GEOLOGICAL SOCIETY OF HONG KONG

香港地質學會

NEWSLETTER

通 訊

第八卷 第三期 一九九零年九月 Vol. 8, Part III, September 1990

GEOLOGICAL SOCIETY OF HONG KONG

NOTES FOR THE GUIDANCE OF CONTRIBUTORS TO THE NEWSLETTER

GENERAL: Articles of a technical nature, as well as reports of interesting events, reviews and other topical items are welcome. Contributions must be short, although exceptions may be made at the discretion of the Society. Tables, figures and half-tone plates must be kept to a minimum and must all be on separate sheets. Typescripts, enquiries and all correspondence should be addressed to the Secretary, Geological Society of Hong Kong, c/o Department of Geography and Geology, University of Hong Kong, Pokfulam Road, Hong Kong. The Society does not assume copyright of material published in the Newsletter. Any other previous, current or expected future use of such material by the author must be stated at the time of submission.

TYPESCRIPTS: Typescripts must be accurate, legible and in their final form. Two complete copies must be sent to the Secretary. Typescripts should be double-spaced, including references, on one side only of A4 paper, with 25 mm margins on all sides. All pages should bear the authors name and be numbered serially. Text supplied on diskette using any conventional word processing package (Wordperfect, Wordstar, Multimate, etc) is preferred to hard copy.

ILLUSTRATIONS: Send the originals of all illustrations, each marked with the author's name. Diagrams should be in black on tracing material or smooth white paper or board, with a line weight suitable for reduction. A metric scale should be included, and North Point (or where relevant, coordinates of latitude and longitude) on all maps. Avoid using fine tones and lines on figures that are likely to be reduced.

REFERENCES: The author is responsible for ensuring that all references are correct. The list of references should be given in full, with no abbreviations.

OFFPRINTS: The Society does not provide authors with free offprints of items published in the Newsletter, but will obtain quotations on behalf of authors of technical articles who may wish to purchase offprints from the printer.

CONTENTS

Geological Society of Hong Kong Newsletter Vol 8 Pt 3 p 2-12

NEW DEBRIS FLOW ON THE FLANKS OF TSING SHAN, HONG KONG

R L Langford[1] & D Hadley[2]

1 *Hong Kong Geological Survey, Geotechnical Control Office*
2 *Scott Wilson Kirkpatrick & Partners*

Abstract

During the night of 10/11 September 1990, a minor local slope failure on the flanks of Tsing Shan (Castle Peak) developed into a major debris flow and deposit. The initial ground movements occurred at an altitude of about 400 mPD, around 200 m southeast of the summit of Tsing Shan. These resulted in a rapidly developing erosional feature for over 600 m from the starting point, before giving rise to the formation of a new deposit on the relatively gently sloping ground in Area 19 of Tuen Mun. The lowest level reached by debris is about 20 mPD. The centre of the deposit is characterized by areas of boulder-rich debris. Subsequent fluvial activity, concentrated within erosional channels, has transported finer material to the bottom of the deposit.

Introduction

The mountain of Tsing Shan (Castle Peak) (583 m) is situated to the west of Tuen Mun new town in the western New Territories of Hong Kong (Figure 1). The geology of the eastern slopes of the mountain is varied, and this is reflected in its morphology. The upper, steep craggy slopes of Tsing Shan are composed of megacrystic fine-grained granite. The middle, less steep and generally grassy slopes are underlain by metasedimentary rocks of the Tsing Shan Formation (Langford *et al* 1989), visible in rare exposures on the hillside and in the stream courses that drain the mountain. To the east of the metasedimentary foothills is a further break in gradient where the slopes typically comprise deeply weathered material of the metavolcanic Tuen Mun Formation. The flanks of the mountain are also characterized by a complex sequence of debris flow deposits of Pleistocene and Holocene age (Langford *et al* 1988).

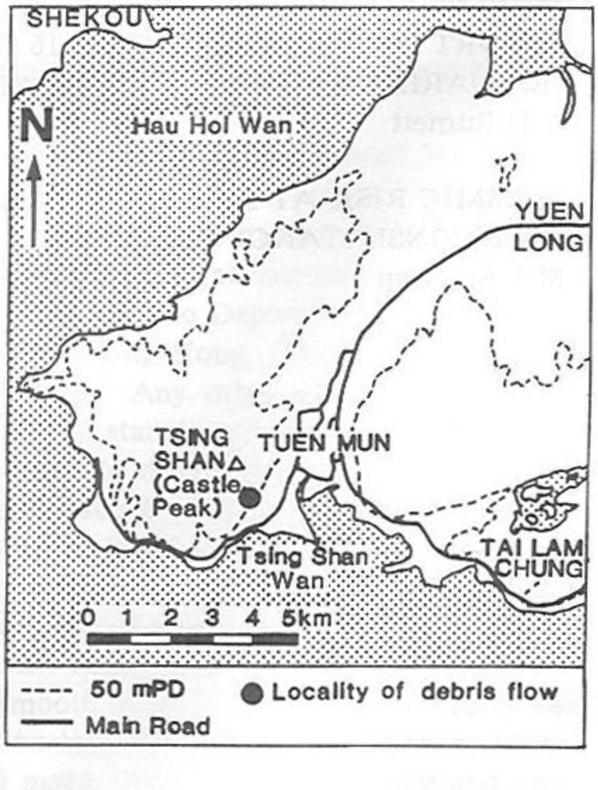

Figure 1 Locality of the new debris flow

During the night of 10/11 September 1990, probably in the early hours of the morning, a minor local slope failure high up on the side of the mountain developed downslope into the largest historically recorded natural slope failure in Hong Kong (Figure 2). The initial movements occurred at an estimated altitude of 400 mPD, most likely during a period of intense local rainfall, and the consequent large debris flow came to rest between 110 and 20 mPD within the former borrow area in Area 19 of Tuen Mun (Frontispiece).

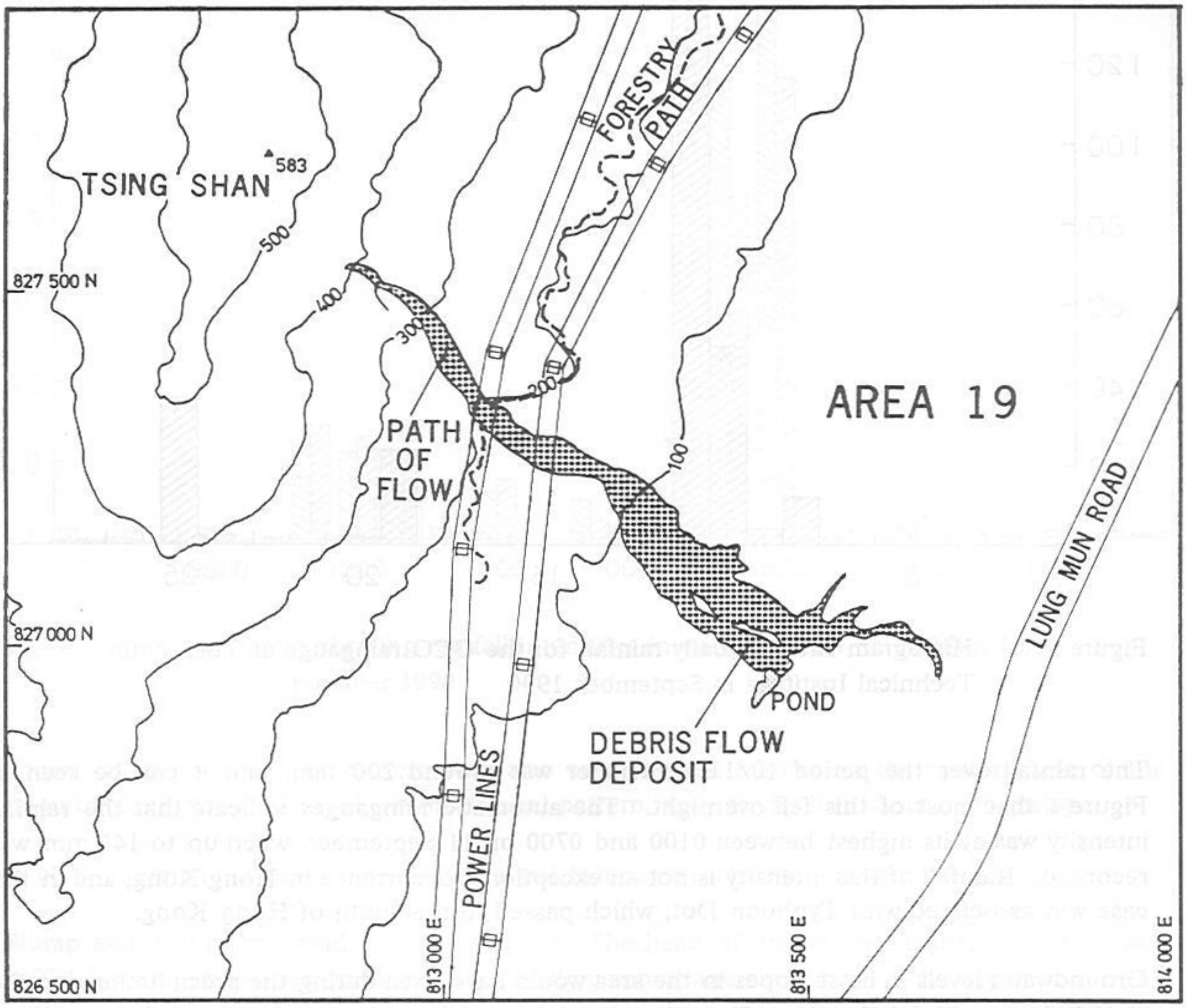

Figure 2 Sketch map showing the path of the flow and the extent of the debris deposit

This paper gives a preliminary assessment of the conditions prior to failure, the mechanism of failure, the development of the flow into a major debris flow (Varnes 1978), and its subsequent deposition at the bottom of the mountain. The field observations described in the paper were made by the authors between 11 and 21 September 1990.

Rainfall

There are three raingauges in the area; one at Tuen Mun Technical Institute in west Tuen Mun which is controlled by the Geotechnical Control Office (GCO), and a pair at Scott Wilson Kirkpatrick & Partners' (SWK's) site office in southeast Tuen Mun. One of the SWK gauges is used by the Royal Observatory as an official recording station. The daily rainfall at the GCO raingauge for September is given as Figure 3. More detailed statistics from both the GCO and SWK raingauges for 10/11 September are given as Figure 4.

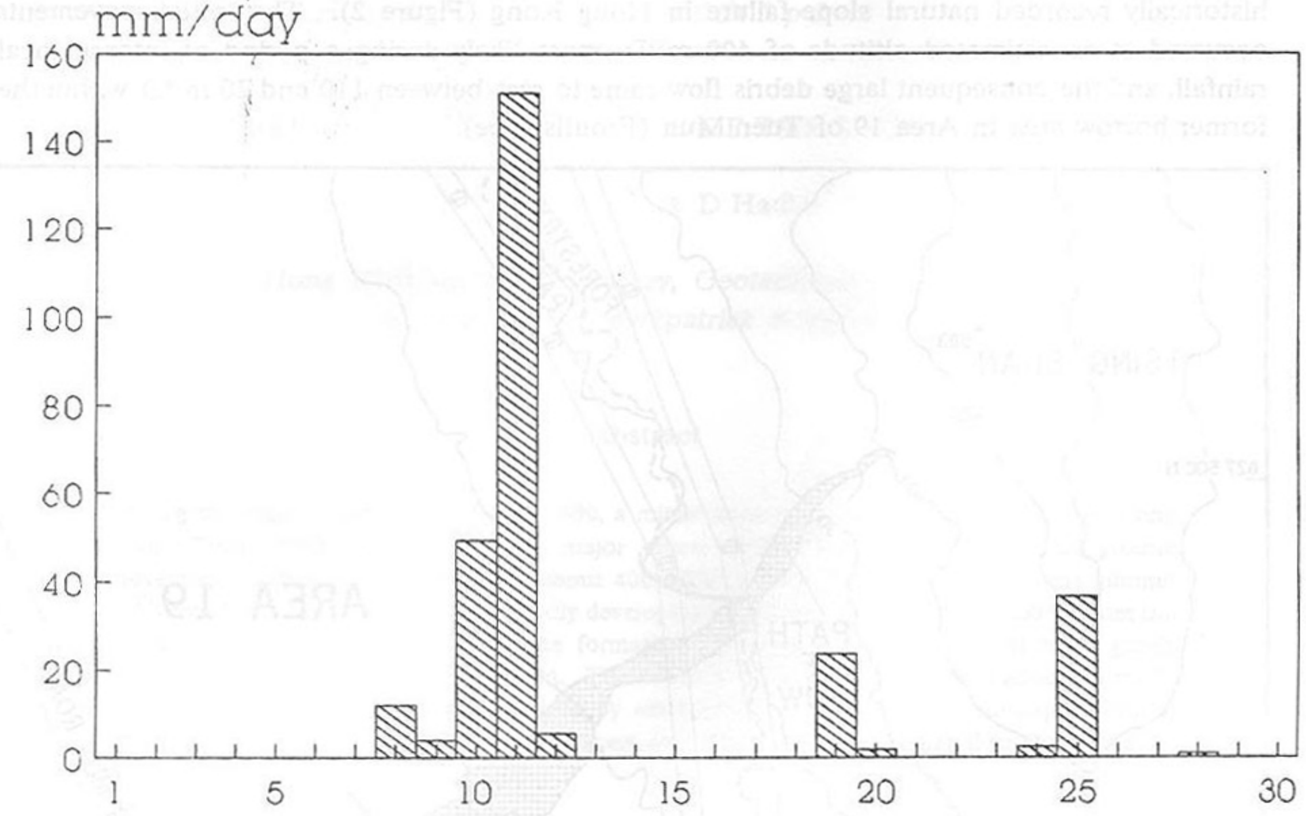

Figure 3 Histogram showing daily rainfall for the GCO raingauge at Tuen Mun Technical Institute in September 1990

The rainfall over the period 10/11 September was around 200 mm, and it can be seen in Figure 4 that most of this fell overnight. The automatic raingauges indicate that the rainfall intensity was at its highest between 0100 and 0700 on 11 September, when up to 140 mm was recorded. Rainfall of this intensity is not an exceptional occurrence in Hong Kong, and in this case was associated with Typhoon Dot, which passed to the south of Hong Kong.

Groundwater levels in most slopes in the area would have risen during the precipitation; locally, complete saturation of soil profiles must have occurred. Prior to the initial failure, which originated on very steep slopes with much exposed rock, an increase in run-off into the local drainage system would have resulted in large flows down natural drainage courses.

Morphology of the debris flow

The debris flow can be conveniently split into three parts for descriptive purposes: the area of initiation of the failure, the eroded channel along which the flow gathered bulk and momentum, and the area dominated by deposition on the shallow ground of Area 19 (Plate 1). The overall extent of the debris flow is given as Figure 2.

Initiation of the debris flow

Like many small-scale natural failures that coincide with heavy rainfall, the initial failure on the side of Tsing Shan, and the consequent development of the debris flow, had no predictable

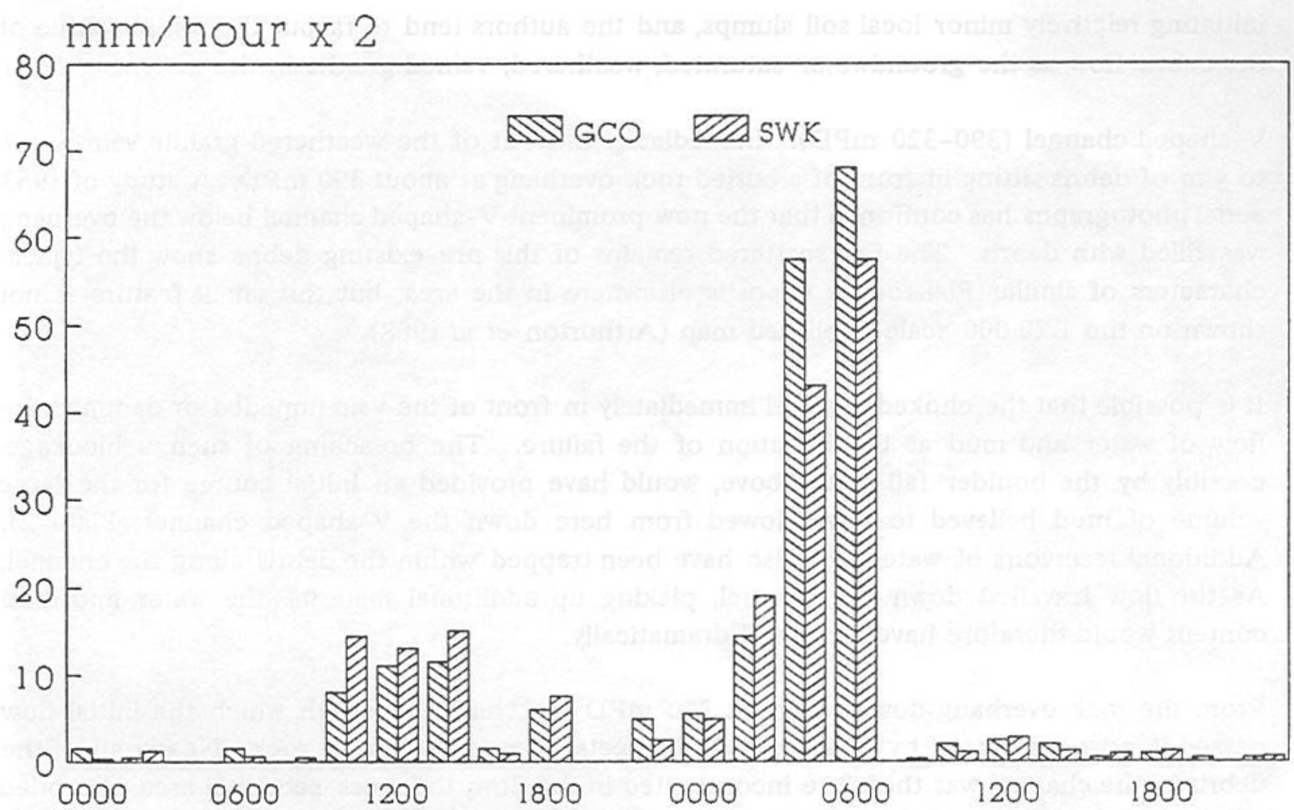

Figure 4 Histogram showing rainfall intensities in east and west Tuen Mun for 10/11 September 1990

cause. Indeed, at that time there were also several small failures on the western side of the mountain, but these followed a more typical pattern, and rapidly lost impetus downslope.

A close examination of the area of the initial failure revealed the following:

Slump and vein at the head (400-390 mPD). The head of the failure occurred at about 400 mPD in what is now a very narrow gully trending approximately 060°. At the upper part of the gully is a small soil slump and boulder fall from a steep area of about 5 m^2. Some of the boulders remain jammed against the thick scrubby vegetation which characterizes the slope. Relatively little water has flowed in this area, as can be seen from the character of the organic soil layer and the local surface features on the boulders. This local event is clearly not the source of the saturated granite soil slurry that is so apparent downslope.

Immediately downslope from the boulders and soil slump is a 10 m long, deeply weathered zone in the granite bedrock. The granite is altered and cut by quartz veins in a zone between 1 and 1.5 m wide, trending approximately 060°. Soil piping, probably caused by excessive groundwater flow in the weathered and fissured vein, is apparent. Mass movement of saturated granite soil from the gully appears to be the start of the main flow, although the cross-sectional area of eroded material would only have been around 2 to 3 m^2.

Whether the boulder fall and associated soil slump above the gully caused the subsequently catastrophic mass movement, or whether the movement of highly fluid soil from the gully led to a subsequent failure above is not clear. There are precedents downslope for the debris flow initiating relatively minor local soil slumps, and the authors tend to favour the initial source of the debris flow as the groundwater-saturated, weathered, veined granite in the gully.

V-shaped channel (390-320 mPD). Immediately in front of the weathered granite vein was 3 to 4 m of debris sitting in front of a buried rock overhang at about 390 mPD. A study of 1963 aerial photographs has confirmed that the now prominent V-shaped channel below the overhang was filled with debris. The few scattered remains of this pre-existing debris show the typical characters of similar Pleistocene deposits elsewhere in the area, but this small feature is not shown on the 1:20 000 scale published map (Arthurton *et al* 1988).

It is possible that the choked channel immediately in front of the vein impeded or dammed the flow of water and mud at the initiation of the failure. The breaching of such a blockage, possibly by the boulder fall from above, would have provided an initial source for the large volume of mud believed to have flowed from here down the V-shaped channel (Plate 2). Additional reservoirs of water may also have been trapped within the debris along the channel. As the flow travelled down the channel, picking up additional material, the water and mud content would therefore have increased dramatically.

From the rock overhang down to about 320 mPD the channel through which the initial flow passed is now dominated by joint-controlled sheets of granite country rock. Nearly all of the debris in the channel was therefore incorporated in the flow; the cross-sectional area of eroded material in the V-shaped channel would have been about 20 m^2 (Plate 2).

Plate 1 Erosional channel cutting through the forestry path, and the debris deposit on the lower ground in Area 19 of Tuen Mun

Plate 2 V-shaped channel immediately below the initial failure, with freshly exposed granite bedrock; note one of the authors standing in front of the rock overhang

Weathered and veined depression (320-280 mPD). The size of the debris flow increased down the V-shaped channel, and a further significant increase in volume occurred between 320 and 280 mPD in an area of deeply weathered and veined granite. The 1963 aerial photographs clearly show a relatively flat, boulder-strewn slope with no obvious incised drainage channel. The flow entered this part of the path from what is now a predominantly smooth rock channel to the north of a rocky knoll. To the south of this knoll there are post-flow minor slumps in the soil. Immediately below these soil failures are exposures of saturated, deeply weathered and quartz-veined granite, from which groundwater seepage was observed 4 to 10 days after the event.

The volume of weathered rock and boulders lost from this area is about 1 000 m^3. To the north of the scoured-out weathered granite, the hillside is strewn with boulders that have tumbled downslope. These boulders form a talus trail which probably occurred at the same time as the main flow in the weathered rock depression, but lost momentum within a short distance.

By the time the debris flow swept over the steep rock sheets at 280 to 260 mPD the body had a cross-sectional area of about 30 m^2 and had reached catastrophic proportions; it was not to stop until it reached the gently sloping ground at the bottom of the mountain. This upper portion of the main body of the flow is the critical part in understanding the overall development from a minor failure to a major erosional channel and new debris flow deposit, although the final bulk of the deposit was also very much determined by the pre-existing debris in the lower parts of the erosional path.

Development of the debris flow erosional channel

Altitude 240 mPD. Just below the large sheets of granite over which the rapidly developing debris flow was gaining momentum the path of the flow joined the main pre-existing stream channel. At this point there is a pocket of weathered granite containing a weathered, foliated basalt dyke trending approximately 060°. These features form a relatively shallow shelf marking the occurrence of extensive lobes of pre-existing debris. The lobes have been eroded to varying degrees by the passage of the flow, adding to the bulk of the debris flow.

A slurry of granite soil can be seen on many surfaces, and the morphology of the flow channel becomes much more clearly defined than in the upper reaches. The dominant process seems to be erosion of pre-existing deposits by a fluid mass of weathered granite and boulders travelling downhill with considerable force. The cross-sectional area at this point had probably reduced to between 20 and 25 m^2, although the velocity would have greatly increased relative to the body scouring the weathered granite above.

Altitude 215 mPD. The path of the flow bifurcated in this region, with the main flow travelling to the north of the channel. It cut through a mixture of boulders from the originally choked stream course and pre-existing mottled Pleistocene debris deposits. A slurry wash-line can be seen some 3 to 4 m above the main erosional line of the flow, which had a cross-sectional area of about 30 m^2 as it approached the forestry path.

Altitude 190 mPD. The forestry path traversing the hillside crossed the old stream course at approximately this altitude. The path was built across the boulders in the stream, with a certain amount of fill being used from cuttings in the weathered Tsing Shan metasedimentary rocks. The path has been completely destroyed and swept away over about 20 m of its length (Plate 1), and the original valley-fill deposits have been severely scoured, although many large boulders still remain *in situ.*

Above the forestry path the flow was still travelling on the northern side of its erosional channel, but as a single body. At a constriction above the path, on the northern side of the valley, the flow overtopped a knoll of debris, forming a boulder-rich deposit on the path and eroding the fill used to form the path. At the path the flow switches from the north side of the erosional channel to the south.

Altitude 170 mPD. The scouring action of the flow, now dominantly travelling in the southern part of the erosional channel, is well illustrated 40 to 70 m downhill from the path (Plates 3 & 4). A slurry of granite soil cakes the hillside for 3 to 4 m above the main scour line, formed as excess water was forced out of the deposit as it travelled downhill. The main scour damaged the surface of pre-existing debris deposits, effectively smoothing them off, and cleared out much relatively loose material from the stream course.

Altitude 150 mPD. A small rock overhang of 4 to 6 m marks a further split in the flow. Although the main flow was travelling on the south side of the channel, a minor flow path developed to the north. Neither flow hit the centre of the rock overhang, and some vegetation was preserved unharmed between the two paths. The minor northern flow was characterized by boulders, while the main body would have been a much more erosive slurry of weathered granite and boulders. The flow channel was 20 m wide, and the cross-sectional area of the flow was probably around 50 m^2.

Plate 3 Erosional channel below the forestry path showing freshly exposed metasedimentary rock and a scoured lobe of pre-existing debris

Altitude 120 mPD. In the 100 m or so that the flow travelled from the small rock overhang it probably reached its maximum destructive force. The flow was constricted in a relatively steep-sided deep channel just before it broke out onto lower ground (Plate 4). The level of washing on either side of the valley is roughly even, and at this point the course of the flow must have straightened out. It was at least 6 m thick, and 25 m across, giving a cross-sectional area of about 100 m^2.

On the north side of the channel the pre-existing debris flow deposits (Arthurton et al 1988) are severely abraded, and the flow came very close to overtopping the edge of a ridge separating the channel from a temporary forestry access road. On the south side of the channel there are exhumed boulders lying below a badly damaged tree-line. The floor of the channel is characterized by clean surfaces in freshly scoured rock exposure.

About 20 m to the east of the constriction are the remains of the concrete intake and stream channel, which is severely abraded and broken by the force of the debris flow (Plates 4 & 5). This point marks a change in slope angle to the gentler ground of Area 19, and beyond this point deposition is dominant.

Deposition of the debris flow deposit

Deposition of small amounts of material was taking place in the wake of the flow throughout its course, but the bulk of the deposit came to rest between 110 and 20 mPD. Whether the entire volume of the flow was generated in its passage down the erosional channel is unclear, but it seems unlikely.

Plate 4 Constriction at the concrete stream intake, and the debris flow deposit spread out in Area 19 of Tuen Mun; note the small pond

Plate 5 Abraded and broken concrete stream intake at the top of the depositional area

The deposit formed as a complex series of lobes and associated erosional channels (Plate 1) on an irregular topography, in part comprising pre-existing bouldery debris deposits. The total estimated volume of the deposit, including reworked material from within the depositional area, is 35 000 m^3, spread over an area about 500 m long by up to 80 m wide.

The main bulk of the deposit lies in the upper part of the depositional area, extending 200 m downslope from the damaged concrete intake, and is composed of a mass of boulders, sand and mud. At its thinnest it is about 1 m, while its thickness may exceed 3 m in the central part. The deposit remains bouldery for a further 130 m, down to the commencement of finer fan deposits. However, its thickness here is generally no more than 1 m, thinning to a few cm.

The water and soil that scoured out the erosional channels in the deposit ultimately formed the alluvial fans that spread out over the flat areas at the bottom of the slope. In places this fluid also cut down into the underlying weathered bedrock. These channels would have formed after the main lobes of debris were deposited, possibly as the heavy rainfall continued to wash material down the eroded stream course, and have spread their much smaller load further downslope.

To the east of the toe a large lobe of relatively fine debris extends to within 100 m of Lung Mun Road, although this deposit is essentially alluvial outwash and is no more than 300 mm thick. To the south of the toe a smaller lobe of debris blocking a trapezoidal channel has resulted in the formation of a pond at the bottom of a concrete cascade.

Summary

Throughout its course, down to the low-lying ground of Area 19, the flow was characterized by erosion. One of the main sources of material in the valley was pre-existing debris, although there are three features of the underlying bedrock geology which are critical:

1 The flow appears to have initiated along a mineralized and weathered zone

2 The flow initially gathered momentum and bulk as it scoured out a buried V-shaped channel

3 A significant bulking of the flow seems to have occurred in a large area of weathered granite in a structurally controlled depression

As the flow gathered momentum it scoured out parts of the existing debris in lower parts of the stream channel, and as it spread over the slopes of Area 19 it had reached a volume of up to 35 000 m^3. Further research into the failure and resulting deposit is now being undertaken by the Geotechnical Control Office, who are producing a detailed map and report.

It is interesting to contrast the relatively small-scale of the new debris flow with the events which must have led to the formation of the extensive older debris flow deposits underlying the flanks of Tsing Shan and forming a veneer up most of its valleys. Similar events elsewhere in the Territory could also be characterized by scoured channels, and any valley characterized by extensive exposed bedrock and an absence of abundant boulder debris may therefore have at its base a Holocene debris flow deposit.

Acknowledgments

The authors are grateful for the permission to publish given by the Director of Civil Engineering Services of the Hong Kong Government, and Scott Wilson Kirkpatrick & Partners. The invaluable early response of A Hansen and Y C Chan, and the cooperation of Special Projects Division, GCO, helped the authors to complete this preliminary interpretation of field observations shortly after the event.

References

ARTHURTON R S, LAI K W & SHAW R (1988). *Tsing Shan (Castle Peak). Hong Kong Geological Survey Sheet 5, Solid and Superficial Geology, Scale 1:20 000.* Geotechnical Control Office, Hong Kong

LANGFORD R L, ARTHURTON R S & LAI K W (1988). Geological survey and ground investigation in Tuen Mun, western New Territories. In: WHITESIDE P G D (ed). The role of geology in urban development. *Geological Society of Hong Kong Bulletin* No 3 p 199–207

LANGFORD R L, LAI K W, ARTHURTON R S & SHAW R (1989). *Geology of the Western New Territories. Hong Kong Geological Survey Memoir No 3.* Geotechnical Control Office, Hong Kong. 140 p

VARNES D J (1978). Slope movement types and processes. In: SCHUSTER R L & KRIZEK R J (eds). *Landslides, analysis and control.* National Academy of Sciences, Washington DC, p 11–33 plus figure

Geological Society of Hong Kong Newsletter Vol 8 Pt 3 p 13-22

NEW COLLECTIONS FOR THE TOLO HARBOUR FORMATION AT MA SHI CHAU, NEW TERRITORIES, HONG KONG

C M Lee[1], M J Atherton[1], He G X[2], Chen J H[2], & Wu S Q[2]

1 *Department of Civil and Structural Engineering, Hong Kong Polytechnic*

2 *Nanjing Institute of Geology and Palaontology, Academia Sinica*

Introduction

Permian strata with fossil evidence in Hong Kong are mainly found at Ma Shi Chau and Centre Island in Tolo Harbour, namely the Tolo Harbour Formation and the Centre Island Formation.

The Tolo Harbour Formation was first defined by Ruxton for rocks occurring on Ma Shi Chau and Centre Island, consisting of banded siltstones and shales, grey shales and siltstones (Ruxton 1960). Fossils collected by Ruxton from the banded siltstones and shales of the Tolo Harbour Formation on the southeast coast of Ma Shi Chau, including Productids (all of which are species of *Dictyoclostus*), bryozoa (*Fenestella* sp), a lamellibranch (*Aviculopecten* sp) and a crinoid ossicle, were identified by H Muir-Wood and H W Ball of the British Museum. The Productids were considered by Muir-Wood to be most probably of Permian age (Ruxton 1960).

The strata exposed on Ma Shi Chau and Centre Island were previously grouped in "the older sedimentary rocks (Lower Cretaceous)" by Grabau (Grabau 1923), in "the Sedimentary Rocks (Perhaps Lower Jurassic or Triassic)" by Heanley (Heanley 1923), in "the Lower Cretaceous Tolo Channel Formation" by Uglow (Uglow 1926), and by Brock and Schofield (Brock et Schofield 1926), and in "the lower Jurassic Tolo Channel Formation" by Grabau (Grabau 1928), Brock and others (Brock *et al* 1936), Williams (Williams 1943) and Davis (Davis 1953).

Allen and Stephens broadly subscribed to Ruxton's opinion, but confined the Permian Tolo Harbour Formation within the narrow southeast coast of Ma Shi Chau, while most of the rocks exposed on Centre Island were assigned to the Bluff Head Formation, considered by them as Lower to Middle Jurassic (Allen & Stephens 1971). These were re-classified as Tolo Harbour Formation and Tolo Channel Formation later by Nau (Nau 1981).

K C Lam measured a short geological section and collected some fossils at a wave-cut platform on the southeast coast not far away from the northeast corner of Ma Shi Chau. In light of the fossils, containing brachiopods (*Antiquatonia*? sp, *Boxtonia* sp, Productoid), bryozoa, crinoid stems and worm trails, Lam considered the Tolo Harbour Formation to be of Permian or even older age (Carboniferous-Permian) (Lam 1973).

Fossil plants (?*Cladophlebis* sp), rugose corals (?*Duplophyllum mikron* Von Schouppe et Stacul) and bryozoa (*Stenopora* sp) were reported respectively in the Tolo Harbour Formation at Ma Shi Chau by P S Nau (Nau 1980), Yim, Nau and Rosen (Yim *et al* 1981), and Nau (Nau 1983).

Two subdivisions of the Tolo Harbour Formation were recognized by Nau when he remapped Ma Shi Chau (Nau 1981). The lower member of the Formation, exposed mainly along the southeast coast, consists roughly of thin-bedded mudstones, siltstones, sandstones and shales, as well as massive mudstones, and contains the marine fossils and plant remains mentioned above. The upper member, with gradual increase in sand content upwards, is well exposed along the northeast coast and comprises siltstones, mudstones and sandstones, with a minor amount of conglomerate. The lower member was considered by Nau to be of Upper Carboniferous to Middle Permian age, while the upper member was considered to be of Middle to Upper Permian (Nau 1981).

Bennett (1984) and Addison (1986) placed the Tolo Harbour Formation in the Permian. Following Nau (1981), Addison divided the Formation into two lithofaces (Addison 1986).

Based on the fossils (brachiopods and bryozoans) collected by C C Wei and himself, C M Lee correlated the Tolo Harbour Formation with the upper Lower Permian Maokou Formation or Kuhfeng Formation in central and eastern Guangdong, China (Lee 1985, 1987).

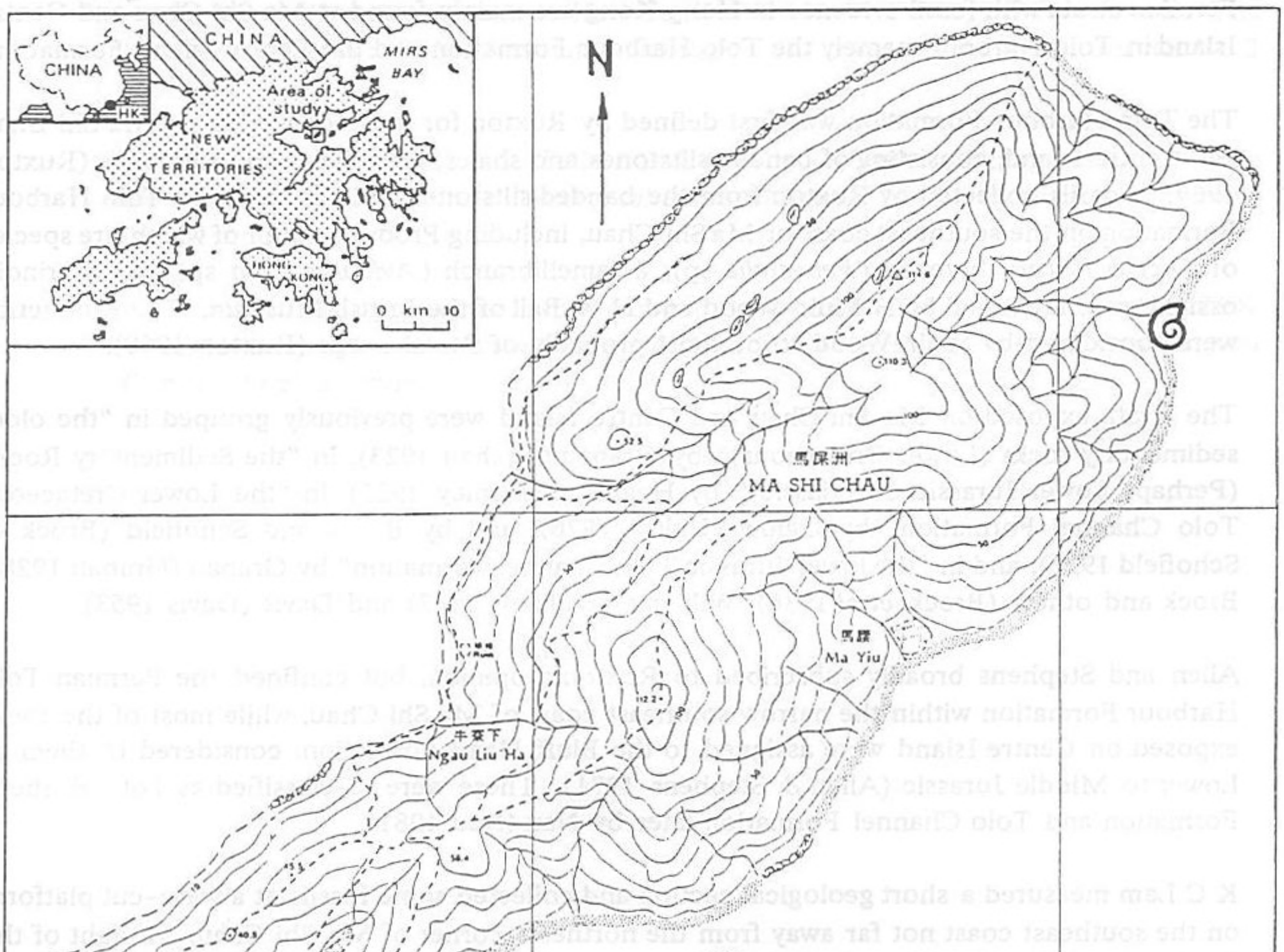

Figure 1 Sketch map showing the fossil locality

During the first half of 1989, the authors visited the strata of the Tolo Harbour Formation at Ma Shi Chau on several occasions. The Tolo Harbour Formation at Ma Shi Chau has been intensively disrupted by folding and faulting. As written by Addison, "The strata on Ma Shi Chau are structurally complex, and the interpretation of stratigraphic relations within the formation is extremely difficult. The strata are involved in syndepositional slump folds as well as a series of northerly plunging minor anticlines and synclines, the limbs of which are often sheared and overturned.... The sequence is divided into two lithofaces following Nau (1980). However, the outcrop is considered to be structurally too complex to warrant formal sub-division" (Addison 1986). A series of new fossil materials, including ammonites, bivalves, brachiopods, gastropods, ostracods, corals, bryozoans and crinoid stems, have been found in pale grey calcareous mudstone at the southeast coast of Ma Shi Chau, nearby a stream outlet about 150 metres to the southwest of the southeast corner of the Island (Figure 1).

According to the preliminary identification the new collections from the Tolo Harbour Formation at Ma Shi Chau include an indeterminable species of one genus of ammonite, ten species of nine genera of bivalves, ten species of seven genera of brachiopods and three indeterminable species of three genera of corals. The gastropods, ostracods, bryozoans and crinoid stems have not been identified yet. Among the new collections, ammonites and ostracods are recorded for the first time in the Tolo Harbour Formation in Hong Kong. The ammonite *Altudoceras* sp, reported by Lee from the Tolo Harbour Formation at Ma Shi Chau (Lee 1987), is not an ammonite but a gastropod fragment.

The new fossil materials which have been identified are listed and discussed as below:

Ammonites (identified by G X He)
- *Paraceltites* sp

Bivalves (identified by J H Chen)
- *Euchondria jiaheensis* Fang
- *Euchondrioides zhuzhouensis* Fang
- cf *Etheripecten sichuanensis* Liu
- *Astartella minuta* Zhang, *Astarella* sp
- *Edmondia rotunda* Beede
- *Palaeoneilo guizhouensis* Chen et Lan
- *Pernopecten* sp
- "*Lima*" cf *minima* Liu
- *Paradoxipecten jiaheensis* Zhang

Brachiopods (identified by Z T Liao, Nanjing Institute of Geology and Palaeontology)
- *Neoplicatifera huangi* (Ustriski)
- *Neoplicatifera* sp
- *Tenuichonetes tenuilirata* (Chao)
- *Tenuichonetes plicatiformis* (Lee)
- *Tenuichonetes* sp
- *Spinomaginifera* cf *shizhongensis* Wang
- *Acosarina indica* (Waagen)
- *Crurithyris* sp
- ? *Cathusia* sp
- ? *Uncisteges maceus* (Ching)

Corals (examined by W H Liao, Nanjing Institute of Geology and Palaeontology)

Allotropiophyllum sp

Paracaninia sp

Bradyphyllum sp

Paraceltites is a common ammonite genus known from the upper Lower Permian in North America, western Europe and the Central Asia region of USSR. In southern China it is widely distributed in the upper Lower Permian Maokou Stage. The representatives of *Paraceltites* have been recorded from both the Wenbishan Formation (the lower part of the Maokou Stage) and the Tongtzeyen Formation (the upper part of the Maokou Stage) in southwestern Fujian Province (Sheng *et al* 1982), from the Lower Member of the Yianchiao Formation, formerly the upper part of the Wenbishan Formation, in central Guangdong Province (Qin 1984), from the upper Lower Permian Tingchiashan Formation in western Zhejiang Province (Sheng *et al* 1982) and from the Kuhfeng Formation in southwestern Hubei Province (Xu & Wei 1977). *Paraceltites* was also reported to occur in the Dangchong Formation (the lower part of the Maokou Stage), treated by Zhou as the zonal fossil of the *Altudoceras-Paraceltites* zone of the Formation, and in the upper part of the overlying Toeling Formation in southern Hunan Province (Zhou 1987). In North America, *Paraceltites* ranges from the Wordian Substage to the Capitanian Substage of the upper Lower Permian Guadalupian Stage (Zhou 1987).

The bivalves from the Tolo Harbour Formation were formerly reported only as an undetermined species of the genus *Aviculopecten* (Ruxton 1960). Now ten species of nine genera have been collected and recognized from the Formation in Ma Shi Chau. The present bivalve fauna is very similar to that occurring in the Maokou Stage of southern Hunan Province, where a more detailed study of the Permian bivalves has been made in recent years.

The upper Lower Permian in southern Hunan was divided into two subdivisions; the Dangchong Formation below and the Toeling Formation above. The Dangchong Formation is composed of bedded black shale, cherty shale, dark grey chert and cherty limestone. The Toeling Formation has been subdivided into three members. The Lower Member is composed mainly of greyish black clay shale, sandy shale intercalated with fine sandstone and siltstone. The Middle Member consists of light grey to yellowish grey fine-grained sandstone, sandy shale, quartzose sandstone and shale interbedded with thin coal seams. The Upper Member is composed mainly of dark grey calcareous mudstone intercalated with thin-bedded limestone (Fang 1987).

Three bivalve assemblages have been classified within the upper Lower Permian strata there; the *Euchondrioides-Euchondria* Assemblage for the Dangchong Formation, the *Schizodus-Pseudomonotis leiyangensis* Assemblage for the Lower and Middle Members of the Toeling Formation, and the *"Lima"-Paradoxipecten* Assemblage for the Upper Member of the Toeling Formation (Fang 1987).

The present bivalve fauna involves both the characteristic genera *Euchondria* and *Euchondrioides* of the *Euchondrioides-Euchondria* Assemblage of the Dangchong Formation, and elements of the two overlying bivalve assemblages of the Toeling Formation. *Palaeoneilo guizhouensis* Chen et Lan was known in the *Schizodus-Pseudomonotis leiyangensis* Assemblage and the *"Lima"-Paradoxipecten* Assemblage, and *Edmondia rotunda* Beede, *Paradoxipecten jiaheensis* Zhang, *Etheripecten sichuanensis* Liu, *Euchondria jiaheensis* Fang and the representatives of *"Lima"*, *Pernopecten* and *Astartella* have been recorded in the *"Lima"-Paradoxipecten* Assemblage (Fang 1987). Besides, *Astartella* cf *minuta* Zhang and *Paradoxipecten jiaheensis*

Zhang were reported to occur in the Lower Member of the upper Lower Permian Yianchiao Formation. *Palaeoneilo* cf *guizhouensis* Chen et Lan has been found from the Upper Member of the Yianchiao Formation, and *Euchondrioides zhuzhouensis* Fang has been recorded from both the Lower and the Upper Members of the Yianchiao Formation at Xingning, eastern Guangdong Province (Yang 1984).

All the brachiopods listed above are the common genera and species known from the upper Lower Permian strata in southern China, and are very similar to those found in the Tongtzeyen Formation (also called Longyen Formation or Jiafu Formation) in southwestern Fujian and eastern Guangdong, and in the Dangchong Formation in southern Hunan (Z T Liao, personal communication). Among the present brachiopods, *Neoplicatifera huangi* (Ustriski), which is selected by the Chinese palaeontologists as the index brachiopod species of the *Neoplicatifera huangi* Assemblage of the Maokou Stage in the South China Region (Sheng *et al* 1982), has also been reported to occur in the upper Lower Permian Kuhfeng Formation in northern Guangdong (Yang 1984) and southern Jiangsu (Sheng 1982), in the Yianchiao Formation in western Zhejiang (Sheng *et al* 1982) and eastern Guangdong (Yang 1984), and in the Maokou Formation in northern Guizhou and northeastern Jiangxi (Sheng *et al* 1982).

Among the three genera of corals, *Allotropiophyllum* ranges from Lower Carboniferous to Lower Permian in China, andfrom Carboniferous to Permian in the USSR. In western Europe this genus was recorded in the Lower Carboniferous. *Bradyphyllum* was known from Middle Carboniferous to Permian in China, and from Middle and Upper Carboniferous in the USSR. *Paracaninia* has a shorter range as compared with the two genera mentioned above; it has been found from the Permian strata in China and the USSR, and from Carboniferous strata in North America.

In light of the above analysis, the authors come to the conclusion that the present new collections from the Tolo Harbour Formation at Ma Shi Chau show a strong late Early Permian aspect and are in support of the suggestion by C M Lee (Lee 1985, 1987) that the Tolo Harbour Formation is of late Early Permian age and can be approximately correlated with the Maokou Stage in southern China Province and the Guadalupian Stage in North America (Table 1).

Acknowledgments

We wish to thank Liao Zhuo-ting and Liao Wei-hua, Nanjing Institute of Geology and Palaeontology, Academia Sinica, for their help in examining the fossils of brachiopods and corals and providing the opinions of geological age and correlation.

References

ADDISON R (1986). *Geology of Sha Tin. Hong Kong Geological Survey Memoir No 1.* Geotechnical Control Office, Hong Kong. 85 p

ALLEN P M & STEPHENS E A (1971). *Report on the Geological Survey of Hong Kong 1967–1969.* Hong Kong Government Press. 116 p plus 2 maps

BENNETT J D (1984). *Review of Hong Kong stratigraphy. GCO Publication No 5/84.* Geotechnical Control Office, Hong Kong, 86 p

UPPER LOWER PERMIAN				SERIES	
MAOKOU STAGE				STAGE / LOCALITY	
Tolo Harbour Formation				Ma Shi Chau, New Territories	Hong Kong
Kuhfeng Fm.	Yianchiao Formation L. Member	Upper Member		Guangzhou, Huaxian, Central Guangdong	Southern China Province
Kuhfeng Fm.	Guanshan Formation L. Member	Upper Member		Renhua, Northern Guangdong	
Kuhfeng Fm.	Yianchiao Formation L. Member	Upper Member		Xingning, Eastern Guangdong	
Wenbishan Formation		Tungtzeyen Formation		Meixian, Eastern Guangdong	
Wenbishan Formation		Tungtzeyen Formation		Yongding, sothwestern Fujian	
Kuhfeng Formation		Yianchiao Formation		Nanjing, Suzhou, Southern Jiangsu	
Yianchiao Formation				Changxing, Northern Zhejiang	
Tingchiashan Formation				Tonglu, Jiande, Western Zhejiang	
Dangchong Fm.	Toeling Formation L. Member	M. Member	U. Member	Jiahe, Yizhang Southern Hunan	
Maokou Formation				Leping, Yugan, Northern Jiangxi	
Maokou Formation				Zunyi, Northern Guizhou	
WORDIAN		CAPITANIAN		SUBSTAGE	N. America Texas
GUADALUPIAN				STAGE	

Table 1 Correlation of the upper Lower Permian Tolo Harbour Formation in Hong Kong

CHEN C Z, ZHANG Z M & XU J T (1974). *Permian Lamellibranchs. Handbook of the stratigraphy and paleontology in southwest China.* Science Press, Beijing, p 302-303 (in Chinese)

DAVIS S G (1952). *The geology of Hong Kong.* Government Printer, Hong Kong, 231 p plus 14 plates & 3 maps

EDITORIAL GROUP OF FOSSIL LAMELLIBRANCHS OF CHINA (1976). *Fossil Lamellibranchs of China.* Science Press, Beijing, 522 p (in Chinese)

GRABAU A W (1928). *Stratigraphy of China. Part 2, Mesozoic.* The Commercial Press, Peking

HEANLEY C M (1923). Some geological excursions around Hong Kong. *The Caduceus (Hong Kong University Engineering Journal)* Vol 20 p 49-58

FANG Z J (1987). Bivalves from Middle and Upper parts of Permian in Southern Hunan, China. *Contribution of Postgraduate of Nanjing Institute of Geology and Palaeontology, Academia Sinica* No 1 p 391-411 (in Chinese with English abstract)

JIA H Z *ET AL* (1977). Rugosa. In: *Palaeontological atlas of central-south China Pt 2.* Geological Publishing House, p 112-240 (in Chinese)

JIN Y G, LIAO Z T & FANG B X (1974). Permian brachiopods. In: *Handbook of the stratigraphy and paleontology in southwest China.* Science Press, Beijing, p 308-313 (in Chinese)

LAM K C (1973). Upper Palaeozoic fossils of the Tolo Harbour Formation, Ma She Chau, Hong Kong. *Hong Kong Geographical Association Bulletin* No 3 p 21-27

LEE C M (1985). Recent developments in Hong Kong stratigraphy. *Geological Society of Hong Kong Newsletter* Vol 3 No 4 p 7-9

LEE C M (1987). An outline of the geology of Hong Kong. *Geology of Guangdong* Vol 2 No 1 p 29-48 (in Chinese)

NAU P S (1980). Fossil plant from Ma Shi Chau Island, Hong Kong. A preliminary note. *Annals of the Geographical Geological Archaeological Society, University of Hong Kong* No 8 p 27-32

NAU P S (1981). Geology of the Ma Shi Chau Island, New Territories, Hong Kong. *Annals of the Geographical Geological Archaeological Society, University of Hong Kong* No 9 p 17-28

NAU P S (1983). Occurrence of *Stenopora* sp in Ma Shi Chau Island. *Annals of the Geographical Geological Archaeological Society, University of Hong Kong* No 11 p 1-5

QIN X L (1984). Ammonoidea. In: *Permian palaeontological atlas of Guangdong* p 134-166 (in Chinese)

RUXTON B P (1960). The geology of Hong Kong. *Quarterly Journal of the Geological Society of London* Vol 115 p 233-260 (plus 2 plates & 1 map)

SHENG J Z, JIN Y G, RUI L, ZHANG L X, ZHENG Z G, WANG Y J, LIAO Z T & ZHAO J M (1982). Correlation chart of the Permian in China with explanatory text. In: NANJING INSTITUTE OF GEOLOGY AND PALAEONTOLOGY, ACADEMIA SINICA (ed). *Stratigraphic correlation chart in China with explanatory text.* Science Press, Beijing, p 153-170 (in Chinese)

UGLOW W L (1926). Geology and mineral resources of the Colony of Hong Kong. *Government of Hong Kong, Legislative Council Sessional Papers* No 7/1926 p 73-77

WILLIAMS M Y (1943). The stratigraphy and palaeontology of Hong Kong and the New Territories. *Transactions of the Royal Society of Canada* Third Series Vol 37 Sect IV p 93-117

WU W S & WANG Z H (1974). Permian corals. In: *Handbook of the stratigraphy and paleontology in southwest China.* Science Press, Beijing, p 296-299 (in Chinese)

XU G H & WEI R Y (1977). Ammonoidea. In: *Palaeontological atlas of central-south China.* Geological Publishing House, p 558-581 (in Chinese)

YANG D L, NI S Z, CHANG M L & ZHAO R X (1977). Brachiopoda. In: *Palaeontological atlas of central-south China.* Geological Publishing House, p 303-470 (in Chinese)

YANG M F (1984). Brachiopoda, Bivalvia. In: *Permian palaeontological atlas,* p 47-125 (in Chinese)

YIM W S, NAU P S & ROSEN B R (1981). Permian corals in the Harbour Formation, Ma Shi Chau, Hong Kong. *Journal of Paleontology* Vol 55 No 6 p 1298-1300

ZHANG R J, WANG D Y & ZHOU Z R (1977). Bivalvia. In: *Palaeontological atlas of central-south China Pt 2.* Geological Publishing House p 470-532 (in Chinese)

ZHANG S Z, YAO Z Q, MO Z G & LI X X (1982). Subdivision and correlation of the Permian continental strata in China. In: NANJING INSTITUTE OF GEOLOGY AND PALAEONTOLOGY, ACADEMIA SINICA (ed). *Stratigraphic correlation chart in China with explanatory text.* Science Press, Beijing, p 171-190 (in Chinese)

ZHAO J K & ZHENG Z G (1977). Late Early Permian ammonites from western Zhejiang and northeastern Jiangxi. *Acta Paleontologica Sinica* Vol 16 No 2 (in Chinese with English abstract)

ZHOU Z R (1987). Early Permian ammonite fauna from southeastern Hunan. In: *Contribution of Postgraduate of Nanjing Institute of Geology and Palaeontology, Academia Sinica* No 1 p 285-348 (in Chinese with English abstract)

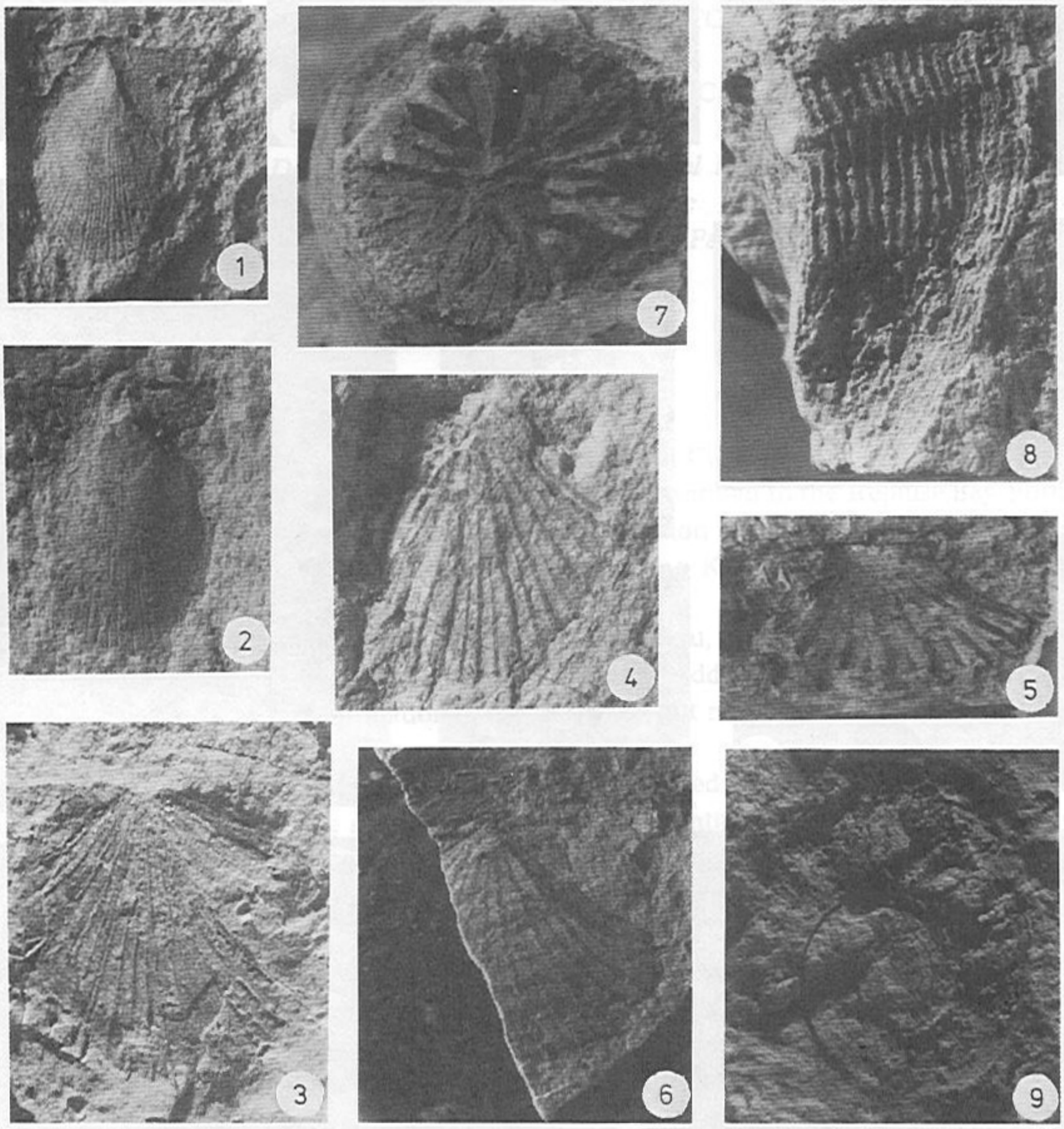

Plate I Fossils from the Tolo Harbour Formation at Ma Shi Chau:

1–2 *Paradoxipecten jiaheensis* Zhang

3 *Euchondris jiaheensis Fang*

4–6 *Euchondrioides zhuzhouensis* Fang

7–8 Corals

9 *Paraceltites* sp

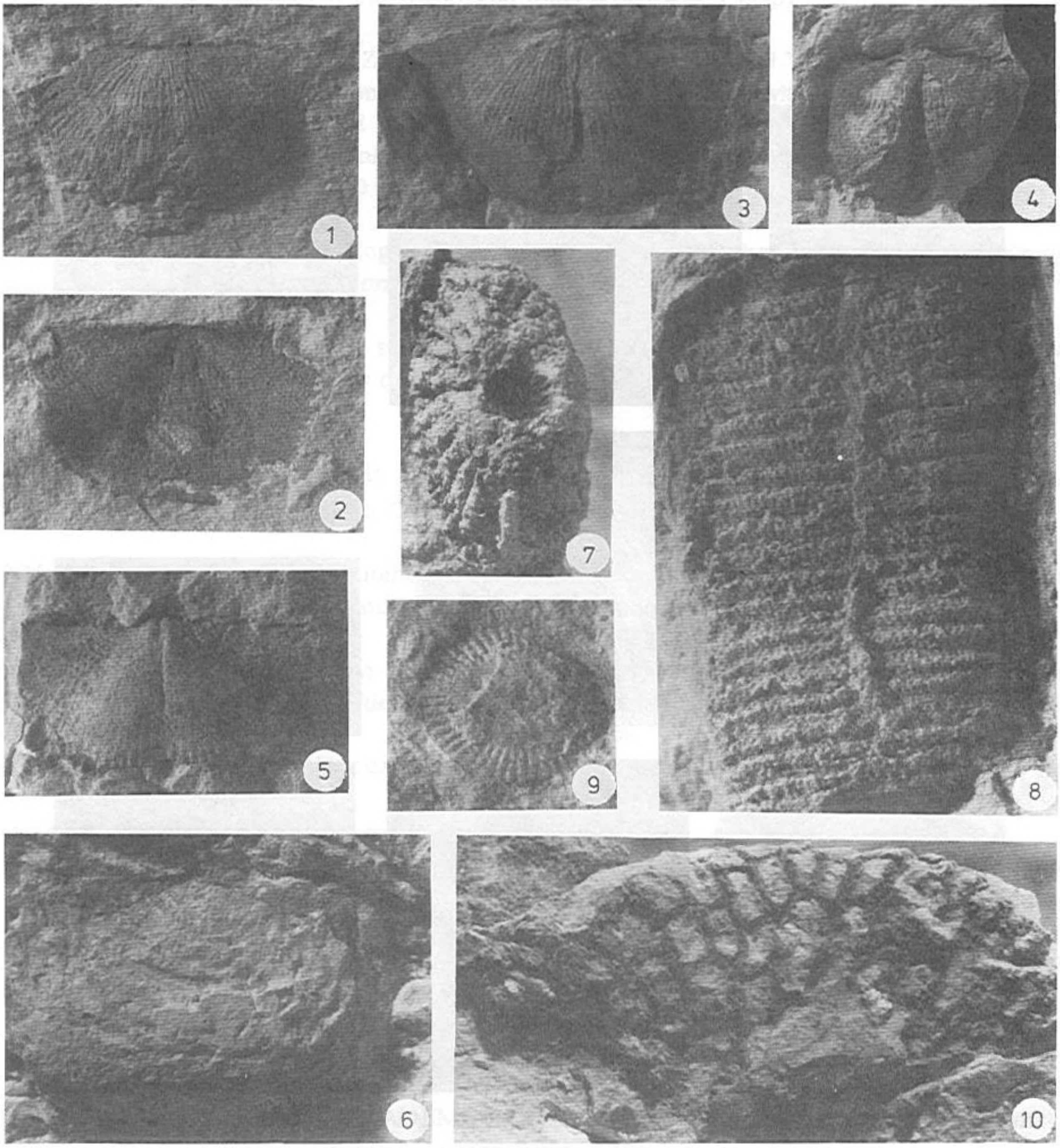

Plate II Fossils from the Tolo Harbour Formation at Ma Shi Chau:

1–3 *Tenuichonetes tenuilirata* (Chao)
4 *Tenuichonetes* sp
5 *Tenuichonetes plicatiformis* (Lee)
6 *Neoplicatifera huangi* (Ustriski)
7 Coral
8–9 Crinoid stems
10 Bryozoan

Geological Society of Hong Kong Newsletter Vol 8 Pt 3 p 23-33

DISCOVERY OF *SULCIFERITES HONGKONGENSIS* (GRABAU) ON THE SOUTH SHORE OF TOLO CHANNEL AND THE GEOLOGICAL AGE OF THE SEDIMENTARY ROCKS AT NAI CHUNG PIER, NEW TERRITORIES, HONG KONG

C M Lee[1], M J Atherton[1], G X He[2], J H Chen[2] & S Q Wu[2]

1 *Department of Civil and Structural Engineering*
Hong Kong Polytechnic
2 *Nanjing Institute of Geology and Palaeontology*
Academia Sinica

Introduction

Sedimentary rocks distributed along the shoreline near Nai Chung pier, including conglomerate, sandstone, siltstone, mudstone and shale, were previously ascribed to the Repulse Bay Formation of Early to Middle Jurassic age as a sedimentary intercalation within volcanic rocks by Allen and Stephens (1971) on the 1:50 000 Geological Map of Hong Kong.

Based on oral communications of C M Lee and P S Nau, that the siltstone and mudstone exposed near Nai Chung pier contains Jurassic fossils, Addison assigned these rocks to the Lower Jurassic Tolo Channel Formation (Addison 1986), but no fossils were listed in his memoir.

During the period of 1985 to 1986 some fossils were collected by P S Nau in the strata near Nai Chung pier. According to the ammonites and bivalves identified and dated by Q J Wu of the Department of Geology, Zhongshan University, Nau considered the age of the rock sequence in which the fossils occur to be Late Triassic (Nau 1986).

More recently, during the winter of 1988 and the spring of 1989, a large number of fossils, including ammonites, bivalves, gastropods and plant remains, were found in the sedimentary rocks near Nai Chung pier by the authors. The preliminary study indicates that the sedimentary rocks exposed near Nai Chung pier are undoubtedly of Early Liassic age.

Stratigraphy

The present paper deals with the sedimentary rocks occurring along the shoreline from the west of Nai Chung pier to the southeast of the pier, with a thickness of over 50 m (Figure 1).

At the base of the sequence is a faulted contact with the Cheung Chau Granite (sic) to the northwest, and at the top it is covered by recent alluvial and marine deposits to the southeast. The strata are monoclinal in structure, striking roughly NNE and dipping to the southeast at steep angles. The lower part of the Nai Chung section, about 20 m in thickness, is composed mainly of fine-grained conglomerate, fine- to medium-grained sandstone and siltstone. The grain-size becomes gradually finer upwards. The middle and upper parts of the section, about 40 m in thickness, are composed largely of colourful siltstone, mudstone and shales, yielding abundant fossils. Owing to the development of cleavage, the bedding of the strata is not clear. Strike faults are very common within the section.

The stratigraphic section in ascending order is as follows (Figure 2).

Subformation Cheung Chau Granite (sic) (Faulted contact)

Bed 1 Sandstone with pebbles; about 3.2 m

Bed 2 Fine-grained sandstone; about 1.3 m

Bed 3 Carbonaceous siltstone; about 2.3 m

Bed 4 Grey-yellow sandstone and fine-grained sandstone; about 2.8 m

Bed 5 Grey black, black carbonaceous shale intercalated with sandstone; about 2.3 m

Bed 6 Argillaceous siltstone; about 3.2 m

Bed 7 Grey-yellow fine-grained sandstone and siltstone; about 4.5 m

Bed 8 Brecciated quartz sandstone, quartzite with gravel; about 2.3 m

Bed 9 Quartzite with quartz pebbles; about 1.9 m

Bed 10 Grey black and black thin-bedded mudstone with ferruginous and argillaceous concretions; about 4.5 m; the upper part yielding many fossils (NC-1)

Ammonites: *Sulciferites hongkongensis* (Grabau), *Sulciferites* cf *angulatoides* (Quenstedt)

Bivalves: *Cardinia toriyamai* Hayami, *Cardinia deshayesi* Terquem, *Luciniola hasei* (Hayami), *Astarte voltzii* (Goldfuss), *Parallelodon sinemurensis* (Martin), *Liostrea* cf *toyorensis* Hayami, *Fimbria*? *regularis* (Fan)

Bed 11 Greyish purple, grey black mudstone and silty mudstone with concretions; about 4.5 m; yielding

Bivalves: *Parainoceramus amygdaloides* (Goldfuss) (NC-2)

Bed 12 Grey black weathering into greyish white mudstone, greyish red mudstone and carbonaceous mudstone, with no concretions; about 10.8 m; containing

Bivalves: *Parainoceramus* sp (NC-3), *Parainoceramus* sp (NC-4), *Parainoceramus matsumotoi* Hayami (NC-5)

Bed 13 Light grey and greyish purple mudstone with chert concretions; about 9.4 m; containing

Bivalves: *Parainoceramus matsumotoi* Hayami (NC-6)

Bed 14 Greyish yellow, grey and greyish purple mudstone with concretions; about 5.8 m; containing

Bivalves: *Parainoceramus matsumotoi* Hayami (NC-7), *Parainoceramus matsumotoi* Hayami (NC-8)

Ammonites: *Arietites* cf *pinguis* (Quenstedt) (NC-8) (collected by P S Nau in 1986)

Bivalves: *Parainoceramus lunaris* Hayami (NC-9)

Bed 15 Black shales; about 2.3 m; containing

Bivalves: *Parainoceramus lunaris* Hayami, *Parainoceramus matsumotoi* Hayami (NC- 1O)

Gastropods and plant remains (NC-10) (Unconformity)

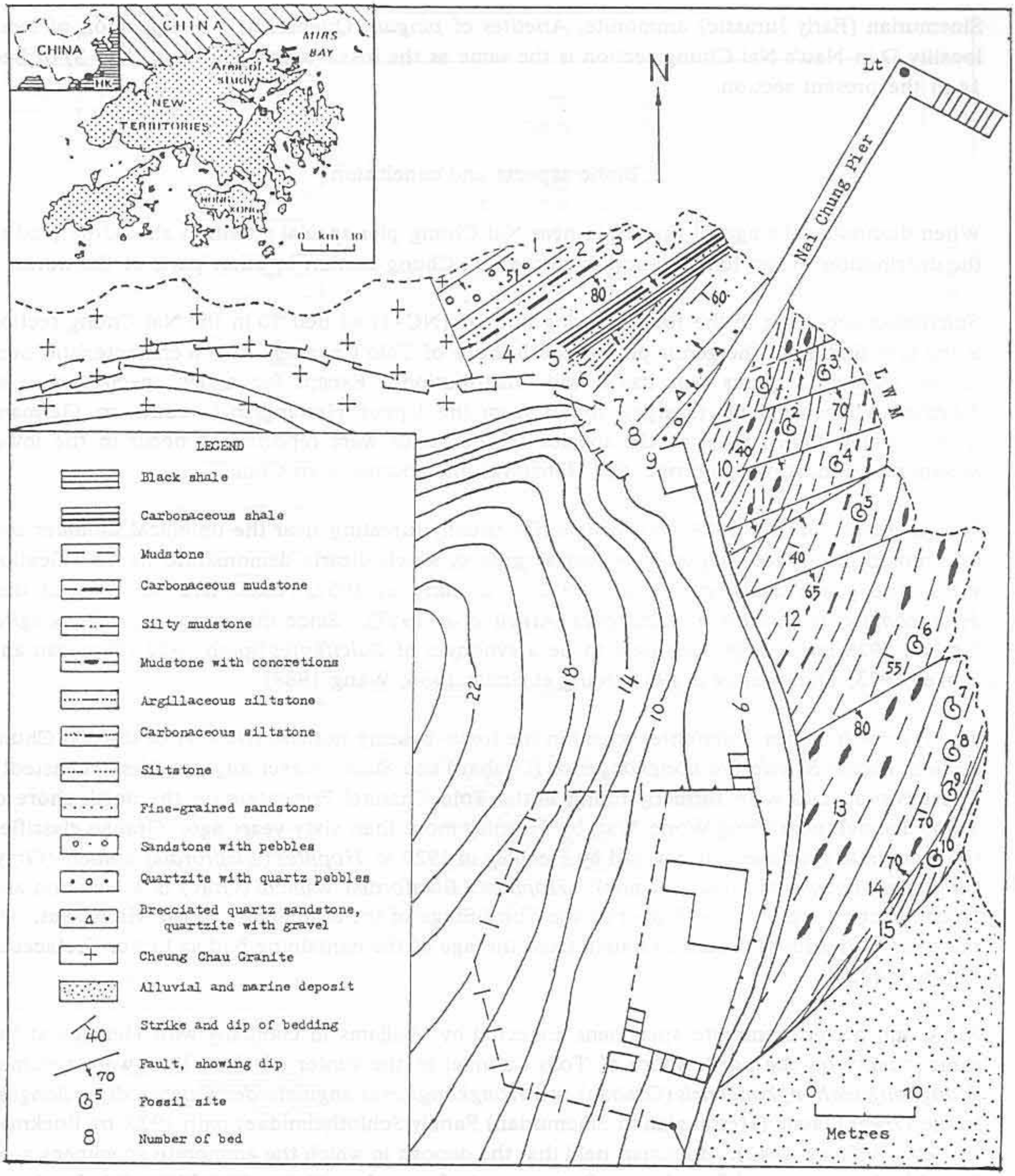

Figure 1 Geological map near Nai Chung Pier, New Territories, Hong Kong

Recent alluvial and marine deposits

It should be pointed out that after his paper concerning the geological age of the strata at Nai Chung pier was published in 1986, Nau found a well-preserved ammonite specimen from the fossil locality D of Bed 11 in his Nai Chung section, where an uncomplete ammonite had been collected by Nau and identified as *Sinoceltites* sp by Q J Wu of the Zhongshan University (Nau 1986). The well-preserved ammonite, with evolute, depressed whorls, strong simple ribs and tricarinate-bisulcate venter, was identified by one of the present writers (G X He) as an Early

Sinemurian (Early Jurassic) ammonite, *Arietites* cf *pinguis* (Quenstedt). The position of fossil locality D in Nau's Nai Chung section is the same as the fossil-bearing horizon (NC-8) of Bed 14 in the present section.

Biotic aspects and conclusion

When discussing the age of the strata near Nai Chung pier special attention should be paid to the distribution of the fossils found from the Nai Chung section in other parts of the world.

Sulciferites occurring in the fossil-bearing horizon (NC-1) of Bed 10 in the Nai Chung section is the first finding of the genus on the south shore of Tolo Channel. It is a characteristic early Liassic ammonite genus and has a wide distribution. Except for a few species, such as *Sulciferites stenorhyncha* (Lange), found from the Upper Hettangian in southern Germany (Schlegemilch 1976), most of the species of the genus were reported to occur in the lower Sinemurian in northwest Europe, the Himalayas and southeastern China.

Hongkongites Grabau 1928, with coarse ribs usually furcating near the umbilical shoulder and interrupted on arched venter by a ventral groove, which clearly demonstrate its classification within the genus *Sulciferites* Spath 1922. As early as 1957, Arkell had pointed out that *Hongkongites* is perhaps a *Sulciferites* (Arkell *et al* 1957). Since the seventies *Hongkongites* Grabau 1928 has widely been held to be a synonym of *Sulciferites* Spath 1922 (Donovan and Forsey 1973; Donovan *et al* 1981; Nang et Smith 1986; Wang 1988).

The species of genus *Sulciferites* found in the fossil-bearing horizon (NC- 1) of the Nai Chung section include *Sulciferites hongkongensis* (Grabau) and *Sulciferites* cf *angulatoides* (Quenstedt). These two species were formerly found in the Tolo Channel Formation on the north shore of Tolo Channel, near Fung Wong Wat, by Heanley more than sixty years ago. Grabau classified the ammonite specimens discovered by Heanley in 1920 as *Hoplites* (*Blanfordia*) *wallichi* (Gray) var *hongkongensis* Grabau (var nov). *Hoplites* (*Blanfordia*) *wallichi* (Gray) is a common and characteristic species of the Upper or the Third Stage of the Spiti Shales of the Himalayas. On the basis of this identification, Grabau fixed the age of the containing bed as Lower Cretaceous (Grabau 1923).

More and better ammonite specimens collected by Williams in company with Heanley at the same locality on the north shore of Tolo Channel in the winter of 1924-1925 were renamed *Hongkongites hongkongensis* (Grabau) and *Hongkongites* cf *angulatoides*(Quenstedt), belonging to the Lower Liassic (Hettangian to Sinemurian) Family Schlotheimidae Spath 1923, by Buckman in 1926 (Williams 1943). Buckman held that the deposit in which the ammonite specimens were found had to be moved from Lower Cretaceous to Lower Jurassic, and might be dated as being of Coroniceratan Age.

Besides the mentioned localities, *Sulciferites angulatoides* (Quenstedt) is also known to be distributed in the Bucklandi Zone, the lowest ammonite zone of Sinemurian Stage, in southern Germany (Schlogelmilch 1976). Since the end of 1950s *Sulciferites hongkongensis* (Grabau) has been widely found in the lower part of the Upper Member of the lower Jurassic Jinji Formation in neighbouring Guangdong Province, China (Lee, 1959; Sun *et al* 1960; Yin *et al* 1964; Fan *et al* 1965; Sun *et al* 1980; Wang et Smith 1986). The *Sulciferites hongkongensis*-bearing bed of the Jinji Formation was assigned to the lowest Sinemurian and represents the oldest Jurassic ammonite horizon known in southeastern China to date (Wang & Smith 1986; Wang 1988).

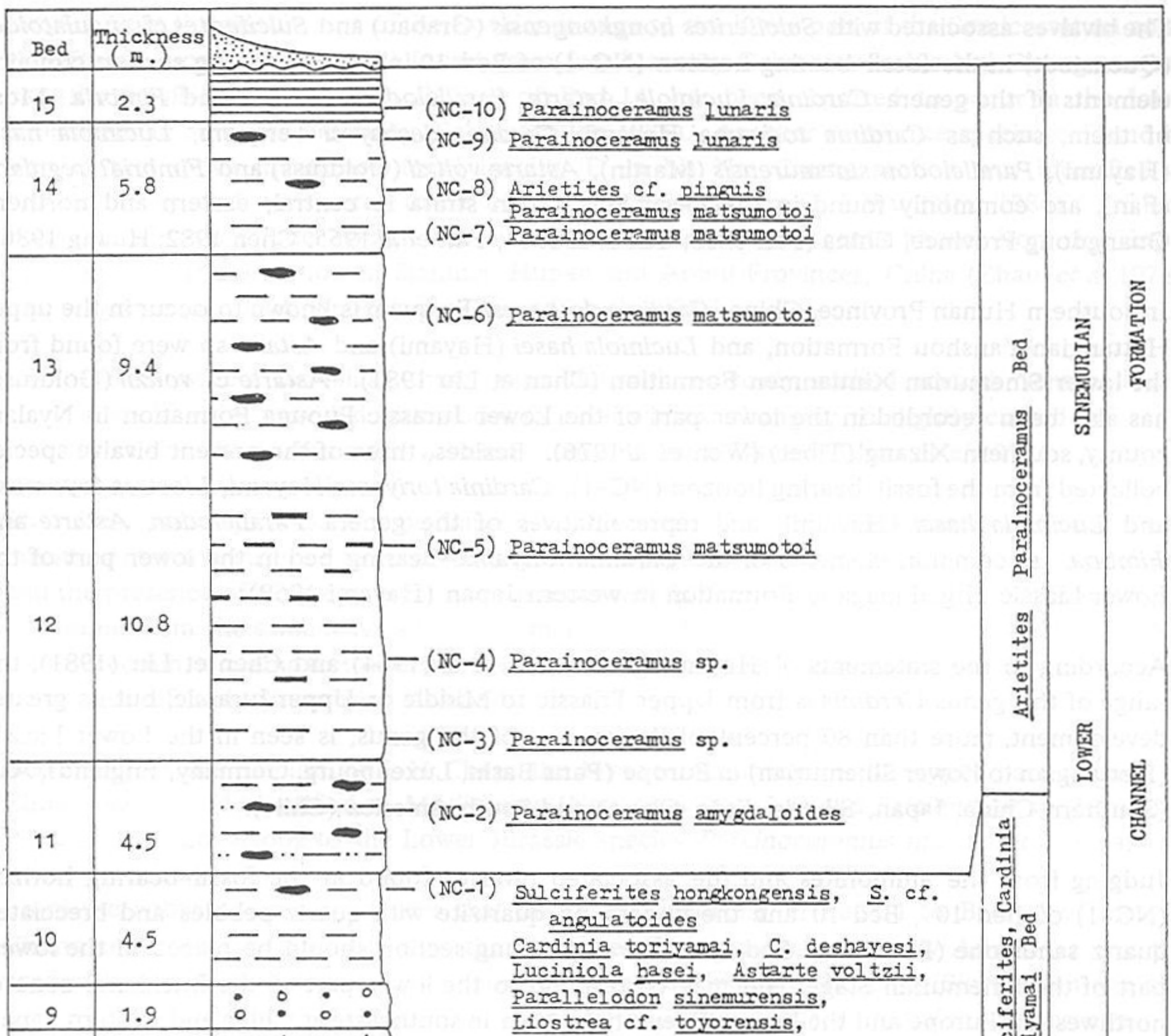

Figure 2 Columnar stratigraphic section near Nai Chung pier

The bivalves associated with *Sulciferites hongkongensis* (Grabau) and *Sulciferites* cf *angulatoides* (Quenstedt) in the fossil-bearing horizon (NC-1) of Bed 10 in the Nai Chung section contains elements of the genera *Cardinia*, *Luciniola*, *Astarte*, *Parallelodon*, *Liostrea* and *Fimbria*. Most of them, such as *Cardinia toriyamai* Hayami, *Cardinia deshayesi* Terquem, *Luciniola hasei* (Hayami), *Parallelodon sinemurensis* (Martin), *Astarte voltzii* (Goldfuss) and *Fimbria*? *regularis* (Fan), are commonly found in the lower Sinemurian strata in central, eastern and northern Guangdong Province, China (Fan 1963; Yin *et al* 1964; Fan *et al* 1965; Chen 1982; Huang 1986).

In southern Hunan Province, China, *Cardinia deshayesi* Terquem is known to occur in the upper Hettangian Yanshou Formation, and *Luciniola hasei* (Hayami) and *Astarte* sp were found from the lower Sinemurian Xintianmen Formation (Chen et Liu 1981). *Astarte* cf *voltzii* (Goldfuss) has also been recorded in the lower part of the Lower Jurassic Pupuga Formation in Nyalam county, southern Xizang (Tibet) (Wen *et al* 1976). Besides, three of the present bivalve species collected from the fossil-bearing horizon (NC-1), *Cardinia toriyamai* Hayami, *Liostrea toyorensis* and *Luciniola hasei* (Hayami), and representatives of the genera *Parallelodon*, *Astarte* and *Fimbria*, are common elements of the *Cardinia toriyamai*-bearing bed in the lower part of the Lower Liassic Higathinagano Formation in western Japan (Hayami 1959).

According to the statements of Hayami (1959), Yin *et al* (1964) and Chen et Liu (1981), the range of the genus *Cardinia* is from Upper Triassic to Middle or Upper Jurassic, but its greater development, more than 80 percent of the species of the genus, is seen in the Lower Liassic (Hettangian to Lower Sinemurian) in Europe (Paris Basin, Luxenbourg, Germany, England), Asia (Southern China, Japan, Siberia, Indo-China) and South America (Chile).

Judging from the ammonites and the associated bivalves found in the fossil-bearing horizon (NC-1) of Bed 10 , Bed 10 and the underlying quartzite with quartz pebbles and brecciated quartz sandstone (Bed 9 and Bed 8) in the Nai Chung section should be placed in the lowest part of the Sinemurian Stage, and may correspond to the lower part of the Bucklandi zone of northwestern Europe and the lowest Sinemurian strata in southeastern China and western Japan.

The fossils collected from the remaining fossil-bearing horizons of the Nai Chung section, (NG-2) to (NC-10) from Bed 11 to Bed 15, embrance *Arietites* cf *pinguis* (Quenstedt), *Parainoceramus matsumotoi* Hayami, *Parainoceramus lunaris* Hayami, *Parainoceramus amygdaloides* (Goldfuss) and *Parainoceramus* sp.

The mentioned species of genus *Parainoceramus* are common in the Lower Jurassic strata in southern China, which are usually associated with the early Sinemurian ammonites (*Coroniceras*, *Arietites*, *Arnioceras*, etc), for instance: the Xintianmen Formation in southern Hunan Province (*Parainoceramus matsumotoi* bed) (Chen & Liu 1981), the *Parainoceramus-Tainonuculana* assemblage of the Upper Member of the Jinji Formation in central and northern Guangdong Province (Chen 1982), the *Arnioceras-Parainoceramus* assemblege of the Third Formation of the Lantang Group in eastern Guangdong Province (Fan *et al* 1965) and the *Coroniceras-Arietites-Parainoceramus* assemblege of the lower part of the Lishan Formation in southern Fujian Province (Cao 1982). Most of the bed and assemblages mentioned above directly overlie the *Sulciferites* and/or *Cardinia toriyamai*-bearing beds. The same case has been also seen in the Lower Liassic Tolo Channel Formation at Sham Chung (Lee 1984) and Pak Kok Tsai (Lai 1989), New Territories, Hong Kong.

Arietites is an index Lower Sinemurian ammonite genus widely recorded in Europe, the Himalayas, southeastern and eastern Asia, and North and South America (Arkell *et al* 1957), ranging from the middle part of the Bucklandi zone to the lower part of the Semicostatum zone. *Arietites* cf *pinguis* (Quenstedt) found from fossil locality D by Nau in his Nai Chung section, now the fossil-bearing horizon (NC-8) of Bed 14, has been reported to occur in the lower Sinemurian in southern Germany (Schlegelmilch 1976). Another ammonite specimen found by Nau at the above mentioned fossil locality D in his Nai Chung section was identified as *Sinoceltites* sp and considered to be of Late Triassic age by Q J Wu (Nau 1986). In fact, *Sinoceltites* is not a Late Triassic but a Late Permian ammonite genus known from the Upper Permian Dalong Formation in Sichuan, Hunan and Anhui Provinces, China (Zhao *et al* 1978). The diagnosis of genus *Sinoceltites* Zhao et Liang 1974 is:

> "Shell widely umbilical, thinly discoidal with narrowly arched smooth venter. Lateral sides provided with nodes in inner whorls, changing to slightly curved or straight ribs on the outer volutions. Suture line ceratitic" (Zhao *et al* 1978)

The "*Sinoceltites* sp" illustrated by Nau (Nau 1986 Plate I,a) with evolute whorls and simple ribs, but no venter and suture line preserved, differs from genus *Sinoceltites* in the absence of nodes and the presence of simple straight ribs on inner whorls. Considering that the "*Sinoceltites* sp" was found from the same fossil site as the mentioned *Arietites* cf *pinguis* (Quenstedt) in the Nai Chung section, it seems to the authors that the *Sinoceltites* sp identified by Wu may be perhaps a fragment of Early Sinemurian Arietitids.

According to the opinion of J H Chen, the bivalves occurring in the upper part of the Nai Chung section and identified as *Modiolus* sp (Nau 1986 Plate I,b) and *Falcimytilus* sp (Nau 1986 Plate I,d) should belong to the Lower Jurassic species *Parainoceramus matsumotoi* Hayami.

From the above analysis it is clear that the fossils occurring in Bed 11 to Bed 15 of the Nai Chung section are characterized by the presence of ammonites of Family Arietitidae and the predominance of bivalve genus *Parainoceramus*, which indicate the Early Sinemurian age and may correspond to the Middle Bucklandi Zone to the Lower Semicostatum Zone in northwestern Europe.

The lower part of the Nai Chung section (From Bed 1 to Bed 7), from which no fossils have been found yet, is overlain by strata containing lowest Sinemurian ammonites and bivalves, and it may be therefore correlated with the Lower Member of the Jinji Formation in Guangdong, the Yanshou Formation in southern Hunan, representing the Hettangian Stage.

In the light of the fossils and the lithological characters, the sedimentary rocks exposed at Nai Chung pier, New Territories, Hong Kong, should be doubtlessly assigned to the Lower Jurassic Tolo Channel Formation and may correspond to the equivalent deposits in southern China and western Japan (Table 1).

It may be concluded based on the distribution of the marine Lower Jurassic strata that during the Early Liassic the sea submerged Hong Kong and other places in south China, including eastern, central and northern Guangdong, southern Fujian and southern Hunan, and formed a tongue like bay stretching into the land. The Early Liassic ammonite and bivalve faunas there are closely related to those of the Circum-Pacific Realm and the Tethyan Realm.

<table>
<tr><th colspan="2">Nai Chung, Hong Kong
This Paper</th><th colspan="3">Guangdong, China
Wang et Smith 1986</th><th colspan="2">Southern Hunan, China
Chen et Liu 1981</th><th colspan="2">SW. Fujian, China
Cao 1982</th><th colspan="2">Western Japan
Hayami 1959</th><th colspan="3">Northwestern Europe
Dean, Donovan et Howarth 1961</th></tr>
<tr><td rowspan="9">Tolo Channel Formation</td><td rowspan="2"></td><td rowspan="9">Jinji Formation</td><td rowspan="6">Upper Member</td><td rowspan="2"><u>Arnioceras</u> Assemblage</td><td rowspan="6">Xintianmen Formation</td><td rowspan="6"><u>Arnioceras</u> —

<u>Parainoceramus</u> Beds</td><td rowspan="9">Lower Part of Lishan Formation</td><td rowspan="2"></td><td rowspan="9">Higashinagano Formation</td><td rowspan="2"></td><td><u>Euagassiceras</u> <u>sauzeanum</u> Subzone</td><td rowspan="3"><u>Arnioceras</u> <u>semicostatum</u> Zone</td><td rowspan="6">Lower Sinemurian</td></tr>
<tr><td><u>Agassiceras</u> <u>scipionianum</u> Subzone</td></tr>
<tr><td rowspan="3"><u>Arietites</u> —
<u>Parainoceramus</u>
Beds</td><td rowspan="3"><u>Coroniceras</u> Assemblage</td><td rowspan="4"><u>Coroniceras</u> —
<u>Arietites</u> —
<u>Parainoceramus</u>
Beds</td><td rowspan="3"><u>Coroniceras</u> Bed

<u>Oxytoma</u> Bed</td><td><u>Coroniceras</u> <u>reynesi</u> Subzone</td></tr>
<tr><td><u>Arietites</u> <u>bucklandi</u> Subzone</td><td rowspan="3"><u>Arietites</u> <u>bucklandi</u> Zone</td></tr>
<tr><td><u>Coroniceras</u> <u>rotiforme</u> Subzone</td></tr>
<tr><td><u>Sulciferites</u>, <u>Cardinia</u> <u>toriyamai</u> Bed</td><td><u>Sulciferites</u> Assemblage</td><td><u>Prosogyrotrigonia</u> Bed
<u>Cardinia</u> <u>toriyamai</u> Bed</td><td><u>Metophioceras</u> <u>conybeari</u> Subzone</td></tr>
<tr><td rowspan="3"></td><td rowspan="3">L. Member</td><td rowspan="3"><u>Hiatella</u> Assemblage</td><td rowspan="3">Yanshou Fm.</td><td rowspan="3"><u>Cardinia</u> <u>scapha</u> Bed</td><td rowspan="3"></td><td rowspan="3"></td><td colspan="2"><u>Schlotheimia</u> <u>angulata</u> Zone</td><td rowspan="3">Hettangian</td></tr>
<tr><td colspan="2"><u>Alsatites</u> <u>liasicus</u> Zone</td></tr>
<tr><td colspan="2"><u>Psiloceras</u> <u>planorbis</u> Zone</td></tr>
</table>

Table 1 Division and correlation of Lower Liassic strata at Nai Chung pier, New Territories, Hong Kong

Acknowledgments

We gratefully acknowledge the support of the Hong Kong Polytechnic and the Academia Sinica. Thanks are also due to Dr M Anson, Head of the Department of Civil and Structural Engineering, Hong Kong Polytechnic, and Prof W S Wu and J T Xu, Director and Deputy-Director of the Nanjing of Geology and Palaeontology, Academia Sinica, for their constant encouragements.

References

ADDISON R (1986). *Geology of Sha Tin. Hong Kong Geological Survey Memoir No 1.* Geotechnical Control Office, Hong Kong. 85 p

ALLEN P M & STEPHENS E A (1971). *Report on the Geological Survey of Hong Kong 1967–1969.* Hong Kong Government Press. 116 p plus 2 maps

ARKELL W J, KUMMEL B & WRIGHT C W (1957). Mesozoic Ammonoidea. In: R C MOORE (ed). *Treatise on invertebrate paleontology, Part (L) Mollusca 4.* Geological Society of America and the University of Kansas Press, Lawrence, p 80-465

ATHERTON M J (1983). Geological excursion to Tolo Channel. *Geological Society of Hong Kong Newsletter* Vol 1 No 4 p 00-00

BENNETT J D (1984). *Review of Hong Kong Stratigraphy. GCO Publication No 5/84.* Geotechnical Control Office, Hong Kong. 86 p

CAO B S (1982). The discovery of Early Jurassic marine strata in Fujian. *Geological Review* Vol 28 No 5 p 490-491 (in Chinese with English abstract)

CHEN J H & LIU L (1981). Discovery of early Jurassic *Cardinia* beds in Rucheng, Hunan. *Acta Palaeontologia Sinica* Vol 20 No 4 p 376-382 (in Chinese with English abstract)

CHEN J H (1982). Liassic bivalve fossils from Mt Jinji of Guangdong. *Acta Palaeontologica Sinica* Vol 21 No 4 p 404-415 (in Chinese with English abstract)

DAVIS S G (1953). *The geology of Hong Kong.* Hong Kong Government Printer, 210p

DEAN W T, DONOVAN D T & HOWARTH M K (1961). The Liassic ammonite zones and subzones of the northwest European province. *Bulletin of the British Museum (Natural History), Geology (Palaeontology) Series* Vol 4 No 10 p 437-505

FAN J S (1963). On Lower Jurassic Lamellibranchia from Guangdong. *Acta Palaeontologica Sinica* Vol 11 No 4 p 508-543 (in Chinese with English abstract)

FAN J S, LAO C Y & ZHU M (1965). On the stratigraphical sequence and geological age of the Lantang Group, Boluo District, Guangdong. *Acta Geologica Sinica* Vol 45 No 2 p 151-163 (in Chinese with English abstract)

GRABAU A W (1923). A Lower Cretaceous ammonite from Hong Kong. *Bulletin of the Geological Survey of China* No 5 Pt 2 p 199-207

GRABAU A W (1928). *Stratigraphy of China. Part 2, Mesozoic.* The Commercial Press, Peking

HAYAMI I (1959). Lower Liassic Lamellibranch fauna of the Higashinagano Formation in west Japan. *Journal of the Faculty of Science, University of Tokyo* Vol 11 Pt 2 p 31-84

HEANLEY C M (1924). Notes on some fossiliferous rocks near Hong Kong. *Bulletin of the Geological Society of China* Vol 3 No 1 p 85-87

HEIM A (1929). Fragmentary observations in the region of Hong Kong compared with Canton. *Geological Survey of Kwangtung & Kwangsi Annual Report* Vol 2 p 1-32 (plus 1 p errata)

HUANG Z H (1986). Discovery of early Jurassic bivalves from Shen Zhen area. *Acta Palaeontologica Sinica* Vol 25 No 5 p 577-584 (in Chinese with English abstract)

LAI K W (1989). A new Lower Jurassic fossil locality - south coast of Pak Kok Shan, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 7 Pt 3 p 15-18

LEE C M (1959). The significance of the Lower Jurassic system found in Guangdong Province. *Geological Newsletter of Guangdong* No 4 p 34- 36 (in Chinese)

LEE C M (1984). Lower Jurassic fossil assemblages at Sham Chung, New Territories, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 2 No 6 p 1-6

NAU P S (1984). Note on ammonites (Arietitidae) from Sham Chung, Tolo Channel. *Geological Society of Hong Kong Newsletter* Vol 2 No 6 p 6-8

NAU P S (1986). Upper Triassic strata along the shoreline at Nai Chung ferry pier, New Territories, Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 4 No 1 p 1-12

RUXTON B P (1960). The geology of Hong Kong. *Quarterly Journal of the Geological Society of London* Vol 115 p 233-260 (plus 2 plates & 1 map)

SCHLEGELMILCH R (1976). *Die Ammoniten des Suddeutschen Lias.* Gustav Verlag, Stuttgart, 212 p

SUN Y Z, CHANG A Z & SHAO J (1960). Division and correlation of the Liassic of central Guangdong. *Acta Palaeontologica Sinica* Vol 8 No 2 p 131-154 (in Chinese with Russian abstract)

SUN Y Z, ZHU G M, LIU G F & SHENG H B (1980). Studies on the Lower Jurassic ammonites from the Kaiping-Enping area, Guangdong. *Acta Palaeontologica Sinica.* Vol 19 No 2 p 68-76 (in Chinese with English abstract)

WANG Y G (1988). 2. China. *Newsletter of Stratigraphy* Vol 19 No 1-2 p 95-130

WANG Y Q & HE G X (1981). Some early Jurassic ammonoids from eastern Himalayas. Series of Scientific Expedition to Qinghai-Xizang Plateau. *Palaeontology of Xizang* No 3 p 314-334 (in Chinese with English abstract)

WANG Y Q & SMITH P L (1986). Sinemurian (early Jurassic) ammonite fauna from Guangdong Region of China. *Journal of Paleontology* Vol 60 No 2 p 1075-1085

WEN S X *ET AL* (1976). Fossil lamellibranchs from the Mt Jolmo Lungma Region. Report of Scientific Expedition in Mt Jolmo Lungma Region (1966-1968). *Palaeontology* No 3 p 1-152 (Science Press, Beijing, in Chinese)

WILLIAMS M Y (1943). The stratigraphy and palaeontology of Hong Kong and the New Territories. *Transactions of the Royal Society of Canada* Third Series Vol 37 Sect IV p 93-117

YIN Z X *ET AL* (1964). The age relationship of the marine Lower Liassic of Guangdong. *Scientia Geologica Sinica* No 3 p 203-210 (in Chinese)

ZHAO J K, LIANG X L & ZHEN Z G (1978). Late Permian cephalopods of southern China. *Palaeontologia Sinica NSB* No 12, 194 p (in Chinese with English abstract)

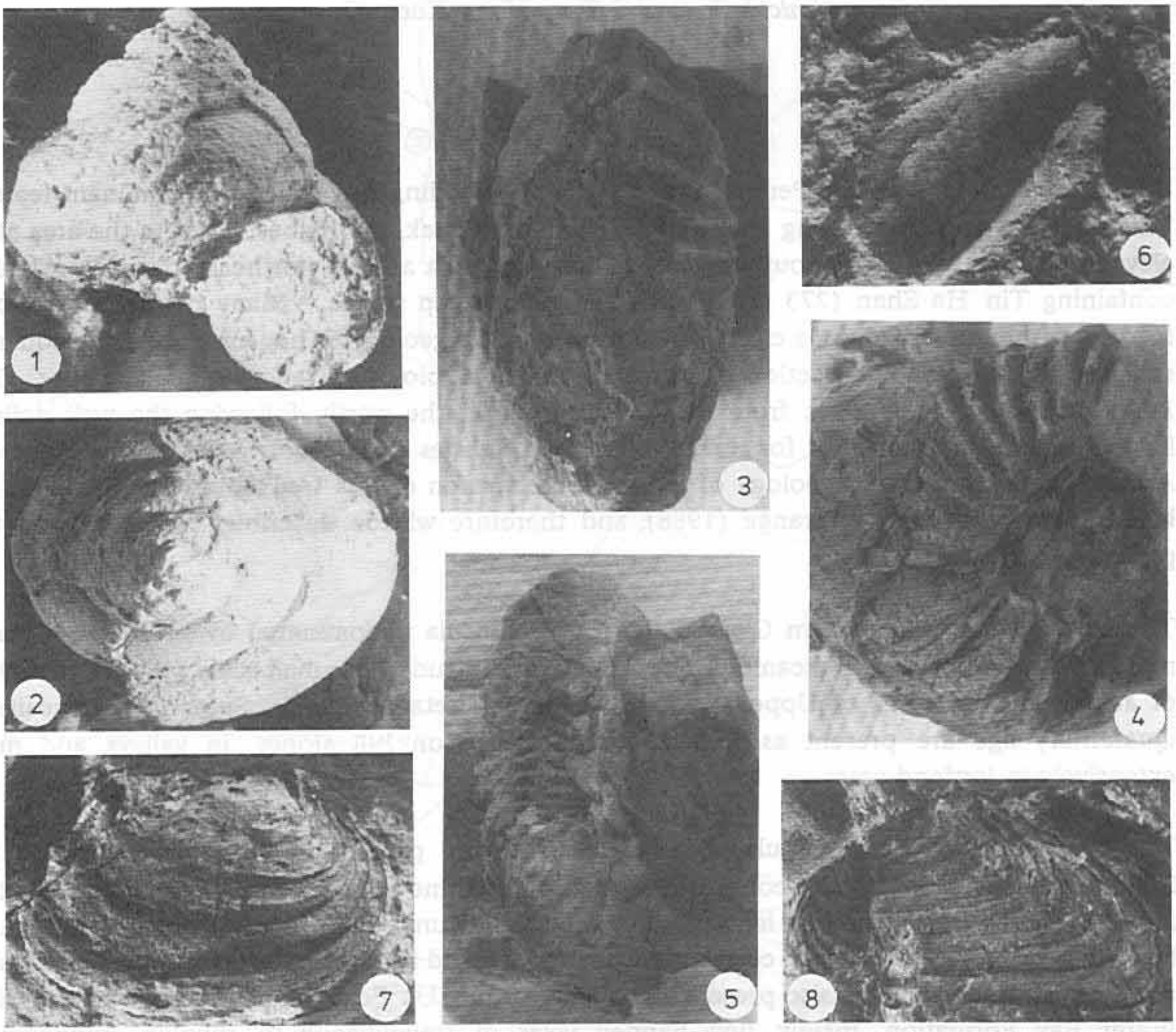

Plate I Fossils from the Tolo Channel Formation at Nai Chung pier:

1–2 Gastropods

3–5 *Sulciferites hongkongensis* (Grabau)

6 *Parainoceramus matsumotoi* Hayami

7 *Luciniola hasei* (Hayami)

8 *Cardinia toriyamai* Hayami

Geological Society of Hong Kong Newsletter Vol 8 Pt 3 p 34-42

GEOLOGY OF HIGH JUNK PEAK TRAIL, CLEAR WATER BAY PENINSULA

A C T So & P J Strange

Geotechnical Control Office, Hong Kong Government

Introduction

Within the Clear Water Bay Peninsula a steep south-trending ridgeline is the dominant feature. This ridgeline rises from Mang Kung Uk to High Junk Peak, the highest point in the area at an elevation of 344 m. In the southern part of the peninsula a short northeast-trending ridgeline containing Tin Ha Shan (273 m) is surrounded by steep slopes. Many of the topographic features within the area have a close relationship with the geology. They have been subsequently sculpted by the combined action of physical, chemical, biological and human activities. The High Junk Peak Trail starts from Mang Kung Uk in the north, following the well-defined footpath along the ridgelines for some 6.6 km, and finishes at Tai Miu in the south (Figure 1). A detailed account of the geology of the southern section of this trail along Tai Miu Wan has been given previously by Strange (1988), and therefore will be described only briefly in this paper.

The solid geology of southern Clear Water Bay Peninsula is dominated by Mesozoic volcanic rocks of the Repulse Bay Volcanic Group. These are intruded by small scale plutons and dykes of acidic igneous rocks of Upper Jurassic to Lower Cretaceous age. Superficial deposits of Quaternary age are present as impersistent outcrops on hill slopes, in valleys and more extensively in lowland areas.

The oldest rocks of the Repulse Bay Volcanic Group present in this area belong to the Silverstrand Formation, which comprises a thick welded fine ash tuff with a prominent eutaxitic fabric throughout. This in turn is overlain by the Mang Kung Uk Formation which is dominated by well-bedded tuffite, breccia, conglomerate, siltstone and sandstone layers. Impersistent lavas and fine ash tuff bands are also present. The Mang Kung Uk Formation is overlain by the Clear Water Bay Formation, mainly flow-banded lavas of trachydacite to rhyolite composition. Individual lava flows average 60 to 80 m in thickness, with the lowest prominent flow (the Tai Miu Wan Member) of trachydacite composition mappable over a distance of about 5 km. Several fine ash tuff horizons are present between lava flows. The highest unit in the volcanic succession within the district is the High Island Formation. This consists of massive, remarkably uniform, fine ash welded tuff. In places this Formation oversteps the Clear Water Bay Formation lavas to rest on the Silverstrand tuffs, and it appears to infill former topographic hollows within the older volcanics. Along the shores of Tai Miu Wan, fissure vents have been recognised, usually in association with quartz syenite intrusions.

Small plutons of fine-grained granite and fine-grained quartz syenite occur in the southern part of the Clear Water Bay Peninsula. Dykes of quartz syenite and quartzphyric rhyolite are also present, the former containing long enclaves of coarse-grained granite. Basalt dykes of presumed Tertiary age are ubiquitous.

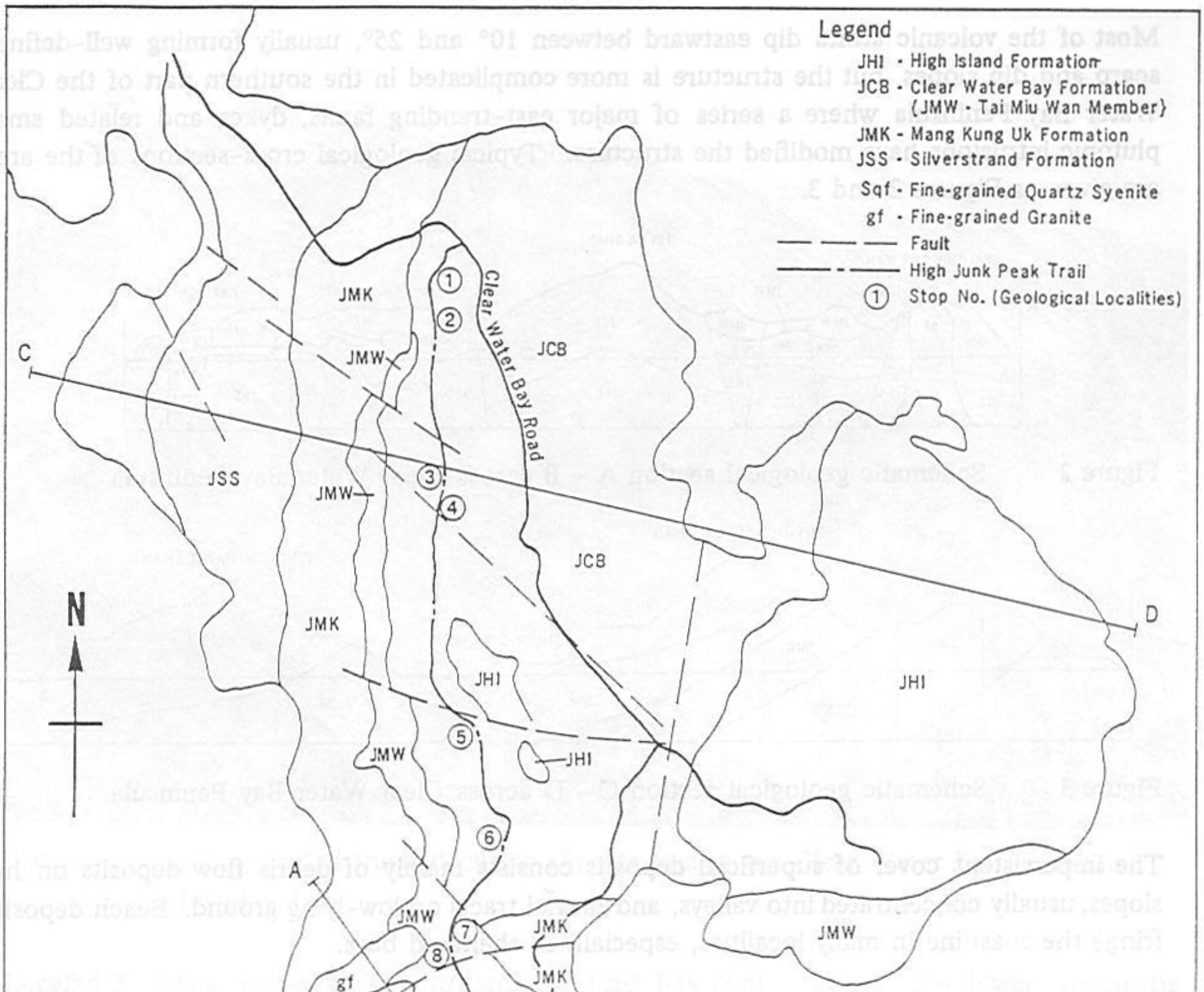

Figure 1 Solid geology of Clear Water Bay Peninsula

Most of the volcanic strata dip eastward between 10° and 25°, usually forming well-defined scarp and dip slopes, but the structure is more complicated in the southern part of the Clear Water Bay Peninsula where a series of major east-trending faults, dykes and related small plutonic intrusions have modified the structure. Typical geological cross-sections of the area are given as Figures 2 and 3.

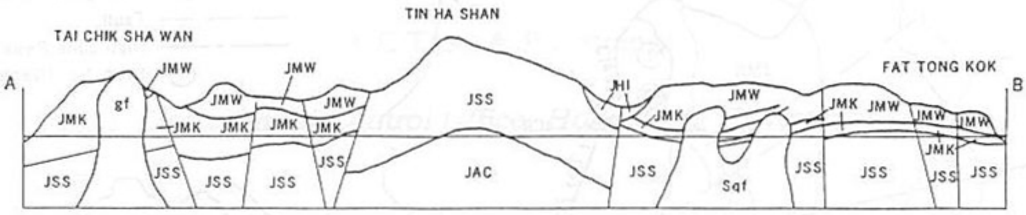

Figure 2 Schematic geological section A - B across Clear Water Bay Peninsula

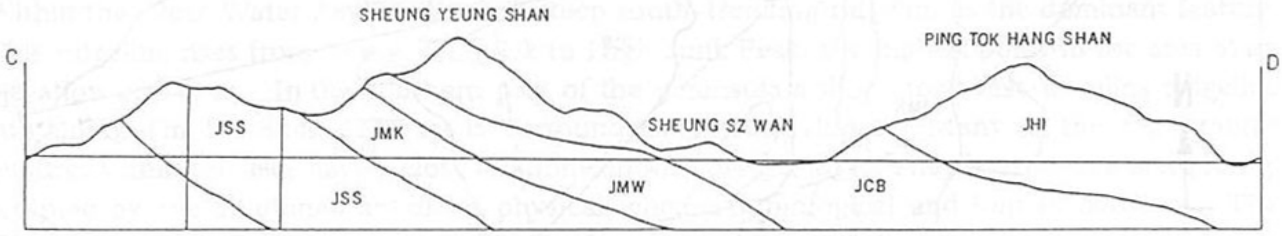

Figure 3 Schematic geological section C - D across Clear Water Bay Peninsula

The impersistent cover of superficial deposits consists mainly of debris flow deposits on hill slopes, usually concentrated into valleys, and alluvial tracts on low-lying ground. Beach deposits fringe the coastline in many localities, especially in sheltered bays.

High Junk Peak hiking trail

The numbers below refer to points marked on the map of the trail. The descriptions given for each locality are based on the observations taken during the remapping programme carried out by the Hong Kong Geological Survey from 1986 to 1988. The geological map (Strange *et al* 1989) and memoir describing the geology (Strange *et al* 1990) are now available to the public.

Locality 1. As we leave Clear Water Bay Road just beyond Mang Kung Uk and climb the footpath from the main road (first KMB No 91 bus stop to the south of Mang Kung Uk Village), look at the stone blocks by the side of the path. You will see contorted wavy banding on the weathered surfaces (Plate 1). The rock is the lava of trachydacite to rhyolite composition, and when extruded from the vent it flowed as a viscous sticky liquid. Some crystallisation took place and streaky layers were formed. As the lava flowed along slowly, these bands became contorted, producing the shapes you see on the rock surfaces. This flow-banding is defined by the orientated feldspar crystals (microlites) (Addison & So 1989) which are well displayed in thin section (Plate 2).

Locality 2. At the top of the first hill, as you cross the old agricultural area, look towards the hill further along the trail and you can see how the various lava flows have formed distinctive features on the landscape. The harder lava layers form escarpments between softer fine ash tuff. The strata dip towards the east at about 20°.

Plate 1 Flow-banded trachydacite to rhyolite lava in the Clear Water Bay Formation; Locality 1

Locality 3. Look westwards here towards the Junk Bay controlled tip. The lower area in the foreground is composed of softer sedimentary rocks such as sandstones, siltstones and mudstones, and is therefore more easily eroded. These sedimentary rocks form the north-striking valley feature through Mang Kung Uk, and are underlain by very hard fine ash tuff deposits. They have been excavated for fill from the borrow areas to the west.

Locality 4. We cross several small faults along the ridge and climb upwards into a tuff layer which separates two lava flows. The tuff is a very fine-grained rock which contains small scattered quartz crystals but has no layering or banding visible.

Locality 5. The trail follows the escarpments created by the harder lava flows. At this point we can look up the hill to the east and see the cliffs of fine ash tuff of the High Island Formation; these are extremely hard, brittle rocks. They form the hill top capping of High Junk Peak and Miu Tsai Tun. These fine ash tuffs are ignimbrites and were deposited as a single massive eruption of very hot ash. Ash returning to the earth's surface remained hot, and pumice fragments in the flow were flattened, producing a eutaxitic welded fabric (Plate 3). The eruption would have covered many square kilometres, and these rocks occur across Port Shelter to High Island. The ash probably cooled as a single unit, and spectacular columnar jointing developed (Plate 4). This is well seen at High Island and on many islands within Port Shelter, but good hexagonal columns can also be seen on High Junk Peak and can be found as fallen blocks around the lower slopes. A cross-section of this area is shown on the Figure 1.

Locality 6. The lava flows here display autobrecciation (Plate 5). This term is used to describe the lava that was already cooling as it flowed along and started to solidify. The semi-solid fragments broke away from the front of the flow and stuck together as rubbly-looking rock masses.

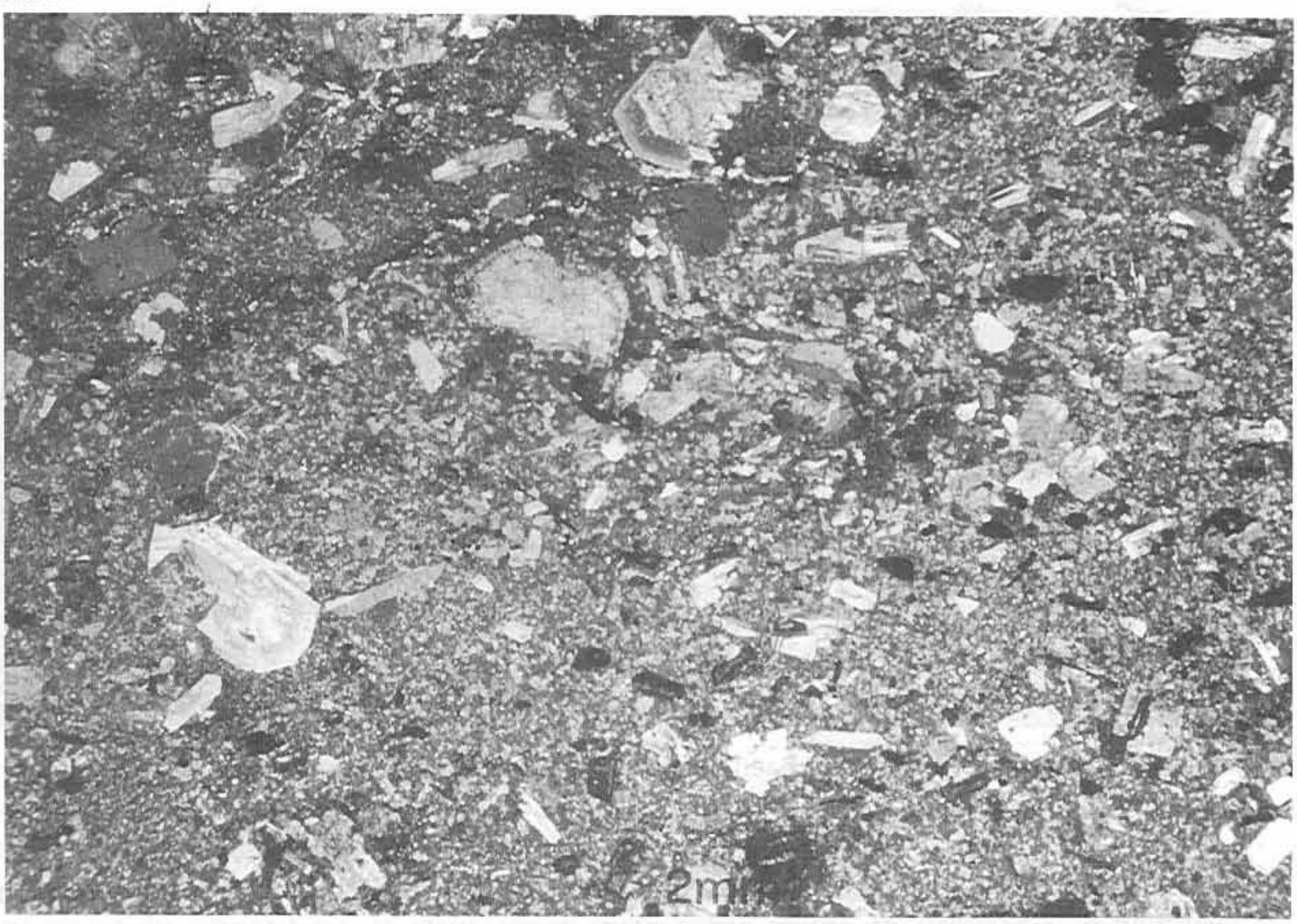

Plate 2 Thin section of flow-banded trachydacite to rhyolite (HK6839) of the Clear Water Bay Formation, showing orientated elongate feldspar crystals; XPL x 10

Locality 7. Just to the west of this locality, along the ridge towards Junk Bay, a small granite pluton has intruded into the volcanic rocks. The granite was very hot and has thermally metamorphosed the nearby volcanic rocks. These have been chemically altered, and new small crystals have grown in the volcanics; these include small reddish brown garnet crystals.

Locality 8. We cross a major fault in the small hollow at this locality and are now on another rock type. This is also a lava but has a different chemical composition and is known as trachydacite. It contains less silica (quartz) and when fresh it has a bluish grey colour.

Locality 9. Boulders of the trachydacite lava are scattered across the hill. Looking southward, along the trail, we see the high hill of Tin Ha Shan in front of us. A fault separates the trachydacite lava from the Silverstrand Formation (described below) which forms Tin Ha Shan.

Locality 10. We have now crossed the fault which divides the lava from the tuffs of Tin Ha Shan. The rocks making up Tin Ha Shan are seen as fallen blocks along the trail in this vicinity. They are streaky and composed of fine dusty ash, together with flattened pumice fragments. The latter are called *fiammé* from the Italian word for "flame", describing their shapes. The rock texture is described as eutaxitic and is typical of the Silverstrand Formation. It was formed as an ignimbrite as described at locality 5.

Plate 3 Thin section of fine ash tuff of the High Island Formation (HK6243), showing deeply embayed quartz and flow fabric; XPL x 10

Locality 11. From locality 10 we have followed around the lower slopes of Tin Ha Shan and seen many large blocks of the eutaxitic tuff with the fiammé visible. These are often weathered out to give the rock a honeycombed appearance (Plate 6). At locality 11 we cross a dyke of quartz syenite, a rock very similar to granite but with less quartz present. A cross-section of the area is given as Figure 2.

Locality 12. Look at some of the boulders which have fallen from up the hill and you can find blocks of eutaxitic tuff, quartz syenite, fine ash tuff and coarse-grained granite. The presence of the coarse-grained granite is interesting since it is not seen outcropping within 10 km of here. It appears to occur as large blocks carried upwards in the centre of the quartz syenite dyke. Immediately below locality 12, on the coastline, a fissure vent can be seen. This is filled with all kinds of rock types, probably partly material which fell back into the fissure when eruption ceased. The vent can only be reached from along the coast and only at low tide. A cross-section of this locality is given as Figure 4.

Locality 13. At the helipad, the dyke of quartz syenite has bulged and forms the flat topped area of the landing site. Many boulders of quartz syenite can be seen,and its main mineral component, euhedral potassium feldspar crystals, stands out clearly.

Locality 14. At the end of the trail, the hollow in the hills, through which the road runs, is along a fault line which has dislocated the rock strata by about 100 m.

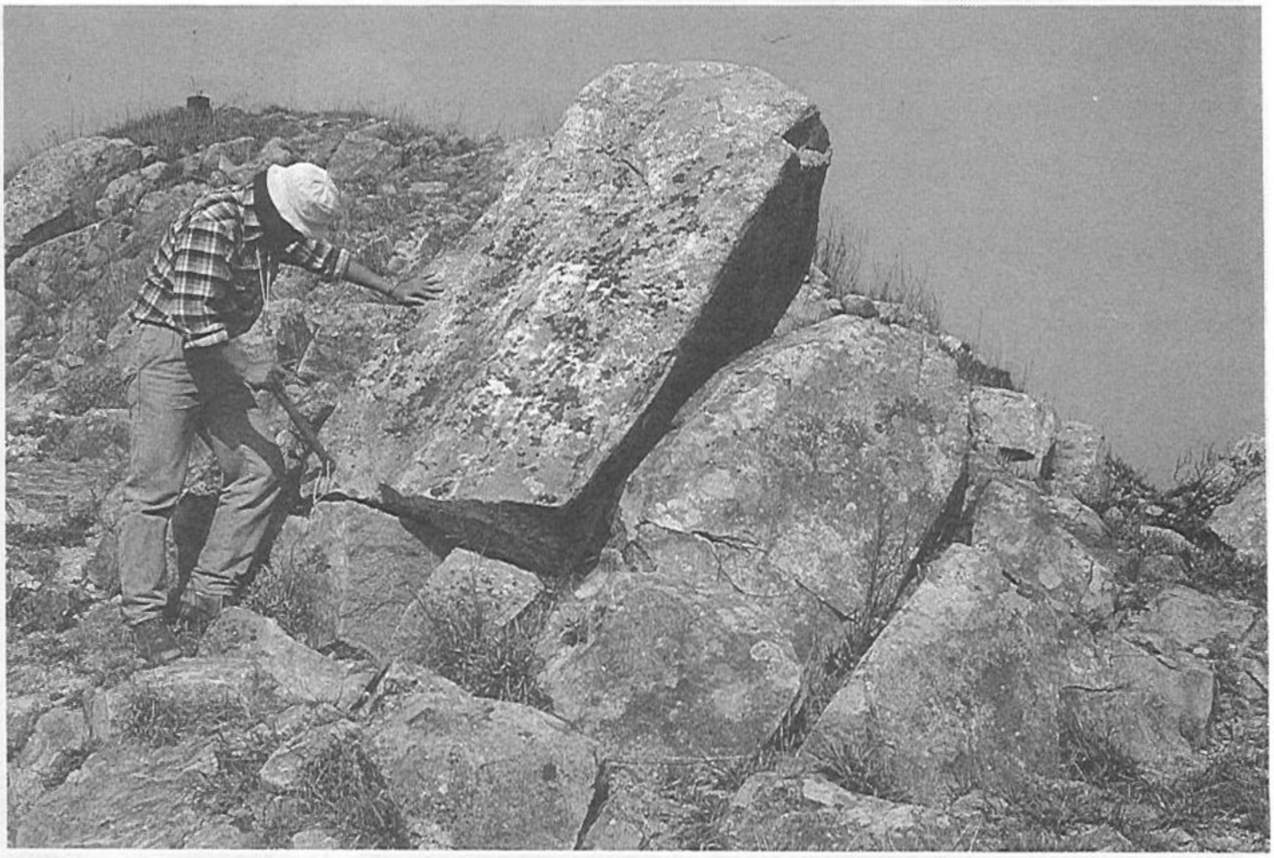

Plate 4 Columnal jointing in fine ash tuff of the High Island Formation at High Junk Peak; Locality 5

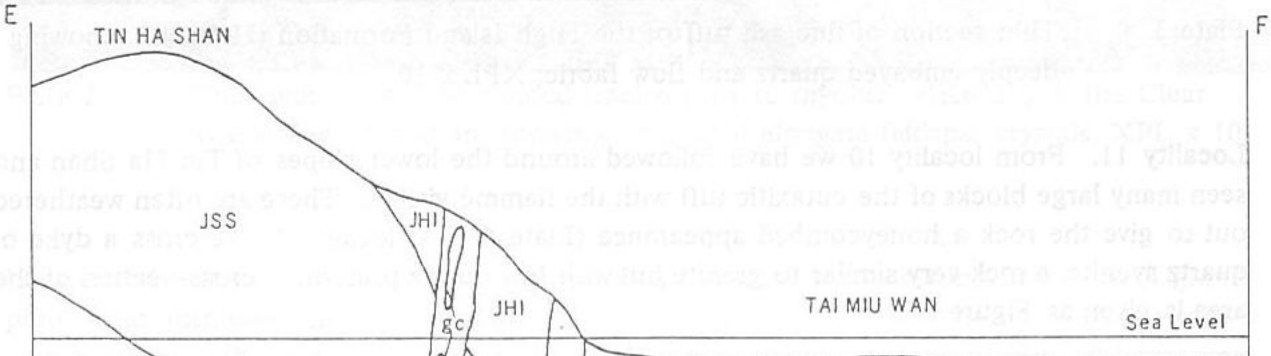

Figure 4 Schematic geological section E – F across Tai Miu Wan

Acknowledgements

We are grateful to R Addison for his valuable comments on the geology of the area, and to C F Chow for drafting the figures. This paper is published with the permission of the Director of Civil Engineering Services of the Hong Kong Government.

Plate 5 Autobrecciated trachydacite to rhyolite lava in the Clear Water Bay Formation; Locality 6

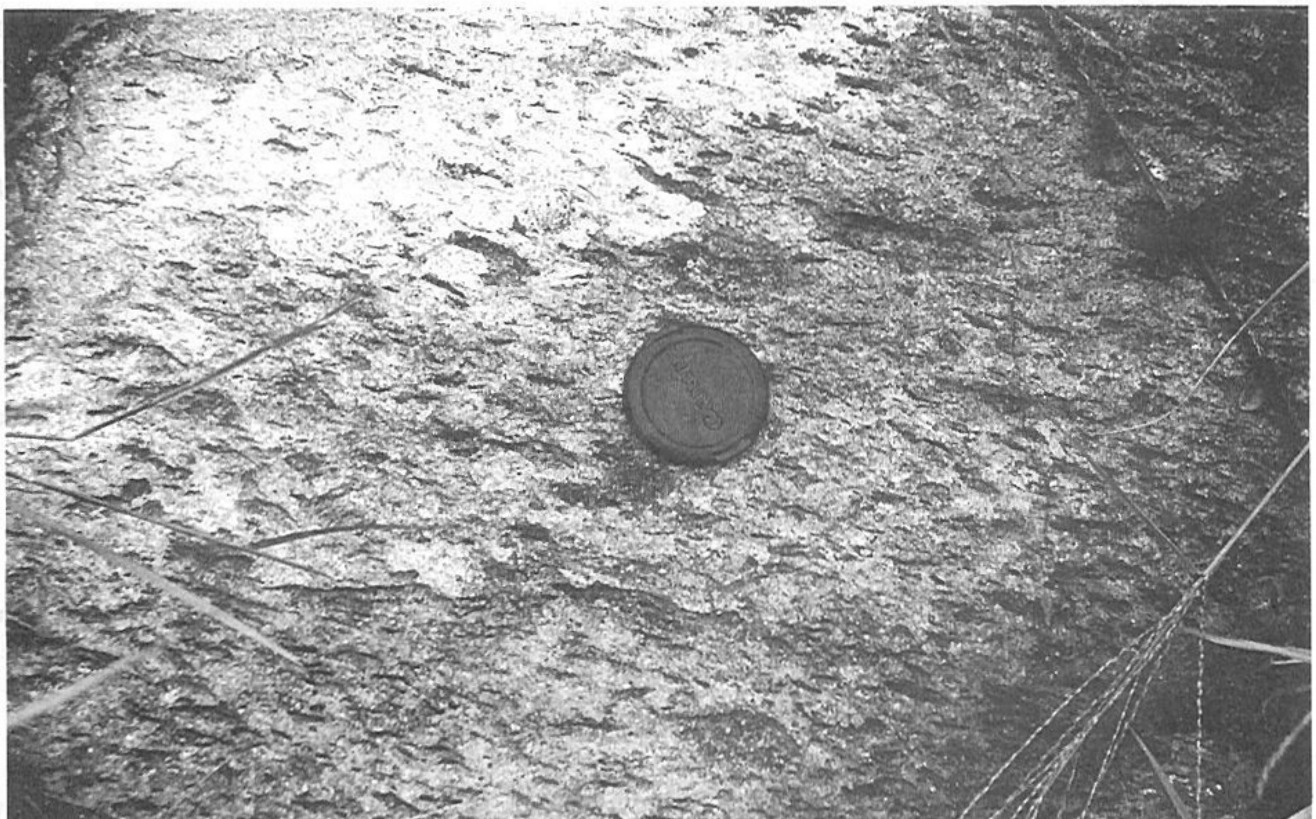

Plate 6 Eutaxitic tuff displaying flow fabric, in the Silverstrand Formation; Locality 11

References

ADDISON R & SO A C T (1989). Textural features, field characters and geochemistry of aphanitic volcanic rocks of eastern Hong Kong. *Geological Society of Hong Kong Newsletter* Vol 7 Pt 4 p 20-31

STRANGE P J (1988). The geology of Tai Miu Wan (Joss House Bay), Clear Water Bay. *Geological Society of Hong Kong Newsletter* Vol 6 p 33-38.

STRANGE P J & SHAW R (1989). *Clear Water Bay. Hong Kong Geological Survey Sheet 12, Solid and Superficial Geology, Scale 1:20 000.* Geotechnical Control Office, Hong Kong

STRANGE P J, SHAW R & ADDISON R (1990). *Geology of Sai Kung and Clear Water Bay. Hong Kong Geological Survey Memoir No 4.* Geotechnical Control Office, Hong Kong. 112 p

---

ILLUSTRATED TALKS AND FIELD TRIPS, NOVEMBER-JANUARY 1990-91

Sunday 11 November. TAI O. Coastal exposures of presumed Carboniferous Tai O Formation, and of Pleistocene alluvial fans and debris flow deposits. Using public transport, led by Dr R L Langford

Tuesday 13 November. NEOTECTONICS IN THE HIMALAYAS by Dr Lewis Owen, Hong Kong Baptist College

Saturday 17 November. TSING SHAN DEBRIS FLOW. See the article in this issue. Using public transport, led by Dr R L Langford

Sunday 2 December. CHEK KENG, SAI KUNG (SHARP PEAK). Beach and mountain walk, by boat from Ma Liu Shui

Early December. MARBLE QUARRIES, SHENZHEN. Contact C M Lee

Tuesday 11 December. GEOLOGY AND VOLCANICS OF THE ETHIOPIAN RIFT VALLEY by Mr Ceri James, Hong Kong Geological Survey

Saturday 22 - Sunday 30 December. EAST GUANGDONG. Led by C M Lee

Friday 18 January. FLUVIAL GEOMORPHOLOGY OF THE UPPER AMAZON BASIN by Dr Ron Neller, Chinese University of Hong Kong

All talks are held in the Mariner's Club, Tsim Sha Tsui, from 6 pm to 7.30 pm. Details of talks and field trips will also be mailed separately to members, and any queries should be addressed to the Programme Sub-committee (see inside front cover).

Geological Society of Hong Kong Newsletter Vol 8 Pt 3 p 43-45

MARINE STUDIES GROUP

REPORT ON THE MEETING OF 16 OCTOBER 1989

"ESTUARINE HYDRAULICS AND ACCRETION IN THE PEARL RIVER ESTUARY"

A D Burnett

Geotechnical Control Office, Hong Kong Government

On the evening of 16 October 1989 the Marine Studies Group of the Geological Society of Hong Kong held a technical meeting at the offices of the Geotechnical Control Office. The theme of the meeting was "Estuarine hydraulics and accretion in the Pearl River Estuary", featuring a talk by David Osorio of Posford Duvivier International Ltd with supporting contributions by Raynor Shaw of the Geological Survey Section of the Geotechnical Control Office, and Nigel Ridley-Thomas of Electronic and Geophysical Services Ltd.

David Osorio initially covered some principles of estuarine mechanics "to remind the geotechnical engineers present of the preoccupations of watery people" and then described how the Pearl Estuary works from a hydraulics viewpoint, with speculation on how these principles might be applied to give an idea of the conditions when the sea levels and land levels were different.

Raynor Shaw spoke on Holocene sea-level change and Nigel Ridley-Thomas commented on the characteristics of the alluvial surface below the marine deposit.

David Osorio opened his presentation by explaining that an estuary is a water body in which relatively clean saline water and fresh silty water mix. The density difference between the ocean and the river water drives circulations in the horizontal and vertical planes. Riverborne silt is flocculated where it enters the salt water and is prevented from moving seawards by the toe of the intruding wedge of salt water. If fresh water and salt water are opposed on each side of a theoretical vertical barrier, with the same surface level, there is an excess unbalanced pressure at the bed on the salty side. In the case of the channels in Hong Kong this excess is about 0.5 m and it is this head which drives the circulations in the Pearl River estuary. If the barrier is withdrawn the wedge of salt water drives up the bed of the estuary while the fresh water flows along the surface. In a closed tank the interface oscillates to and fro and the surface eventually comes to rest with the salt water below and the fresh on top. In a river mouth, however, the wedge is arrested by the seaward flow of the fresh water and if this river flow does not vary it remains balanced in one place.

The speaker emphasised that the vertical circulations necessary to sustain the wedge in one place remain toward the river along the bed and toward the sea along the surface. Further, the river and oceanic waters in some estuaries are well mixed up while in others the wedge is very well defined. In the Pearl River the separation is exceedingly well defined. In the whole length of over 300 km where the influence of the fresh water discharge can be felt, most of the change at the toe of the wedge can occur in about 1 km.

The next point noted was that mud settles at the toe of the salt water wedge. The mechanism is that the suspended solids flocculate as they pass into the more saline water and then fall into the lower part of the water column where there is no transport upstream. In a straight narrow river the wedge is two dimensional, that is, it can be adequately defined by a single longitudinal section. In a wide symmetrical estuary the coriolis acceleration keeps the fresh silty water to the right hand side going seaward and the clear oceanic water to the right hand side going landward. So a horizontal circulation is superimposed upon the vertical circulation and the wedge becomes skewed. If the estuary is also asymmetrical there is a further complication. The speaker indicated that the most fundamental way of describing what was going on was to plot the lines of constant salinity (or density). The toe of the wedge in summer defines the seaward limit of the region of rapid siltation very well.

In summer the suspended solids concentration falls by an order of magnitude from Shajaio Power Station to Castle Peak Power Station and the change in water colour can be seen very clearly from a boat in the estuary. In winter the whole pattern moves up into the delta but the silt content of the fresh water also falls dramatically as the carrying capacity of a stream varies in the order of a fourth power of its speed.

The speaker then pointed out that all these things should be simulated in the WAHMO 3 DSL Model. However he noted that while this model reproduced the pattern of salinities over Hong Kong waters and the eastern part of the estuary rather well, it seemed to be incorrect along the east side so that the isohalines which, the speaker was convinced, run from north to south in nature, run east-west in the model. He believed, however, that the WAHMO extension would resolve this contradiction one way or the other.

Osorio then speculated what would happen if the river bed level falls and the wedge moves landward. He felt that as much of the deep channel is an erosion-resistant alluvium or decomposed rock and the scope for lower bed levels was likely to be rather well defined and limited, it followed that at lower sea levels the wedge, (and its silt deposition area) would be seaward of its present position. Hence if sea-level change could be specified it might be possible to calculate the area of siltation for each phase of the siltation. It would be necessary, however, to assume that peak flows in the river had not changed dramatically, or at least to make an informed estimate of the discharge for the former sea levels. To estimate past rates of siltation it would also be necessary to assume that sediment loads were similar to those currently observed. This would be a further leap but a case study had shown that this sort of balance seemed to hold for the Barron Delta in north Queensland, Australia, which is in a similar latitude to Hong Kong.

Raynor Shaw then spoke on Quaternary sea-level change by discussing the likely magnitude, timing and complexity of these events in the Hong Kong region. With the aid of slides he illustrated by means of a sea-level curve that some 16 000 to 18 000 years ago the global sea-level was some 150 to 160 m below its present level. A complex rise in sea-level then occurred during which the coastline migrated from its ancient position, some 240 km offshore, to near the present position. At the -30 m level the sea had barely reached Hong Kong, only penetrating local deep valleys such as the East Lamma and Ma Wan Channels. By about 6 000 BP the sea-level had approximately reached its present level and only minor fluctuations are believed to have occurred since that time. At 8 000 years BP the sea-level curve predicts a -20 m sea-level. Shaw noted that a recently dated sample from a marine core at about -19 mPD gave a date of 8 080 years.

However, the Holocene sea-level rise was far from uniform, and local and global complexities existed producing stillstands (eg at say -16 m) with periods of regression and then stability. As the sea-level rise proceeded the surface of the transgression would also have changed as a result of the erosion and deposition. Also, the configuration of the proto-Pearl River delta changed; at about 6 000 BP the sea was well inland near Guangzhou, but subsequent deposition has pushed the coast seaward despite the sea-level remaining reasonably constant.

The model illustrated by Nigel Ridley-Thomas was a Pearl River section from Boca Tigris through East Lamma to Po Tai. He speculated that with lower sea-levels the salt wedge was further seaward and hence siltation was further seaward. As the sea-level rose the salt wedge moved inland up the delta and the silt deposition zone at the wedge toe moved upstream; the seaward silt being slowly covered by ever deepening water which left these materials undisturbed.

Upon completion of the formal presentations the Group Chairman, Colin Dutton, invited questions from the audience and a vigorous discussion ensued. The questions were mainly concerned with the origin of the sediments occurring in the Pearl River, offshore and Mirs Bay. The speakers believed that even after the main delta salt wedge precipitation had occurred the residual 20-40 ppm of suspended silt still had the potential to migrate and settle out in the quieter oceanic waters and in the remoter areas like Mirs Bay. Discussion also covered the size of flocks formed in the salt water wedge toe area, the nature of the circulatory movements which are known to redistribute dumped marine spoil, the thickness and character of the Holocene muds as compared with the deeper marine clays, the effect of typhoons on the seabed, sedimentation patterns in deltas, and the paucity of good offshore geotechnical data in both Hong Kong and adjacent Chinese waters.

Hong Kong Geological Society Newsletter Vol 8 Pt 3 p 46-48

"SEISMIC RISK AT DAYA BAY GREATER THAN FOR NW EUROPE" SAYS CONSULTANCY REPORT

M J Atherton

Department of Civil and Structural Engineering,
Hong Kong Polytechnic

The long awaited "Risk assessment on the environmental aspects of Daya Bay Nuclear Power Station" for the Hong Kong Government was published in July 1990 by the United Kingdom Atomic Energy Authority (Cook *et al* 1990).

The 200 page report cover risks due to fire, rainfall, floods, earthquakes, typhoons, tsunami, wind and aircraft impacts, with about 40 pages devoted to earthquake risks, and it includes quotes from papers by the Geological Society of Hong Kong and M J Atherton.

Quotations from the report:

"The region around Daya Bay is not highly seismic and is probably too far from even the nearest highly active tectonic plate boundary zones for these to be an important source of strong motion at the site. However, the region itself is not seismically quiescent and the historical record shows it capable of producing larger earthquakes more often than is the case, for example, in North West Europe. The site survey and microseismic monitoring suggests that there are no significant seismogenic features within a few kilometres of the site. However, the ground motion from larger earthquakes occurring tens of kilometres from the site would not necessarily attenuate rapidly enough with distance for them to be insignificant sources of strong motion at the site.

A review of the seismic hazard is given in Appendix 1 to this report. The conclusion of the review is that the seismic hazard for the Guangdong site is uncertain and that the design level of 0.2 g peak horizontal ground acceleration for the SSE is consistent with the best estimate of the seismic hazard for the 10^{-4} annual exceedence frequency, Figure 2.4. In addition the hazard curve does not tail off rapidly at higher "g" levels and so predicts that "g" levels necessary for initiating damage are not readily discounted, and may indeed be expected for Daya Bay and the surrounding region at annual probabilities below about 10^{-5}.

The three curves shown on Figure 2.4 represent the range of results obtained from the various computer simulations of the seismic hazard described in Appendix 1. The curves were derived by estimating the lower and upper limits of the simulated seismic hazard and interpolating between these limits to obtain the medium curve. Since the original simulations of the hazard do not form a statistical set it is not possible to derive statistically rigorous confidence limits or central estimates."

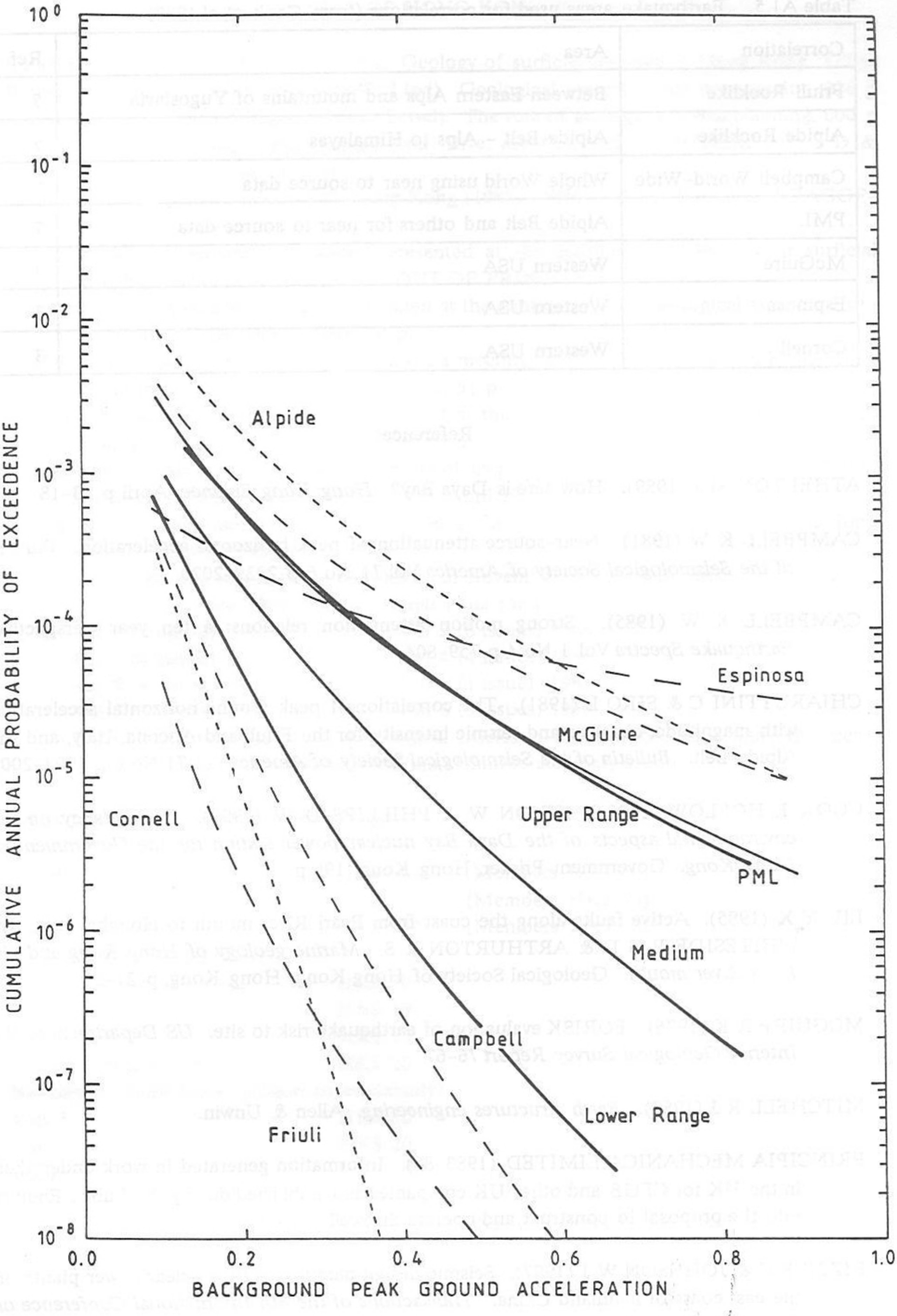

Figure A1.4 Seismic hazard using different correlations (from Cook *et al* 1990)

Table A1.5 Earthquake areas used for correlations (from Cook *et al* 1990)

Correlation	Area	Ref
Friuli Rocklike	Between Eastern Alps and mountains of Yugoslavia	5
Alpide Rocklike	Alpide Belt - Alps to Himalayas	5
Campbell World-Wide	Whole World using near to source data	6
PML	Alpide Belt and others for near to source data	7
McGuire	Western USA	3
Espinosa	Western USA	3
Cornell	Western USA	3

References

ATHERTON M J (1989). How safe is Daya Bay? *Hong Kong Engineer* April p 13-18

CAMPBELL K W (1981). Near-source attenuation of peak horizontal acceleration. *Bulletin of the Seismological Society of America* Vol 71 No 6 p 2039-2070

CAMPBELL K W (1985). Strong motion attenuation relations: a ten year perspective. *Earthquake Spectra* Vol 1 No 4 p 759-804

CHIARUTTINI C & SIRO L (1981). The correlation of peak ground horizontal acceleration with magnitude, distance and seismic intensity for the Friuli and Ancona, Italy, and the Alpide Belt. *Bulletin of the Seismological Society of America* Vol 71 No 6 p 1993-2009

COOK I, HOLLOWAY N J, NIXON W & PHILLIPS D W (1990). *Consultancy on the environmental aspects of the Daya Bay nuclear power station for the Government of Hong Kong.* Government Printer, Hong Kong, 196 p

LIU Y X (1985). Active faults along the coast from Pearl River mouth to Honghai Bay. In: WHITESIDE P G D & ARTHURTON R S. *Marine geology of Hong Kong and the Pearl River mouth.* Geological Society of Hong Kong, Hong Kong, p 21-28

MCGUIRE R K (1976). EQRISK evaluation of earthquake risk to site. *US Department of the Interior Geological Survey Report* 76-67

MITCHELL R J (1983). *Earth structures engineering.* Allen & Unwin.

PRINCIPIA MECHANICA LIMITED (1983-85). Information generated in work undertaken in the UK for CEGB and other UK companies and published during the Public Enquiry into the proposal to construct and operate Sizewell B PWR

RIZZO P C & JOHNSON W J (1987). Seismic design parameters for nuclear power plants on the east coast of mainland China. *Transactions of the 8th International Conference on Structural Mechanics in Reactor Technology* Vol K(a) Pap K1/11 p 57-82

GEOLOGICAL SOCIETY OF HONG KONG PUBLICATIONS LIST

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

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

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

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

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

Abstracts No 1. Abstracts of papers presented at the meeting on "Geology of surficial deposits", September 1983, 79 p - OUT OF PRINT

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

Abstracts No 3. 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. Abstracts of papers presented at the conference on "The role of geology in urban development", December 1986, 65 p

Abstracts No 5. 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. Abstracts of papers presented at the conference on "Karst geology in Hong Kong", January 1990, 58 p

Newsletter. Published regularly; bi-monthly from November 1982 to November 1985, quarterly in 1986, 1987 and 1989, and as a single issue for 1988

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

Each Newsletter contains short technical articles in addition to Society and other news; A4 format, in English with an occasional Chinese summary section

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)
Marine geology and gravel resources of Hong Kong	HK$ 30	
Abstracts No 2	HK$ 10	
Abstracts No 3	HK$ 15	
Abstracts Nos 4, 5 & 6	HK$ 20	
Newsletter, Single Issue (subject to availability)		
Vols 1-3	HK$ 10	
Vols 4-6	HK$ 20	
Vol 7	HK$ 25	

Annual Society Subscription (including overseas postage)	HK$ 100	(Newsletter free to members)

Cover Photograph: Debris flow deposit and scar on the slopes of Tsing Shan, western New Territories. Photograph courtesy of D Hadley (see article this issue)

Publications are available from:

The Secretary
Geological Society of Hong Kong
c/o Department of Geography and Geology
University of Hong Kong
Pokfulam Road
HONG KONG

ISSN 1010-335X