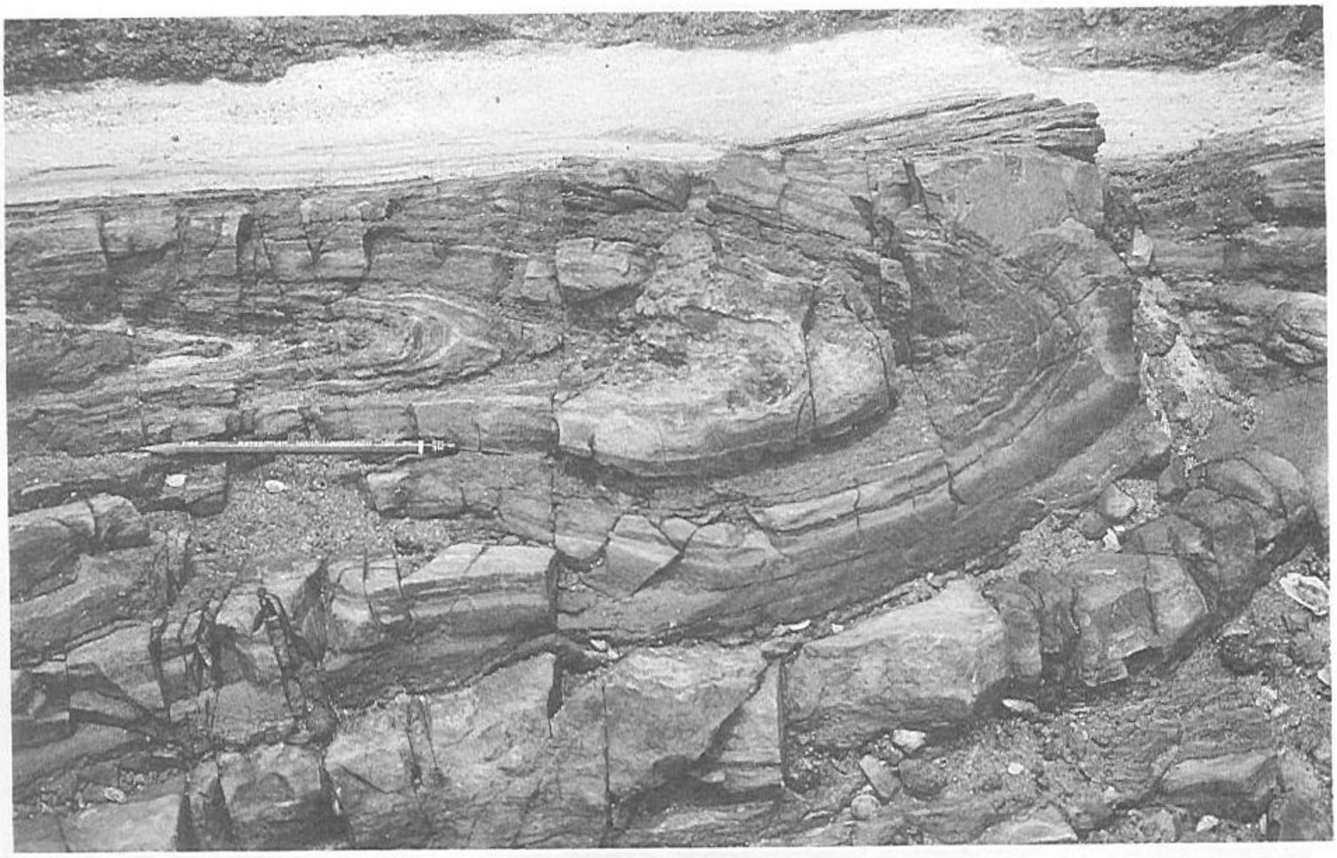


Plate 10 *Convolute bedding - a small isoclinal fold with one limb truncated along an intra-formational erosion surface. The overlying (light-coloured) bed is not folded (8B, east)*

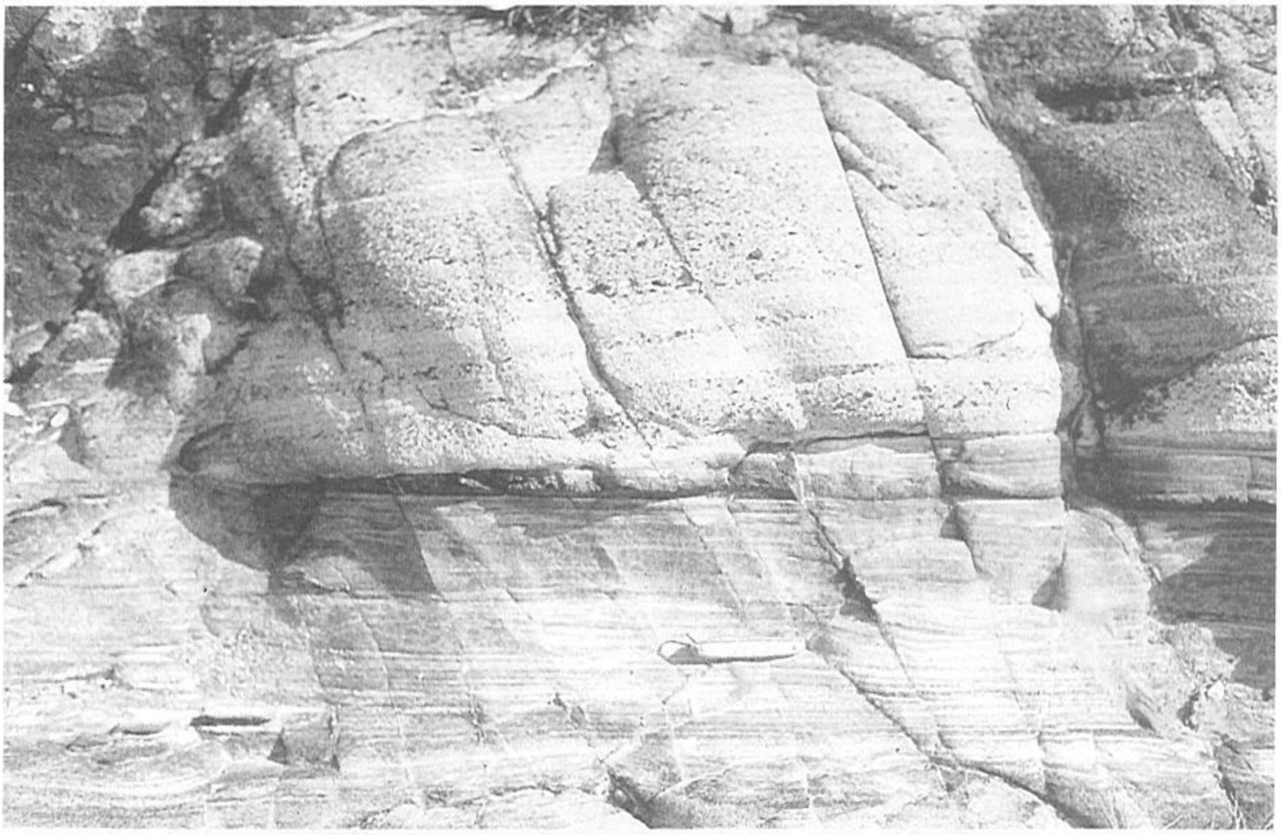


Plate 11 Current bedding in finely stratified volcanic sandstones (8B, west)

We have now reached a conspicuous feature, an extensive field of rounded boulders of crystalline tuff, centred at 4A/5A. These are the remains of a debris flow deposit (landslip) from the adjacent hillside. Between the boulders, isolated outcrops of well-bedded volcaniclastics can be seen, with intense folding (convolutions). At the western edge of the boulder field, there are outcrops of well-bedded volcanic sandstones and cherty volcanic mudstones with some black mudstones and shales. Dips here are generally southeast by south. The next 30 m, near the high water mark, is the best part of the beach to see exposed faults, there being a series of high-angle faults trending generally south-southeast, ie close to the prevailing dip (5A; Plate 7). Then the sequence of well-bedded volcanic sandstones, mudstones and cherty mudstones resumes a regular east-southeast dip (5B/6B) now at angles of 35 to 50°. Some contortions of the strata are seen locally.

At 6A, at the high-water mark, we come to a large outcrop of a coarse-grained rock with many lithic clasts (pebbly volcanic sandstone, Plate 8). This looks like a straightforward lithic lapilli tuff. A few metres further along (6A/6B) is another thick unit of similar appearance. This is a bed of tuff or tuffite some 7 m thick which extends right across the beach. As noted by Strange *et al* (1990) it is agglomeratic in part, especially at or near the base, and fine-grained and cross-laminated towards the top. It shows spheroidal weathering of joint-bounded blocks. At the base of this relatively thick bed, especially near the high water mark, evidence of sudden loading of the underlying sediments can be seen in the form of brecciation and flame structures (Plate 9).

Continuing eastwards, the regular repetition of thin beds resumes, with cherty volcanic mudstones (? fine ash tuffs) prominent. There is an extensive area of faulting and brecciation of these rocks centred on 7B and extending into 8B. Several small, tight folds can be seen here (8B, Plate 10). Other examples can be found elsewhere along the beach (eg, at 1A/2A and 5A; see Figure 2). These folds are typically intraformational and, presumably, syndepositional. Each affects a bedding unit a few tens of centimetres thick with undeformed beds above and below. The folds typically have both limbs more or less parallel to the bedding and hinges plunging parallel to the dip. They do not show a consistent direction of closure, but are taken to be a form of convolute bedding, ie caused by deformation during consolidation and before final lithification.

We have now reached almost the upper limit of the sedimentary sequence. Line 7/8 is about the furthest eastern extent of any beds which have the appearance of ordinary non-volcanic black mudstones or shales. The rocks at 8B are volcanic mudstones, cherty mudstones and sandstones, the latter being commonly greenish and showing delicate stratification and cross bedding in the form of fine banding of light and dark-coloured grains (Plate 11). There is again much small-scale faulting. The degree of sorting and stratification rapidly diminishes at 9B, so that eastwards, the rocks soon lose any conspicuous "sedimentary" appearance. Over the final 50 m to the ferry pier (10B/10C) the exposed rocks are weathered tuff, lapilli tuff and volcanic breccia, crudely sorted and banded in places but without any distinct bedding (Plate 12).

Fossils and the age of the strata

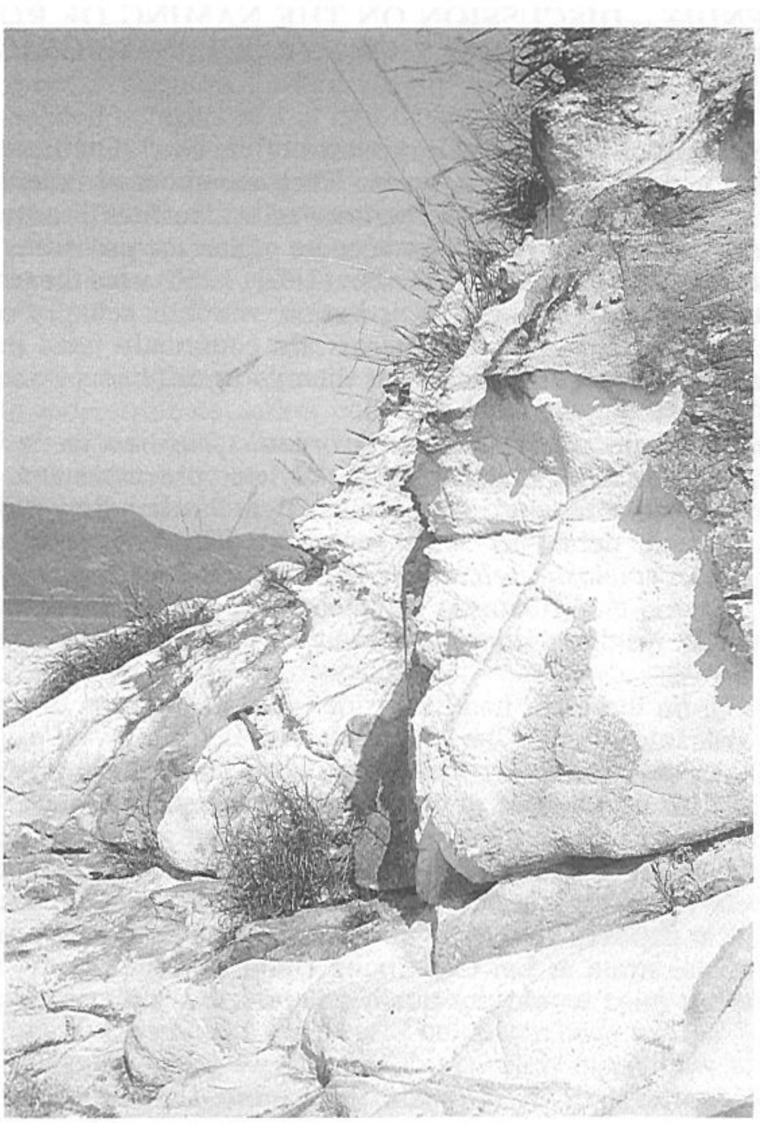
Finding recognisable fossils in this sequence requires care and patience. Only plants have been found, in the form of leaves, stems and silicified wood. Descriptions and identifications can be found in Williams (1943), Dale & Nash (1984) and Nau (1986). Among the genera identified are *Cladophlebis* and *Equisetites*. Williams and Nau both quote expert opinion that such material as is identifiable suggests a Jurassic (in the case of Nau's paper, Lower Jurassic) age. However, Chinese geologists working with a Hong Kong Polytechnic research team have recently reported afresh on the flora at this locality, with several additional species identified in newly-collected material, and their conclusion is that this flora, taken with that collected in the same formation near Cheung Sheung about 2.5 km to the south, and at two localities in Lantau Island, collectively indicate an early Early Cretaceous age (Lee *et al* 1990).

Conclusion

Taking the section as a whole, the main points of interest are:

1. The various volcanic and other sedimentary rock types that can easily be distinguished
2. The evidence of continuing pyroclastic deposition during this relatively quiet period between major volcanic eruptions
3. Identification of sedimentary textures and structures; bedding, sorting by grain size and composition, and load, cut-and-fill and flame structures
4. Evidence of deformation; overall dip and local variations, small-scale folds and faults, convolute bedding and brecciation

The exposed rocks and structures can best be explained in terms of intermittent sedimentation in shallow water, perhaps a river or lake, with contemporaneous volcanic activity and attendant ground movements.



Piate 12 *Weathered tuff near Lai Chi Chong pier (10B)*

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APPENDIX - DISCUSSION ON THE NAMING OF ROCKS THAT MAY BE PARTLY OF PYROCLASTIC ORIGIN

Are the rocks sedimentary or volcanic? Or mixtures of the two? On these questions depends the identification and naming of the rock types. They are either sedimentary rocks pure and simple, or tuffaceous sedimentary rocks (sometimes called "tuffites"), or tuffs (Schmid 1981). However, problems arise when trying to take account of surface processes which may rework or redeposit particles of pyroclastic origin. Fisher (1961, 1966) uses the terms pyroclastic and epiclastic strictly to describe modes of *fragmentation*, which is actually correct according to the meaning of "clastic". However, these terms are commonly used in a wider sense, to include mode of deposition as well. This leads directly to differences such as the following.

According to Fisher & Schminke (1983), a *pyroclastic fragment* is "a fragment produced directly from volcanic processes". Irrespective of later processes that may recycle such fragments, such as by water or wind, they remain pyroclastic. Reworking or recycling of unconsolidated pyroclastic debris by water or wind does not transform pyroclasts into epiclastic fragments. An *epiclastic volcanic fragment* is produced by weathering and erosion of volcanic rocks. Reworked pyroclastic fragments are derived from the remobilization of loose materials. A rock resulting from these processes would still be pyroclastic, ie a tuff.

Cas & Wright (1987), on the other hand, consider that, in the case of *epiclastically* formed deposits (sic) of volcanic origin, the fact that the detritus was originally fragmented pyroclastically is incidental to the fact that epiclastic mechanisms were responsible for final *deposition*. This is a broader use of the term epiclastic, as more or less synonymous with "clastic sedimentary" but excluding "pyroclastic deposition". According to Cas & Wright, "pyroclastic deposits are those which have a demonstrated pyroclastic mode of fragmentation *and* a demonstrated pyroclastic mode of deposition" and epiclastically "reworked" or redeposited pyroclastic deposits cannot be called tuff. This is in sharp contrast to Fisher & Schminke. Most of the strata at Lai Chi Chong could be called "tuff" using the Fisher & Schminke criterion, but most would not qualify as tuff according to the criterion of Cas & Wright.

For practical purposes, the term "tuffite" is often used to describe rocks which are believed to contain substantial amounts of both detritus (fragments derived from pre-existing rocks by surface processes) and pyroclasts. Alternatively, the appropriate sedimentary rock name can be used with the qualifier "tuffaceous". This signifies a certain proportion of pyroclastic particles in.a sedimentary rock. It indicates contemporaneous volcanic activity. It does not include, for example, particles derived from the erosion of older volcanic rocks.

Clearly, it is often difficult or impossible to distinguish or to draw the line between stratified tuffs and tuffaceous sedimentary rocks or tuffites; moreover it can depend on the definition of the terms "pyroclastic" and "epiclastic" adopted, as illustrated above. One way to skirt round this problem is to use the non-genetic term "volcaniclastic". The term 'volcaniclastic' covers all fragmental aggregates wholly or partly of volcanic parentage. Thus we have the following hierarchy of names:

VOLCANICLASTIC

EPICLASTIC   EPICLASTIC/PYROCLASTIC(MIXTURES)   PYROCLASTIC

Unconsolidated volcaniclastic deposits are volcanic gravels, sands, silts or muds. The lithified equivalents are volcanic conglomerates (breccias), sandstones, siltstones and mudstones. *If* all or some particles in the rock show clear evidence of pyroclastic fragmentation, then any of the terms "tuff", "tuffite" or "tuffaceous" can be used as appropriate, but in the case of tuff, depending on whether or not evidence of pyroclastic deposition is also required.

This creates no problem in the case of the massive rocks of igneous appearance, or rocks with volcanic textures, to which the term "tuff" is usually applied in Hong Kong without hesitation. In the case of the bedded deposits at Lai Chi Chong, the prevailing sharp separation of the sediments into distinct beds of widely different grain size does suggest hydraulic processes of sorting. On the other hand, some of the coarse beds could be direct air-fall deposits, and thus tuffs. The localized brecciation below some such beds, suggesting impact, strengthens this possibility. But this is not certain, so for the sake of consistency the volcaniclastic rocks in the bedded sequence have been called volcanic mudstones, sandstones or conglomerates in the foregoing description, and *interpreted* as tuffs where this appears to be justified.

The volcanic sandstones and conglomerates are basically light- to medium-grey rocks, with quartz, feldspar and indeterminate darker coloured fragments. The colour is variable, often with yellow, pale green or brown tones. The visible grains are generally subangular to subrounded. Particle sizes tend to be fairly uniform but it is common to find scattered clasts (rock fragments, both rounded and angular) of much larger than average size. Most of these rocks could be seen as either tuffs or tuffaceous sediments.

Some of the volcanic sandstones show extremely fine banding due to concentrations of particles of different colour, light and dark. The light particles are mainly quartz and feldspar, the dark ones indeterminate but presumably consisting of fine-grained volcanic ash for the most part.

Of the fine-grained rocks, the least problematical are the black mudstones and shales which show no sign of any volcanic origin and which often contain small, indistinct plant remains or black, shiny "coaly" fragments.

Apart from these, there are many thin fine-grained beds, generally pale grey in colour, which are called "volcanic mudstone" any of which could be fine ash tuff or tuffaceous mudstone.

The very common "cherty" volcanic mudstones, as the name implies, are hard, fine-grained rocks with a tendency to conchoidal fracture. The cherty beds usually stand out as positive features. They are generally some centimetres thick, rarely more than 30 cm, and often very persistent laterally, some beds extending right across the beach. Because of their hard, brittle nature, they are strongly jointed. The fresh rock is medium to dark grey or black, becoming light-grey or brown on weathering. Using a hand lens, small angular crystal fragments can be seen, and sometimes pieces of what looks like black volcanic glass (obsidian). These fragments clearly show their volcaniclastic origins when seen in thin section, having sharply angular forms with some (rare) concave surfaces. Presumably the overall cherty nature of the rock is due to a high content of silica in sub-microscopic particle sizes, derived from volcanic dust. These rocks could be in large part derived directly from falls of fine volcanic ash (dust) into water, and thus be fine ash tuffs.

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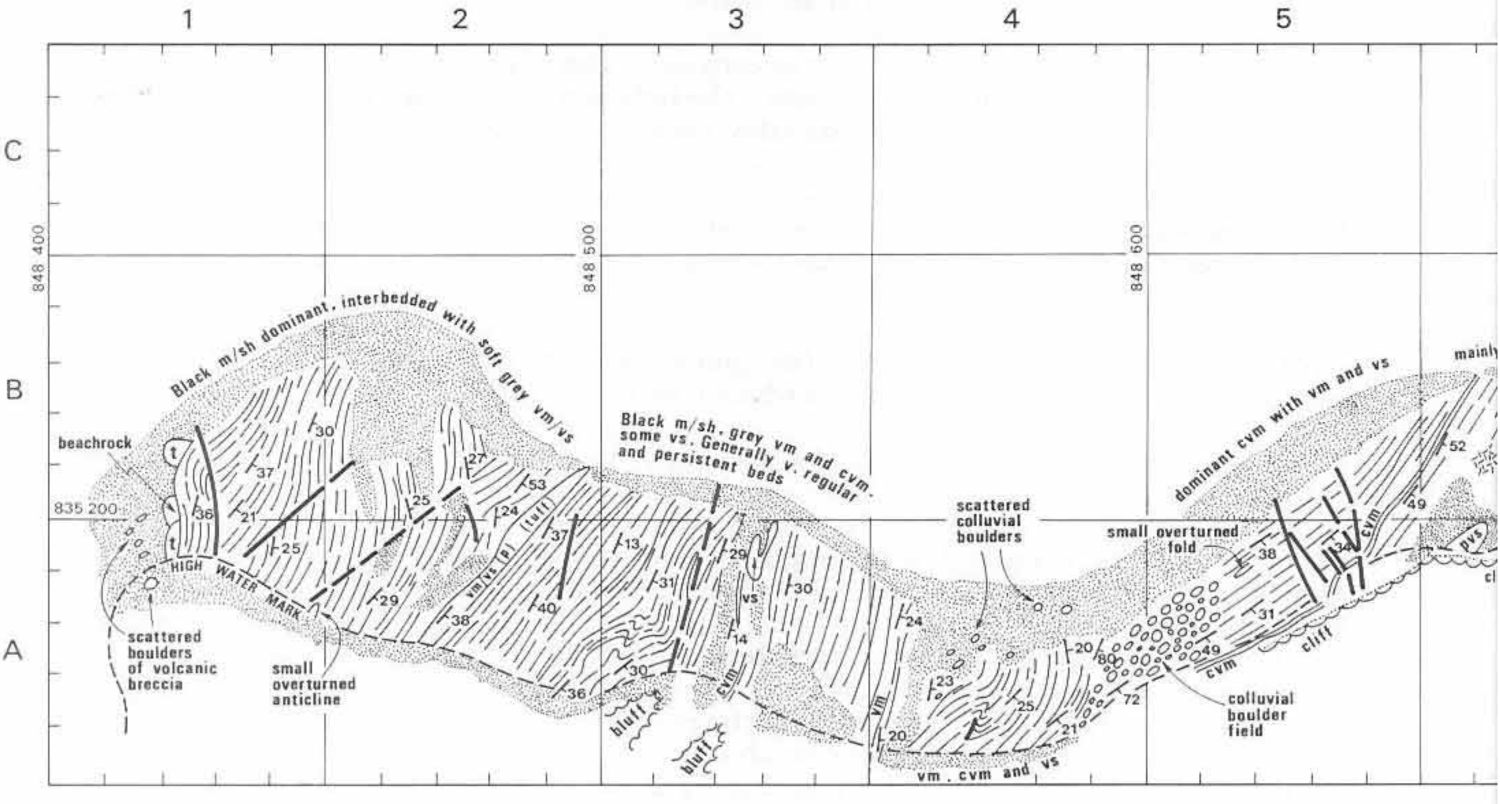
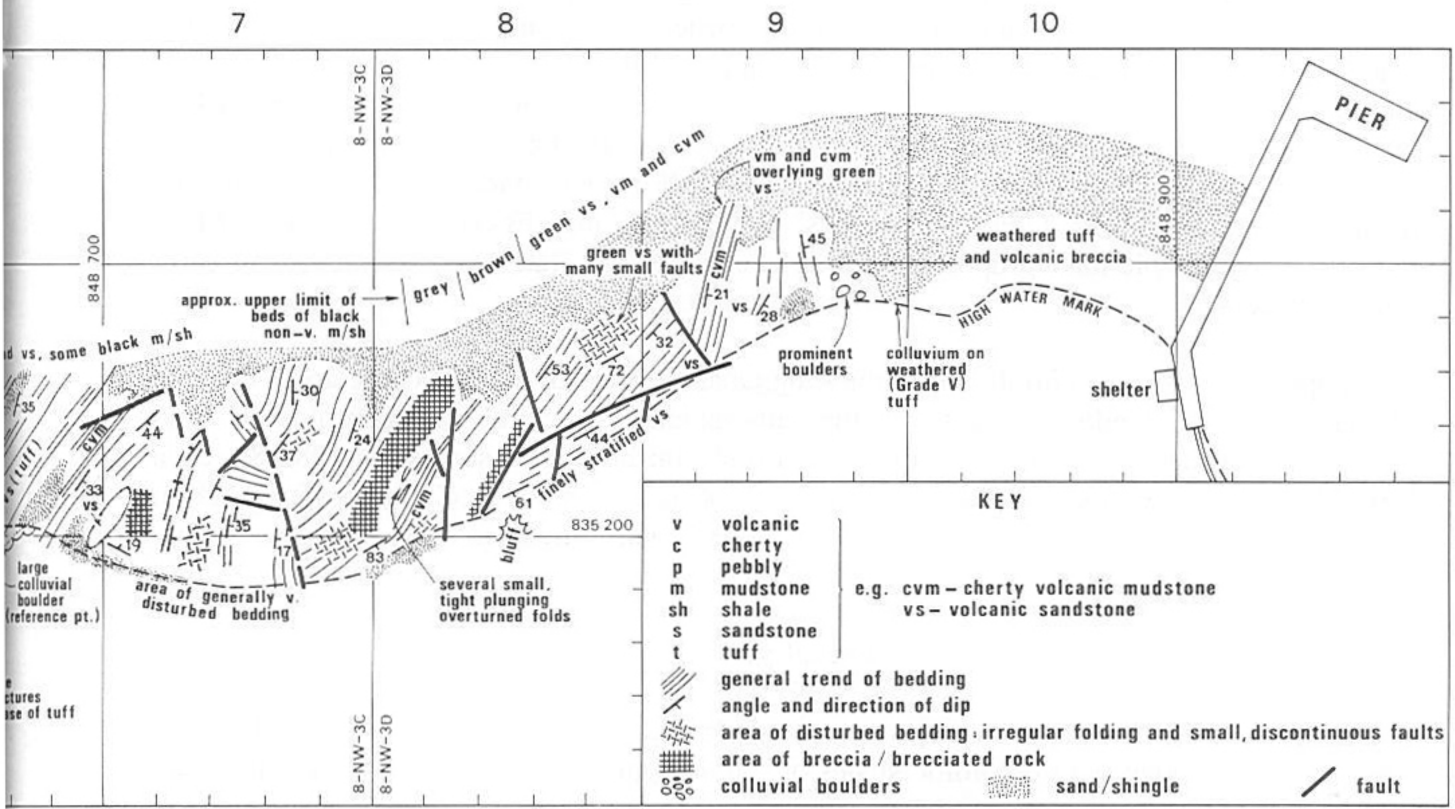


Figure 2 *Geological sketch map of the shoreline west of Lai Chi Chong pier. Scale approx 1:1 400*

Field guide to the geology of the shoreline west of Lai Chi Chong pier, Tolo Channel



Geological Society of Hong Kong Newsletter Vol 9 No 1 p 34-49 (1991)

ON THE AGE OF THE PING CHAU FORMATION

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Introduction

The age of the rocks on Ping Chau Island in Mirs Bay "has long been a mystery". This was said by M J Atherton in the Bulletin of Hong Kong Polytechnic (November 1989 p 19). Since the first surveys by Heanley (1923) and by Brock *et al* from 1923-33, there have been many different ideas presented in the literature; sixty years of controversy in fact. The ideas include: "Upper Triassic-Lower Jurassic" (Nau; Lee 1985); "Lower Jurassic" (Williams 1943; Davis 1953); "Middle-Lower Jurassic" (Allen & Stephens 1971); "Late Mesozoic" (Heanley 1923); "Upper Jurassic" (Peng 1971; Bennett 1984); "Lower Cretaceous or Upper Jurassic" (Heanley; Ruxton 1960); "Upper Cretaceous" (Lee 1987); and "Eocene" (Lee 1985). More recently, some people have proposed "Middle Cretaceous" or "late Early Cretaceous or early Late Cretaceous".

This paper discusses the correlation of the Ping Chau rocks with the Mesozoic and Cenozoic sequences of Guangdong based on the lithological, structural, palaeontological and paleoclimatical data taken from the Ping Chau rocks during a new survey, in 1988-89, by a China-Hong Kong cooperative team. Its conclusion is to support Lee's suggestion (1985); Lee correlates the Ping Chau rocks with the Eocene Buxin Formation of central Guangdong.

General geology

The strata on Ping Chau Island comprise black shale and dark grey or dark brown calcareous siltstone, interbedded with dolomitic shales or marls, approximately 100 m thick. They are distributed in an area less than 1.2 km^2 (Figure 1). On this crescent-shaped island there is no other kind of rock exposed, such as red beds, except the black series. The rocks of the black series, even the shales, are very hard. They are neatly arranged with a gentle dip angle of 14 to 19°, and are slightly folded to form an incompletely arrested plunging syncline of which the axis extends in a northeasterly direction. Faults within the rocks are undeveloped in scale and lead to little displacement of the rocks. On the other hand, there exists a sizeable fault on the east side of the island, according to K W Lai (oral communication), but the fault is now invisible because it is covered by the sea.

The strata underlying the Ping Chau black series are unknown. K W Lai says that the substrata seem to be red beds, according to seismic geophysical data, and are distributed on the north and west sides of the island; they probably belong to the Port Island (or Mirs Bay) Formation.

Abundant pyrite and gypsum can be readily found in many horizons of the Ping Chau rocks. Some kinds of facies mineral such as zeolites and acmite have been reported in the rocks by Peng (1971), indicating a brackish or saltwater deposition. In our view they may be formed under a saltwater and a reducing limnetic environment because of the development of pyrite and gypsum and the absence of common fossil animals living in a normal environment such as ostracods, bivalves, gastropods, conchostracans, etc.

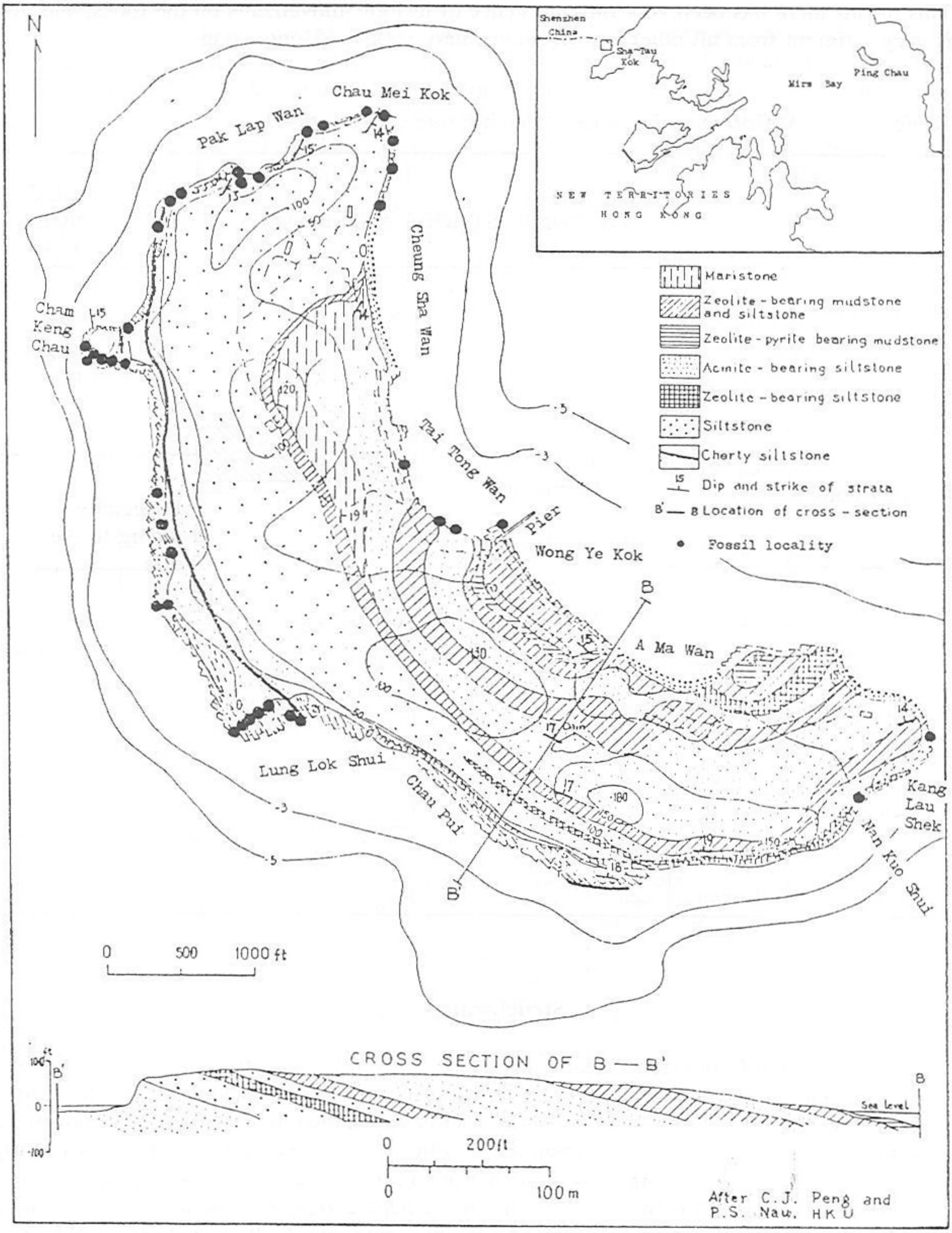

Figure 1 *Geological map of Ping Chau Island*

Plant remains are common in the shales and some siltstone horizons, while insects are rare in the fossil association. Many of the plant and insect fossils are fragmentary in occurrence. It indicates that the organisms were transported by water currents for a distance, and are not *in situ*. However, they are well-preserved as pointed out by A C Seward (Heanley 1923). For example, the carbonaceous material of the plants is still well preserved (mainly lignitoid). This means there has been very little influence of tectonic movements on the rocks, and this is very different from all other known sedimentary rocks of Hong Kong.

Table 1 Mesozoic and Cenozoic tectonic stages in South China

AGE		TECTONIC STAGES AND PHASES			STRONGLY INFLUENCED REGIONS
Tertiary	Upper		2	Himalayan	Strong to the west, but slight to the east
	Lower	(Ping Chau Formation)	1		
Cretaceous	Upper	(Port Island Formation)			Especially strong to the east
			2	Yanshanian	
	Lower	(Pat Sin Formation)	1		
Jurassic	Upper	(Repulse Bay Volcanic Group)			
	Middle				East and west
	Lower	(Tolo Channel Formation)	2	Indosinian	
Triassic	Upper		1		
	Middle				
	Lower				

Structural setting

The Mesozoic and Cenozoic tectonic movements happening in south China are traditionally divided into three; the Indosinian in the early Mesozoic, the Yanshanian in the late Mesozoic, and the Himalayan in the Cenozoic (Table 1). It is well known that the strongest movement affecting southeast China is the Yanshanian, of which the main phase is in Late Jurassic-early Early Cretaceous; the remainder was in the late Early Cretaceous-early Late Cretaceous. According to the plate tectonic theory this movement corresponds to the suture between continental blocks. It caused widespread volcanic eruptions, faulting and close folding of strata, with frequent intrusive bodies and dykes also occurring in this region. As a result, the structure in the sedimentary rocks formed before or during the Yanshanian is complex. For example, the volcanic Repulse Bay Volcanic Group of Hong Kong, and the corresponding Gaojiping Group of Guangdong, are the outcome of the main phase of this movement, while the tuffaceous Pat Sin Formation of Hong Kong, corresponding to the Guancaohu Formation of Guangdong, is the indication of the remaining phase of the movement (Table 2).

The Gaojiping Group of Guangdong contains a black series or grey-yellow series over 100 m thick, seen in many places, although the Group consists mainly of volcanics. This group is like the Repulse Bay Volcanic Group of Hong Kong. However, a lot of tuffaceous beds can be easily found in the sedimentary series of either the Gaojiping Group or the Repulse Bay Volcanic Group. For the latter examples are seen at Lai Chi Chong, Cheung Sheung, etc, where there are many beds of tuff or tuffaceous sandstone and conglomerate. But material of volcanic origin has never been found in the Ping Chau rocks. Moreover, we have discovered many Angiosperm plants in the Ping Chau Formation. They are very young; the earliest occurrence is Early Cretaceous and they have thrived since the Late Cretaceous, especially in the Cenozoic. Therefore it is impossible to correlate the Ping Chau Formation with the Late Jurassic-early Early Cretaceous Gaojiping Group or the Repulse Bay Volcanic Group.

Table 2 Brief features of the Jurassic and Cretaceous formations in Guangdong, and their correlation to Hong Kong

AGE	FORMATION	DISTRIBUTION	PRINCIPAL LITHOLOGICAL CHARACTERS	THICKNESS (m)	CORRESPONDING ROCKS IN HONG KONG
Upper Cretaceous	Dengta Group or Dalongshan Formation or Nanxiong Formation	West Central North	Red beds with a few green-yellow intercalations	1000-2000 (each intercalation less than 1 m)	Port Island Formation or Mirs Bay Formation
upper Lower Cretaceous	Luoding Group or Guancaohu Group or Baizushan Group	West East Central	Red beds containing tuffaceous beds	600-1000	Pat Sin Formation
lower Lower Cretaceous - Upper Jurassic	Gaojiping Group	Central and East	Volcanics with blackish and grey tuffaceous shales and sandstones	2000 (sediments about 100 m or more)	Repulse Bay Volcanic Group
Middle Jurassic or upper Lower Jurassic	Zhangping Group	limited to East	Red beds with a few intercalations of brown-green shale	1000 (intercalations less than metres)	? Tuen Mun Formation
lower Lower Jurassic	Jinji Formation	widespread	Black, grey and brown shales, siltstones and sandstones	100-300	Tolo Channel Formation

Speaking about the Cretaceous and the upper Lower Jurassic or Middle Jurassic red beds of Guangdong, geologists have found only few green-yellow beds and they are very thin (a few metres thick). However, it is difficult to lithologically correlate the few metres of dark beds directly with the 100 m of the black series of Ping Chau. If there are lithofacies changes between the Ping Chau black series and the Guangdong red beds, as assumed by some people, where and what is the transition between them? Up to now we have never found any records on the transitional Cretaceous or Upper, Lower or Middle and Middle Jurassic in the Guangdong region or in Hong Kong.

On the other hand, there are many localities of Lower Tertiary age in Guangdong bearing a black series similar to the Ping Chau rocks, especially strata in the localities systematically surveyed such as Sanshui, Xinghui, Maoming, Huiyang, the Leizhou Peninsula, the Beibu Gulf, etc (Figure 2). Conspicuously, Wang *et al* (1985) synthesized the biostratigraphical data of these localities and concluded that there may be a united sedimentary basin (paleolake) of Lower Tertiary age in the area around Guangzhou. This basin is geographically very close to Ping Chau (Figure 2). The Lower Tertiary of this basin, typically developed at Sanshui, has been measured and contains three parts: the lower red beds with some dark grey intercalations towards the top, the middle black series, and the upper beds with some dark grey or yellow-grey intercalations towards to the bottom. The middle part is 100 to 300 m thick, and the lower and upper parts are respectively 180 to 380 m and 850 to 1700 m thick (Hou *et al* 1982). Thus, the Ping Chau rocks can be lithologically correlated with the middle part of the Lower Tertiary of this basin (Table 3).

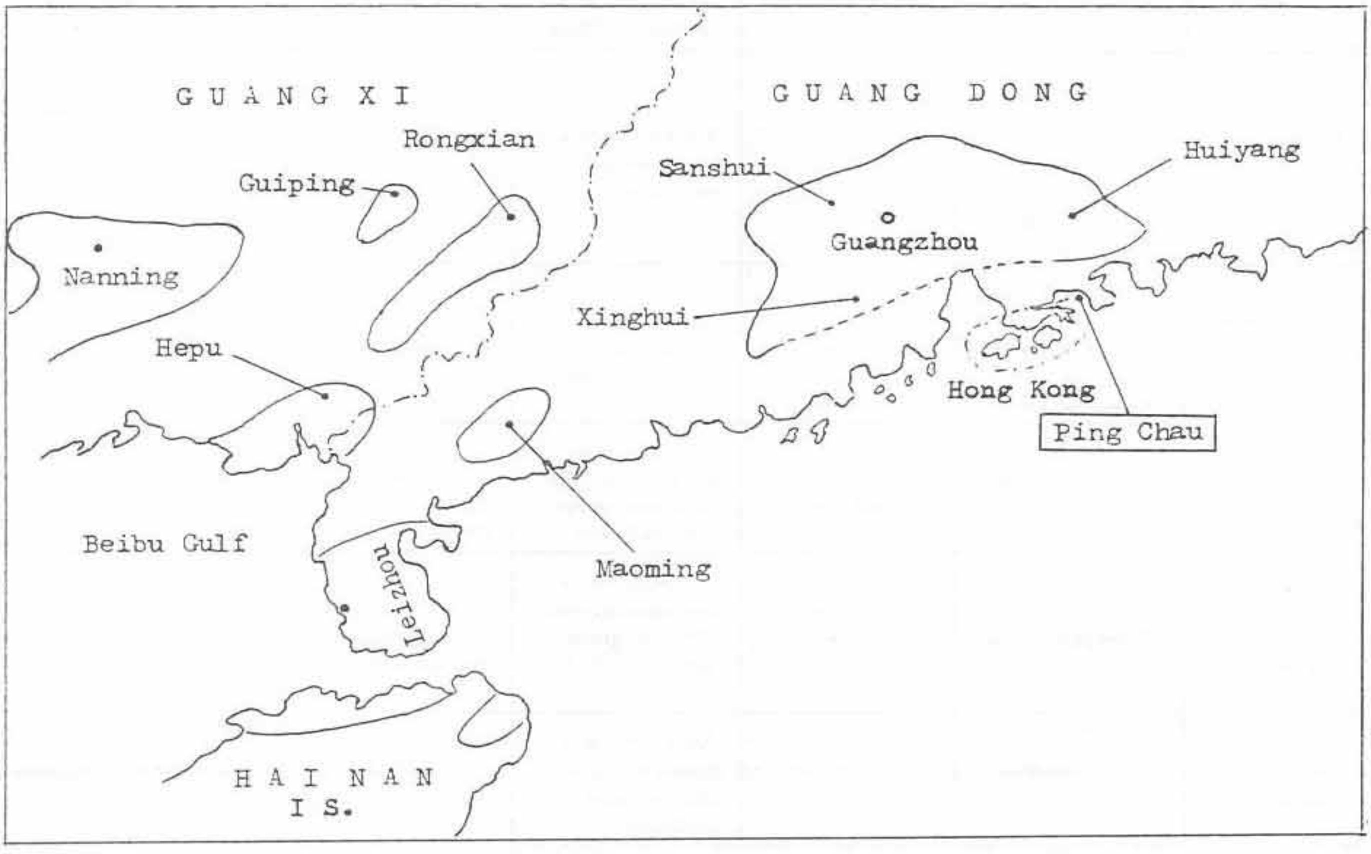

Figure 2 Lower Tertiary paleogeographical map taken from Wang et al (1985). The localities marked with black point bear black-series of the age which can be correlated with the Ping Chau rocks

Furthermore, similar successions of Lower Tertiary sediments have also been recorded in Maoming, the Leizhou Peninsula and the Beibu Gulf of southwest Guangdong (Sun *et al* 1981; Hou *et al* 1982), and even in south Guangxi such as in the Nanning basin (Figure 2 & Table 3). In each of these successions there exists a corresponding black series (some times with oil shales or coal seams) which is palaeontologically dated as Eocene or upper Paleocene to Eocene. This indicates that the black series of Eocene or Late Paleocene to Eocene age is common in distribution in the southern region of South China, and thus the correlation of the Ping Chau rocks with those of the region is certainly reasonable in the light of lithology.

In addition, if the red beds of the Late Cretaceous Port Island Formation are confirmed to be the substrata of the Ping Chau Formation, and the red conglomerates of the Kat O Formation are the overlying beds of the discussed formation as we think, the Lower Tertiary succession of Hong Kong can directly and more easily be correlated with that of Guangdong.

Table 3 *Principal characteristics of lithology of the Lower Tertiary in central and southwest Guangdong and south Guangxi, with a suggested correlation to Hong Kong*

AGE	HONG KONG	CENTRAL GUANGDONG			SOUTHWEST GUANGDONG		SOUTH GUANGXI
		HUI YANG	SAN SHUI	XING HUI	MAO MING	LEIZHOU PENINSULA & BEIBU GULF	NAN NING BASIN
Oligocene	Kat O Formation (red beds) ?	?	San Shui Formation (red beds) Huayong Formation (red beds)	?	?	Weizhou Formation (red beds with some grey and black intercalations)	Yongning Formation (coal measures)
	?	?		?	?		
Eocene	Ping Chau Formation (black beds containing bituminous material)	Black beds	Buxin Formation (black beds containing bituminous material)	Black beds	Black beds (containing coal seams, oil shales and bituminous material)	Liushagang Formation (black beds bearing oil shales, with some red beds in the lower part)	Yongjiang Formation (coal measures)
	?	?			?		
Paleocene	?	Red beds	Xinzhang Formation (red beds and some dark grey intercalations)	Red beds ?	?	Changliu Formation (red beds)	Liuniu Formation (red and brown beds)
Upper Cretaceous	Port Island Formation (red beds)		Dalongshan Formation (red beds)			K_2	?

Paleoclimatical comparison

Many papers describing the Mesozoic paleoclimatical divisions of China have shown in their research conclusions that there existed an arid subtropical or tropical climatic zone in South China in the Cretaceous, especially in the upper Lower and Upper Cretaceous, as illustrated by Wang *et al* (1985) (Figure 3). The Guangdong region and its neighbouring areas are included in this arid zone, but the humid climatic zones of the age, respectively located in northeast China and south Tibet, are very far away from the Guangdong region.

However, the Ping Chau rocks, containing over a 100 m thickness of black series and rich plants, may not indicate an arid climate. Furthermore, many plant forms, such as palms (*Sabalites*), may reflect a warm humid to semi-humid climate. Moreover, lignitoid materials, which are rich in the Ping Chau rocks, also appear in the black series of Lower Tertiary age yielding coal seams in southwest Guangdong. All these facts mean that the paleoclimate shown by the Ping Chau rocks is closer to a humid zone rather than to an arid zone.

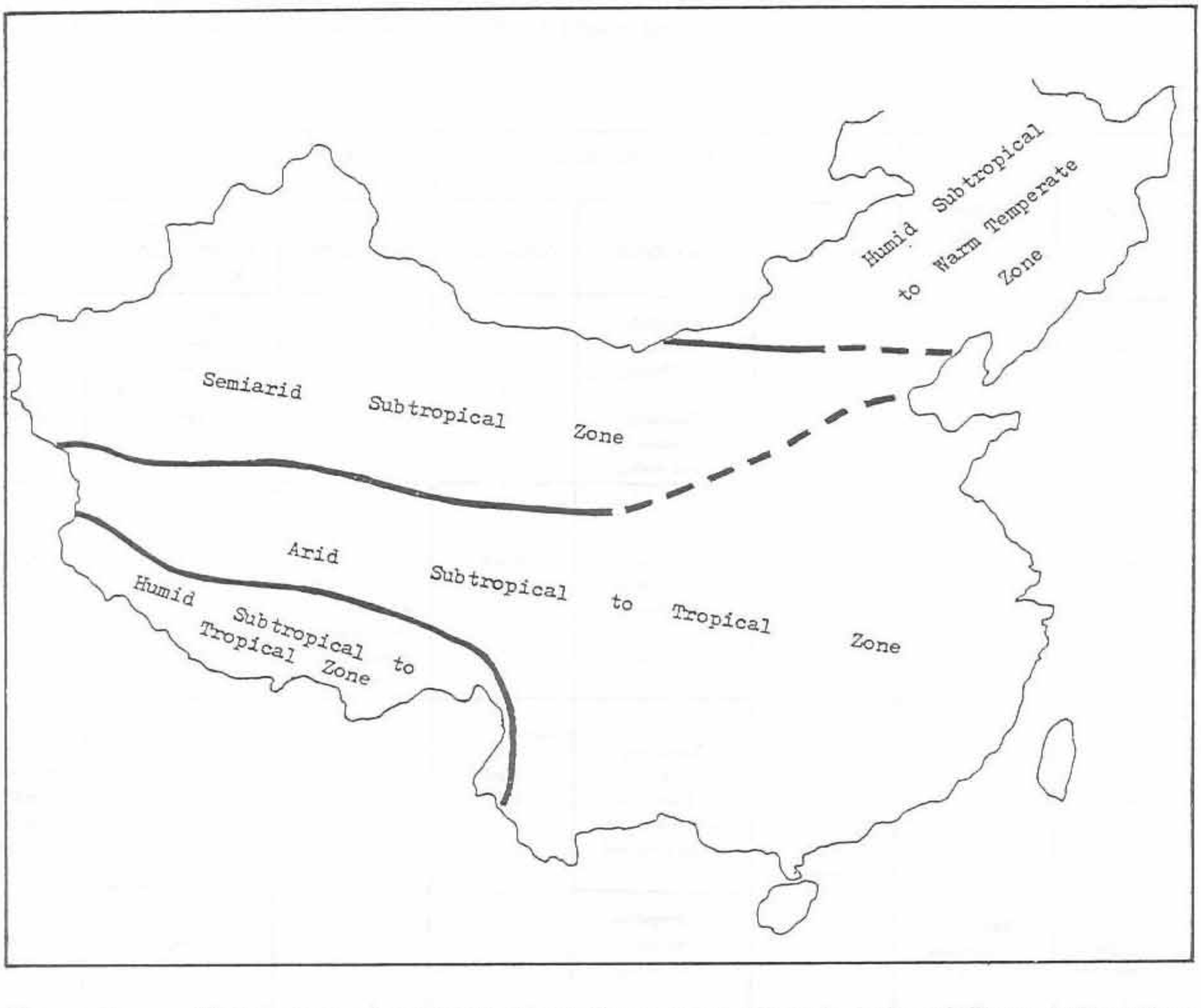

Figure 3 *Sketch map showing the Late Cretaceous climatic belts of China (after Wang et al 1985). On this map the Guangdong region is located at the Arid subtropical to tropical zone*

Correspondingly, Wang *et al* (1985) pointed out that there existed a humid climatic zone in the Early Tertiary in the south part of South China, extending from south Tibet eastwards to southern Fujian. The Guangdong region, and Hong Kong certainly, is included in this humid zone on their map (Figure 4). In our view the paleoclimatic characteristics reflected by the Ping Chau rocks are just in line with this humid zone.

The Ping Chau rocks contain much gypsum, and this is also found in the Lower Tertiary sediments of central and southwest Guangdong. This gypsum may have been transported from other places not very far away from Ping Chau and the equivalent parts of Guangdong by water currents. It means that Ping Chau and these localities of Guangdong may be located at a transitional palaeogeographical position between the humid and the arid paleoclimatic zones, although they basically belong to the humid zone. Therefore, the boundary line between the humid and arid zones on the map of Wang *et al* (1985) should be moved south at its eastern part, because there is insufficient evidence to support the view that the Lower Tertiary red bed development of northern Guangdong, southern Jiangxi and the greater part of Fujian is part of the humid zone.

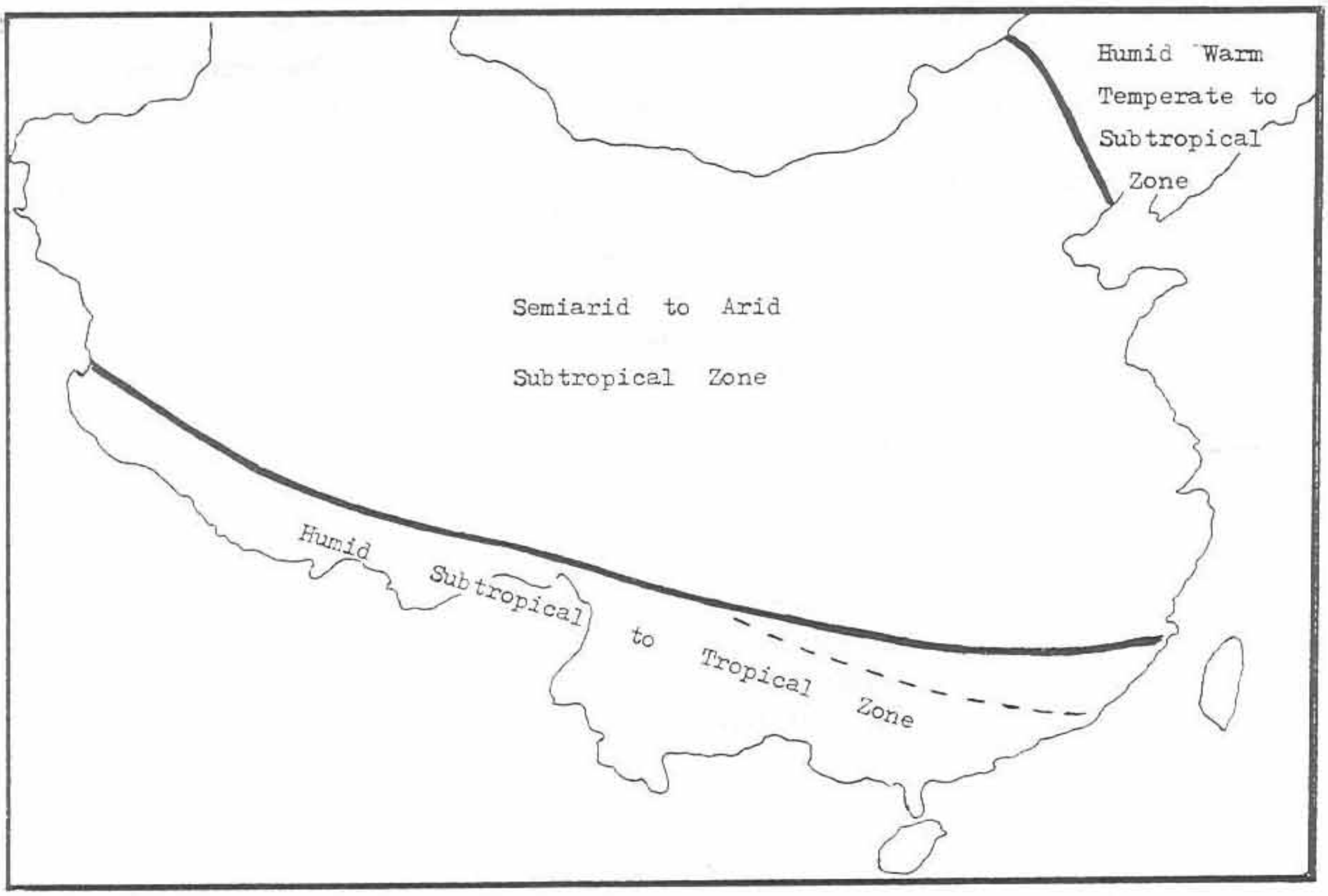

Figure 4 *Sketch map showing the Early Tertiary climatic belts of China (after Wang et al 1985), with a slightly altered boundary line between the arid zone and the southern humid zone*

Palaeontological discussion

Previous records

There exists only two previous discussions on the age of the Ping Chau rocks based on palaeontological collections (Williams 1943; Nau & Wu (1990), although many investigations have been made and many ideas have been proposed.

Williams's (1943) "Lower Jurassic" view was supported by A C Seward's identification of some plant fragments, namely *Ptilophyllum* or *Otozamites*, *Neuropteris* and palm-like forms. However, these determined genera of Seward are not restricted to the Jurassic, but range up to Upper Cretaceous according to Z Y Zhou (in his report on the re-examination of the plants collected by P S Nau from Ping Chau).

The insect fossil, identified as *Otiorhynchites williamsi* Cok. by T D A Cokerell, is quoted as "may be Cretaceous, Eocene or later", because "the Otiorhynchid weevils are very numerous and characteristic in the Eocene (Green River) rocks and they were undoubtedly present in the Cretaceous" (Williams 1943 p 101 & 116). It is a pity that the Cokerell's suggestion was not really adopted by Williams.

The plant fossils from Ping Chau collected by Peng and Nau in 1976, and described by Nau & Wu (1990) were re-examined in late 1989 by Z Y Zhou and listed as follows:

> *? Sapindopsis* sp, *Amesoneuron* sp, *Otozamites* sp, *Otozamites* spp, *Brachyphyllum* sp, *Nilssonia* sp, *Carpolithus* sp, *? Carpolithus* sp,

Zhou stated that this floral assemblage contains older members such as *Nilssonia* and *Otozamites*, and *Ptilophyllum* as recorded by Williams (1943), which "abundantly and commonly in the Jurassic and can extend to Upper Cretaceous, but have never been found in the Tertiary". The palm-like fossil (*Amesoneuron* sp) "can be judged as an indeterminable element of the Arecaceae" (a family of palms); "the greater development of the palms is in the Tertiary, but some are known from the Upper Cretaceous". "The dicotyledonid (*? Sapindopsis*) can correspond to that from the IIB zone of the Potomac Formation, of which the age is estimated to be of late Early to early Late Cretaceous". So that his conclusion on the age of the Ping Chau flora is of "middle Cretaceous", ie, late Early Cretaceous or early Late Cretaceous.

An insect fossil collected by Peng and Nau was identified as cf *Liutaiproshole* sp by Q B Lin who reported that, "It may be Cretaceous, but some forms can possibly be seen in Tertiary" (his conclusion is not only for this fossil, but also comprehensively on the examination of the photographs of our insect collection from Ping Chau; see below).

Our collection

1 Plants

More than 200 plant specimens have been obtained from the Ping Chau rocks by the team. They belong to three forms, ie, Pteridophyta, Gymnospermae and Angiospermae, of which the generic or specific names are listed in Table 4 (initially identified by S Q Wu).

Table 4 A list of macroplants from Ping Chau (collected by the team; identified by S Q Wu)

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, cf *Glyptostrobus europaeus* (Brongn.) Heer, *Glyptostrobus?* sp, *Sphenolepis? densifolia* Cao, cf *Sphenolepis kurriana* (Dunker) Schenk, *Schizolepis* sp, *Pityolepis* sp, *Pityolepis?* sp
Angiospermae	*Cinnamomum* sp, *Nectandra guangxiensis* Guo, cf *Ocotea 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?* sp (*Carpites?* sp), *Carpites* spp, *Carpites?* sp

Although some generic names in the list are not very reliable (marked with question marks), they may reflect a floral outline. Among the total of 35 determinable or indeterminable genera (or species), 17 belong to the Angiospermae, 15 to the Gymnospermae and 3 to the Pteridophyta. That is to say, this flora is dominated by the Angiosperms and the Gymnosperms. As is well known, the development age of Angiosperms is from the Late Cretaceous, especially in the Cenozoic. So there is a strong possibility that the age of the flora may be Cenozoic. The trouble with age determinations for palaeobotanists is that there are some "older" elements in this flora such as those forms classed as Gymnospermae of which the ranges are restricted to Mesozoic (Upper Triassic-Cretaceous) according to previous records. Therefore, the identifier (S Q Wu) inclines towards the Upper Cretaceous in age. However, we should not simply adopt this suggestion because of the obvious contradiction to the conclusion derived from the lithological, paleoclimatical and structural, and some paleontological evidence.

Moreover, a palm fossil (discovered by P S Nau from the locality Nan Kuo Shui on the southeast shore of Ping Chau Island) should be brought to paleobotanists attention (Figure 5), as it is a fossil truly resembling modern palms and is especially similar to the Eocene one which was reported with the name *Sabalites chinensis* Eudo from Liaoning, northeast China (Anon 1978 p 160, Plate 147, Figure 1). A similar form has been also recorded from the Lower Tertiary Huangniuling Formation (Eocene), namely *Sabalites* cf *taishuensis* Takahashi (Feng *et al* 1977 p 262, Plate 106, Figure 1).

2 Insects

About 36 insect specimens have been found from the Ping Chau rocks by the team. Their photographs were sent to the Nanjing Institute of Geology and Palaeontology, Academia Sinica, for examination. Q B Lin of the Institute offers a name list for these photographs as follows:

> Gryrinidae gen et sp ind, Cicadellidae gen et sp ind, *Coleoptera* sp, Bibiorridae gen et sp ind, and Cupididae gen et sp ind

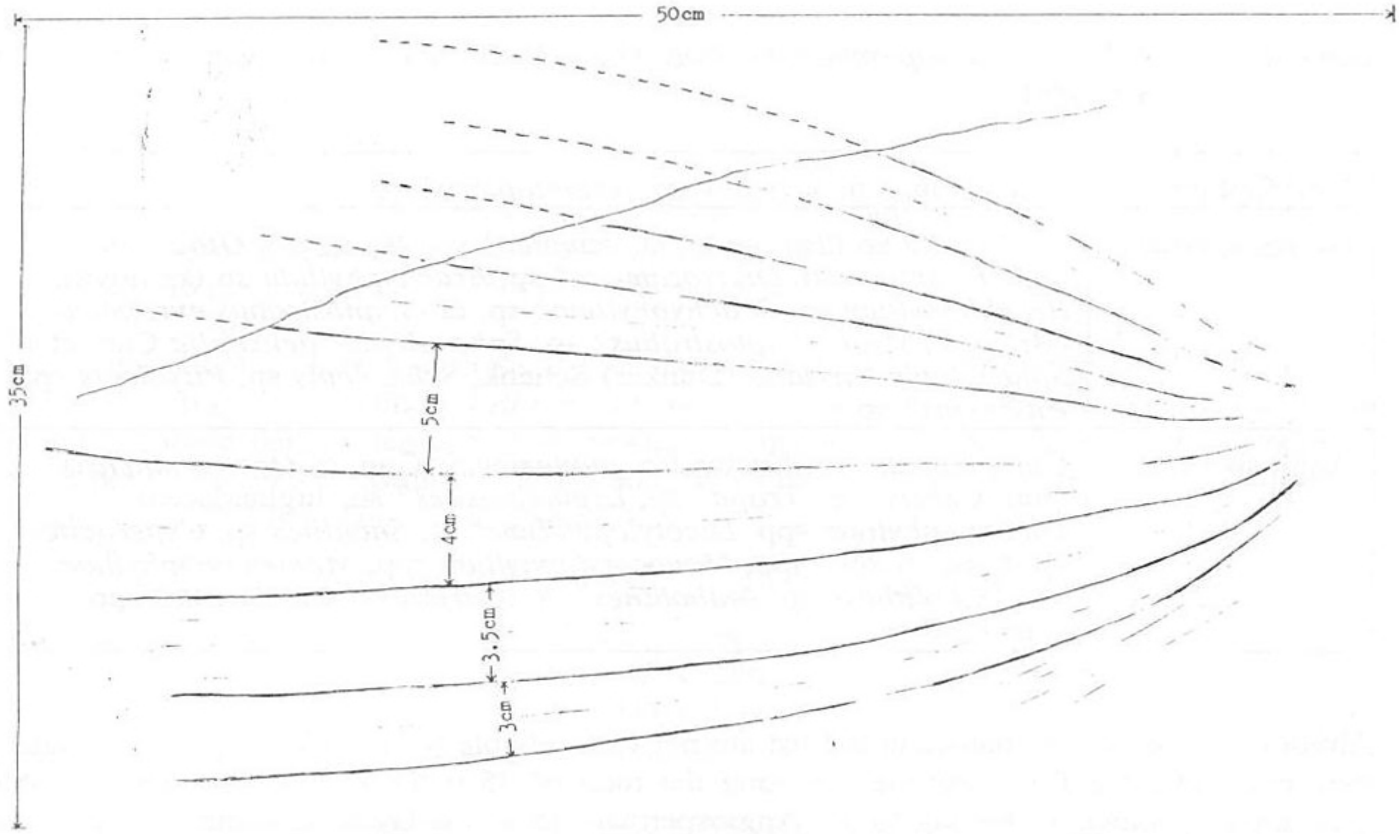

Figure 5 Sketch of a palm fossil from the Ping Chau Formation

In his letters Lin emphasized that, "These insect forms may be Cretaceous or Tertiary in age, because some were found from the Upper Cretaceous Taizhou Formation of Jiangsu, and some are like those of the Tertiary of the Sanshui basin of Guangdong".

3 Sporo-pollens

From a sample (Hong Kong Rock Collection No 8336) which was collected by the team and K W Lai from the Ping Chau rocks, the Nanjing Institute of Geology and Palaeontology has obtained rich sporopollens. The results of the identification by the Institute are listed in Table 5.

Referring to the 17 genera and species identified by the Nanjing Institute, the geological ranges have been also recorded in the "Atlas of Palaeontology of Central South China" (Ma *et al* 1978). Among them, 13 ranged from Mesozoic to Cenozoic, whereas the other 4 are limited to the Tertiary. Moreover, all of the 5 determinable species are restricted to the Tertiary or to the Lower Tertiary, such as *Ulmoideipites tricostatus* and *Engelhardtioidites punctatus*.

The genera or species listed above are widely distributed in Tertiary strata, especially in south China, and some of them, such as *Ulmipollenites minor*, *Ulmoideipites* and *Plicapollis*, have been used as indicators of Lower Tertiary age when they occur in abundance (Hou *et al* 1982). An example is that of the spore-pollen flora from the Beibu Gulf area (Sun et al 1981), of which the related forms are quoted in Table 6, with their occurrences. From this example we can not conclude that their age is limited to the Mesozoic since the evidence strongly suggests that they belong to the Lower Tertiary period.

Conclusion

Based on the analysis of the data from palaeontology, lithology, palaeoclimate and structure, the authors believe that the Ping Chau Formation is Lower Tertiary in age, and corresponds to the black series of Upper Paleocene to Eocene age in central and southwest Guangdong.

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Table 5 Sporopollen list from the Ping Chau Formation

GROUP	GENUS OR SPECIES	RANGE (following Ma *et al* 1978
Spores	*Pterisisporites*	M_2 - K_2
	Lygodiumsporites	J - K_2
	Verrutetraspora	Up Cr-R
	Lygodioisporites	M_2 - K_2
	Toroisporis	M_2 - K_2
Gymnospermae pollens	*Pinuspollenites*	M_2 - K_2
	Abietineaepollenites	M_2 - K_2
	Taxodiaceaepollenites	Cr - R
	Classopollis	J - E_1
	Inaperturopollenites	M_2 - K_2
	Ephedripites	M_2 - K_2
Angiospermae pollens	*Ulmipollenites*	R
	Ulmipollenites minor	R
	Ulmoideipites	Cr - R
	Ulmoideipites tricostatus	E_1 - E_2
	Triporopollenites	M_2 - K_2
	Plicapollis	Up Cr-E_3
	Plicapollis granulatus	E_1 - E_3
	Quercoidites	R
	Quercoidites minor	E_1 - N_2
	Engelhardtioidites	R
	Engelhardtioidites punctatus	E_3

M_2 - Mesozoic; K_2 - Cenozoic; J - Jurassic; R - Tertiary; E - Paleogene (Lower Tertiary); E_1 - Paleocene; E_2 - Eocene; E_3 - Oligocene; N - Neogene (Upper Tertiary); N_2 - Pliocene

Table 6 An example of the stratigraphic occurrence of the present seventeen sporopollen species (genera) of the Ping Chau Formation present in the Beibu Gulf area (after Sun et al 1981)

SPECIES AND GENUS / AGE	Paleocene	Eocene / Oligocene	Oligocene	Miocene	Miocene	Miocene	Pliocene
	Chang Liu Fm	Liushagang Fm	Wei Chou Fm	Xia Yang Fm	Jiao Wei Fm	Deng Lou Jiao Fm	Wang Lou Gang Fm
Ulmipollenites minor	—	—	—				
Ulmoideipites tricostata	—	—					
Quercoidites minor	—	—	—	—	—	—	—
Pterisisporites	—		—				
Lygodiumsporites	no record						
Verrutetraspora	no record						
Lygodioisporites	no record						
Toroisporis	no record						
Pinuspollenites		—	—	—	—	—	—
Abietineaepollenites		—	—	—	—	—	—
Taxodiaceaepollenites	—	—	—	—	—	—	—
Classopollis	no record						
Inaperturopollenites			—				
Ephedripites		—	—	—	—	—	
Engelhardtioidites				—	—	—	—
E punctatus	no record						
Plicapollis granulatus	no record						
Triporopollenites	no record						

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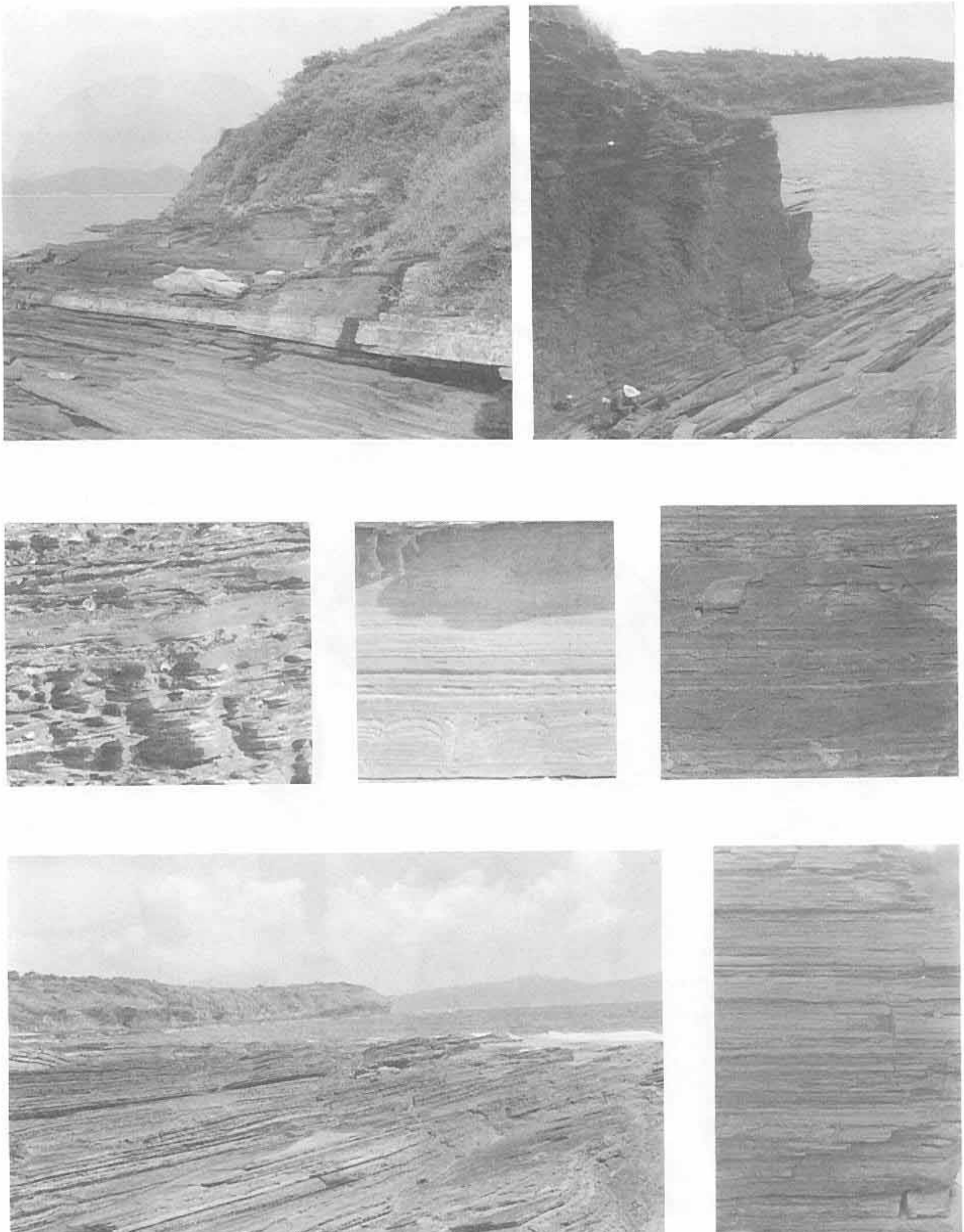

Plate I *Rocks on Ping Chau*

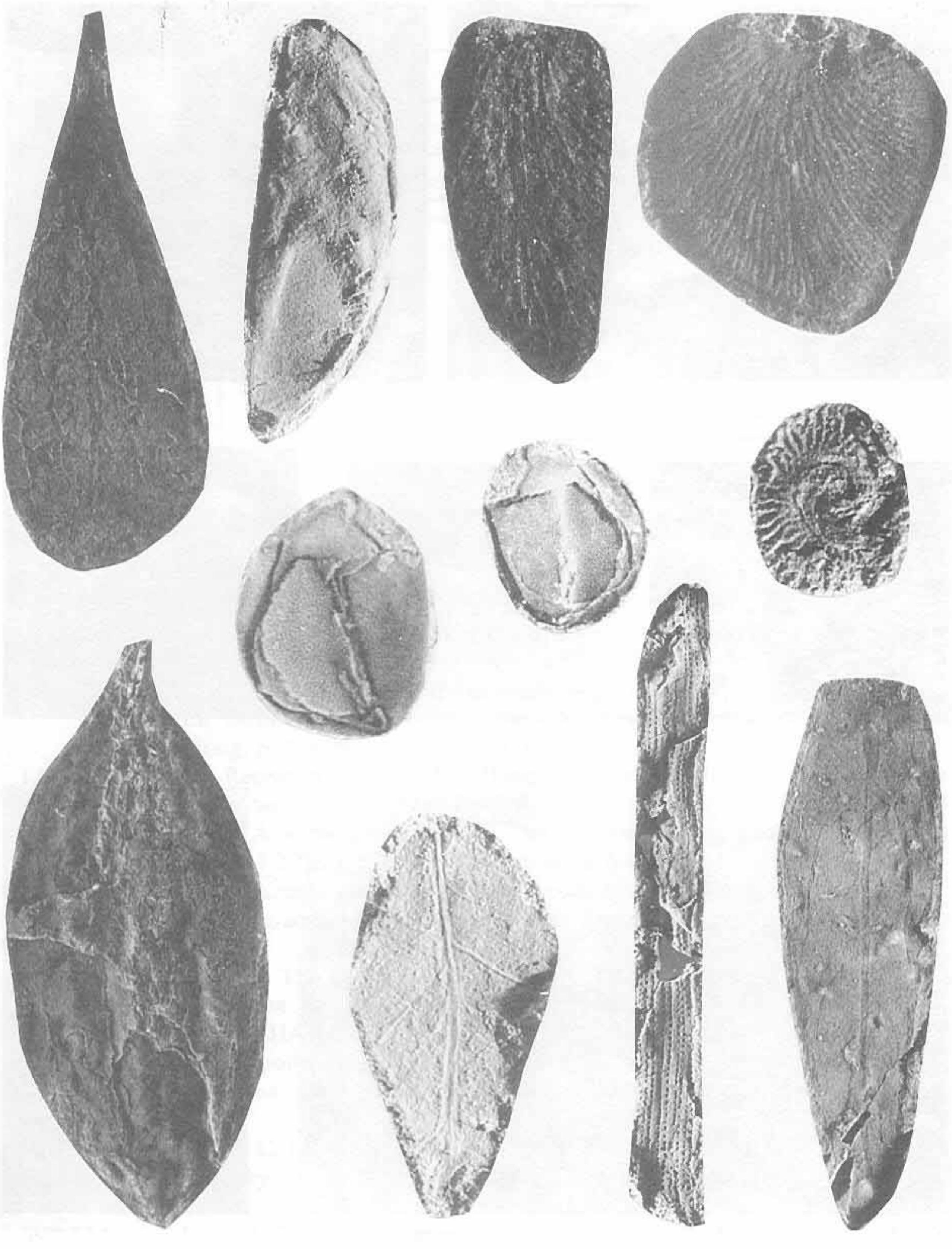

Plate II Plant fossils from the Ping Chau Formation

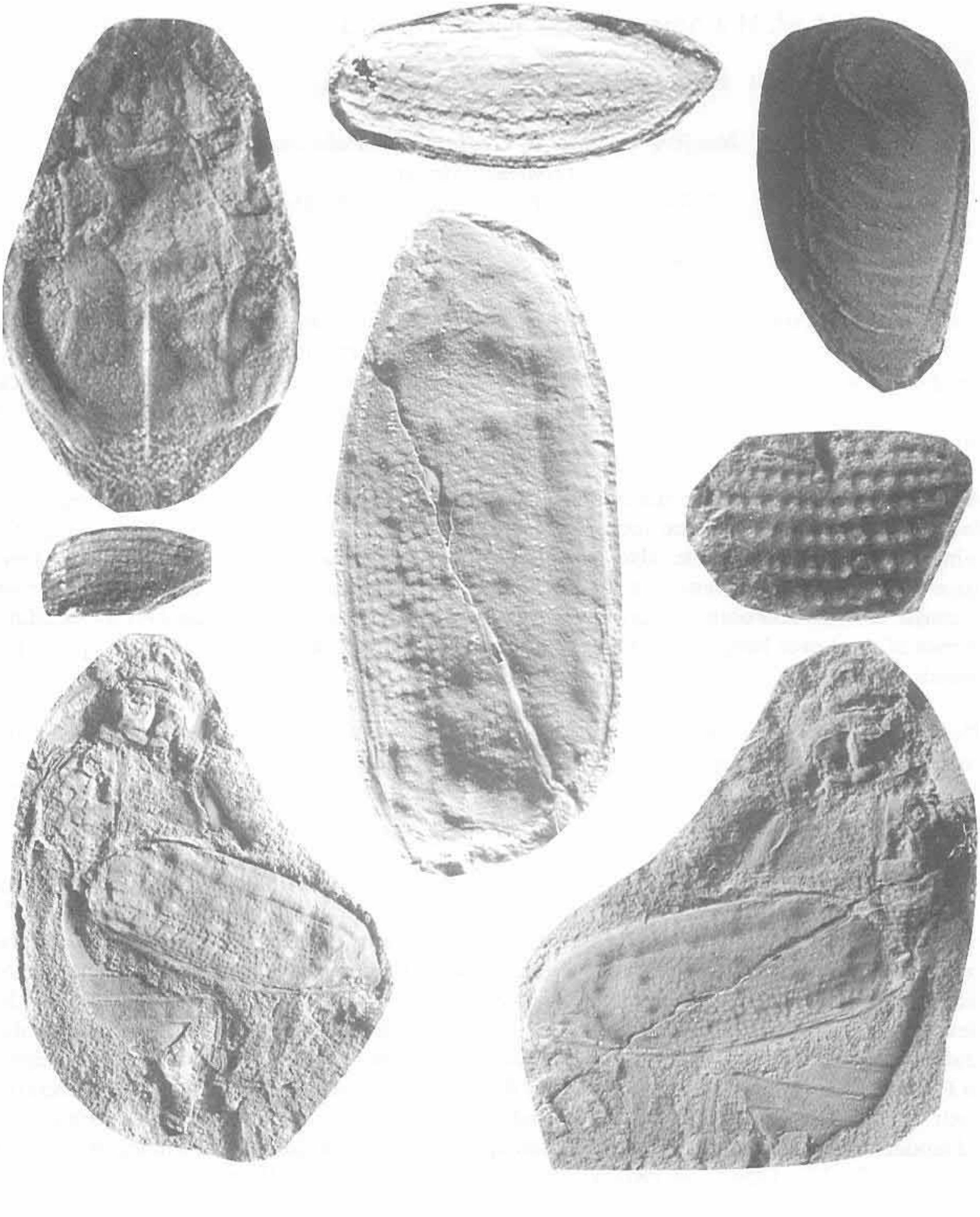

Plate III Insect fossils from the Ping Chau Formation

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DISCOVERY OF ANGIOSPERM FOSSILS FROM HONG KONG - WITH DISCUSSION ON THE AGE OF THE PING CHAU FORMATION

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The Ping Chau Formation only outcrops on Ping Chau island at the northeast corner of Mirs Bay in the New Territories, Hong Kong; the island measures about 1.2 km^2. The strata are composed of dark grey siltstone, mudstone, marlite and shale, intercalated with a 0.61 m thick layer of cherty sandstone. The shale does not occupy a predominant position, and its thickness is not great.

Almost all of the rocks are dolomitic, while bitumenized plant ichnofossils are frequently found on the surface of some rocks bearing rich pyrite all over the island. The authigenic minerals zeolite and acmite also appear on the rock surface. The zeolite is abundant, appearing at the upper horizons of the Ping Chau Formation in the form of columnar or granular crystals and oolitic or porphyritic crystals. The acmite is distributed on the bedding planes of the lower horizons of this formation in the form of radial aggregates or gypsum (?) pseudocrystals.

These deposits were probably laid down under brackish water conditions, and cannot be easily correlated with other deposits in Hong Kong. The dip of this formation is gentle, with a thickness of at least 132 to 305 m or even more (Nau 1979 p 33, 36; Allen & Stephens 1971 p 5; Williams 1943 p 99).

The Ping Chau Formation yields abundant plant and insect fossils, which were discovered by Williams from the west shore about half a mile north of Tai Tong as early as in 1924-1925; elsewhere, Brock also obtained some fossil-like imprints (Williams 1943 p 99). Seward considered that one of Williams' specimens was a forked racnis, and the other, a single leaflet, appeared to be a pinnule of *Neuropteris*, but it could not be said with certainty. In Seward's opinion, the large specimen in Brock's material was analogous in appearance to the leaf axis of a modern palm. There was a pinnate frond on the same slab, which might belong to Ptilophyllum or probably to *Otozamites*, implying a Jurassic age. It is difficult to identify such a large specimen: the opinion that it is analogous to a palm was probably a misunderstanding. It is similar to an imprint specimen from the Jurassic of France, which had been described by Lignier in 1907 as *Propalmophyllum liasium*. However; no evidence has been found to support the existence of palms in the Jurassic.

Based on Seward's opinion, Williams considered the age of the Ping Chau rocks as Jurassic, possibly Lias. In addition, Williams also discovered the fossil elytrum of an insect. Cockerell considered that this elytrum appeared to represent some kind of otiorhynchid weevils, which he described as a new species, *Otiorhynchites williamsi*. In his opinion, the otiorhynchid weevils were rather abundant and characteristic during the Eocene, and they undoubtedly appeared in the Cretaceous. However, at present we know very little about these insects older than Eocene. In his conclusion he stated that *Otiorhynchites williamsi* was not available for determining the age of the Ping Chau rocks, because it might be Cretaceous, Eocene or even later. Williams said Cockerell wrote later of the possibility that the beetle's age was Late Jurassic, but not Lias.

Heanley's bitumenized plant ichnofossils were collected from the northwest corner of Ping Chau. In his personal correspondence with Heanley, Seward considered these fossils as probably belonging to the Early Cretaceous or Late Jurassic.

All these are the earliest palaeontological discoveries related to Ping Chau rocks, with opinions on geological ages varying from Jurassic (probably the Lias), Late Jurassic, to Late Jurassic-Early Cretaceous. Thus it can be seem that there exists great difficulties in determining the geological age of the Ping Chau rock formation.

In February and September-October, 1989, the Specialized Research Group carried out a large amount of geological field work on the Ping Chau Formation of Ping Chau island, with the collection of abundant fossil plants and a certain number of insect fossils. Most attractive is the discovery of relatively numerous angiosperm fossils, with various types of monocotyledonous leaves, and dicotyledonous leaves, flowers, fruits and seeds, bringing forth a new hope of further exploration into the age of the Ping Chau Formation.

The angiosperms originated from the late Early Cretaceous. They were rather few both in species and in number during the first stage of their development, but they flourished, even occupying a predominant position in the plant kingdom after the Late Cretaceous. Therefore, the fact itself that angiosperms were discovered from the Ping Chau Formation has determined the geological age of this formation as not older than the late Early Cretaceous, thus ruling out the opinions of previous scholars who determined the age of the Ping Chau Formation as Jurassic to early Early Cretaceous.

What age should the Ping Chau Formation actually be attributed to? This paper explores the geological age of the Ping Chau Formation based on the fossil plant material contained therein. According to a preliminary identification, the plant fossils collected in this study include more than 40 species, which are taxonomically listed as follows:

- Pteridophyta
  - Equisetales: *Equisetum?* sp
  - Filicales: *Salvina?* sp, *Adiantopteris* sp, Filicinae (a fertile pinna), pteridophyte (pinnules of various species)
- Gymnospermae
  - Cycadopsida
  - Bennettitales: *Otozamites* sp (? sp nova), *Otozamites?* sp (? sp nova), *Otozamites?* sp, *Otozamites* sp, *Dictyozamites?* sp
  - Cycadophyte: small pinna
- Coniferopsida
  - *Brachyphyllum* sp (sp nova), *Brachyphyllum* sp, *Brachyphyllum?* sp, cf *Glyptostrobus europaeus* (Brongn) Heer, *Glyptostrobus?* sp, *Sphenolepis? densifolia* Cao, cf *Sphenolepis kurriana* (Dunker) Schenk, *Schizolepis* sp, *Pityolepis* sp, *Pityolepis?* sp
  - Coniferales: branches and leaves of various kinds

Angiospermae

Dicotyledoneae

Cinnamomum sp, *Nectandra* cf *guangxiensis* Guo, cf *Ocotea sinensis* Guo, *Cercis?* sp, *Trapa?* sp, *Leguminosites?* sp, Juglandaceae, *Dicotylophyllum* spp, *Dicotylophyllum?* sp

Monocotyledoneae

Sabalites sp, *Cyperacites* sp, *Cyperacites?* spp, *Monocotylophyllum* spp, *Monocotylophyllum?* sp

Flowers, fruits and seeds of Angiospermae

Antholithes? sp, *Antholithes?* sp (*Carpites?* sp), *Carpites* spp, *Carpites?* spp

Others: leaf fossils, leaves of aquatic plants?

In the condition of preservation, the fossil plants collected are rather fragmentary, and mostly tough and tensile. In particular they are those rather strongly cutinized, coriaceous or xylemized plants, or the relatively tough and tensile parts of certain plants, such as the branches or leaves of Coniferales, the pinnae and their fragments of cycadophyte, the leaves of monocotyledons, the fruits and seeds of angiosperms, etc.

The comparatively tender and delicate parts are poorly preserved, such as the fronds of pteridophytes and the leaves of dicotyledons, indicating that these plants had undergone a process of transportation before they were preserved as fossils, instead of being buried *in situ*. This would inevitably bring difficulties to our identifying work, and also interfere with our recognition on the overall features of the floras in this area.

In spite of all these, from the list of this plant fossil group it still can be seen that the flora of the Ping Chau Formation is made up of three component parts, namely pteridophytes, gymnosperms and angiosperms. Among them, the angiosperms occupy a prominent and important position, with an outstanding dominance both in taxa and in quantity over other groups. The appearance of the angiosperms and their dominant proportion imply a younger age of this flora.

The gymnosperms in this flora occupy a proportion only next to the angiosperms, including the two genera of the Bennettitales, *Otozamites* and *Dictyozamites*. The Bennettitales were a group of extinct plants, which made its first appearance in Late Triassic, and became flourishing in the Jurassic and then began to decline in the Early Cretaceous; according to the present record, they became completely disappeared in the Late Cretaceous.

As the principal elements of the gymnosperms in this flora, the coniferales are distributed very extensively over Ping Chau, and can be found in almost all of the horizons containing fossil plants. Of course, this is related to the comparatively tough and tensile structures of these plants which could stand transportation and were suitable for preservation as mentioned above.

The pteridophytes occupy a much less important position in this flora, and are very few both in taxa and in number. Such a composition is extremely similar to that of the Late Cretaceous and Cenozoic floras, because the Late Cretaceous-Cenozoic floras are also dominated by angiosperms, which differ from the Mesozoic floras dominated by gymnosperms and from the Palaeozoic floras dominated by pteridophytes and pteridosperms.

Among the discovered angiosperms, the dicotyledons *Cinnamomum* and *Nectandra* first appeared in the early Late Cretaceous; they occurred in abundance in the Tertiary and continued to flourish up to the present time. *Nectandra guangxiensis* was discovered from the Bali Formation (K_2^1) of Yongning, Guangxi; while *Ocotea sinensis* occurred in the Changchang Formation (Late Palaeocene to early-middle Eocene) of Hainan Island.

The genus *Trapa* is extensively distributed in Late Cretaceous to Tertiary and persists to the Recent in the Northern Hemisphere; in China it can be found from the Late Cretaceous (*Trapa microphylla*) and early Pleistocene (*Trapa? natans* L) of Heilongjiang, the Eocene Series of Fushun, the Pliocene Series of Eryuan, Yunnan, and from the deposits of the Late Tertiary lignite basin in the Central part of Yunnan Province. In addition, plants of this genus (*Trapa paulula*) also have been found to occur in the Second Member of the Buxin Formation (early Tertiary) at Honggang, Sanshui, Guangdong.

The genus *Leguminosites* is distributed in the Tertiary of the Northern and Southern Hemispheres; in China, plants of this genus also have been discovered from the Xigaze Group (K_2 of Xizang and the Upper Member of the Hunchun Formation (K_2) in Jilin. The genus *Cercis* is distributed in the Eocene Series to the Pleistocene Series of North America and the Oligocene of Europe; in China, plants of this genus also have been discovered from the Oligocene Series of Jinggu, Yunnan and the Shanwang Formation (Miocene) of Shandong.

Among the monocotyledons, the genus *Sabalites* of the Palmae made its first appearance in the Late Cretaceous; it was distributed very extensively in the Northern Hemisphere during early Tertiary, but began to decline gradually during late Tertiary. In China this genus was distributed in the Eocene Series of Fushun and the Tertiary of Guangdong and Guangxi.

The genus *Cyperacites* is distributed in the Cretaceous (K_1^2) to Tertiary in different parts of the world; in China this genus is also distributed in the Shanwang Formation (Miocene) of Linqu, Shandong, and the Xigaze Group of the Jolmo Lungma District in Xizang (Tibet).

Among the pteridophytes, the genus *Salvina* is distributed in the Late Cretaceous up to the Recent; in China it has also been discovered from the Dayu Group (K_2) of Benxi, Liaoning, the Eocene Series of Fushun, and the Changchang Formation of Hainan Island.

The genus *Adiantopteris* is distributed in the strata of the Late Triassic (Carnic) and the Early Cretaceous in Japan; it is also distributed in the Upper Jurassic to Lower Cretaceous strata in Siberia of USSR and Northeast China (Kimura & Ohana 1987).

The gymnosperms appear to be a little older in features, with only a slightly younger genus *Glyptostrobus* ranging from Late Cretaceous to Recent. The species *Glyptostrobus europeaus* has been discovered from the Eocene in Fushun, Liaoning, and the strata of Late Cretaceous (Senonian) in Hunchun, Jilin. All the others are Mesozoic elements, such as *Brachyphyllum*, *Otozamites*, etc, with their youngest forms discovered from the Late Cretaceous. *Sphenolepis? densifolia* has been discovered from the Dongshan Formation (K_1) of Dongshan, Heilongjiang. *Sphenolepis kurriana* is an element of the Wealden (K_1^1) in West Europe, and also can be found in the Potomac Group of North America; in China it appears in the Chengzihe Formation (J_3-K_1) and its overlying strata, the Muleng Formation (K_1^1) in Jixi, Heilongjiang. *Schizolepis* is distributed in the strata of Late Triassic to Late Jurassic or early Early Cretaceous in the Northern Hemisphere, while *Pityolepis* is also distributed in the strata of Late Jurassic to Early Cretaceous in the Northern Hemisphere.

The following is a summary of the geological and geographical distribution of the elements from the flora of the Ping Chau Formation as mentioned above:

1 There are 7 genera confined to the Mesozoic in distribution, namely *Adiantopteris*, *Otozamites*, *Dictyozamites*, *Brachyphyllum*, *Sphenolepis*, *Schizolepis* and *Pityolepis*, among which *Brachyphyllum* and *Otozamites* might persist up to Late Cretaceous.

2 There are 9 genera and species which made their first appearance in the Late Cretaceous, namely *Salvina*, *Glyptostrobus europaeus*, *Cinnamomum*, *Nectandra*, *Trapa*, *Leguminosites*, Juglandaceae, *Cyperacites* and *Sabalites*.

3 Two of the genera and species only appeared in the Tertiary ever before, ie, *Ocotea sinensis* and *Cercis*.

4 Five genera of the plants had already appeared in Cretaceous but only flourished in the Tertiary, including *Cinnamomum*, *Nectandra*, *Trapa*, *Leguminosites* and *Sabalites*.

As mentioned above, the appearance of angiosperms in the Ping Chau Formation has determined the geological age of this formation as at least later than the late Early Cretaceous. However, no angiosperm groups of the late Early Cretaceous have been found to appear in this formation. In addition, according to statistical data, the angiosperm fossils are very few in number during the early stage (late Early Cretaceous) of its appearance, occupying only 25% of the total number. However, among the flora of the Ping Chau Formation, the angiosperms occupy a dominant proportion.

All these have determined the age of the flora from the Ping Chau Formation to be unlikely to belong to the late stage of Early Cretaceous. Among the plants with older features there are two genera, *Otozamites* and *Brachyphyllum*, which might have a distribution up to the Late Cretaceous. While among the plants with younger features, there are 9 genera and species occurring in the Late Cretaceous. Since in the Late Cretaceous, younger and older elements occurred together in relatively great abundance, the Ping Chau Formation may be tentatively determined as Late Cretaceous in age. On the other hand, there are also somewhat younger elements in the Ping Chau Formation. As mentioned above, two of the genera and species appeared only in the Tertiary; while among those plants appearing in the Late Cretaceous, five genera of them were comparatively flourishing in the Tertiary. For this reason, it is not impossible that the Ping Chau Formation might be Tertiary in age.

The flora of the Ping Chau Formation is a flora full of contradiction. It is not feasible to determine the age wholly based on either the older forms or the younger forms. However, it seems more appropriate to temporarily determine the age as Late Cretaceous taking into consideration both forms.

The co-existence of older and younger elements may be briefly interpreted as follows:

1 Such a phenomenon is related to the extent of research work, and is especially influenced by palaeontological discoveries and the extent of studies in this field. Of course, this also has something to do with the living and burying environments of the organisms. In the vast expanse of China, the Late

Cretaceous and Early Tertiary were mostly red beds, and the climate was dry and unfavourable to the growth of plants. As a result, only a small number of fossil localities have been discovered, and the research work is also comparatively insufficient. For this reason, people still have not much knowledge about whether those plants occurring in the terminal stage of the Mesozoic might persist to the Cenozoic, such as some of the above mentioned Bennettitales elements and Coniferales plants discovered from the Ping Chau Formation. The fact that these plants have not been discovered from younger strata would make people have an impression about the older features of these plants. Likewise, those elements discovered from the Tertiary would be taken as younger forms when they have not been found from the Cretaceous.

2 The Coniferales plants have a stronger adaptability to their environments. At the present time, the Coniferales have a very extensive distribution in China from south to north, and from the tropics to frigid zones. However, particular examples also can be found. One of them is the *Metasequoia*, which has been flourishing in the border area between Sichuan and Hubei in China all along up to the Recent, and has thus become a famous relict plant. Of course, the environments there have not undergone abrupt changes since the Tertiary. For this reason, it is not impossible that some plants of the Coniferales which were flourishing in the Mesozoic might persist to the early stage of the Cenozoic under a specific environment, such as *Brachyphyllum*, etc. Likewise, it is also possible that some elements of Bennettitales might survive in the early stage of the Cenozoic, such as *Otozamites* and *Dictyozamites*. A precedent like this can be found in Guizhou, where the genus *Gigantopteris*, which was flourishing in the Permian, became a remaining element in the Feixianguan Formation (T_1) in the early stage of the Mesozoic (Wu *et al* 1982). Nevertheless, such case is merely a possibility; one should still maintain a careful attitude before it has become a fact, and this is also the reason why the age of the Ping Chau Formation has been tentatively determined to be the Late Cretaceous as mentioned above.

The Ping Chau Formation also yields sporopollen fossils, which have been analyzed and identified by Nanjing Institute of Geology and Palaeontology, Academia Sinica, with the age determined as Late Cretaceous. The following is a list of these sporopollen fossils:

Pteridophyta: *Pterisisporites*, *Lygodiumsporites*, *Verrutetraspora*, *Schizaeoisporites*

Gymnospermae: *Pinuspollenites*, *Abietineaepollenites*, *Taxodiaceaepollenites*, *Podocarpidites*, *Rugubivesiculites*

Angiospermae: *Ulmipollenites*, *Subtriporopollenites*, *Rhoipites*, *Aquiapollenites crassus* Song, Li et Zhang, *Jianghanpollis*, *Jiangsupollis striatus* Song

According to rough statistical data, about half of the above 17 genera are distributed in the Lower Tertiary of South China, including *Pterisisporites*, *Lygodiumsporites*, *Abietineaepollenites*, *Ephedripites*, *Ulmipollenites*, *Ulmiodeipites*, *Plicapollis* and *Quercoidites*. Therefore, it is not absolutely impossible that the age of these sporopollen plants might be dated to the Early Tertiary.

In addition, the Ping Chau Formation also yields fossil insects, which have been identified by Nanjing Institute of Geology and Palaeontology, Academia Sinica, as; cf *Liutaiproshole* sp, Gyrinidae, *Coleoptera* sp, Cicadellidae, Bibiorridae, etc. Their age has been determined as the Cretaceous(?), with some forms, however, being regarded as Tertiary in age. This indicates that there is not much conflict between the age determined by the distribution of sporopollen and insect fossils, and that determined by plant fossils. This determines the age of the Ping Chau Formation as Late Cretaceous, but not ruling out the possibility of belonging to the early stage of the Tertiary.

In South China, no angiosperm-bearing floras have been discovered from the late stage of the Early Cretaceous. Late Cretaceous floras are found from the Bali Formation (K_2^1) of the Shiwandashan District, Guangxi, including the Coniferales *Brachyphyllum rhombimamiferum* Guo, and the angiosperms *Cinnamomum hesperium* Knowlton, *Cinnamomum newberryi* Berry, *Nectandra prolifica* Berry, *Nectandra guangxiensis* Guo, etc (Guo 1979a p 223-224).

The Early Tertiary floras in South China can be found from the Buxin Formation (early-middle Eocene) in the Sanshui Basin, Guangdong, containing the bryophyte *Marchantites* sp, the pteridophytes *Equisetum* sp and *Lygodium kaulfassii* Heer, and the angiosperms *Palibinia angustifolia* (Li) Li, *Palibinia laxifolia koronia*, *Cinnamomum naitoanum* Huzioka et Takahasi, *Goeppertia ovalifolia* Engelhardt, *Euommia brevirostria* Guo, *Trapa paulula* (Bell) Brown, etc (Guo 1979a p 225-226).

In South China the Early Tertiary flora also can be found from the Changchang Formation of the Changchang Group in the Changchang Basin of Hainan Island, containing the pteridophytes *Osmunda lignitum* (Giebel) Stur. and *Salvina* sp, and the angiosperms *Cyclocarva scutellata* Guo, *Nelumbo protospeciosa* Saporta, *Cinnamomum larteti* Watelet, *Ocotea sinensis* Guo, *Citrus niger* Guo, *Sabalites szei* Guo, *Sabalites changchangensis* Guo and *Nordenskioldia borealis* Heer (Guo 1979a p 226).

In addition, this flora can be seen in the Nadu Formation (late Palaeocene to early-middle Eocene) of the Shangsi Basin, Guangxi, with the angiosperms *Dryphyllum puryerensis* Berry, *Sabalites szei* Guo, *Sabalites changchangensis* Guo, etc, and also in the Lower Member (Eocene) of the Nadu Formation in the Haiyuan Basin of Ningming, Guangxi, with the angiosperm *Nelumbo nipponica* Endo (Guo 1979a p 226-227).

The flora of the Ping Chau Formation shares three genera in common with the Bali Formation of Guangxi, namely *Brachyphyllum*, *Cinnamomum* and *Nectandra*. It also shares three genera in common with the Buxin Formation (early-middle Eocene) in the Sanshui Basin of Guangdong, ie, *Equisetum*, *Cinnamomum* and *Trapa*, and four genera in common with the Changchang Formation of the Hainan Island, ie, *Salvina*, *Cinnamomum*, *Ocotea* and *Sabalites*.

As compared with the above-mentioned two floras of different ages from three difference localities, the flora of the Ping Chau Formation is much more abundant. The members of our Specialized Research Group and colleagues from Hong Kong, altogether up to seven persons, have spent more than ten days in collecting palaeontological specimens over Ping Chau, which has a total area of only 1.2 km^2. It should be admitted that the extent of research work on the Late Cretaceous-Early Tertiary strata and palaeo-organisms appears to be far inferior to that on Palaeozoic and Mesozoic. Nevertheless, starting from the present data, we would like to put forth a bold viewpoint on a Late Cretaceous age for the Ping Chau Formation.

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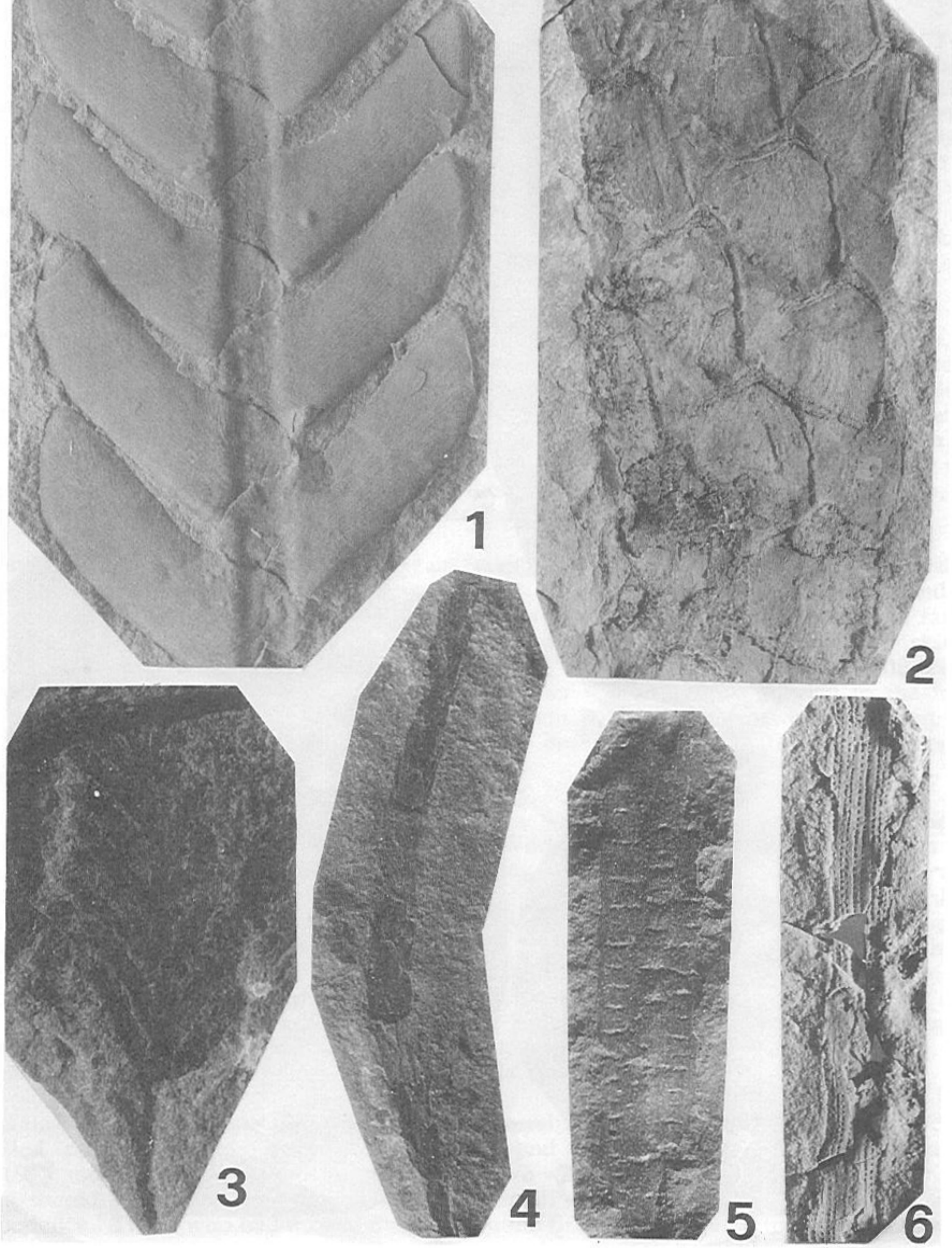

Plate 1 1 *Otozamites* sp (?sp nova); 2 *Brachyphyllum* sp (sp nova); 3 *Sphenolepis? densifolia* Cao; 4 cf *Glyptostrobus europaeus* (Brongn.) Heer; 5 *Monocotylophyllum* sp 1; 6 *Monocotylophyllum* sp 2; (all enlarged)

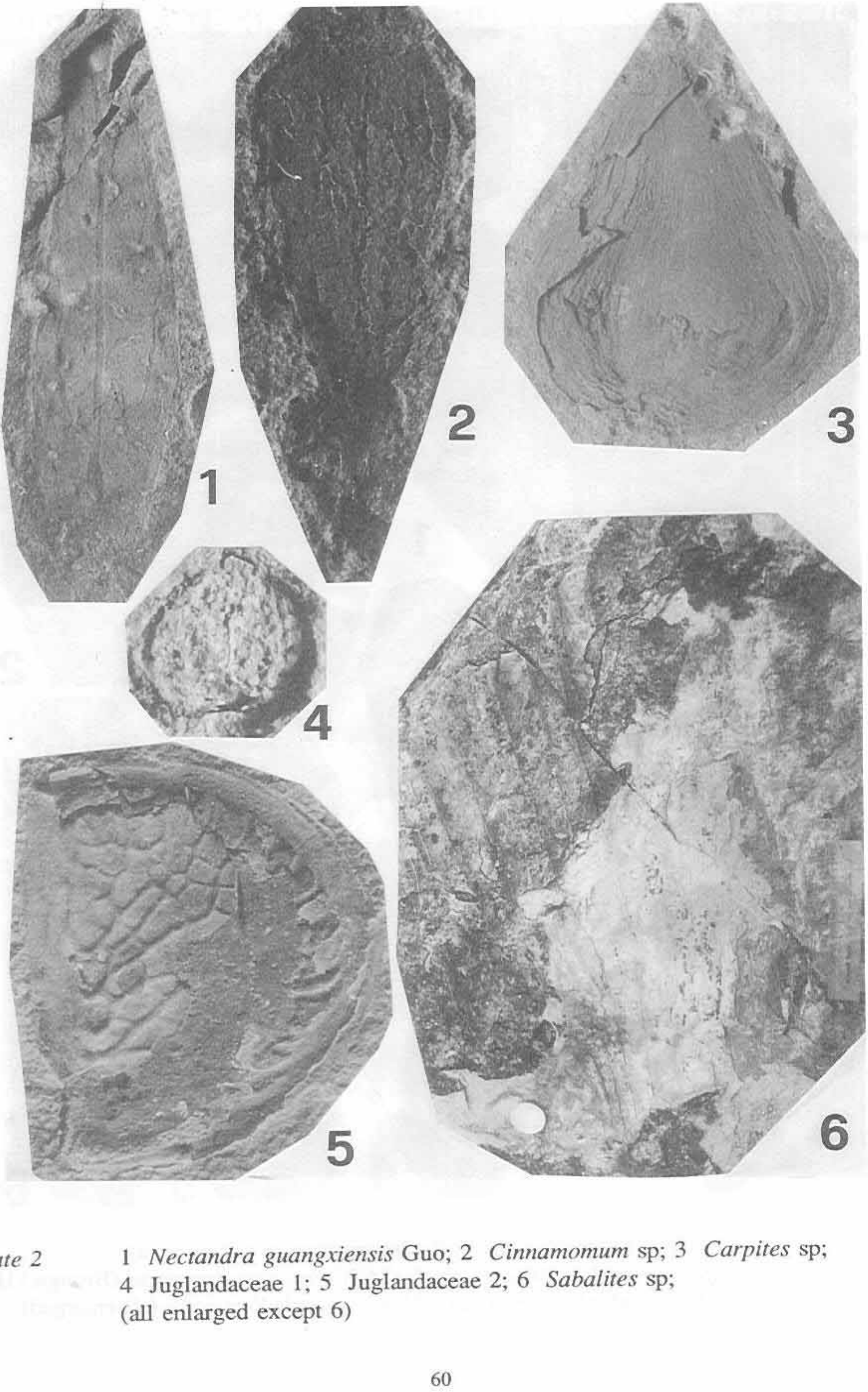

Plate 2 1 *Nectandra guangxiensis* Guo; 2 *Cinnamomum* sp; 3 *Carpites* sp; 4 Juglandaceae 1; 5 Juglandaceae 2; 6 *Sabalites* sp; (all enlarged except 6)

VISIT BY THE HONG KONG GEOLOGICAL SOCIETY TO EAST GUANGDONG AND SOUTH FUJIAN
22-30 December 1990

Dr Brian G Dutton

(A brief description of some of the "highlights" by a non-geologist member of the party.)

When invited to joint the expedition by an old friend from university days, I leapt at the opportunity to visit a part of China "off the beaten track", and so it was that I found myself on the Saturday afternoon at the China Ferry Terminal as the oldest member of a group which included seven other non-geologists and had, as its youngest member, Benjamin, aged $3^1/_2$.

Our first night was spent at sea, on board the ship Nan Hu and was memorable for the seemingly random way in which various members found themselves berthed in cabins taking from one to eight, and for the first of many Chinese-style breakfasts which were to include such delicacies as chickens' feet, fishballs and various soups.

Next day in Shantou, after settling in to the first of a series of government guest houses, all comfortable and well-equipped but possessed of a variety of individual plumbing systems which required careful research and experimentation to get the best results, we made a long but exhilarating climb to see microlitic granite containing vugs of crystals and incorporating also a shrine. This was followed by a visit to a manifestation of the Tropic of Cancer in the form of a large ball representing the earth pierced by a hole and supported on pillars. It was claimed that by standing on a small circle on the ground and looking up through the hole, the sun would, at a certain moment pass overhead and cast no shadow.

Monday 24 December saw us at sea again, taking a 2½ hr sail to the "closed" island of Nan'ao where, were reliably informed, we were the first Caucasians to be allowed to land for many years. Be that as it may, there was no doubt that western children were a real rarity, for time and again, the local ladies would dart out to touch their hair, or stroke their skin in disbelief. It was here that we saw our first 'seismic evidence' in the form of the displaced steps of a temple. It was Christmas Eve, and after dinner we paid a visit to the local seismological station. There were but few street lights and, on emerging and looking up at the brilliantly starry sky, one could easily imagine one saw the star of Bethlehem amongst them.

Christmas Day started dramatically. We were woken around 6 am not by the sound of Santa's sleighbells but by the cry of "fire"! Dr. Workman's children's room exhaust fan had caught fire and the flames had ignited the polystyrene ceiling tiles, filling their room with black sooty smoke. Fortunately, they had earlier noted the location of the fire extinguishers and no real harm was done. The day was mostly spent travelling, first back to Shantou by boat and then on to Dongshan Island, visiting a Tungsten mine on the way. Although we were allowed to walk along a horizontal tunnel, well-lit and carrying an electric rail-line, it proved impracticable for us to descend the shaft. The day finished with a visit a night club in a four- star hotel fully equipped with strobe and flashing lights and playing a range of music from waltzes to disco. In this part of China, mixed sex dancing is not customary, and the couples dancing were either 2 boys or 2 girls.

Boxing Day we stayed on Dongshan making several local visits including one to a circular walled "compound" of houses, three stories high and somewhat damaged by the earthquake in 1918 and by Japanese bombs more recently. We were invited to visit a house; the kitchen was shared by three well-behaved pigs in a small sty and overall it was a fascinating experience. Those who had missed the disco on the first night made up for it on the second!

The 27th saw us making the longest drive of the trip-right down to Haifeng but the day was agreeably interspersed at Lingchitsen with a walk to an outcrop of ultrabasic rocks where we were told, occurrence of diamonds had been anticipated but, alas our party, despite some intensive hammering, failed to locate any!

Next day was dedicated to more local trips, including the Yingpingshan tin ore mine. This was unfortunately closed for maintenance but, whilst this meant that once again we could not descend the mine, our guide borrowed a geological hammer to break open the processing plant gates to allow us to see the machinery. We also visited a totally self-contained Agricultural Commune where we were yet again besieged by local children fascinated to view Western and Hongkongian visitors.

Our final night was spent at Huidong and on the journey down, we visited a lead mine and it was a case of third time lucky! We were allowed down and so, duly equipped with hard hats and torches, most of us descended to the second level, and then were walked some way along the actual tunnels. On emerging, it was a time for photographs so we could prove to our friends how brave we had been! The evening saw us participating in a splendid banquet (not the first of the trip) and it was my privilege to express the appreciation of the non-geologists to both our Chinese hosts and to the Geological Society itself for this unique opportunity to gain an insight into present-day China, and to experience the overwhelming friendliness of its people.

On Sunday it was time to return to Hong Kong but not before we had done some successful fossil-hunting, finding a lower Jurassic ammonite, and being stopped by customs officials on suspicion of smuggling. Then, as if in some mysterious acknowledgment that the trip was over, the skies darkened and the first rain of the trip descended after a week of perfect weather.

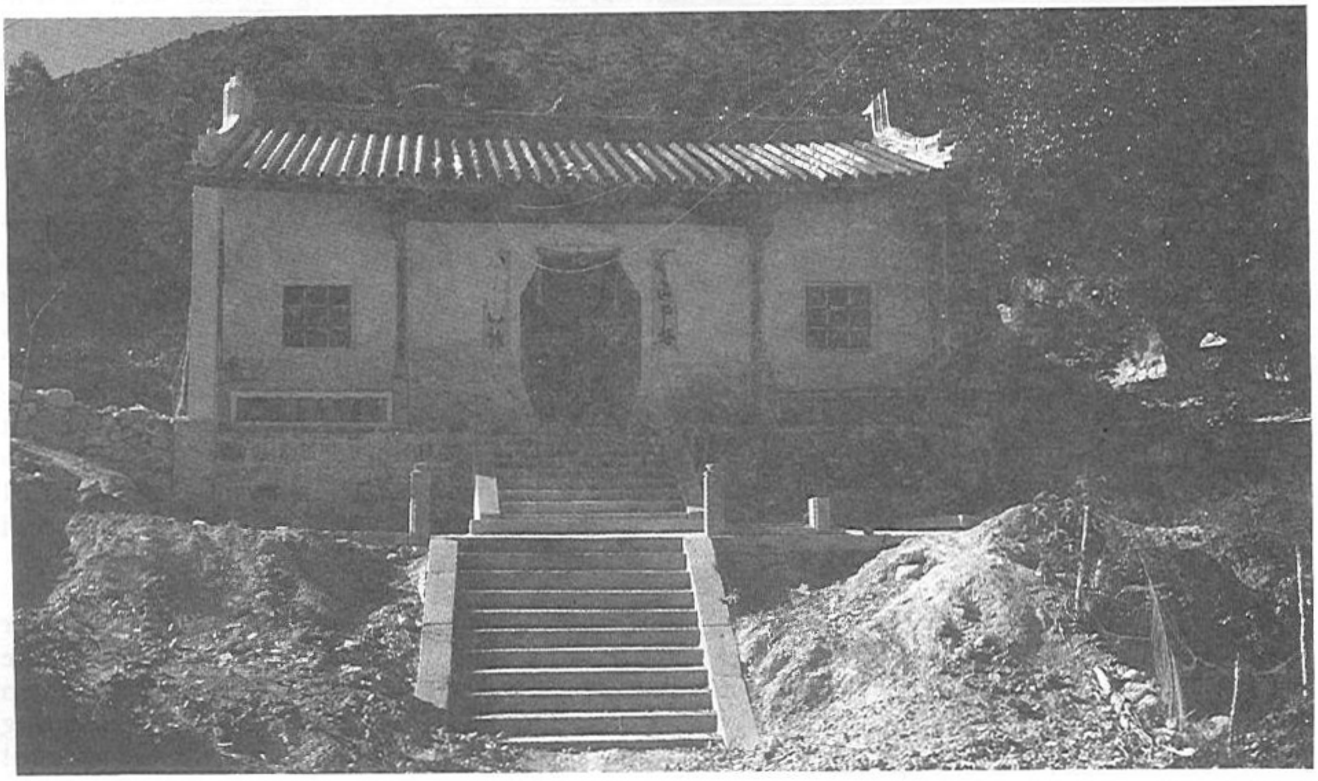

Plate 1 Temple on Nan'ao, with steps laterally displaced in the 1918 earthquake

ANNOUNCEMENTS

From the Editor

The first issue of the 1991 Newsletter is being printed using a laser printer, continuing the policy of 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. Please consider very carefully whether you have any material which is suitable, and send it to us for publication. If you have an interesting photograph we can publish it without the need for text.

Karst geology in Hong Kong

Bulletin No 4, "Karst geology in Hong Kong", should be available from the printers soon. Any conference participants will automatically receive their copy. Any orders for copies should be sent, with HK$ 100 in draft or cheque (payable to 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 will address aspects of seismicity, tectonic geology, seismic hazards and earthquake countermeasures, with an emphasis on the problem of seismicity and earthquake hazards reduction in Eastern Asia and neighbouring areas. The conference is organized by the Geological Society of Hong Kong with the support and cooperation of the Guangdong Seismological Society. The second circular and further details can be obtained from K W Lee, Charles Haswell and Partners (Far East) Ltd, 3/F Bay Tower, 2-4 Sunning Road, Causeway Bay, Hong Kong.

Annual General Meeting

The Society will hold its AGM in May, and members will be advised in a circular of the details. All committee posts are by election, but please note that it takes time to organize a postal ballot in the case of more than one nomination for a post. Please send nominations for committee positions, proposed and seconded by Society members, to the Secretary.

BOAT TRIP TO DESTINATIONS IN TOLO CHANNEL

Sunday 12 May 1991

This boat trip will provide a rare opportunity to visit Centre Island (Tolo Harbour Formation). We will also land at Fung Wong Wat/Pak Kok Tsai (Bluff Head and Tolo Channel formations) and other remote spots on the coast of Tolo Channel as time permits. A sampan will be hired for landings.

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. YOU WILL BE CONTACTED ONLY IF THERE ARE NOT ENOUGH PLACES TO ACCEPT YOUR BOOKING.

Booking slip: TOLO CHANNEL, 12 MAY 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.

GEOLOGICAL SOCIETY OF HONG KONG PUBLICATIONS LIST

Bulletin No 1 (1984). Geology of surficial deposits in Hong Kong, 177 p. YIM W W S (Editor)

Bulletin No 2 (1985). Geological aspects of site investigation, 236 p. MCFEAT-SMITH I (Editor)

Bulletin No 3 (1987). The role of geology in urban planning, 600 p. WHITESIDE P G D (Editor)

Bulletin No 4 (1990). Karst geology in Hong Kong, 239 p. LANGFORD R L, HANSEN A & SHAW R (Editors)

Marine geology of Hong Kong and the Pearl River mouth (1985), 96 p. WHITESIDE P G D & ARTHURTON R S (Editors)

Marine sand and gravel resources of Hong Kong (1988), 221 p. WHITESIDE P G D & WRAGGE-MORLEY N (Editors)

Abstracts No 1 (1983). Abstracts of papers presented at the meeting on "Geology of surficial deposits", September 1983, 79 p

Abstracts No 2 (1984). Abstracts of papers presented at the conference on "Geological aspects of site investigation", Dec 1984, 50 p

Abstracts No 3 (1986). Abstracts of papers presented a meeting on "Sea-level changes in Hong Kong during the last 40 000 years", May 1986, 51 p

Abstracts No 4 (1986). Abstracts of papers presented at the conference on "The role of geology in urban development", December 1986, 65 p

Abstracts No 5 (1988). Abstracts/Extended Abstracts of six papers presented at a meeting on "Future sea-level rise and coastal development", April 1988, 79 p

Abstracts No 6 (1990). Abstracts of papers presented at the conference on "Karst geology in Hong Kong", January 1990, 58 p

Newsletter

Vol 1 (7 issues) 1982-3	Vol 4 (4 issues) 1986	Vol 7 (4 issues) 1989
Vol 2 (6 issues) 1984	Vol 5 (4 issues) 1987	Vol 8 (4 issues) 1990
Vol 3 (6 issues) 1985	Vol 6 (1 issue) 1988	Vol 9 (2 issues) 1991

Prices (including postage in Hong Kong):

Bulletin No 1	HK$ 60	(Members HK$ 40)
Bulletin No 2	HK$ 70	(Members HK$ 50)
Bulletin No 3	HK$ 130	(Members HK$ 100)
Bulletin No 4	HK$ 100	
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Cover photograph: Oblique aerial photograph of the opencast workings at Ma On Shan magnetite mine, with slope instability seen above the mine benches. Photograph courtesy of Geotechnical Control Office.

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