GCO PUBLICATION No. 5/84

REVIEW OF HONG KONG STRATIGRAPHY

J.D. Bennett

Geotechnical Control Office
Engineering Development Department
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FOREWORD

This Report examines aspects of the regional geological framework of Hong Kong as related to southeastern China. The broad stratigraphic and tectonic histories of the region are discussed, and a detailed review is made of the local stratigraphy and its relationship to the regional setting. The report concludes with a summary of current knowledge and provides suggestions for further investigation.

The Report is essentially a review of published information available up to September 1983. Its purpose is to provide background information for the current geological survey programme of the Geotechnical Control Office. The primary aim of this programme is to remap geologically the entire Territory at a scale of 1:20 000 to replace the existing 1:50 000 map produced in 1972.

The Report was prepared in the Geotechnical Control Office by Dr J.D. Bennett of the British Geological Survey, under the terms of Consultancy Agreement CE/29/82 awarded to the Natural Environment Research Council, U.K. by the Engineering Development Department of the Hong Kong Government.

(E.W. Brand)
Principal Government Geotechnical Engineer
December 1984

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SUMMARY AND RECOMMENDATIONS

1. The regional geological setting and evolution of the south China continental block during the Late Proterozoic and Phanerozoic is outlined to provide background for the more detailed review of the stratigraphy of Hong Kong.

In gross terms the southern Chinese continent developed by the progressive accretion of ever younger belts of rocks onto the Proterozoic cratonic nucleus. This nucleus, termed the Yangtze paraplatform by Huang (1978) stabilised some 700 Ma ago.

In terms of the geology of Hong Kong and, indeed, of much of the present coastal region of southeastern China, the most significant event which occurred was the early Yenshanian orogeny during the Late Jurassic. This resulted in the emplacement of granitoid bodies of batholithic dimensions and the accumulation of extensive and thick subaerial volcanic deposits. This magmatic episode provides an important time marker and the stratigraphy of Hong Kong can be broadly reviewed in terms of pre-Yenshanian, Yenshanian and post-Yenshanian phases.

Only tantalising glimpses of the pre-Yenshanian geological history of the Territory are revealed. In China a fairly full Palaeozoic and early Mesozoic record is present, major breaks occurring during the Silurian (Caledonian orogeny) and the Triassic (Indosinian orogeny). A gradual change in conditions took place during this period from predominantly marine in the early Palaeozoic to predominantly continental immediately preceding the onset of the Yenshanian activity.

A continental environment effectively persisted throughout the post-Yenshanian phase to the present day although global rises in sea level since the mid-Tertiary, culminating in the pronounced Holocene marine transgression, resulted in renewed marine deposition in the coastal areas of southern China during the Quaternary.

The mid-Tertiary was also a time of intense tectonic activity and marked the final stages in the opening of the South China Sea, although crustal attenuation and rifting commenced during the Paleocene (Holloway 1982). No Tertiary deposits are recorded in the Territory but elsewhere, onshore to the north and especially offshore to the south, thick sequences of largely continental clastics of this age were deposited in fault-controlled basins and troughs. The attenuated continental margin was progressively submerged during the later Neogene reflecting tectonic downwarping and fault-controlled subsidence and the rise in sea level noted above, to produce the drowned nature of the present coastline and the continental shelf.

2. The stratigraphy of Hong Kong established by Allen and Stephens (1971) is shown in Table 1 in the main body of the report. The present review incorporates the more recent developments which affect both the pre- and post-Yenshanian phases of the geological history of the Territory but it is provisional and a more definitive assessment must await the completion of the remapping programme and the coordination and synthesis of the results.

Limited palaeontological evidence has allowed the extension of the stratigraphic column to the Middle Devonian and correlation with contiguous strata in the Shenzhen Economic Zone permits the tentative recognition of rocks of Lower Carboniferous age in the northwest of the Territory. A preliminary stratigraphy is also now emerging for the Quaternary marine and alluvial superficial deposits. The provisional stratigraphy of Hong Kong, at it can be assessed in 1983, is summarised in Table 3 in the main body of the report.

The pre-Yenshanian (ie. pre-volcanic) sedimentary formations which were mainly assigned a Lower to Middle Jurassic age by Allen and Stephens (1971) are now mostly believed to be of Late Palaeozoic age. The Bluff Head Formation is provisionally reassigned to the Middle Devonian on limited paleontological evidence.

The Lok Ma Chau Formation is tentatively regarded as Lower Carboniferous in view of its contiguity with formations considered to be of this age in Shenzhen, but direct evidence for the age correlation is presently lacking in Hong Kong. The status of the Tolo Harbour Formation (Permian) is confirmed by additional palaeontological data acquired since Allen and Stephens undertook their survey. Uncertainties remain, however, and the satisfactory mapping and correlation of all these older sedimentary units is rendered difficult by the frequent absence of distinctive lithologies to serve as marker horizons, the usually limited and often poorly preserved fauna and flora, and the commonly tectonic nature of the major contacts (where, indeed, the different units occur in contact at all).

Allen and Stephens (1971) did not attempt a formal lithostratigraphic breakdown of the Repulse Bay Formation. The volcanic and associated sedimentary rocks of the formation resulted from the early Yenshanian activity and are broadly coeval with the plutonism associated with the same event. Significant changes and probable upgrading of the formation to group status can be anticipated to result from the remapping programme. Uncertainty concerns the status of some of the sedimentary units which Allen and Stephens (op.cit.) correlated with the volcanic formation, particularly those sediments which appear to underlie the volcanics and whose lower contacts are not exposed (eg. in the Tolo Harbour - Tolo Channel area, Starling Inlet, Crooked Harbour and Mirs Bay). Correct assessment of the stratigraphic position of these rocks will require careful mapping of the contact relationships with the overlying volcanics but much will also depend upon whether useable palaeontological evidence can be found. In Lantau, it should be noted, rocks showing a similar general relationship to the volcanic deposits were accorded separate formational status by Allen and Stephens (op.cit.), ie. the Tai O Formation, and it may be argued that their treatment of these sedimentary rocks was not entirely consistent.

The post-Yenshanian geology of Hong Kong is represented by the Port Island Formation and by a wide range of Quaternary superficial deposits and the restricted outcrops of the Kat O Formation. The

Port Island Formation red beds rest unconformably on the Repulse Bay Formation although the lower contact is locally tectonic and to the north these rocks are overthrust by the Repulse Bay volcanics. A skeletal Late Pleistocene - Holocene stratigraphy is emerging from the recent studies of the superficial deposits, mainly at proximal offshore sites where up to two repeated cycles of alluvial and marine deposition have been identified and dated in a preliminary manner using radiocarbon techniques.

3. Provisional correlations with the succession in southern Guangdong are indicated in Table 4 in the main body of the report.

4. The main recommendations arising from the review and the aspects requiring particular attention during the programme can be summarised as follows :

   (i) The boundaries and relationships reported by Allen and Stephens (1971) and subsequent workers should be critically scrutinised. The possibility of re-instating certain earlier boundaries and subdivisions discounted by Allen and Stephens may also require reconsideration (see (viii) below).

   (ii) Special attention should be given to utilising all available surface and subsurface information in critical sections, particularly contact zones, and consideration given to pitting, trenching and drilling where adequate data is not otherwise available, either in surface exposure or in existing subsurface records. Drilling of specialist stratigraphic boreholes will be desirable (e.g. see (iii) below).

   (iii) The correlation and status of the Lok Ma Chau Formation requires clarification and, if possible, direct evidence established for the ?Lower Carboniferous age of the unit. In furtherance of this aim palaeontological examination of the limestones reported from the formation in the Yuen Long area should be undertaken if suitable, unmetamorphosed material is encountered. The generally poorly exposed nature of the crop makes desirable the drilling of stratigraphic boreholes in the northern and southern sectors to document the succession and the relationships to the volcanic rocks of the Repulse Bay Formation more adequately.

(iv) The mapping and correct interpretation and correlation of the older (i.e. pre-volcanic) sedimentary formations are likely to remain problematical. Particular efforts should be made to ascertain their inter-relationships and the relationships between them and the Repulse Bay Formation. The elucidation of their structural histories may assist this work. Opinions differ, for example, with regard to the mapping and interpretation of certain of the outcrops on Ma Shi Chau, Nau (1981) assigning to the Tolo Channel Formation rocks correlated by Allen and Stephens (1971) with the Bluff Head Formation. Clarification of the (thrust?) relationship between the Tolo Channel and Bluff Head Formations on the northern side of Tolo Channel is required.

(v) The age, status and relationships of the Tai O Formation to the overlying volcanic rocks require scrutiny. The same applies to the rocks in similar relationship to the volcanics elsewhere (e.g. Tolo Harbour - Tolo Channel, Starling Inlet, Crooked Harbour) which are presently assigned to the Repulse Bay Formation. In view of the limited and/or relatively isolated and discontinuous nature of the outcrops of these sediments their correct age assignment will depend heavily on whether palaeontological evidence is forthcoming. Trenching and drilling to check equivocal contact relationships and to intersect the local base of these units (to ascertain whether they represent 'older basement', a sedimentary unit overlying older basement, or a sedimentary intercalation within the volcanic pile) should be considered.

(vi) Attempts should be made to erect a formal lithostratigraphic subdivision of the Repulse Bay Formation. This should be feasible even though the relative ages of the mapped units may be broadly comparable or reflect facies variations rather than a strict superposition of units of progressively younger age. The collection of material for age determination work on a sheet by sheet basis during the survey should assist in refining the chronostratigraphy of the volcanic pile and facilitate the Territory-wide synthesis of these rocks when the routine mapping exercise is completed. Upgrading of the formation to group status (i.e. Repulse Bay Group) and the recognition of a number of new constituent formations and lesser units can be anticipated.

(vii) The nature of the relationship between the plutonic and volcanic rocks should be examined and the contacts between the various plutonic units erected by Allen and Stephens (1971) checked. Map representation of the broad lithological variations occurring within the major units using some form of superimposed ornamentation would probably assist the non-specialist user of the maps. Chemical studies may permit the "finger-printing" of the different bodies and assist in confirming or refuting the existing model. Isotopic age determination studies will also be relevant in this respect and the comments on this topic noted in (vi) above are equally valid for the plutonic rocks. On a regional (i.e. Territory-wide) scale the assessment of the granitoid rocks, including their subsurface relationships and distribution would be immeasurably assisted by a carefully planned gravity survey. If suitably scaled this technique may also be capable of revealing significant variations and subdivisions of the granitoids for coordination and synthesis with the field, petrographic, chemical and isotopic data.

(viii) The variations in intensity of deformation within the crop of the Port Island Formation can be noted. The view has been expressed that two subdivisions of the formation can be established on this basis, one of Early Cretaceous, the other of Late Cretaceous age. It is perhaps more valid to recall that the rocks presently mapped as Port Island Formation were considered by previous workers to comprise two separate units (of considerably different ages), namely the Pat Sin and Mirs Bay Formations (e.g. Brock et.al. 1936). The justification for this subdivision, bearing in mind the marked variations in deformation apparent in the Port Island Formation, will merit scrutiny. It should also be noted that certain of the sedimentary rocks cropping out on the southern shore of Starling Inlet and mapped as Repulse Bay Formation by Allen and Stephens (1971) were previously correlated with the Port Island Formation (Ruxton 1960) and the Pat Sin Formation (Brock et.al. op.cit.).

(ix) The remapping programme should aim to examine and document more fully the emerging stratigraphy shown by the Quaternary superficial deposits. Emphasis to date has been accorded to offshore sites. Particular attention should now be given to coordinating the available onshore data, including control drilling and trenching as necessary. The main target for this work will be northwestern and northern parts of the New Territories which up to now have been rather neglected from the geological point of view.

1. INTRODUCTION

1.1 TERMS OF REFERENCE

The report is prepared in fulfilment of clause 3(1)(e) of the Brief to Agreement CE 29/82. This requires the Consultants to :

> "review the existing Stratigraphic Column of Hong Kong and submit a Report of findings"

1.2 SCOPE AND PROCEDURE

The restricted land area of the Territory (c. 1 000 km^2) makes it unsatisfactory to consider the local stratigraphy in isolation from that of the adjacent parts of the Chinese mainland. To help achieve this an outline is first given of the regional stratigraphy, geological setting and evolution of southern China based on a review of a limited number of the more recent English language publications. This study is necessarily incomplete but it is hoped that it will provide a framework within the context of which the local stratigraphy can be more effectively considered.

Within Hong Kong various factors complicate the establishment of a detailed stratigraphic succession. These include the nature of the terrain, the often limited bedrock outcrop, the high degree of chemical weathering and the masking effects of transported deposits, all of which mitigate against a correct assessment of stratigraphic and structural relationships. The area is strongly faulted and this, in conjunction with the highly indented, drowned coastline and the presence of widely scattered islands also renders difficult, if it does not entirely preclude effective and reliable correlation. The increasing availability of offshore data, albeit normally of limited depth penetration, lends hope that in the future some of the gaps will gradually be filled, although interpretation of the data will still be subject to the same tectonic constraints as studies carried out onshore. The present status quo appears to be one of striking a balance between a rather generalised, over-simplistic model and that of erecting a plethora of lithostratigraphic units which meet the broad requirements of international convention* but whose correlation and relative ages may remain uncertain.

The review of the local stratigraphy which follows the section outlining the regional setting adopts as its datum the stratigraphic column established by Allen and Stephens (1971) and their units and the mutual inter-relationships between them are considered systematically. Allen and Stephens' work, although meeting general approval and acceptance, is now in need of some revision and is capable of some further refinement.

The present report is based largely on a desk study of available literature and maps, including work published since Allen and Stephens carried out their survey, and on limited and general reconnaissance undertaken by the Consultants. The review does not anticipate the conclusions of work currently being done by Dr. R. Addison in the central New Territories (1:20 000 map sheet 7) and can only be regarded as provisional and liable to modification in the light of the results of the 1:20 000 scale survey of the whole Territory. A fuller, more meaningful statement on the stratigraphy of Hong Kong and its relationships with Guangdong Province must await the completion, coordination and synthesis of the results of that programme.

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* Lithostratigraphy (rock stratigraphy) is defined (Holland et.al. 1978) as the description of local rock successions in terms of named and described units (primarily formations) and their spatial relationships. These units are described in terms of observable and recognisable petrological, mineralogical, geochemical, or general palaeontological characters. Holland et.al. (op.cit.) also note that the boundaries of lithostratigraphic units are not defined to imply isochronous surfaces but to provide an observable framework of rock for reference in subsequent correlation and interpretation. Defined units should have, or, (with reasonable certainty) be believed once to have had, physical continuity. Once established, the lithostratigraphic units comprising the local succession should be age-correlated so far as is possible with the international standard chronostratigraphic scale, principally using biostratigraphic and geochronometric methods.

2. REGIONAL GEOLOGICAL SETTING

2.1 INTRODUCTION

This section of the report outlines the geology of southeastern China to provide a background against which the stratigraphy of Hong Kong can be reviewed. The account emphasises the general geological features and draws heavily on a limited number of relatively recent English language publications and on a translation of notes accompanying the geological atlas of China (Anon 1973). (The translation was made by the Chinese Language Division of the Home Affairs Branch in 1983). A lack of consistency in the literature may be noted with respect to nomenclature and delineation of the major geological and tectono-magmatic units occurring in the region.

The general geology is shown in Fig. 1 and the main units referred to are indicated in Figs. 2 and 3. The geological history of southeastern China since the Late Proterozoic has been one of repeated cycles of sedimentation, tectonism and magmatic activity, and a close interplay between these different facets is evident. In part the cycles have overlapped each other spatially and have involved the reworking of the existing basement in addition to the newly formed cover, but a general shift of tectonic and magmatic activity southeastwards with time is indicated (Hsieh 1962, 1963, referred to in Jahn et.al. 1976), demonstrating the accretionary development of this part of the Chinese mainland outwards from the Proterozoic nucleus during the Phanerozoic.

2.2 PROTEROZOIC

Upper Proterozoic deposits assigned to the Sinian suberathem (c. 1 700 to 600 Ma) were involved in repeated orogeny, culminating in the stabilisation of the Yangtze paraplatform during the Yangtzian orogenic cycle c. 700 Ma ago (Huang 1978). Movements of this age are also variously referred to as Chiangkiangian and Jinming c. 800 Ma ago (Compilation Group of the Geological Map of China 1977* and Guoqiang 1980 respectively). The Jiangnan uplift or geanticlinal belt

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* This reference is subsequently abbreviated to Compilation Group 1977.

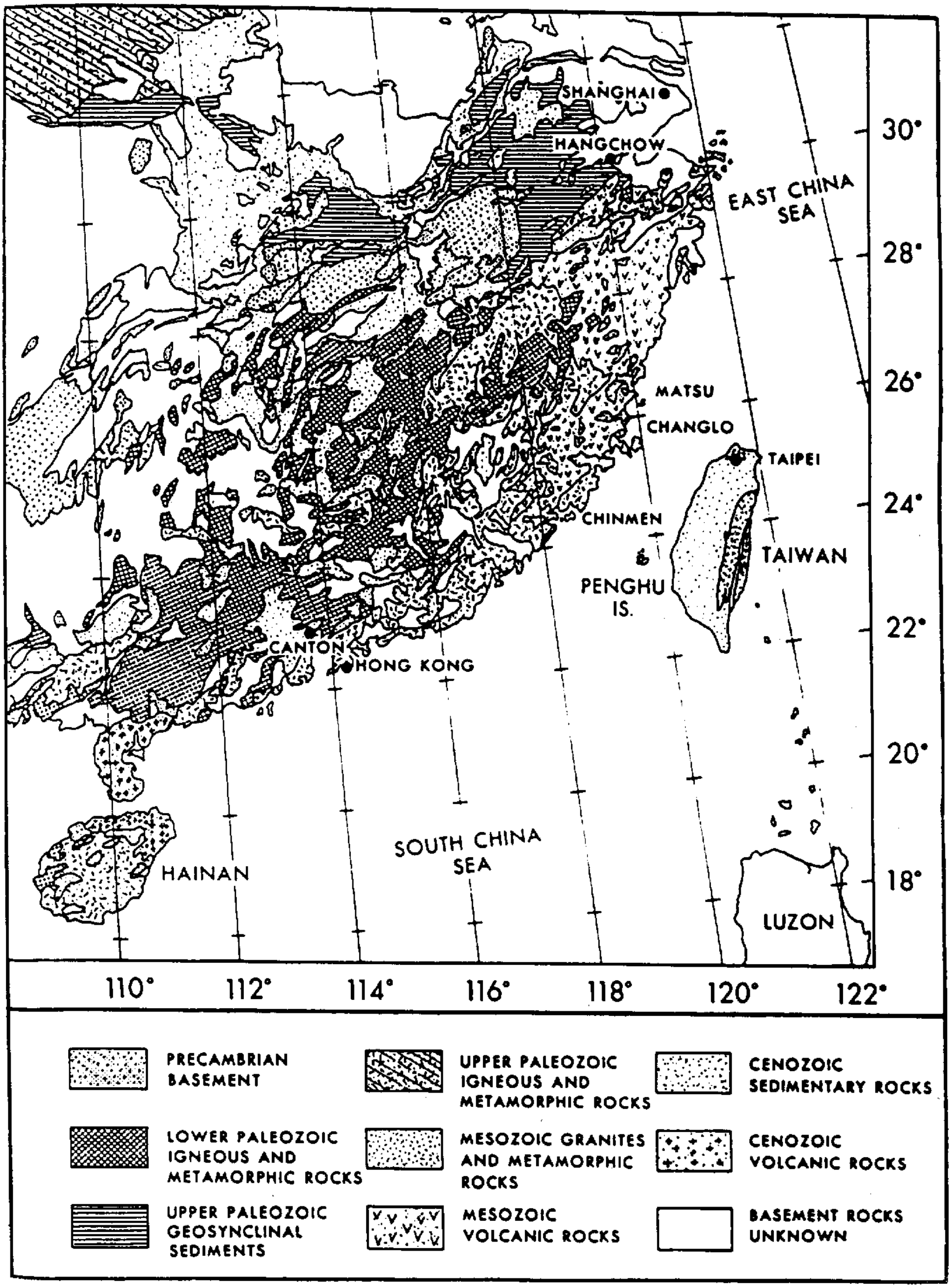

Fig. 1 Geology of southeastern China (based on Terman and Woo (1976) and Ho (1967), taken from Hahn et al. 1976, Fig. 2).

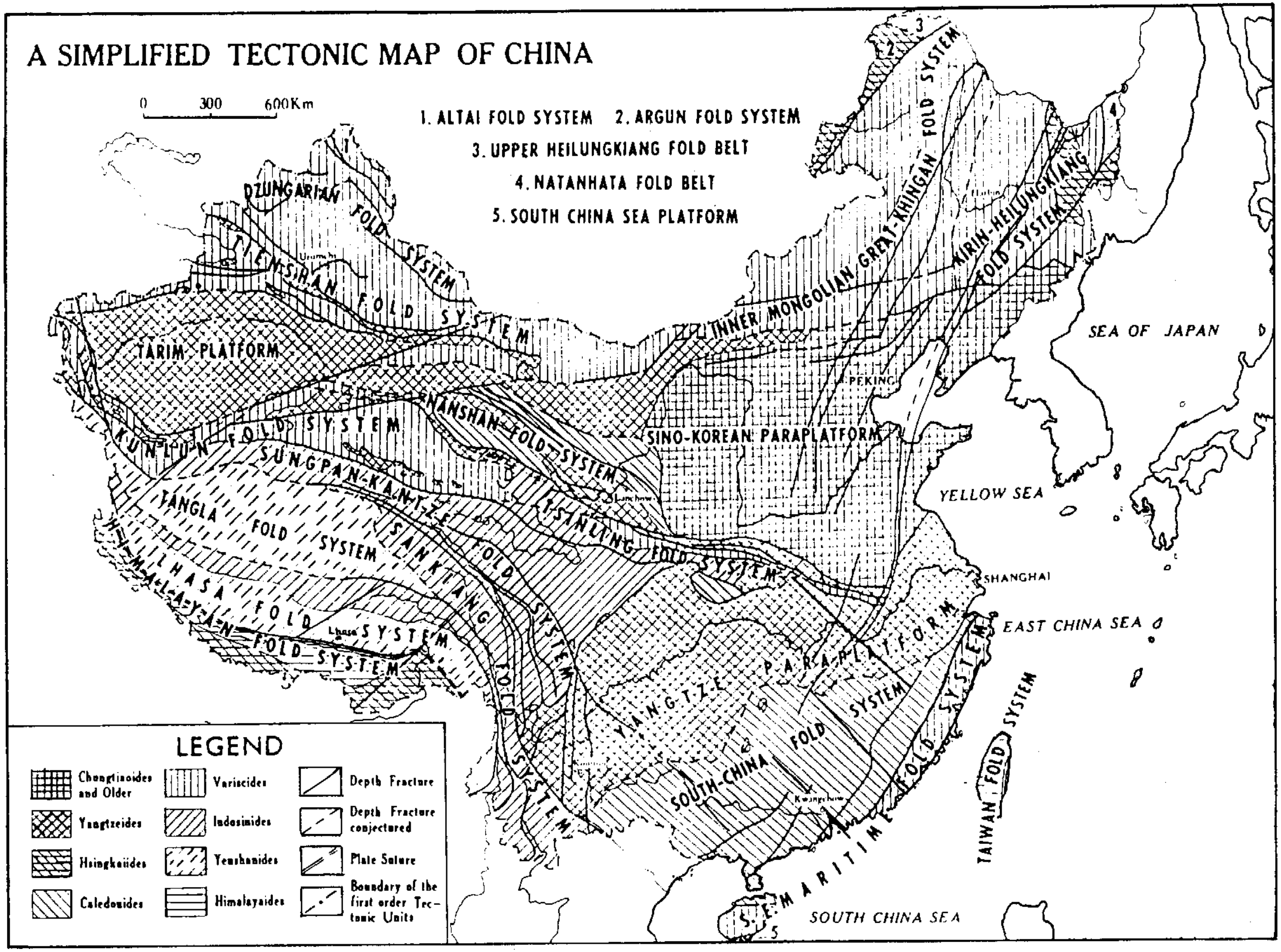

Fig. 2 Major tectonic units of China (Huang 1978).

(Jahn et.al. 1976; Nanjing University Geology Department 1980*) forms the nucleus of the more extensive paraplatform (so-called by Huang (op.cit.) to indicate that, unlike a platform, it remained relatively mobile and active) and was regarded by Jahn and his co-workers as marking the effective southern limit of the South China Craton during the Late Proterozoic. Other workers (e.g. Anon. 1973) considered Precambrian rocks to exist considerably further to the south, constituting the South Sea Platform and flooring the northern part of the present South China Sea.

2.3 PALAEOZOIC

The Proterozoic nucleus is flanked to the south by a broad mobile belt referred to by Huang (1978) as the South China Fold System. Jahn et.al. (1976) recognised a number of individual tectonic units in the same belt and referred them collectively to the Cathaysian Fold System. The belt was interpreted by Guoqiang (1980) as a major Palaeozoic marginal basin, the Zhejian-Fujian-Guangdong belt (Fig. 3) constituting a late Sinian-early Palaeozoic island arc developed above a westward dipping subduction zone. This zone was considered to be located along the prominent and long-lived Lishui- Zhenghe-Dabu deep fault (Fig. 3), also referred to as the Shaoxing-Lishui-Nanping-Haifeng line and the Dapu-Haifeng line (Anon. 1973).

Hong Kong is located within this marginal basin/mobile belt which was active throughout the Palaeozoic and Mesozoic, although the character of the belt changed with time. The area forms part of Grabau's (1924) Cathaysia old land which he regarded as dating back to the Precambrian. It is now considered to be essentially of Caledonian age (Huang 1978; Nanjing 1980) and to comprise a thick (7 000 to 11 000 m) sequence of Sinian (800 to 600 Ma) and lower Palaeozoic marine geosynclinal sediments consisting predominantly of flysch and greywacke formations, graptolitic shales, intermediate to basic volcanics and more local developments of carbonates. These

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* Referred to subsequently as Nanjing 1980

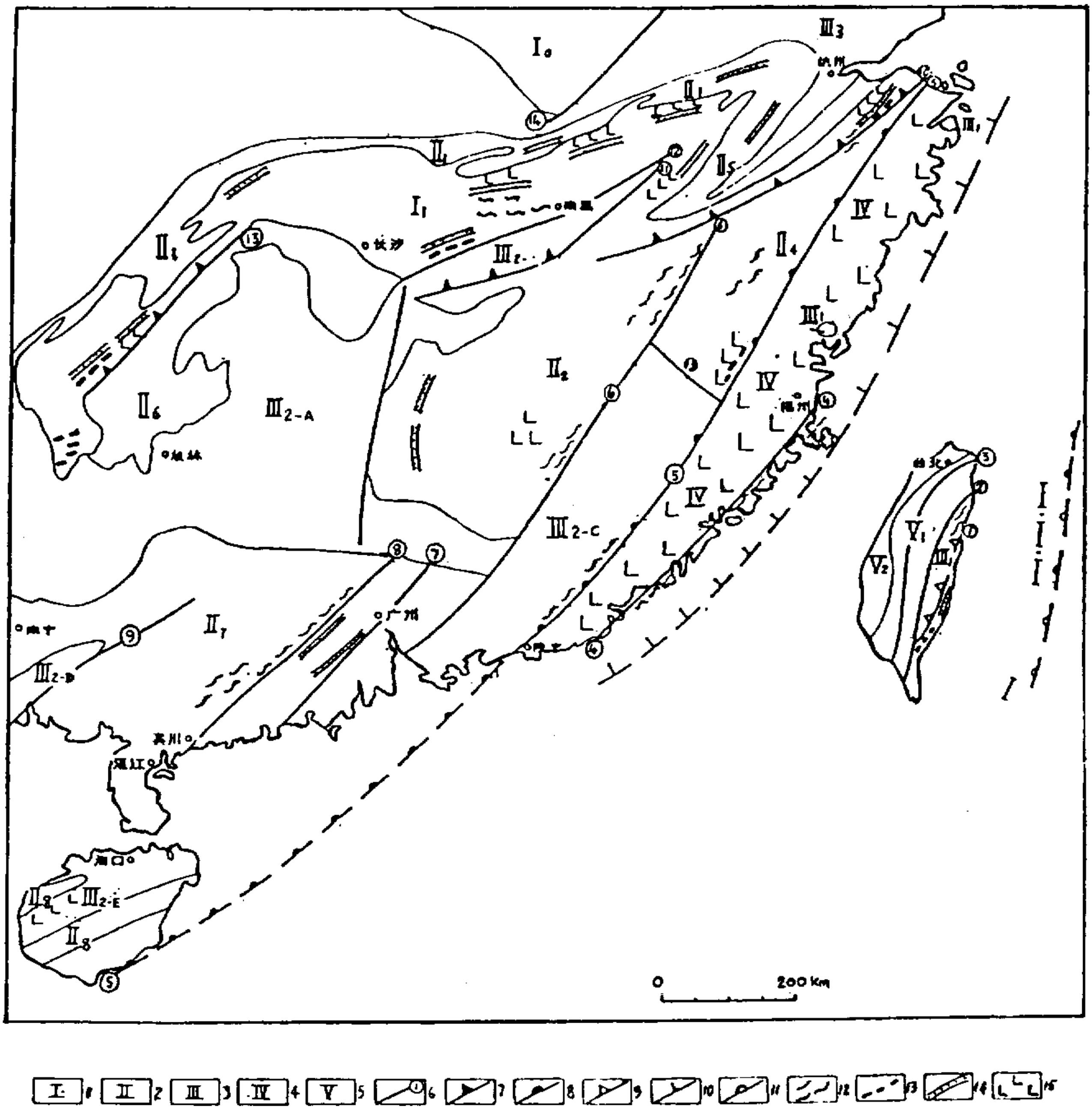

Fig. 3. Tectonic elements of southeastern China (Nanjing University Geology Department 1980). Selected key : I_1 Jiangnan geanticlinal belt; III_{2-c} Southwest Fujian-East Guangdong Hercynian-Indosinian depression; IV Zhejiang-Fujian-Guangdong coastal Yenshanian volcanic belt; (4) Changle-Nan'ao deep fault; (5) Lishui-Zhenghe-Dabu deep fault and boundary of the Caledonian fold belt; (6) Shaowu-Heyuan deep fault; (7) Lianping-Guangzhou-Enping deep fault; (8) Sihui-Wuchuan deep fault (the Sihui-Wuzhou rift belt of Anon. 1973?); L ornament signifies volcanic rocks; pecked, ticked lines offshore indicate the boundaries of the Yenshanian volcanic belt (—⊥— —⊥—) and the Himalayan mobile belt (—Δ— —Δ—); triangular symbol (—Δ— —Δ—) marks the bouldary of the Hercynian-Indosinian fold belt in eastern Taiwan.

deposits were affected by Caledonian movements which culminated in the Silurian. A major unconformity separates the lower Palaeozoic strata from the Devonian and younger rocks.

The Caledonian movements resulted in well developed folding on E to NE trends and associated migmatisation and metamorphism. The southern front or boundary of the Caledonian orogeny is considered (Nanjing 1980; Huang 1978) to coincide with the prominent NE-trending Lishui-Zhenghe-Dabu deep fault (Guoqiang's (1980) subduction zone) which, if extrapolated southwestwards, passes to the south of Hong Kong.

To the southeast of the Lishui-Zhenghe-Dabu fracture Huang (1978) distinguished the Southeastern Maritime Fold Belt in eastern Guangdong, Fujian and Zhejiang and considered it to be of Variscan age (Carboniferous-Permian). He noted that because the zone was strongly transformed by Mesozoic tectonism and extensively covered by Jurassic and Cretaceous continental volcanics its true significance and character had long remained misjudged. Nevertheless, it may be observed that other workers (e.g. Nanjing 1980) recognise only a composite Hercynian-Indosinian cycle(c. 340 to 185 Ma, Carboniferous-Early Jurassic) and they noted that the effects of this event were not restricted to the coastal belt, but occurred also to the north of the southern Caledonian front, where they were superimposed on the Caledonian basement.

The post-Caledonian, end-Silurian hiatus was followed by renewed marine deposition throughout the late Palaeozoic and into the early Mesozoic. Deposition was to a large extent structurally controlled, the younger rocks unconformably overlying the folded Caledonian basement. Nanjing (1980) distinguished three structural patterns as being characteristic of the Hercynian-Indosinian cycle : (i) Hercynian-Indosinian fault depressions; (ii) Hercynian-Indosinian basins superimposed on zones of post-Caledonian uplift; and (iii) Hercynian-Indosinian remnant geosynclines. Hong Kong is situated within the Southwest Fujian-Eastern Guangdong Hercynian-Indosinian depression (Fig. 3), a NE-trending zone bounded to the southeast by the Lishui-Zhenghe-Dabu deep fault and to the northwest by the

Shaowu-Heyuan deep fault which crosses the Pearl River estuary between Guangzhou and Hong Kong. Other workers (e.g. Anon 1973) also remarked the tectonically active nature of the area during this period and that epeirogenic movements gave rise to repeated and often localised emergence and submergence, local disconformities and marginal discordant overlaps. Particularly strong movements occurred in the Late Triassic and Early Jurassic, which marked the close of this second major Phanerozoic cycle.

The upper Palaeozoic formations comprise paralic and terrigenous sediments (Compilation Group 1977). These include post-Caledonian Lower Devonian molasse deposits, Middle and Upper Devonian shales and continental clastics and upper Palaeozoic to lower Mesozoic marine carbonates, shales and some coal-clastic sequence (Jahn et.al. 1976). These deposits are estimated to total some 3 000 to 4 000 m (Nanjing 1980).

In Guangdong only the upper Palaeozoic deposits are prominently developed, although older rocks are reported. Nan (1979)* recorded the presence of a Cambro-Sinian basement throughout the province. Ordovician formations are absent from East Guangdong but are represented elsewhere by neritic clastics and graptolitic shales. Anon (1973) also recorded carbonaceous shales and minor volcanics of the same age in the province. Silurian deposits (marine shales with graptolites and other fauna) are present only in West Guangdong. In Shenzhen the Geological Bureau records Sinian and Ordovician units on its 1:50 000 scale map of the Zone, but expresses some doubts as to the correctness of these assignations (Burnett 1983). The ?Sinian deposits consist of quartzites, and gneisses, while the ?Ordovician comprises fine-grained, in part feldspathic sandstones, slates and shales.

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* This and succeeding references to Nan (1979) are based on the summary of his work given by Nau and Yim (1983). The regional subdivision of Guangdong into East, Central, etc. used in the present report is shown in Fig. 4 and is taken from Nau and Yim (op.cit.).

Following the Caledonian hiatus deposition, continuous in the west, spread northwards and eastwards during the Devonian, progressively overstepping the folded Cambro-Ordovician sequences during the middle and later parts of the period. The Devonian comprises neritic, littoral and fluvial deposits and Lower and Middle Devonian sandstones, shales and conglomerates with coral, brachiopod, fish and plant remains are recorded (Anon. 1973). These deposits tend to become coarser from west to east. By the Late Devonian neritic carbonates and fine-grained clastic sediments were being deposited in North, Central and West Guangdong. Basal limestones with brachiopods gave way upwards to calcareous mudstones (marls) and sandy shales which preserve marine fauna and plant remains. A facies change is recorded near Mei Xian where sandstones and sandy conglomerates are reported to overlap the lower Palaeozoic strata (Anon 1973).

Marine conditions persisted throughout most of the province in the Carboniferous and Early Permian when neritic carbonates and clastics and littoral deposits including coals were laid down (Nan 1979). The presence of both marine and continental clastics and coals of early Late Permian age suggest variable conditions of emergence and submergence, probably reflecting Hercynian movements, although the Hercynian-Indosinian cycle peaked considerably later (c. 190 Ma, Late Triassic-Early Jurassic (Huang 1978)). In the Shenzhen Economic Zone (Burnett 1983) Devonian and Carboniferous clastic and carbonate sequences are well developed in the Linghua fault zone. The argillaceous rocks and carbonates are in places strongly recrystallised and converted to garnet staurolite biotite schists and tremolite-bearing marbles. The metamorphism is ascribed by the Geological Bureau to dynamic metamorphism associated with powerful NE-faulting. Permian formations are not recorded in the zone and a significant break is identified between the Upper Carboniferous and the Upper Triassic-Lower Jurassic formations.

2.4 MESOZOIC

The Mesozoic saw the gradual emergence of the Chinese landmass as a result of post-Indosinian uplift and the subsequent powerful and widespread Yenshanian event (Jurassic-Cretaceous). Continental

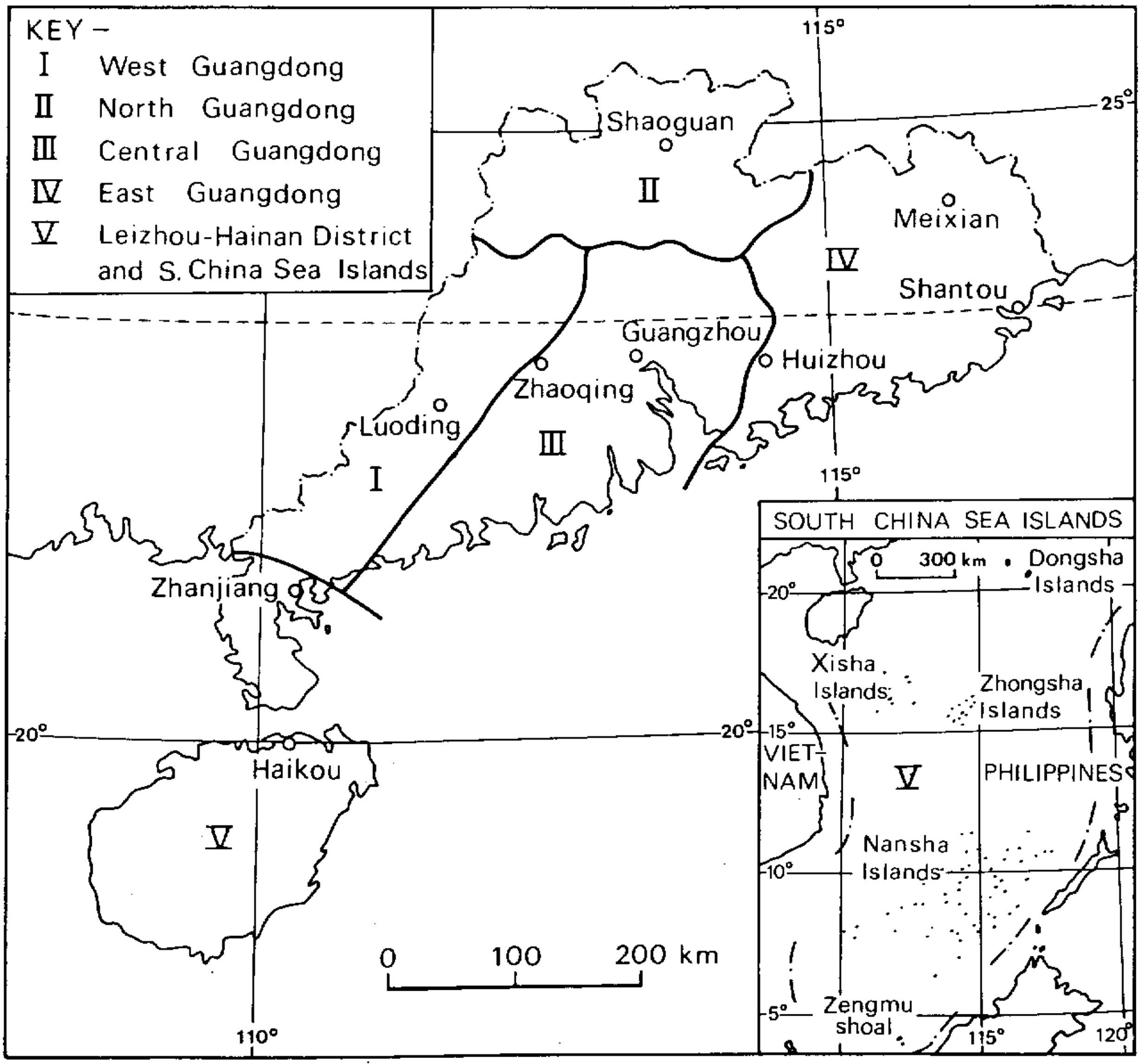

Fig. 4 The stratigraphic regions of Guangdong Province (from Nau and Yim 1983, based on Nan 1979).

deposits became increasingly common, including red beds, coals, and volcanics showing considerable variation in facies and thickness (Compilation Group 1977). Deposition was closely linked with deformation and the development of fault-controlled basins.

The Triassic of southern China retains in part a marine character, as do parts of the Jurassic-Cretaceous succession of parts of south and west China. Lower Triassic deposits comprise neritic and lagoonal (magnesian) carbonates, sandstones and shales, with intercalated gypsum, halite and volcanic horizons (Compilation Group 1977), the assemblage providing a general indication of the depositional and climatic environment at the time. Upper Triassic formations are predominantly continental in character although marine conditions persisted in East Guangdong with the continued deposition of neritic carbonates and clastics. Elsewhere the sequence comprises sandy shales with plant remains, conglomerates and important coal-bearing strata (Anon 1973) deposited in an intermontane lacustrine and paludal environment. The change in character of the deposits reflected an important Indosinian hiatus and unconformity between the Middle and Late Triassic and subsequent uplift (e.g. Anon 1973; Nan 1979). Holloway (1982) noted the Triassic unconformity to be of regional significance throughout the South China Sea area.

The Jurassic and Cretaceous sequences in southern China were deposited in inland, intermontane basin, volcanic basin and marine environments (Compilation Group 1977). The basins were structurally controlled in consequence of block faulting associated with differential uplift following the Hercynian-Indosinian cycle and as a result of the polyphase Late Jurassic-Cretaceous Yenshanian event. The deposits consist mainly of continental, fluvio-lacustrine clastics with intercalated coals (Jurassic) and volcanic rocks. Volcanic activity dominated the Late Jurassic period. Initially, it was predominantly andesitic but it became increasingly acidic with time (Nanjing 1980). The intensity of activity increased towards the southeast and increasingly younger volcanic rocks are reported in this direction also. Maximum developments are correlated with the Zhejian-Fujian-Guangdong coastal Yenshanian volcanic belt (Fig. 3) where the sequence is estimated to total some 5 000 m. Marine deposits are restricted to the present day coastal areas and to Taiwan (Compilation Group 1977); they comprise volcanics and bathyl cherts.

In Guangdong the Early Jurassic was marked by a marine transgression and the deposition of neritic and mixed marine and terrestrial sediments and volcanics in the North, Central and Eastern districts (Anon 1973; Nan 1979). These deposits were overlain unconformably or in part disconformably by Middle and Upper Jurassic intermontane lacustrine clastics, lavas and pyroclastics following early Yenshanian deformation. Middle Jurassic paludal deposits are recorded in East Guangdong. Similar sequences were deposited during the Cretaceous although volcanic activity was noted to be lacking in North and West Guangdong in the Early Cretaceous (Nan op.cit.). Gypsum and halite deposits are recorded in the Upper Cretaceous formations of the eastern, central and northern parts of the province. Deposition was discontinuous and localised; movements associated with the Yenshanian orogeny resulted in numerous unconformities, notably between the Middle to Upper Jurassic formations and the older deposits in North and Central Guangdong, between the Upper Jurassic volcanics and Middle Jurassic deposits in East Guangdong (overlapping onto pre-Middle Jurassic strata), and between the Lower Cretaceous-Upper Jurassic, Upper Cretaceous-Lower Cretaceous, and the Lower Tertiary-Upper Cretaceous strata.

In the Shenzhen Economic Zone marine clastics of Upper Triassic-Lower Jurassic age gave way to a varied sequence of Upper Jurassic subaerial volcanic extrusive and pyroclastic deposits with some tuffites (Burnett 1983). The volcanic activity waned during the Lower Cretaceous and continental red beds sedimentary sequences dominated the Cretaceous Period. The Upper Cretaceous rocks include granitoid clasts, presumably indicating the unroofing of the Yenshanian intrusives by that time.

The extensive Yenshanian magmatic activity (see also section 6) and deformation has been ascribed to the large scale subduction of the Mesozoic Pacific Ocean floor along the eastern edge of the Asian continental margin (Jahn et.al. 1976). Larsen and Pitman (1972) demonstrated particularly rapid sea floor spreading during the mid-Cretaceous (110 to 85 Ma). Ben-Avraham (1978) featured a Cretaceous subduction zone between the China continental block and the Kula oceanic plate, the convergence zone being located close to the present coastline of southern China and coinciding broadly with the southeastern boundary of the Yenshanian volcanic belt shown in Fig. 3.

Recent reconstructions by Holloway (1982) for the Triassic and Middle Jurassic to mid-Cretaceous periods are shown in Fig. 5. The eastwards extension of the Red River suture shown in Fig. 5a is conjectural. The Yenshanian magmatism and uplift is ascribed to NNW-directed plate motion and subduction but the known distribution onshore in southern China of Mesozoic intrusive and extrusive rocks requires adjustment to be made to the NW limit of the magmatic arc shown in Fig. 5b. The arc is apparently broader than that shown by Holloway (op.cit.). This may perhaps be explained by variations in dip of the subduction zone and/or to the displacement of the zone by transcurrent faulting comparable in sense with that postulated in the extreme SW of the area shown in the figure, along the margin of the Sunda block. This explanation may be more appropriate for the present area than the view advanced by Uyeda and Myashiro (1974) that the great width of the zone of Mesozoic magmatism in eastern Asia resulted from the subduction of hot, active spreading ridges. However, the reconstructions remain speculative.

2.5 CAINOZOIC

The Mesozoic-Cainozoic boundary is not marked by significant changes in environment nor by major hiatus although unconformable relationships are recorded, e.g. in Western and Eastern Guangdong (Nan 1979). On a gross scale, however, deposition was largely continuous from the Cretaceous to the Paleocene (Compilation Group 1977).

Despite reported higher sea levels in pre-Miocene times (a global fall in sea level of some 400 m occurred during the Early Miocene, D.R. Workman pers. comm. 1983*) continental conditions persisted

* Lecture to members of the Geological Society of Hong Kong, June 1983. Subsequent reference in this report to D.R. Workman, pers. comm. 1983 also refer to this presentation.

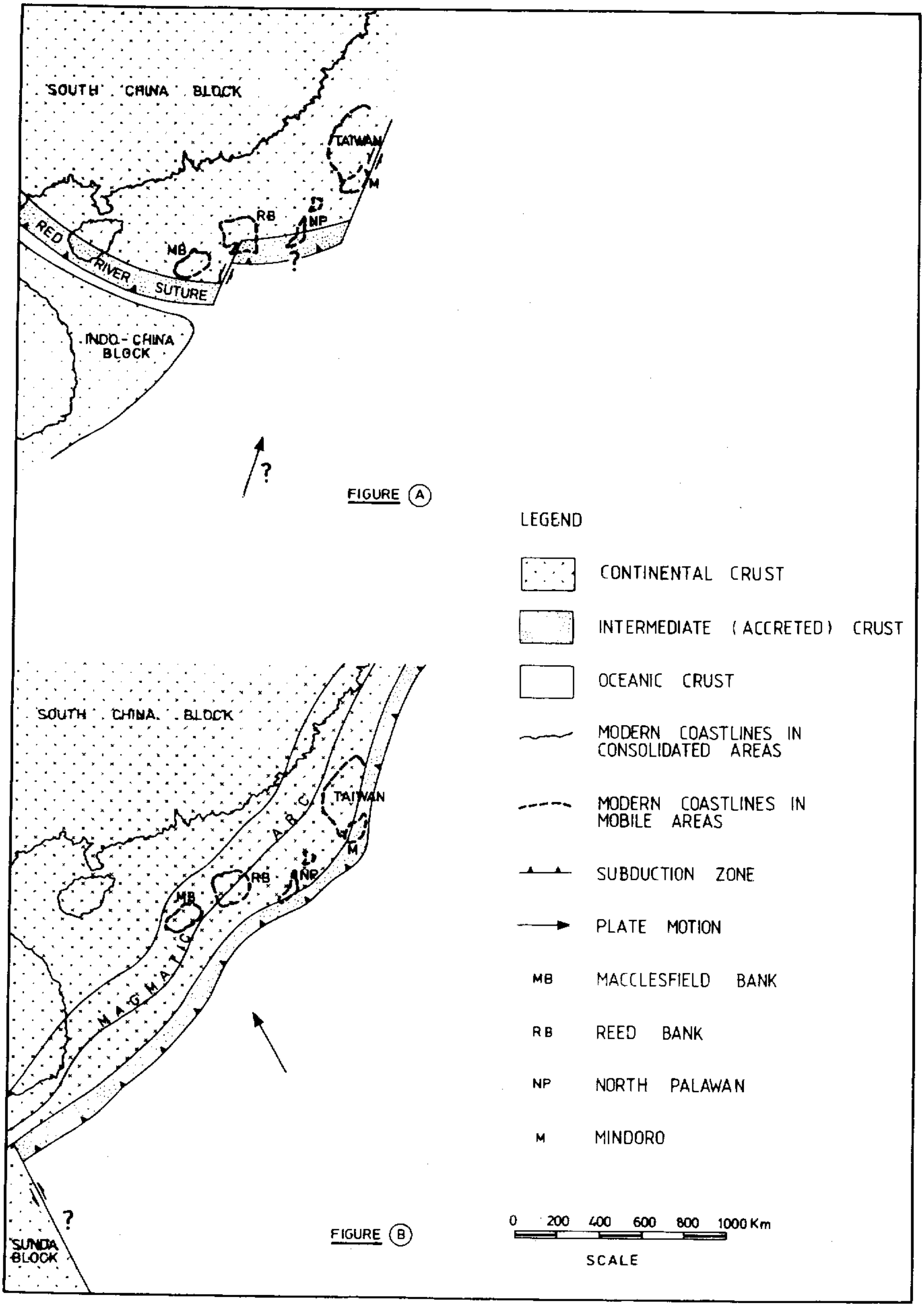

Fig. 5 Reconstructions of the South China Sea area a) during the Late Triassic, b) during the Middle Jurassic to mid-Cretaceous (Holloway 1982).

throughout the Paleogene and in most present-day onshore areas during the Neogene also. Red beds sequences accumulated in fault-controlled basins and rifts onshore and on the present-day continental shelf. The Neogene deposits are noted to rest unconformably on the older Tertiary formations (Anon. 1973). They comprise a broadly similar sequence of fluvial and lacustrine deposits on the mainland but littoral and neritic clastics are present in the Hainan area (Nan 1979). These reflect a Late Tertiary marine transgression (Anon. 1973 and see below) and the onset of more variable conditions during the Quaternary, culminating in the particularly prominent Holocene transgression and the submergence of the continental shelf. Rift-controlled basalts of Late Tertiary and Quaternary age formed in the Hainan sector, and transitional continental-marine deposition persisted offshore throughout the Quaternary to the present day, e.g. the deltaic sedimentation of the Pearl River estuary.

In Guangdong the Tertiary succession is reported to be dominated by lacustrine and fluvial clastics although marine deposits are intercalated with the continental sediments in the Leizhou-Hainan sector (Fig. 4) and volcanic activity persisted in Central Guangdong during the Eocene-Oligocene. Gypsum and halite deposits of the same age are also recorded there (Nan 1979), suggesting a warm, rather arid climatic regime at that time. Coal and oil shales are associated with lacustrine and paludal deposits of Paleogene and Neogene age in West Guangdong and Hainan, and oil and gas with the Paleogene formations of Central and West Guangdong. Fluvial and piedmont deposits of Pliocene age (5 to 1.8 Ma) are developed in West Guangdong. During the Quaternary the province was characterised by rather limited deposition of continental and littoral deposits and the volcanic activity already noted in the Hainan sector. The development of bauxite deposits in the Leizhou-Hainan area during the Holocene implies a warm humid climate and a phase of dominant chemical weathering and intense leaching.

Recent work on the continental shelf to the south of Hong Kong indicates the presence of considerable thicknesses of Tertiary deposits in a major ENE-trending fault controlled basin (Feng and Zheng 1982; Workman 1983). The older deposits are mostly clastics of continental nature with associated pyroclastics and volcanic extrusives, presumably associated with the faulting. The mid and Late Tertiary sequences show a transition to shallow marine conditions and the complete succession ranges from 6 000 to 9 500 m in thickness, indicating the scale of contemporaneous downfaulting and downwarping which occurred.

The accretionary model for the growth of southern and eastern China noted in section 1 is substantiated throughout Southeast and East Asia by the gross disposition of belts of Cretaceous and younger rocks which broadly mimic the present outline of the continent (D.R. Workman pers. comm. 1983). The studies by Chinese workers (e.g. Anon 1973; Huang 1978; Feng and Zheng 1982) indicated that the northern part of the South China Sea is floored by a continental basement of metamorphic and sedimentary rocks of Palaeozoic, possibly greater age and by Mesozoic granitoids. At the present day the crust along the southern seaboard of China is some 35 km thick (Huang op.cit.).

The post-Cretaceous period, however, saw the attenuation and rifting of the southern China continental margin. Holloway (1982) in a useful synthesis of the evolution of the South China Sea recognised four synchronous pre-Neogene unconformities of regional significance (Fig. 6). Noting these and the facies relations within the unconformity-bounded sedimentary units (a gross transition southwards from terrestrial to marine carbonate facies in each case), he inferred a common pre-Neogene history for the region. The unconformities identified occurred (i) during the Triassic, coincident with the Indosinian orogeny and the suturing of the Indochina and South China blocks along the Red River line (Fig. 5); (ii) Late Jurassic, perhaps related to the early Yenshanian orogeny and magmatic activity; (iii) the Cretaceous-Paleocene boundary, coincident with late Yenshanian activity and the onset of attenuation and rifting of the continental margin; and (iv) the mid to Late Oligocene, associated with the initiation of active sea floor spreading.

According to oil industry seismic data the end-Cretaceous unconformity corresponded to the inception of tensional conditions and block

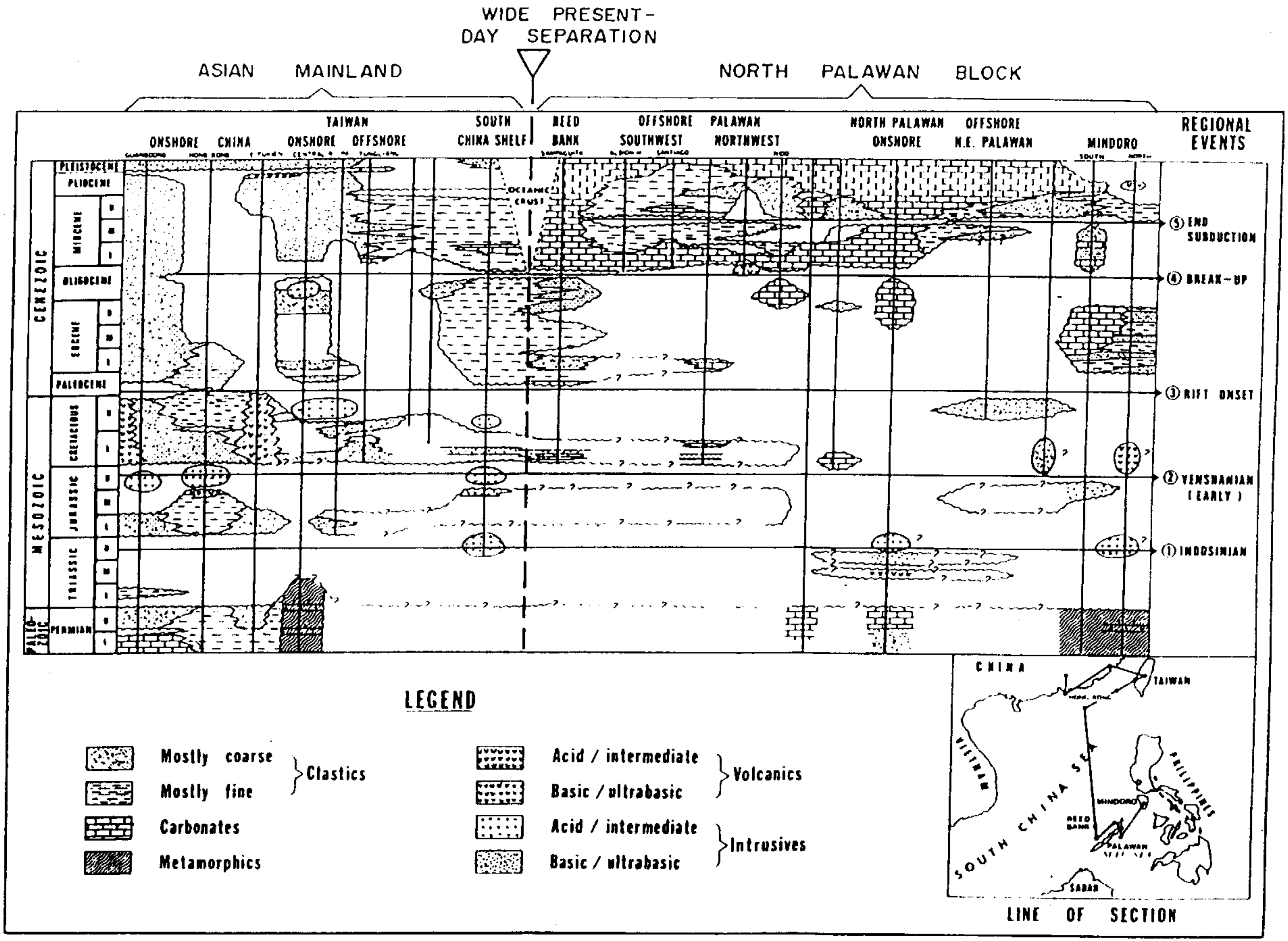

Fig. 6 Lithostratigraphy of the northern and southeastern margins of the South China Sea (Holloway 1982).

faulting of the southern China continental margin, the rift and semi-rift structures acting as loci for the deposition of the Tertiary deposits. Holloway (1982) estimated that up to 85 per cent stretching occurred in the western sector of the South China Sea during the end-Cretaceous to mid-Oligocene interval, considering the attenuation to be achieved probably by S-dipping listric faulting. Stretching of this order implies the southward migration of the southern margin of the China continent by some 700 km. In the eastern sector of the South China Sea continental break-up occurred about an E-W spreading centre situated to the W of the present day position of Luzon and this resulted in the creation of oceanic crust during mid-Oligocene to Middle Miocene times (c. 32 to 15 Ma, although D.R. Workman pers. comm. 1983 noted that Chinese workers now consider that active spreading may have continued as late as 7 Ma). The present day situation is summarised in Fig. 7.

2.6 MAJOR MAGMATIC EVENTS

All the major orogenic events (i.e. Late Proterozoic, Caledonian, Hercynian-Indosinian and Yenshanian) were accompanied by predominantly granitoid magmatism. The activity involved repeated intrusive cycles in partially superimposed belts. The latter, however, showed a gradual shift to the southeast with time. The disposition of the magmatism resulted in the formation both of composite intrusions, comprising granitoid bodies of various periods or events, and intrusive masses representing repeated intrusions during the same event, as exemplified by the Yenshanian rocks.

Workers from Nanjing University (Nanking 1974) recognised four major tectonono-magmatic cycles, summarised by Jahn et.al. (1976) as follows :

(i) Proterozoic. Granitic and granodioritic intrusions emplaced in the axial zone of the Jiangnan uplift during the Xuefengian cycle c. 910-840 Ma.

(ii) Early Palaeozoic. Intrusive activity associated with the Caledonian movements. The early Caledonian granitoids (c. 480 Ma) are predominantly syntectonic autochthonous types

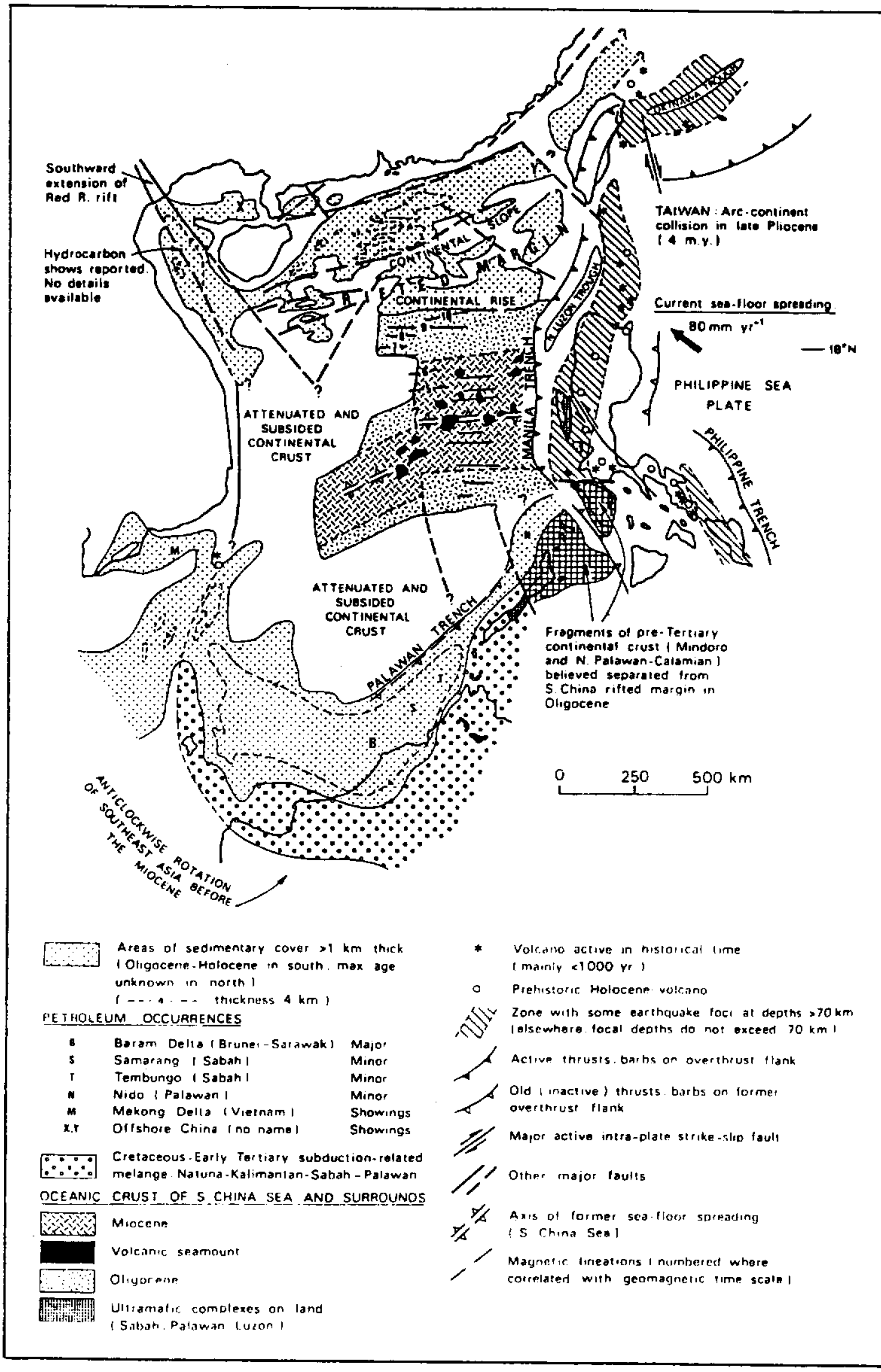

Fig. 7 Major structural features of the South China Sea Basin (Workman 1983).

(Nanjing 1980). They are mostly granodioritic and derived by regional migmatisation and metamorphic processes. The late Caledonian (c. 400 Ma) intrusions were emplaced into a more stable basement and are semiautochthonous or allochthonous. They are mainly unmetamorphosed biotite granites of magmatic affinity and are widely distributed. However, comagmatic volcanics are notably lacking.

Anon (1973) reported the Caledonian intrusives to display a broad E-W trend.

(iii) Late Palaeozoic to early Mesozoic. The Hercynian-Indosinian granites (c. 225-184 Ma) comprise smaller plutons developed throughout the Caledonian terrain. Anon (1973) and Nanjing (1980) noted that the Hercynian-Indosinian fault depressions with a general NE trend acted as loci for the granite emplacement (e.g. the Sihui-Wuzhou rift belt (Anon. 1973)).

(iv) Middle to late Mesozoic. Two major events are recognised during this period, collectively comprising the Yenshanian cycle*. The first event, during the Middle to Upper Jurassic is prominently represented in the Southwest Fujian-Eastern Guangdong Hercynian-Indosinian depression (Fig. 3). The second, mid-Cretaceous event gave rise to the extensive batholithic developments particularly well expressed in the coastal zone to the southeast of the Lishui-Zhenghe-Dabu Deep Fault.

Attempts have been made to relate the Yenshanian magmatism to the subduction of oceanic lithosphere beneath the Eurasian continental plate (see sections 2.4 and 2.5). Jahn et.al. (1976) observed that the Mesozoic magmatic activity was not preceded by major marine geosynclinal subsidence but that the products were emplaced in and on an uplifted continental landmass. They considered the volcanic rocks to represent a genetically related cap to the underlying batholith.

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* The Yenshanian events are dated at 170 to 130 Ma and 120 to 80 Ma (Jahn et.al. 1976); at 190 to 140 Ma and 130 to 90 Ma (Anon. 1973); and at 185 to 137 Ma and 137 to 67 Ma (Nanjing 1980).

The Nanjing workers (Nanjing 1980) also stressed the association between the plutonic rocks and comagmatic volcanics in the Zhejiang-Fujian-Guangdong coastal Yenshanian volcanic belt, and regarded the granites in this belt as belonging to their syntexis type, i.e. derived from mixed continental crustal and mantle material, developed along an active continental margin. They noted that the Yenshanian granitoids show a general sequence from early diorites through granodiorite and quartz monzonite to granite sensu stricto and that the younger the rock the higher its level of emplacement. They also recorded a decrease in the K_2O : Na_2O ratio from NW to SE and concluded that the Yenshanian magmatic activity was related to underthrusting of the Asian continental plate by the Pacific Ocean plate during the Mesozoic (see also section 2.4).

3. REVIEW OF HONG KONG STRATIGRAPHY

3.1 INTRODUCTION

The review of Hong Kong stratigraphy is undertaken with reference to the stratigraphic column established by Allen and Stephens (1971). The succession proposed by them (Table 1) is generally accepted by local workers although in the light of recent developments there is scope for revision and refinement. A meaningful reassessment will, however, have to await the completion and synthesis of the 1:20 000 remapping programme and an obvious prime requisite of that work will be to test the validity of the Allen and Stephens model and the later modifications noted in this review. This will involve inter alia checking the lines mapped by Allen and Stephens (op.cit.) and the validity and relative ages and relationships of the units which they distinguished. In the following sections an attempt will be made to draw attention to those contacts or relationships which appear to be particularly critical or suspect, and thus worthy of careful re-examination.

The early work in the Territory (e.g. by Heanley 1924, Brock and Schofield 1926, Heim 1929, Brock et.al. 1936, Williams 1943, Williams et.al. 1945) resulted in a rather confused stratigraphy and

Table 1. Hong Kong stratigraphic column (based on Allen and Stephens 1971)

Age	Formation	Major lithology
Holocene & Pleistocene		Transported terrestrial and marine deposits, residual deposits
Pleistocene	Kat O Fm.	Volcanic-bearing breccias and conglomerates
———	Unconformity	———
Lower Cretaceous	Port Island Fm.	Red beds (conglomerates, pebbly sandstones and mudstones)
———	Unconformity	———
	Repulse Bay Fm.	Acid tuffs and lavas, agglomerates, intercalated sediments
	Tai O Fm.	Sandstones, shales, siltstones, often graphitic
Middle & Lower Jurassic	Lok Ma Chau Fm.	Metamorphosed sedimentary and subordinate volcanic rocks
	Bluff Head Fm.	Quartz sandstones, conglomerates, siltstones and shales
	Tolo Channel Fm.	Pyritic shales, siltstones, quartz sandstones
———	Unconformity	———
Permian	Tolo Harbour Fm.	Pyritic shales, siltstones, quartz sandstones
	(Base not seen)	

Notes 1. Upper Jurassic granitoids and associated dyke rocks intrude, *inter alia*, the Repulse Bay Formation. They do not intrude nor do they contribute to the Port Island Formation.

2. The order in which the pre-Repulse Bay Formation sedimentary units of Jurassic age are listed does not necessarily imply their relative stratigraphic position.

a multiplicity of terms and units. As a result, Ruxton (1960) effected a major reappraisal, redefining many of the existing stratigraphic units and rationalising and simplifying the nomenclature. Allen and Stephens (1971) modified and built upon Ruxton's sweeping changes, continuing the rationalisation process in accordance with the internationally accepted Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature 1961) which had not been published when Ruxton (op.cit.) undertook his work.

Work accomplished since 1971 indicates that some revision of Allen and Stephens' stratigraphic classification is now needed, particularly of the older (i.e. pre-Repulse Bay Formation) sedimentary formations and of certain of the recent marine and alluvial deposits. An apparently consistent lithostratigraphy, if not a fully satisfactory chronostratigraphy, appears to be emerging for the latter. Modifications to the internal subdivision and stratigraphy of the Repulse Bay Formation may also be anticipated from the remapping programme.

In gross terms the succession established by Allen and Stephens (1971) comprised a sedimentary unit of Permian age (Tolo Harbour Formation) followed, with assumed major unconformity as no Triassic deposits were mapped, by Lower and Middle Jurassic sedimentary and volcanic formations. The volcanic activity, giving rise to the Repulse Bay Formation, was followed by the deposition of a continental red beds sequence of Cretaceous age. No Tertiary formations were recorded and the Quaternary is represented mainly by varieties of superficial deposits; limited outcrops of coarse clastics considered to be of (Early?) Pleistocene age (Kat O Formation) were identified. Plutonic activity of batholithic dimensions was considered to have post-dated the deposition of the volcanic rocks but was believed to pre-date the red beds sequence as no intrusive relationships were noted in those rocks.

The following sections of the report should be read in conjunction with the Allen and Stephens 1:50 000 scale geological maps and to avoid the need merely to restate their results a general familiarity with their work is assumed. The units recognised by Allen and

Stephens will be reviewed in ascending stratigraphic order in so far as this is possible (the relative ages of certain of the Jurassic sedimentary formations, for example, are not known with certainty). The relationships within and between the units will be discussed and critical or problematical aspects noted in the hope that this will provide some guidance for future workers.

The plutonic rocks will be considered separately although it should be borne in mind that they, just as much as the supracrustal deposits, form an integral part of the stratigraphic succession. Modern treatment of these rocks is to extend to them the conventional lithostratigraphic approach used for the volcanic and sedimentary formations (cf. Cobbing et.al. 1977, Pitcher 1978).

3.2 TOLO HARBOUR FORMATION

The term Tolo Harbour Formation (THF) was introduced by Ruxton (1960) for rocks occurring on the southeastern shore of Ma Shi Chau and on Centre Island. These rocks were previously grouped in the Liassic Tolo Channel Formation of Brock et.al. (1936). Ruxton (op.cit.) noted that the base of the formation was not exposed and, on palaeontological grounds (see below) assigned the THF to the Permian. He considered the formation to be overlain unconformably by the Bluff Head Formation on Centre Island.

Allen and Stephens (1971) broadly subscribed to Ruxton's interpretation although they modified the boundary of the formation on Ma Shi Chau and assigned the adjacent succession (mapped only as undifferentiated older sedimentary rocks by Ruxton) to the Bluff Head Formation (section 3.4). However, they did not recognise the latter on Centre Island nor were they entirely happy with the assignment of the rocks on Ma Shi Chau to it, expressing uncertainty as to the nature of the contact between the THF and the Bluff Head Formation at that locality. Both require re-examination.

More recently, Mr. M.J. Atherton, in correspondence with Dr. E.A. Stephens (January 1981) and in Atherton (1983b) expressed the opinion that the THF is also represented at Sham Chung, at the northeast entrance to Three Fathoms Cove, and he reported the presence there of Permo-Carboniferous marine fossils in beds of THF aspect. The Sham Chung sequence was correlated with the Tolo Channel Formation (Early Liassic) by Brock et.al. (1936) and with Repulse Bay Formation by Allen and Stephens (1971, see also section 3.7).

The assignment of a Permian age to the formation by Ruxton (1960) made it the oldest stratigraphic unit then known in the Territory and extended the stratigraphic column considerably further back than had been indicated before. No rocks older than Lower Liassic were shown on the 1936 map (Brock et.al. 1936) although Ruxton records that as early as 1923 Schofield had suggested a Permo-Carboniferous age for the sedimentary rocks on Ma Shi Chau and Centre Island, a view sustained by the observations of Ruxton himself and Allen and Stephens (1971) and further corroborated by later workers (e.g. Lam 1973; Nau 1980; Yim et.al. 1981; Lai et.al. 1982; Atherton 1983a). Marine and plant fossils are recorded and Nau (op.cit.) postulated deposition under alternating marine and terrestrial conditions.

The recent discovery of fossil fish remains of reported Devonian age in the Bluff Head Formation on Harbour Island (Lee 1982, see section 3.4) has further extended the stratigraphic column. It emphasises the need to confirm the status and validity of Allen and Stephens' (1971) correlation of the Ma Shi Chau rocks with the Bluff Head Formation and to elucidate the nature of the inter-formational contact there, which requires either a significant unconformity or a major fault separating rocks of considerably disparate age (Permian as against either Liassic or Devonian).

Lai et.al. (1982), reporting the results of work carried out on Ma Shi Chau in the mid-1970's followed Allen and Stephens (1971) by retaining the Bluff Head Formation, which they showed to be faulted against the THF. They subdivided the THF into Lower and Upper Permian sequences, noting the former to contain marine fossils, the latter to have been deposited initially under terrestrial conditions but to have been subjected to a later marine incursion. Lai and his colleagues correlated the Lower Permian strata with the Ma Hou (Maokou) Formation of Guangdong Province and the Upper Permian succession with the Lungtan (Longtan) and Cheung Hing (Changsing?) Formations (see their Table 1 and section 4 and Tables 3 and 4 of this report).

Nau (1981) remapped Ma Shi Chau and interestingly did not recognise the Bluff Head Formation, correlating the rocks so assigned by Allen and Stephens (1971) partly with an expanded THF but mainly with the Tolo Channel Formation (see section 3.3). Nau subdivided the THF into upper and lower members but noted the contacts to be faulted.

The relationships and correlation of the sedimentary formations in Tolo Harbour clearly remain problematical. Interpretation and understanding are complicated by the absence of readily distinguishable lithologies and marker beds and by the rather sporadic, poorly preserved fauna and flora which the rocks contain. The beds are strongly faulted and correlations are further hampered by the natural breaks in outcrop by the waters of the harbour.

In any future work attention should be directed inter alia to addressing the following questions :

(i) Is the Bluff Head Formation indeed present on Ma Shi Chau as advanced by Allen and Stephens (1971) and Lai et.al. (1982), or is the sequence there representative of an expanded THF and Tolo Channel Formation succession as proposed by Nau (1981)?

(ii) If the Bluff Head Formation is deemed to be present what is the nature of its relationship with the THF? If the contact is an unconformity, which unit is the older, i.e. can the proposed Devonian age for the Bluff Head Formation be sustained? If the contact is faulted what is the nature of the faulting, i.e. high angle thrusting emplacing older (Devonian) Bluff Head Formation in the northwest over the younger (Permian) THF in the southeast of the island, or normal faulting dropping down younger (Jurassic) Bluff Head Formation against the older THF?

3.3 TOLO CHANNEL FORMATION

The term Tolo Channel Formation (TCF) was originally applied to rocks outcropping on Ma Shi Chau and Centre Island in Tolo Harbour and on the north and south sides of Tolo Channel near Fung Wang Wat Bay, Sham Chung and northwest of Lai Chi Chong (e.g. Brock et.al. 1936; Williams 1943; Davis 1952). The formation was not recognised by Ruxton (1960) who variously grouped the rocks at these localities with his undifferentiated older sedimentary rocks and the THF (Ma Shi Chau, Centre Island, Sham Chung); with the Bluff Head Formation (Fung Wang Wat Bay); and with the Repulse Bay Formation (Lai Chi Chong).

Allen and Stephens (1971) re-introduced the term but restricted the formation to the coastal outcrops southwest of Fung Wang Wat Bay. They noted that the base of the formation was not exposed and considered the formation to be overlain conformably by the Bluff Head Formation, both units forming part of a normal, N-younging sequence. However, they admitted that the contact was partly faulted and that this, in conjunction with intrusive activity in the contact zone precluded the establishment of positive stratigraphic relationships. (The 1:50 000 map clearly shows the entire contact to be faulted). Allen and Stephens (op.cit.) justified the formational status of the TCF rocks on the grounds that a significant facies change from marine to deltaic conditions is represented by the upward passage to the Bluff Head Formation.

The TCF is considered to be of early Liassic age on palaeontological evidence, namely the presence of the ammonite *Hongkongites hongkongensis* (Heanley 1924, see e.g. Ruxton 1960, Allen and Stephens 1971) and on this basis the enclosing shales were considered to be of marine origin. Recently, however, examination of the shales, while revealing no further ammonites, did result in the discovery of plant remains (Atherton 1983a), suggesting a possible terrestrial or alternating marine - terrestrial/littoral environment.

In 1969 Dr. C.J. Peng discovered an unidentified ammonite at the southwestern end of Ma Shi Chau in rocks correlated by Allen and

Stephens (1971) with the Bluff Head Formation. The sequence in which the ammonite was found is overlain unconformably by the Repulse Bay Formation (Nau 1981). Only a relatively minor break in deposition is required if, as proposed by Nau, the ammonite-bearing beds are correlated (largely on palaeontological grounds) with the TCF as defined by Allen and Stephens (op.cit.). Nau also noted that the rocks on Ma Shi Chau which he correlated with the TCF show an apparently simpler deformation history than the older THF beds, with which they are in fault contact, a point made also by Allen and Stephens but with respect to the Bluff Head Formation/THF relationships. Unlike Allen and Stephens, however, Nau (op.cit.) was unable to recognise satisfactorily rocks showing affinities with the Bluff Head Formation along the northeastern coastal section of the island.

Future investigations should aim to resolve the relationships between the TCF and the Bluff Head Formation at the type locality and to clarify the correlations on Ma Shi Chau.

Allen and Stephens' (1971) resurrection of the TCF near Fung Wang Wat Bay appears to be justified by later events. Ruxton's (1960) incorporation of the TCF within the Bluff Head Formation at this locality cannot be sustained if a Devonian age for the latter is accepted (see section 3.4). The relationships of the two units at the type locality still, however, require clarification. A Devonian age for the Bluff Head Formation implies the need for a significant thrust fault between the two units, emplacing rocks of Devonian age southwards to a position structurally above the younger TCF.

On Ma Shi Chau, Nau's (1981) work, if accepted, simplifies the gross stratigraphic-structural relationships by indicating a N to NW-younging sequence from (SE) THF-TCF-Repulse Bay Formation (NW). If this is correct the along strike extension of the Bluff Head Formation may be sought offshore to the southeast of Ma Shi Chau while representatives of the THF and TCF may occur to the northwest of (i.e. overlying) the main Bluff Head Formation outcrops flanking Plover Cove. The intensity of faulting observed onshore and the apparent necessity for (high angle) thrust fault tectonics will complicate this simple model but may also account for possible variations in thickness or even the elimination of individual units in the areas beneath the waters of Tolo Harbour and the Plover Cove Reservoir.

3.4 BLUFF HEAD FORMATION

The Bluff Head Formation (BHF) is well developed along the northern side of Tolo Channel where it forms a steep to moderate N-dipping, N-younging sequence. The uncertainties regarding its correlation on Ma Shi Chau were noted in sections 3.2 and 3.3. Allen and Stephens (1971) also mapped it on the small island in the centre of Tolo Channel to the south of Harbour Island, where a vertically dipping, possibly N-younging sequence (cf. the main outcrop) is reported (Atherton 1983b). The presence of white quartzites to the southwest of Three Fathoms Cove, mapped as part of the Repulse Bay Formation by Allen and Stephens (op.cit.) may also be noted (see section 3.7).

Allen and Stephens (1971) regarded the BHF as a deltaic sequence of post-early Liassic age by virtue of its apparent conformity with the underlying fossiliferous TCF. Recently, however, Lee (1982) discovered fossil fish remains (Placodermi) near the presumed base of the BHF on Harbour Island, noting that these fish flourished during the Middle Devonian (c. 350 Ma). This discovery further extended the stratigraphic column and has important structural and stratigraphic implications, particularly with regard to the supposedly older formations (i.e. the TCF and the THF) and, indeed, to the relationships with the overlying Repulse Bay Formation (see below). Lee's (op.cit.) suggestion, however, that the rocks in which the fossils occur should be renamed (he suggested adopting the term Harbour Island Formation) is unnecessary : the discovery does not require the redefinition of the BHF, only a revision of its age (from Early Jurassic to ?Middle Devonian).

Ruxton (1960) regarded the upper contact of the BHF with the overlying volcanic rocks as an unconformity. Allen and Stephens (1971) favoured an essentially transitional and conformable relationship, particularly in the eastern Plover Cove - Bluff Head section, although they noted a disconformable relationship on Ma Shi Chau (cf. Nau 1981, see section 3.3).

Ruxton's (1960) work predated the construction and filling of the Plover Cove Reservoir and he presumably had the advantage of natural coastal outcrops on which to base his opinion. At present-day water levels in the reservoir and with only limited, essentially "artificial" exposures to examine the relationships will be less easy to discern. Reconnaissance by the Consultants of the water's edge exposures at the eastern end of the reservoir failed to indicate unequivocal relationships or to recognise the major sedimentary horizon mapped by Allen and Stephens (1971) at the base of the Repulse Bay Formation. It is worth noting, too, that the dip values shown on the 1:50 000 map to the north of Fung Wang Wat Bay are noticeably lower in the Repulse Bay Formation sediments than in the underlying BHF succession, favouring a gross discordancy between the two units and lending credence to Ruxton's (op.cit.) interpretation. Ruxton also noted discordancy at Bluff Head itself and remarked on the significant reduction in thickness of the BHF between the reservoir and Bluff Head.

Although the upper contact relationships of the BHF merit careful examination during the remapping programme Ruxton's (1960) interpretation is favoured and is strengthened by Lee's (1982) discovery, although more palaeontological evidence in support of his important find would be helpful and should be sought. A significant break must be represented by this contact if the Devonian age for the BHF is accepted. In the absence of evidence for thrusting (the relationships of the volcanic rocks to the older rocks on Ma Shi Chau preclude this) an unconformable relationship appears to be most probable. Reverting to the speculative model outlined in section 3.3, this would require the elimination by progressive overstepping in an easterly direction of the TCF and the THF in the Plover Cover Reservoir section, allowing Jurassic volcanics to rest directly upon and to overstep the Devonian deltaic deposits to the east of the reservoir. This is a simplistic and speculative model and it excludes the complications likely to result from faulting.

3.5 LOK MA CHAU FORMATION

The Lok Ma Chau Formation (LMCF) crops out in the north and west of the New Territories, but for the most part is poorly exposed. It was considered by Allen and Stephens (1971) to be of Jurassic age and to pre-date the Repulse Bay Formation which crops out extensively to the south and east (cf. Brock et.al. 1936; Ruxton 1960). (It may be noted that Brock and his colleagues regarded the formation as the metamorphosed equivalent of their Pat Sin Formation, a unit which incorporated inter alia much of what is now mapped to the north of Plover Cove as the Port Island Formation of Lower Cretaceous age, see section 3.8).

In the northern sector of the outcrop Allen and Stephens (1971) considered the LMCF to be overfolded and inverted and thus to overlie the volcanic rocks in a structural sense but to underlie them stratigraphically. They noted evidence of minor thrusting in the metasediments which dominate the formation but unlike Ruxton (1960) did not recognise the contact with the volcanic rocks as a major thrust. (The contact certainly merits careful examination during the remapping programme. The development of the relatively gently dipping planar fabric indicated by Allen and Stephens (op.cit.) and interpreted as an axial planar structure could possibly have developed as a result of thrust tectonics. Further evidence for their overfold should be sought. Lai (1977) broadly accepted Allen and Stephens' model and showed an overturned anticlinal axial trace in the formation, in large measure underlying an area concealed by superficial deposits along the border and in the Yuen Long sector. Lai's structure merges obliquely with the Cheung Chau (Castle Peak) granite between Yuen Long and Tuen Mun).

Elsewhere, in the western part of the outcrop the relationships and certain distinction between the LMCF and the Repulse Bay Formation sediments are problematical and the reliable correlation of the rocks to one or other of these units is difficult. Preliminary coordination of subsurface data suggests the existence of a narrow graben structure between the Cheung Chau granite of the Castle Peak peninsula and the Sung Kong granite to the east (M. Nash pers. common. 1983). The graben contains a sequence of sediments underlain by metasediments which are possibly representative of the Repulse Bay Formation and the LMCF respectively. Particular attention to the problem will be required during the remapping programme.

Although the gross relationships favour a pre-Repulse Bay Formation age for the LMCF considerable uncertainty remains as to its correct stratigraphic position and to its internal constitution. It may indeed, either in whole or in part, be considerably older than the Jurassic. It is of interest that Allen and Stephens (1971) noted a strong resemblance between the LMCF and the BHF and considered their correlation to be very likely.

More recent (i.e. post-Allen and Stephens) interpretations, particularly by workers familiar with the geology of Guangdong Province, considered the LMCF to be of Palaeozoic age (partly it may be suspected because of the metamorphic character displayed by the constituent lithologies). Lai (1977) believed the formation to be pre-Permian and thus it would challenge the reassigned BHF as the oldest formation present in Hong Kong. Ha et.al. (1981) also subscribed to this view. They accorded a probable Carboniferous age to a sequence of LMCF metasiltstones, limestones, marbles and quartzites which occur buried beneath the superficial deposits in the vicinity of Yuen Long. The limestones were reported to have yielded a fossil but no identifications had been made when their work was published. General support for these views is provided by the relationships along the strike of the LMCF in the Shenzhen Economic Zone. The 1:50 000 geological map of the Zone maintained by the Shenzhen Geological Bureau (see also Burnett 1983) shows the LMCF to be grossly contiguous with variably metamorphosed Carboniferous strata, comprising limestones and dolomites (in places fossiliferous, elsewhere completely recrystallised), phyllites and micaceous quartzites, and with a Lower Carboniferous Visean sequence of sandstones, shales (in part graphitic), coal beds and conglomerates. More restricted outcrops of Devonian age which also occur broadly along the strike of the formation, although not directly contiguous with it, comprise variably metamorphosed (to garnet-staurolite grade) metasedimentary rocks.

A more detailed correlation of the successions is not possible at present, although the general lithological similarities can be noted. The LMCF remains poorly understood, partly as a result of its badly exposed nature and significant revisions may perhaps be expected from the new survey. The relationships between the LMCF and the Repulse Bay Formation sediments in the southern sector of the outcrop require particular attention. Any advances that are made, however, will rely heavily on subsurface information to substantiate a careful reexamination of the available surface exposures. The drilling of stratigraphic boreholes in the northern and southern sectors should be seriously contemplated to permit the formation to be defined more rigorously.

3.6 TAI O FORMATION

The Tai O Formation (TOF) was defined by Allen and Stephens (1971) and accorded a Middle to Lower Jurassic age. Outcrop is restricted to a section on the northern coast of western Lantau and to the Brother Islands and Reef Island. The sediments comprising the unit were originally included in the Pat Sin Formation (Brock et.al. 1936; Davis 1952) which comprised all the sedimentary formations previously reviewed and also the rocks of the Port Island Formation (see section 3.8). Ruxton (1960) grouped the TOF sequence with his undifferentiated older sedimentary rocks.

An assessment of the status of the TOF and its correlation with the other sedimentary rocks in the Territory is rendered difficult by its restricted outcrop and physical separation from the other formations. The base of the TOF is not exposed but it is intruded by the Cheung Chau Granite near Sha Lo Wan which sets an upper age for the formation.

Ruxton (1960) regarded the contact between the sedimentary rocks and the Plover Cove Formation volcanics (now termed the Repulse Bay Formation, see section 3.7) to be unconformable. In support of this relationship on Lantau he noted that Uglow (in Jones 1927) had claimed that a period of folding existed between rocks then assigned to the BHF and the younger Plover Cove volcanics. Ruxton also recorded a transgressive relationship between the Tai Mo Shan porphyry (now considered to be part of the Repulse Bay Formation) and the older sedimentary series near Sha Lo Wan. This is not obvious from an examination of Ruxton's admittedly small-scale map of the Territory nor, apparently, was it confirmed by Allen and Stephens (1971). (Some confusion appears to exist in the literature in respect of the reported transgressive relationship and the locality given. Allen and Stephens (1971) appear to have assumed that Uglow was referring to the outcrop of the TOF and probably to the Sha Lo Wan area mentioned by Ruxton but were unable to verify the relationship in that area. As a result they believed that the grid reference cited by Ruxton, and stated by him to be derived from Uglow, was in error. The coordinates quoted by Ruxton refer in fact to an area southwest of Shek Pik Reservoir where Ruxton's (op.cit.) map shows the Tai Mo Shan porphyry to be in contact with undifferentiated Plover Cove volcanic rocks. Allen and Stephens (op.cit.) subsequently mapped at this locality a blunt wedge of acid lavas showing a discordant relationship (at the 1:50 000 scale) with sedimentary rocks also assigned to the Repulse Bay Formation. It is possible, therefore, that the transgressive nature of the Tai Mo Shan porphyry mentioned by Uglow refers to this area and not to the Sha Lo Wan area on the north coast as Allen and Stephens appear to have assumed. The grid reference given by Uglow and reported by Ruxton (op.cit.) could thus be correct).

Allen and Stephens (1971) considered the TOF to be overlain conformably by the Repulse Bay Formation in the main outcrop on Lantau although they recognised that the evidence was not conclusive. They noted the TOF to resemble sedimentary intercalations occurring elsewhere within the volcanic sequence (e.g. at Starling Inlet, Crooked Harbour, Lai Chi Chong). However, in the absence of an exposed base to verify an interbedded relationship between the sediments and the volcanics and in view of the considerable distances separating outcrops of the TOF and the other sedimentary units, they considered that independent formational status was justified.

During the remapping programme on Lantau the upper contact of the TOF should be examined carefully in view of the equivocal nature of the evidence given by Allen and Stephens (1971). Trenching may be required.

No fossils are yet reported from the outcrop although this may reflect thermal metamorphism, Allen and Stephens noting that the indurated appearance of the crop is similar to that described on West Brother Island by Ruxton (1957). However, in his 1960 publication Ruxton indicated two ?fossil (or fault?) localities on his map, one to the north of Tai O, the other west-northwest of Sham Wat, but no reference was made to either in the text. In the absence of any palaeontological information consideration may need to be given to testing the base of the formation by drilling, to evaluate whether the TOF merits separate formational status or whether it is more correctly correlated with and forms an intercalation within the Repulse Bay Formation.

Allen and Stephens (1971) also assigned the rocks comprising East and West Brother Islands and Reef Island to the TOF. Ruxton (1957) considered the rocks there to represent a deltaic coal-bearing sequence. Comparisons may be noted with e.g. rocks assigned to the THF which appear to have been deposited under conditions varying between marine and terrestrial. Davis (1952) also remarked a resemblance between the rocks exposed on the Brother Islands and the LMCF and this correlation is tentatively favoured on structural grounds in the Western New Territories Geotechnical Area Study report (in preparation, M. Nash pers. comm. 1983). The presence of similar lithologies in broadly contiguous rocks of Carboniferous age in the Shenzhen Economic Zone was noted in the previous section. If these correlations are valid then a significant unconformity should be expected between the TOF (Carboniferous?) and the overlying volcanic rocks (Jurassic). This is contrary to current opinion (Allen and Stephens 1971). An alternative which may usefully be considered is that the LMCF as presently defined may be in part Jurassic, in part older (R. Addison pers. comm. 1983).

To conclude, therefore, the correlation of the TOF and its correct position in the stratigraphic column remains uncertain and its relationships with units above and below merit further study. Onshore and offshore drilling and site investigation studies (e.g. in the section between Castle Peak Bay and the Brother Islands) may prove helpful and geophysical methods could assist in characterising the nature of the pre-TOF basement. However, the metamorphism and induration of the formation, particularly on the Brother Islands, favour the presence of intrusive rocks at no great depth in the North Lantau channel area and suggest that the lower contact may well be intrusive. If this is so the true stratigraphic status of the TOF is likely to remain uncertain unless more direct dating proves possible.

3.7 REPULSE BAY FORMATION

The Repulse Bay Formation (RBF) is the most extensive of the lithostratigraphic units occurring in the Territory. Prior to 1960 the volcanic rocks were assigned to a number of separate formations at various levels in the stratigraphic column (e.g. see Brock et.al. 1936; Williams et.al. 1945). Ruxton (1960) broke with precedent, demonstrating that all the units previously recognised (e.g. Repulse Bay Volcanics, Tai Mo Shan Porphyry, Shelter Volcanics, Rocky Harbour Volcanics) formed part of a unified, essentially conformable sequence which he named the Plover Cove Formation. Allen and Stephens (1971) accepted Ruxton's assessment and rationalisation but on grounds of precedence reinstated the term Repulse Bay in lieu of that introduced by Ruxton.

Unlike some of the older sedimentary formations little attention has been accorded to the RBF since Allen and Stephens concluded their work. The present review, therefore, refers mainly to the 1971 study and the comments made in the following paragraphs are provisional and particularly liable to modification as the remapping programme proceeds. The new survey will almost certainly result in considerable revision and refinement of the lines and subdivisions shown for the formation on the 1:50 000 geological map of the Territory.

The RBF was assigned to the Middle to Lower Jurassic on the basis of its broad stratigraphic relationships and the sparse palaeontological data gleaned from sedimentary intercalations within the succession. The contact relations between the RBF and the older sedimentary units were considered in the previous sections. The relationships can be summarised by noting a possible conformable contact with the TOF and an unconformable contact with the BHF (of Allen and Stephens 1971; TCF of Nau 1981) on Ma Shi Chau. A similar uncomformable relationship (cf. Ruxton 1960) must also be postulated to the east of Plover Cove if a Devonian age for the BHF is accepted, although Allen and Stephens (op.cit.) mapped a conformable contact. The relationship between the RBF and the LMCF remains equivocal; if a Carboniferous age for the latter is upheld (?)then that contact also must represent a signification discontinuity.

Allen and Stephens (1971) mapped a considerable section of central Lantau as undifferentiated RBF but elsewhere were able to break the volcanic pile down into six lithological units at the 1:50 000 scale. They noted the difficulties of stratigraphic correlation within the formation and expressed the opinion that the mapped units should not be formally construed as lithostratigraphic in the strict sense although, taking the units at their face value, to have done so would not appear to be precluded by the requirements of international convention (see footnote, section 1.2). However, not all the units distinguished by Allen and Stephens were clearly defined and demarcated and their age relationships often remained in doubt. Nevertheless they did note similarities between the succession at different localities and recognised a general sequence from coarse tuffs (RBc) at the base through sediments (RBs), tuffs (RBp), welded tuffs and banded lavas (Rbvp) to rhyolites (RBv) at the top of the succession.*

In the Sai Kung Peninsula the general succession is of this type and within the area Allen and Stephens (1971) were able to distinguish similarities between the more detailed successions at a number of localities. Note can be made in particular of the extensive unit of acid lavas overlying a mixed sequence of lavas and tuffs in the extreme eastern part of the peninsula. The recognition here of separate lithostratigraphic units would seem to be justified although elsewhere the relationships of the RBv are more varied (see below). Also of general interest in the Sai Kung area is the elliptical

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* Abbreviations used are taken from the 1:50 000 map and report by Allen and Stephens (1971).

but asymmetric distribution of the volcanic units about an ENE-aligned core of coarse tuffs (RBc) which form the lower part of the succession to the north of Hebe Haven and Sai Kung. The coarse-grained nature of the dominant lithology comprising the core and the rather orderly distribution and relationships of the various units around it (on the 1:50 000 scale) make it possible to speculate on the presence here of a volcanic centre or an alignment of centres.

In the area to the south and west of Tai Mo Shan in the central New Territories the relationships mapped by Allen and Stephens (1971) indicate a generally gently dipping succession from RBc at the local base through RBp and agglomerate, locally developed intercalations of RBs, RBc, RBp to RBc on Tai Mo Shan. This apparently relatively straightforward sequence clearly differs from the Sai Kung succession. It is interesting to speculate that this in itself may be significant and that the differences imply different courses of events in separate fault blocks. However, it should be noted that Allen and Stephens (op.cit.) expressed a need for caution in interpreting this apparently simple succession in the Tai Mo Shan area, in particular having regard for the distribution and relationships between the RBp and the RBc. They believed that these two units could be in part contemporaneous and warned that the mapping of the volcanics in the area is generalised.

A further point of interest noted by Allen and Stephens (1971) concerns the virtual restriction of the RBc to the south of a line extending southwestward from Tai Po and the predominance of RBp to the north of the Tai Po - Lam Tsuen - Kam Tin valley line. The coarse tuff (RBc) that does occur intercalated with the RBp to the east-northeast of Yuen Long is reportedly of different character to the coarse tuffs further south. Allen and Stephens (op.cit.) favoured some form of structural control and on this basis it is possible to speculate on the existence in the Territory of three comagmatic but essentially independent zones of ? broadly contemporaneous volcanic activity, the zones being separated by deep fractures permitting each zone a certain individuality of character and expression.

Elsewhere in the Territory the mapped relationships provide glimpses of an internal stratigraphy and the hope that the remapping programme will permit a more satisfactory breakdown and understanding of the rocks comprising the volcanic pile. On Lantau, for example, some 1.5 km northwest of Lantau Peak the acid lavas (RBv) again form the highest unit in the local sequence (cf. Sai Kung Peninsula), although the succession is extremely limited and restricted by faulting. Elsewhere on Lantau and on Hong Kong Island the acid lavas are more usually intercalated with sediments and pyroclastic deposits rather than capping them (e.g. SE of Tai O, N of Tong Fuk, S of Mount Kellett, Cape d'Aguilar).

On the southern side of Tolo Channel in the section to the east of Three Fathoms Cove Allen and Stephens (1971) mapped a broadly E-younging sequence passing from sediments at the base through RBp, RBs, (RBp), RBv to RBc at the top of the sequence. The contact between the RBv and the RBc is partly faulted. The lower sedimentary unit outcropping at Sham Chung merits comment. Allen and Stephens (op.cit.) correlated the sediments with the RBF. The base of the unit is not exposed, however, and their treatment may be considered inconsistent by comparison with their assessment of the TOF on Lantau, which in gross terms appears to display comparable relationships to the overlying volcanics. It is regarded as significant that the Sham Chung sediments were previously correlated with the older (i.e. pre-volcanic) sedimentary formations (see Brock et.al. 1936; Davis 1952) and the nature and correct interpretation of the contact with the overlying RBp is clearly critical. A reassessment of the stratigraphic status of the Sham Chung sediments is required, and Atherton's (1983b) note that Permo-Carboniferous fossils have been recovered from them supports correlation with the THF. Examination of the 1:50 000 map also favours a pre-RBF age for the sediments. The map suggest a subhorizontal contact between the sediments and the overlying RBp and an angular discordancy between the two units is favoured by the moderate to steep dip values recorded in the underlying rocks. The outcrop trends of the two sedimentary units also differ significantly, the more easterly, stratigraphically and structurally higher unit near Lai Chi Chong clearly being intercalated within the volcanic sequence. Williams (1943) reported Jurassic plant remains from the Lai Chi Chong horizon in keeping with its position.

Numerous intercalations of sedimentary rocks occur elsewhere within the volcanic pile. Allen and Stephens (1971) distinguished two types of sedimentary unit, one thin and laterally impersistent, the other thick and cropping out over a large area. The former type was considered to be of fluviatile or lacustrine character, the latter possibly of marine origin. The thinner units provide useful local marker horizons and it is probable that considerably more sedimentary material exists in the volcanic sequence than has presently been mapped. Significant developments are reported, for example, on Lantau.

In considering the broad stratigraphy of the RBF, the more extensive deposits are of probably greater significance and their correct interpretation more critical. Allen and Stephens (1971) noted that they occur in four main areas : on the south side of Starling Inlet, near Lai Chi Wo on Crooked Harbour, at the Chinese University, and north of Ma On Shan.

The sediments at Starling Inlet and Crooked Harbour were reported by Allen and Stephens (1971) to show both conformable and disconformable relationships to the underlying tuffs (RBp) but they observed that tuffs within the sedimentary units were rare. Brock et.al. (1936) distinguished more limited sedimentary outcrops in the area which they assigned to the Pat Sin Formation and which predated their Rocky Harbour volcanic unit, while Ruxton (1960) correlated the Starling Inlet rocks with the Port Island Formation (see section 3.8).

In a recent study Yim (1983b) described an angular unconformity within the sedimentary sequence to the east of Lai Chi Wo, Crooked Harbour, noting the basal conglomerate above the break to contain volcanic and quartzite clasts. The deposition of the upper sediments at least post-dated some of the volcanic activity but the gross relationships of this sedimentary enclave to the volcanic succession is unfortunately not considered. The general impression given by the 1:50 000 map is that the Lai Chi Wo sediments and those outcropping on the coast to the west-northwest of Kuk Po are restricted to the lower ground and possibly unconformably underly the volcanic deposits. There is scope for clarification of the relationships in these sections.

Opinions differ also regarding the status of the small outcrop mapped as RBs by Allen and Stephens (1971) at Lodge Point. They presumably accepted Ruxton's (1960) implied conformable sequence passing upward from welded rhyolitic tuffs into the sediments. Earlier records reported the presence of limestone-bearing shales and limestone breccia in the Lodge Point succession although these are no longer exposed. However, limestones are not described from other sedimentary units occurring within the RBF and Lai's (1977) correlation of the Lodge Point sediments with the Permian, in fault contact with the volcanics, merits consideration. In short, a pre-RBF age for at least some of the sedimentary rocks outcropping in this part of the northeastern New Territories should not be ruled out.

The same view is held for the steeply dipping sedimentary rocks occurring in the vicinity of the Chinese University and for the outcrops to the west and north of Ma On Shan and on the western shore of Three Fathoms Cove (e.g. see Davis 1952; Ruxton 1960; Atherton 1983a and pers. comms. 1982-83). Allen and Stephens (1971) correlated all these developments with the RBF.

In the absence of palaeontological evidence and unequivocal contact relationships correlation of these rocks is difficult and uncertain. In view of their spatial association, correlation between the Three Fathoms Cove outcrops and the Sham Chung rocks (THF?) may be considered reasonable, although Atherton (op.cit.) also noted lithological resemblances between some of the former rocks and the TCF exposed on the northern side of Tolo Channel, several kilometres to the northeast. Lithological similarities are also noted between the broad Ma On Shan outcrop and the BHF. The Ma On Shan rocks, mainly quartzites, certainly underly a part of the volcanic sequence but in turn appear to be underlain by volcanic rocks to the northwest. They also occur at a considerably higher level than the main BHF outcrop or, indeed, any of the other pre-RBF sedimentary units (but this may reflect later structural control). Quartzites, dolomites and limestones are also reported from the Ma On Shan iron mine (Davis 1964) and the presence of carbonates at that locality may perhaps be taken as a further indication of a pre-RBF age for the outcrop. However, at the present time the sedimentary rocks in this area and at Chinese University remain enigmatic.

The other major development of sediments grouped with the RBF and whose relationships to the volcanics are uncertain is that which constitutes Ping Chau in Mirs Bay. These rocks were mapped as the TCF by Brock et.al. (1936) and subsequently termed the Peng (sic.) Chau Formation by Williams (1943). Ruxton (1960) assigned them to the Plover Cove Formation after discovering a tuff horizon in the sequence. The available palaeontological evidence supported a Jurassic, probably post-Liassic age (Williams 1943; Ruxton 1960). Allen and Stephens (1971) accepted Ruxton's correlation but observed that the Ping Chau sequence could not be readily correlated with other sedimentary units in Hong Kong.

In a more recent appraisal of these rocks Nau (1979) noted them to differ from the normal sedimentary intercalations in the volcanic pile and described Ruxton's tuff band as a cherty siltstone. He reported C.J. Peng as favouring(in 1978;see also Peng 1971a,b) the reinstatement of the term Ping Chau Formation. The palaeontological evidence broadly favoured correlation with the RBF. Nau (op.cit.) appeared effectively to discount Ruxton's (1960) main argument for the correlation, i.e. the evidence for contemporaneous volcanic activity. In view of the reported lithological differences between the Ping Chau and other sedimentary sequences and the relative isolation from other outcrops there would appear to be grounds for supporting Dr. Peng's view and according the rocks formational status while recognising their probable general contemporaneity with the RBF.

In summary, the remapping of the RBF can be expected to result in a considerable revision of the lines and units shown and described by Allen and Stephen's (1971). Their work, however, provided a tentative lithostratigraphic framework which requires testing and developing during the new survey. Particular attention has been drawn to the possible development of structurally controlled, relatively independent sequences of volcanic activity and to the uncertainty regarding the status and present correlation with the RBF of some of the sedimentary outcrops occurring in juxtaposition with the volcanics at different localities. It is probable that elevation of the formation to group status will be justified in the future when the internal stratigraphic relationships and subdivisions are more clearly defined. The RBF clearly forms part of a major volcanic episode which has profoundly influenced the geology not only of the Territory but of a considerable part of the southeastern China coastal region.

3.8 PORT ISLAND FORMATION

The Port Island Formation (PIF) of Early Cretaceous age was defined by Ruxton (1960) and incorporated rocks previously mapped as the Mirs Bay and Pat Sin Formations (Brock et.al. 1936). Allen and Stephens (1971) accepted Ruxton's definition and retained his terminology but they reassigned some of the rocks outcropping on the southern shore of Starling Inlet to the RBF.

The PIF is restricted to the northeast of the Territory. It overlies the RBF unconformably and is considered to post-date the early Yenshanian magmatic activity. No minor intrusives are reported to cut the succession and the absence of clasts of plutonic intrusive rocks indicates the probable deposition of the formation prior to the unroofing of the major intrusions. The top of the succession is not exposed and the formation is truncated in the north by overthrust volcanic rocks. Both the upper and lower contacts merit examination during the remapping programme, the former particularly because it was originally regarded as an unconformity between the sediments and the overlying Rocky Harbour Volcanics (Brock et.al. 1936).

In addition to the overthrust nature of the upper contact, however, attention should also be drawn to the presence of shearing and the development of cleavage elsewhere in the unit, particularly in the basal section. Allen and Stephens (1971) related the cleavage to folding prior to the development of gently dipping shears (subparallel to bedding) but locally (e.g. southeast of Brides Pool) they mapped a short thrust section in the volcanic rocks immediately underlying the unconformable lower contact of the PIF. A cataclastic fabric also characterises the formation near Brides

Pool and the general relationships to the underlying volcanics, certainly in this central section of the crop are of interest.*

It is also of interest to observe the contrast in the degree of deformation which is evident between the outcrops in the Brides Pool section and on Port Island, the type locality of the formation. This has led to the view that the two developments are of different age, the Port Island outcrops being Upper Cretaceous and thus according with the division established for the red beds in China (M.J. Atherton pers. comm. 1983, views believed to be attributed to C.M. Lee).

The use of intensity of deformation as a criterion of age is not without hazard and further evidence to support this thesis is needed before it can be reasonably accepted. Interpretation will nevertheless be hampered by the disconnected nature of the outcrops of the presumed different successions. The relationships in China cited by Allen and Stephens (1971) indicated an unconformity between the Lower and Upper Cretaceous red beds, and intercalated lavas are recorded in the younger sequence. No volcanics have yet been reported from within the PIF succession but this does suggest a possible means of testing the hypothesis. It is also worth noting that the earlier workers considered most of the mainland outcrop of the PIF to be correlated with the older Pat Sin Formation (see Brock <u>et.al.</u> 1936; Davis 1952) but they did distinguish the Mirs Bay Formation in the area to the northeast of Plover Cove and on Port Island itself. On this basis there would appear to be some support for a subdivision of the PIF and the contact shown by Brock <u>et.al.</u> (<u>op.cit.</u>) to the

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* Allen and Stephens (1971) report that the cleavage affecting the PIF is fold-related (Tolo Channel anticline?) but note that it penetrates the underlying volcanic rocks to only a limited depth below the unconformity. The cleavage is said to be steeply dipping by comparison with the normally shallow-dipping thrusts and shears which cut the cleavage. The relationships may simply reflect differences in competency and the generally more susceptible nature of the PIF lithologies to cleavage-producing deformation compared with the volcanic rocks. Alternatively it may be that the cleavage is in some manner related to differential movement in the contact zone. It would appear that the matter would repay structural investigation.

south of the Double Haven merits re-examination. Davis (1952) noted the Mirs Bay sediments to have been "laid down on the eroded weathered surface of the Pat Sin." However, it seems likely that the rocks referred to by him as Pat Sin were those now correlated with the BHF and therefore not relevant to the present issue.

3.9 CAINOZOIC

No Tertiary formations are presently recorded in Hong Kong (Allen and Stephens 1971) although earlier workers assigned the Mirs Bay (PIF in part) and Rocky Harbour (RBF in part) sequences to the Eocene and Miocene respectively. The Eocene age for the Mirs Bay red beds supposed a Late Cretaceous age for the plutonic activity, but this was not borne out by later work, particularly the radiometric data reported by Allen and Stephens (op.cit.), which dates the plutonic activity as Late Jurassic (165 to 135 Ma) and ascribes the late shearing which affects the PIF to a mid-Cretaceous age (92 ± 2 Ma).

Recent work offshore, however, has indicated the accumulation of considerable thicknesses of rift-controlled sediments of Tertiary age, and Holloway (1982) noted the Cretaceous-Paleocene boundary to represent an unconformity of regional extent and significance. The tectonically controlled deposition of continental clastics is also recorded onshore in the southern part of the Chinese mainland.

The youngest formation mapped in the Territory is the Kat O Formation (KOF). This is restricted to limited outcrops in the extreme northeast and to a single locality on the shores of Deep Bay in the northwest. The formation was defined by Ruxton (1960) and was observed to rest unconformably on the RBF in the northeast and to be in probable fault contact with the LMCF in the northwest. Its generally youthful appearance gave rise to the opinion that it was probably not significantly older than the Territory's extensive alluvial, marine and colluvial superficial deposits and Allen and Stephens (1971) accorded it a Pleistocene age on their 1:50 000 map. No convincing evidence for this age was given, however, and there is no good reason why the deposits could not be significantly older (i.e. Tertiary). On Kat O Chau the youthful aspect of the formation is illusory and a reflection of intense subaerial weathering and breakdown of the deposits exposed in cliff-section. The same deposits on the wave-cut platform are lithified. The dip values recorded by Allen and Stephens (op.cit.) and the probable faulted relationship with the LMCF indicate post-depositional deformation, more probable if a Tertiary age for the formation is accepted.

Ruxton (1960) reported the KOF (amongst others) to be transected by marine platforms, in the case of the KOF at 70 and 40 ft (c. 21 and 12 m) above present sea level. Current opinion, however, (e.g. see Meacham and Yim 1983) casts doubt on the significance and origins of the high level marine surfaces of the type mentioned above and documented more fully by Berry (1959, 1961). The presence of such surfaces would appear to require eustatic and/or tectonic gyrations of a scale not adequately supported by the available evidence (cf. Meacham 1975) although recent relative uplift as evinced by raised beaches, terraces and incised drainage is widely reported (e.g. Davis 1952, Grant 1960, Allen and Stephens 1971). Huang et al. (1983) invoked neotectonic activity to account for terraces and raised coral platforms in the southern China coastal region but it cannot be demonstrated that uplift occurred on the scale needed to sustain the levels of the surfaces reported by Ruxton and Berry.

Davis (1952) noted that the marine deposits laid down in former rias (e.g. Deep Bay - Sham Shui area) are mostly found below the 10 m contour level. The development of the drowned coastline of Hong Kong is ascribed to the global Holocene transgression. Huang et al. (1983) considered the Holocene sea levels in the southern China coastal region to be similar or at most 3 to 4 m higher than at the present day. Meacham and Yim (1983) broadly concurred with Huang and his colleagues and found no acceptable evidence for higher sea levels in Hong Kong since the Holocene transgression. Sea levels in the mid-Tertiary were appreciably lower than at the present day (-1 000 m, W.W.S. Yim, in oral presentation of Yim 1983c). Yang and Xie (1982) reported the lowest Quaternary sea level in eastern China to have occurred 18 000 years B.P.* and a sea-level rise of the order of 40 m during the early Holocene is accepted by Zhao and Zhang (1982). The latter noted a peak at c. +3 m some 5 000 to 6 000 years B.P. Since then the sea-level gradually declined to present levels but showed fluctuations of 1 to 2 m above and below the present datum. In Hong Kong Kendall (1976) estimated the Late Pleistocene sea level (>15 000 years B.P.) to be at least -80 mPD (Hong Kong Principal Datum, c. 1.19 m below mean sea level) and Meacham (1975) concluded that present sea levels were attained about 4 000 years B.C., but that a significant rise of 15 to 20 m occurred between 7 000 and 4 000 B.C., i.e. during the early to mid-Holocene.

A general stratigraphy is now beginning to emerge from recent studies of the Quaternary superficial deposits of alluvial and marine origin which constitute the flat coastal plains and the lower sections of the main valleys and the areas offshore. Considerable information now exists in site investigation records although little progress has been made at anything more than local coordination. Preliminary attempts have also been made recently to classify and place in a stratigraphic context the mass wastage (colluvial) deposits of the Territory although at present with less rigorous controls and therefore less convincingly. These attempts must be viewed circumspectly at the present time.

Kendall (1976), Yim (1983a,c) and Yim and Li (1983) reported a reasonably consistent stratigraphic sequence of Late Pleistocene and Holocene marine and alluvial deposits overlying weathered bedrock and residual deposits from sea floor locations at High Island, Lei Yue Mun Bay, Chai Wan and Chek Lap Kok. A similar sequence is indicated at Tide Cove (Whiteside 1983), Tai O (Dickson 1983) and from onshore sites (e.g. Davis 1952; Allen and Stephens 1971). When complete a repeated sequence of alluvial and marine deposits is present although disconformities and scouring are reported, locally eliminating at least the lower marine unit and resulting in lower and upper alluvial deposits occurring in contact. In most near-shore

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* By convention (see Holland *et al.* 1978) age B.P. is age in years before 1950.

areas only one marine horizon overlying alluvium and weathered bedrock/residual deposits is reported (Yim and Li op.cit., Whiteside op.cit.).

Table 2 is a general summary based on the limited radiocarbon data available. The age of 33 400 years B.P. given for the Lower Alluvium nears the limits of the analytical method and should be considered a minimum age. Yim (1983a,c) and Yim and Li (1983) noted a general correlation between the succession established for the Hong Kong sea-floor deposits and that determined elsewhere in Southeast Asia (e.g. Aleva et al. 1973; Batchelor 1979). The Quaternary sea level changes appear to have affected in a similar manner the wider area of the South China Sea.

Table 2. General stratigraphy and tentative ages of near-shore sea-floor superficial deposits (from Yim 1983a and Yim and Li 1983).

Horizon	Tentative age	Remarks
Upper Marine	< 8 000 years B.P.	Post glacial
Upper Alluvium	8 000 - 33 400 years B.P.	Last glacial*, possibly 16 420 - 27 000 years B.P.
Lower Marine	28 000 - 30 000 years B.P.?	Last interglacial
Lower Alluvium	> 33 400 years B.P.	Second last glacial
Residual deposits and weathered bedrock		Pre-second last glacial

* Glacial and interglacial events occur within the Dali (equivalent to Würm) glaciation, 70 000 to 10 000 years B.P. (Huang 1983).

In the Pearl River delta Huang et al. (1983) reported a threefold subdivision of the deposits, distinguishing (from the top downwards) flood plain deposits, marine and deltaic deposits, and fluvial deposits. This sequence compares with the known onshore and nearshore sequences in Hong Kong. The review of available C^{14} results undertaken by Huang and his colleagues dated the marine deposits at 6 000 to 2 700 years B.P. Material of terrestrial origin yielded ages greater than c. 20 000 years B.P. and these sediments could be correlated with either the Upper or Lower Alluvium of Hong Kong workers.

Lai and Taylor (1983) described three classes of colluvium and attempted to relate each to changes in palaeoclimate and palaeoenvironment during the Quaternary. They considered the oldest (class I) deposits to have been formed in the Early to mid-Pleistocene while the colluvium of the other classes may belong to the Late Pleistocene and Holocene respectively. Liu (1983) correlated the development of the residual deposits and the older colluvium with the mid-Pleistocene and the younger deposits with the Holocene. Some overlap with the deposition of the alluvial and marine deposits is apparent if these age assignments are accepted. The relationships between the deposits developed by mass wastage and by fluvial and marine processes remain little studied but A.J. Willis (in oral presentation of Willis and Shirlaw (1983)) reported colluvial deposits to underlie the alluvial - marine sequence at Wanchai and an open mind should perhaps be kept regarding the nature of some of the 'lower alluvial' deposits?

The age assignments considered for the colluvial deposits are thus only loosely controlled and need to be viewed with particular caution. No precise correlation with glacial or interglacial climatic regimes is yet possible, although this subject will be examined in the Consultants' report on the superficial deposits of the Territory.

3.10 PLUTONIC INTRUSIVE ROCKS

Allen and Stephens (1971) rationalised the nomenclature and assignment of the predominantly granitoid rocks and made a relatively early attempt to treat them in accordance with lithostratigraphic principles, a procedure which finds general favour in modern granite studies (e.g. Cobbing et al. 1977, Pitcher 1978).

The granitoid bodies were emplaced into and thus post-date at least part of the volcanic succession. Granitoid clasts do not contribute to the PIF red beds sequence nor is there evidence of plutonic intrusive activity affecting those beds. A pre-PIF age for the intrusions is therefore indicated, the absence of clasts implying that the granitoid bodies were not unroofed and eroding when the PIF was being deposited. Radiometric data reported by Allen and Stephens (1971) give ages of between 163±35 and 140±7 Ma for the intrusive activity (Middle to end-Jurassic or earliest Cretaceous). The age range compares closely with the Mesozoic thermal event of 170 to 130 Ma reported for southern China by Jahn et al. (1976) and the activity is correlated with the early Yenshanian orogeny.

The granitic rocks of Hong Kong are ascribed to a single intrusive episode of calc-alkaline magmatic activity. Allen and Stephens (1971) were able to break down this episode into four phases on the basis of field evidence and the radiometric data. The phases defined a repeated cycle of increasing alkalinity, from granodiorite to alkali granite during phases 1 and 2, and from monzonite to granite during phases 3 and 4. The field evidence relied mainly on the contact relationships between the rock types and their relationships with respect to a conspicuous porphyry dyke swarm which was considered to represent a key time marker. Uncertainties in the assignment of rocks to a particular phase or in the relationships between particular units were indicated as requiring further attention during any subsequent work.* The radiometric data reported by Chandy and Snelling in Allen and Stephens (op.cit.) indicate high Sr^{87}/Sr^{86} ratios; these are believed to indicate a crustal as opposed to a mantle origin for the magma.

The remapping programme should clearly test the validity of the boundaries mapped between the different granite units by Allen and Stephens (1971) and particularly should attempt to resolve the uncertain relationships outlined in the preceding footnote. Recent

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* Note can be taken of the uncertainty regarding the relative ages of the Tai Po Granodiorite and the Sung Kong Granite; the relationships and possible correlation of the Sung Kong and Cheung Chau Granites; and the distinction in places between the Cheung Chau, Sung Kong and Hong Kong Granites (see Allen and Stephens 1971).

investigations of granitic terrains indicate the importance of a systematic study of rock texture as an aid to the lithostratigraphic classification and evaluation of these rocks (e.g. Pitcher 1978, Cobbing 1981; see also Cobbing and Mallick 1982). The acquisition of additional chemical and radiometric data should allow the further refinement and more rigorous control and finger-printing of the mapped units and advance the understanding of their relationships and the phasing of their emplacement. The reported presence by Allen and Stephens (op.cit.) of granite xenoliths (Sung Kong Granite?) in the Tai Po Granodiorite possibly lends slight support to the existence of pre-Yenshanian plutonic elements in the Territory although the nearest known pre-Mesozoic igneous rocks occur in the Guangzhou area (Fig. 1 and Anon. 1973, the latter (Plate 23) showing a belt of Indosinian (Triassic) granite and monzonitic granite on the eastern side of the Pearl River mouth to the north of Deep Bay).

Confirmation of the relationships between the intrusive rocks and their predominantly volcanic cap will be of particular interest. Allen and Stephens (1971) noted the plutonic and volcanic rocks to show comparable radiometric ages, and to be comparable in their range of composition. They also noted the relative abundances of the different rock types to be similar. A genetic relationship between them can be postulated on this basis and in view of their close spatial distribution. Chemical data will be of assistance in confirming or repudiating this thesis and in indicating whether or not a common magma source can be postulated, while the field relationships will benefit from closer scrutiny. It can be postulated that the scenario is one involving the emplacement of the granitoid rocks to increasingly higher levels in their own volcanic ejecta as time progressed. Significant marginal chilling of the plutons where they are in contact with the volcanic cover and prominent thermal (contact) metamorphic effects in the adjacent volcanics are not powerfully expressed although both are recorded. This may suggest that a general measure of thermal equilibrium existed between the two groups and that either the plutonic rocks were emplaced in a relatively cool state into already (partly?) cooled volcanic rocks or that the volcanic pile was itself still relatively warm, and was produced during an earlier stage of essentially the same magmatic event.

Allen and Stephens (1971) noted that the main outcrop of the Tai Po Granodiorite to the west-southwest of Tai Po followed a NE structural trend and that this same line may have exerted some control over the nature of the volcanic rocks deposited to the north and south. It is tempting also to speculate that the granodiorites may represent the roots of fault-controlled fissure eruptions. Allen and Stephens (op.cit.) also mapped only sporadic intrusions in the extreme east of the Territory (Sai Kung Peninsula). This may indicate that the intrusives are not uncovered at the present erosion levels or that only limited penetration occurred in this (possibly stratigraphically the highest) section of the volcanic pile.

In conclusion, a gravity survey would help to resolve questions of this type and should contribute significantly to an understanding of the plutonic geology of the Territory. It would assist in delineating the subsurface distribution of the plutonic rocks and the nature of the plutonic envelope. It may also further the internal subdivision of those rocks and could provide useful structural information and thus assist in assessing whether or not significantly different relationships characterise the basement geology of the major fault blocks.

4. CONCLUDING REMARKS

4.1 REVISED HONG KONG STRATIGRAPHY (PROVISIONAL)

The stratigraphy of Hong Kong, incorporating changes resulting from work carried out since 1971, is summarised in Table 3 (column 2, Hong Kong 1983, provisional). The table also presents the succession established by Allen and Stephens (1971) and permits comparisons with the more recent information available for Guangdong and the Shenzhen Economic Zone. It is emphasised that the column presented here for Hong Kong is provisional and will remain so until the remapping programme is completed and the results for the whole Territory fully assessed. Future modifications are possible and refinements should certainly be anticipated.

Table 3. Comparative stratigraphic tables, Hong Kong and Guangdong (Phanerozoic)

PERIOD/SYSTEM	HONG KONG (1971)	HONG KONG (1983 PROVISIONAL)	CENTRAL GUANGDONG (NAN 1979)[1]	EAST GUANGDONG (NAN 1979)[1]	EAST GUANGDONG (HUANG)[2]	GUANGDONG (ANON. 1973)	SHENZHEN (BURNETT 1983)
HOLOCENE	x	x	x	x	x	x	
PLEISTOCENE	KOF ?	KOF ?[3]	x	x	x	x	NO DATA FOR CANOZOIC DEPOSITS
NEOGENE	–	–	x	x	–	x	
PALEOGENE	–	–	HUAYONG FM. XIBU FM BUXIN FM DALIANGSHAN FM	x	TANHSIA FM.	PANGXHIA GP. & LUOFUZHEI FM.	
UPP CRETACEOUS	–	–[4]	NANXIONG GP.	NANXIONG GP.	---?--- NANXIONG GP.	NANXIONG GP.	x
LR CRETACEOUS	PIF[5]	PIF[5]	–	GUANCAOHU GP.	YANGSHIHLAU FM.	GUANGCAOHU GP	x
UPPER JURASSIC	EARLY YENSHANIAN	GRANITOIDS[6]	GAOJIPING GP	GAOJIPING GP.	? KAOCHIPING GP.		x
MIDDLE JURASSIC	RBF TTT[7]	RBF TT?[7]	BAIZUSHAN GP	ZHANGPING GP.	MALUNG OR WEILUNG FM.	BAIZUSHAN AND ZHANGPING GPS.	–
MIDDLE AND LOWER JURASSIC	TOF[8] LMCF BHF TTT	TOF ?[8]					
LOWER JURASSIC	TCF[9]	TCF[9]	JINJI FM.	JINJI FM.	LANTANG FM.	JINJI FM.	x
UPPER TRIASSIC	–	–	XIAOPING FM. LESSER YUNWU MTN GP	DADING FM. XIAOPING FM.	–	XIAOPING GP	( ) x
MIDDLE TRIASSIC	–	–	–	–	–	HUANGPEN GP	–
LOWER TRIASSIC	–	–	DAYE GP	DAYE GP	x	–	–
UPPER PERMIAN	THF[10]	THF ?[10]	LONGTAN FM.	DALONG FM. LONGTAN FM.	ⓧ	DALONG GP. LONGTAN GP	–
LOWER PERMIAN			GUFENG FM MAOKOU FM. QIXIA FM.	GUFENG FM QIXIA FM.		x	–
UPPER CARBONIFEROUS	–	–	CHUANSHAN GP	CHUANSHAN GP		CHUANSHAN GP	x
MIDDLE CARBONIFEROUS	–	–	HUANGLONG GP	HUANGLONG GP ?	ⓧ	HULIEN AND HUANGLONG GPS.	x
LOWER CARBONIFEROUS	–	LMCF ?[11]	ZIMENQIAO M. CESHUI M. SHIDENGZI M. MENGGONGAO FM.	ZHONGXIN FM		DATANGJIE AND YANGUANJIE GPS.	x
UPP DEVONIAN	–	–	MAOZIFENG FM. TIANZILING FM	SHUANGTOU GP		MAOZIFENG AND TIANZILING GPS.	x
MIDDLE DEVONIAN	–	BHF ?[12]	LAOHUAO FM. GUITOU FM.	LAOHUAO FM.	ⓧ	LAOHUAO GP	x
LOWER DEVONIAN	–	–	–	–		GUITAO GP.	–
SILURIAN[13]	–	–	–	–	–	WENTANSHAN, LINGHIA AND LIANTAU GPS.	
UPP ORDOVICIAN	–	–	LONGTOUZHAI GP	–			
MIDDLE ORDOVICIAN	–	–	CHANGKENGHUI FM.	–	ⓧ	CHANGKENGSHUI GP.	ⓧ?
LOWER ORDOVICIAN	–	–	XIAHUANGKENG FM. XINCHANG FM.	–		XIAHUNGKENG & XINGUANO GPS.	
CAMBRIAN	–	–	BACUN GP	BACUN GP	? x	–	–

KEY:

- x ROCKS OF THIS AGE PRESENT, UNITS NOT DEFINED OR NAME UNKNOWN
- – ROCKS OF THIS AGE NOT PRESENT OR NOT IDENTIFIED
- ? AGE OF UNIT OR CONTACT TYPE UNCERTAIN
- T TECTONIC CONTACT
- 1, 2 ETC. SEE NOTES LISTED SEPARATELY
- ⓧ GENERALISED SYSTEM AGE ONLY

- ——— CONFORMABLE CONTACT
- • • • • UNCERTAIN CONTACT OR UNITS NOT IN CONTACT
- ≈≈≈ MAJOR UNCONFORMITY
- ~~~ UNCONFORMITY
- – – – – DISCONFORMITY
- NO SYMBOL CONTACT RELATIONSHIP NOT SPECIFIED IN SOURCE REFERENCE

NOTES TO ACCOMPANY TABLE 3

1. Succession after Nan (1979, in Nau and Yim 1983). See present report Fig. 4 for boundaries of Central and East Guangdong.

2. Succession after Huang, see Allen and Stephens 1971, Table 8.

3. The KOF is post-Jurassic (RBF). Convincing evidence for a Pleistocene age is lacking. There appears to be no good reason why the unit could not be of Tertiary age.

4. The Port Island facies of the PIF is considered by some Hong Kong workers to be possibly of Late Cretaceous age and to correlate with the Nanxiong Group.

5. The PIF rests unconformably on the RBF; the contact is locally tectonic. The major end-Jurassic - early Cretaceous discontinuity is correlated with the early Yenshanian orogeny, see also note 6.

6. Plutonic activity post-dates the RBF in gross terms (intrusive relationships are evident) and pre-dates the deposition of the PIF. However, the limited available radiometric data indicate plutonism and vulcanicity to be broadly coeval and magmatism is ascribed to the early Yenshanian event.

7. Contacts between the RBF and the other Middle and Lower Jurassic sedimentary units identified by Allen and Stephens (1971) were reported to be in part conformable and in part tectonic. More recent investigations additionally confirmed unconformable relationships (e.g. Nau 1981; Lai et al. 1982).

8. The pre-RBF sedimentary formations of Jurassic age (cols. 1 and 2, 1971 and 1983 respectively) are not necessarily listed in their correct stratigraphic order. Normally, these formations do not occur in juxtaposition except to the southwest of Fung Wang Wat Bay (TCF-BHF) where the contact was considered by Allen and Stephens (1971) to be essentially conformable but partly faulted. The

relationship of these two units now requires particular consideration in view of the Devonian age proposed for the BHF.

The rocks mapped as TOF by Allen and Stephens (1971) may possibly be correlated with the LMCF. They may, therefore, either be significantly older than is shown in col. 2 of the table or the LMCF as presently mapped may comprise rocks of disparate ages (i.e. Jurassic and Carboniferous) and require future subdivision and redefinition (see also note 11).

9. A major discontinuity is assumed as no Triassic deposits are recorded in the Territory. This can be correlated with the Late Triassic Indosinian orogeny and a major regional unconformity (Holloway 1982).

10. The THF is probably Early to mid-Permian but may possibly be Late Carboniferous in age. Lai et al. (1982) distinguished Upper and Lower Permian members and noted the possible correlation of the former with the Lung Tam and Cheung Hing Formations of north-central Guangdong and of the latter with the Tsai Ha and Mau Hou Formations. They cited work by K.C. Shing on the Permian System in China.

11. The LMCF is tentatively assigned to the Lower Carboniferous (see note 8). It is contiguous with the Ceshui Member/Ceshui Formation of this age which is represented in Central Guangdong and Shenzhen.

12. A Middle Devonian age is provisionally indicated for the BHF on the basis of important but limited palaeontological evidence (Lee 1982).

13. The absence or restricted presence of Silurian deposits reflects the culmination of the Caledonian orogeny at that time.

The major changes between the 1971 and 1983 successions involve :

(i) the more detailed but at this stage preliminary subdivision of the Pleistocene-Holocene marine and alluvial superficial deposits (not indicated in Table 3);

(ii) the relative ages and chronostratigraphic correlations of the pre-RBF sedimentary formations, most of which were previously (i.e. 1971) considered to be of Lower and Middle Jurassic age; and

(iii) the status of certain of the sedimentary rocks previously incorporated in the RBF (not indicated in Table 3).

Allen and Stephens (1971) considered the Jurassic sedimentary formations to comprise a simple, essentially conformable sequence, involving a change from marine conditions at the base through deltaic and fluviatile conditions to terrestrial conditions immediately prior to the onset of the subaerial volcanic activity in the Middle Jurassic. They noted that precise correlation between the Jurassic sedimentary formations was not possible. The lithological assemblages are not generally distinctive, palaeontological evidence is limited and often poorly preserved, and where the different units are in juxtaposition, the contacts are frequently uncertain or tectonic. Correct interpretation and correlation of these older (i.e. pre-RBF) sedimentary rocks is thus often exceedingly difficult. However, if the more recent evidence (based partly on limited but interesting palaeontological evidence) is accepted, it is improbable that the simple transition proposed by Allen and Stephens (op.cit.) can be sustained in detail, although a change from marine to continental conditions occurred on the gross scale.

On the basis of the limited palaeontological evidence presently available the fluviatile-deltaic deposits comprising the BHF are the oldest rocks known in the Territory (Middle Devonian). The possible assignment of the LMCF to the Lower Carboniferous depends entirely on the apparent contiguity of the formation with rocks believed to be of this age in the Shenzhen Economic Zone. No direct evidence yet exists in Hong Kong for this correlation. The limestones recently reported from the Yuen Long area will clearly require checking for palaeontological evidence during the new survey, providing that suitably unrecrystallised material can be found.

The relationships between the LMCF and the BHF and between the LMCF and the THF remain uncertain as the units do not occur in contact. A Permian age for the THF is established, however, and correlation with the LMCF is precluded if the correlation of the latter with the Carboniferous strata of Shenzhen is accepted. Similarly, in view of the different ages assigned to the BHF and the LMCF (Devonian and ?Carboniferous or Jurassic respectively) it is not likely that they can be correlated, as had been previously suggested by Allen and Stephens (1971).

The possible reassignment to the pre-volcanic formations of certain of the sedimentary rocks incorporated in the RBF by Allen and Stephens (1971) was noted in section 3 of the report. This applies particularly to the more extensive developments of sediments which appear to underlie the volcanics and whose base is not exposed.

With the exception of the TOF all the known or possible pre-volcanic sedimentary sequences are restricted to the northern part of the Territory and particularly to the Tolo Harbour-Tolo Channel "line" where tantalising glimpses of the older basement are revealed in a structural high.

Holloway (1982) documented a regional break throughout the South China Sea during the Triassic which he noted to coincide with the Indosinian orogeny. No Triassic deposits are recorded in the Territory and this favours the existence of a major unconformity between the Palaeozoic and Mesozoic successions. Although this is almost certainly correct on the gross scale, the relationship is more difficult to substantiate in detail owing to the limited occasions on which the two successions are in contact. On Ma Shi Chau an unconformity is now reported between the RBF and rocks correlated by Allen and Stephens (1971) with the BHF, but which Nau (1981) reassigned to the Lower Jurassic TCF (see below). To the east of the Plover Cove Reservoir Allen and Stephens (op.cit.)

reported a transitional contact between the BHF and the overlying volcanics and the relationships there clearly require further study in view of the apparent Devonian age for the BHF. It is of interest to note that no magmatic rocks have yet been mapped in the Territory which can be related with any certainty to the Indosinian event although Triassic intrusives are reported a short distance to the north (Anon. 1973 and see section 3.10).

The relative ages and the correlation of the pre-volcanic sedimentary formations of Jurassic age (TCF, TOF?) remain uncertain. They are assigned to the Jurassic on sparse palaeontological evidence or in view of their mapped relationships to the overlying volcanic rocks. Nau (1981) recorded an unconformity on Ma Shi Chau between rocks which he assigned to the TCF (but which Allen and Stephens (1971) mapped as BHF) and the overlying RBF. Allen and Stehpens (op.cit.) considered the relationship between the TOF and the RBF to be conformable and, indeed, noted the possibility of including the TOF within the RBF. On this basis the TCF would seem to predate the TOF but the two units nowhere occur in contact and the true relationship remains speculative, particularly if any credence is given to a possible correlation of the TOF and the LMCF.

Little comment can be made at this juncture of the internal stratigraphy of the RBF and significant modifications to the informal subdivisions and contacts mapped by Allen and Stephens (1971) can be anticipated from the future work. Some general conclusions were noted in section 3.7 regarding the possible recognition of a gross stratigraphy in the unit and it was speculated that broadly contemporaneous activity occurred in structurally independent blocks, coeval with plutonic activity at depth.

The Mesozoic closed with the deposition of continental deposits referred to the PIF. The possibility of subdividing these rocks to accord more closely with reported relationships in China and with earlier interpretations in the Territory (e.g. Brock et al. 1936, Davis 1952) was noted for reference during the remapping programme. However, the application of the structural character of the formation as a means of achieving this subdivision should be viewed with caution.

The effect of the more recent investigation of the Quaternary deposits has been to indicate in a preliminary fashion the existence of a relatively consistent stratigraphy in the Upper Pleistocene and Holocene superficial deposits. There is ample scope for their further study, and the extensive spreads in the northwestern part of the New Territories in particular merit systematic attention.

4.2 PROVISIONAL CORRELATION WITH SOUTHERN GUANGDONG

Provisional correlations with southern Guangdong are shown in Table 4.

The Middle Devonian BHF is represented in Guangdong by the Guitou and Laohuao Formations (Nan 1979), the former correlation being preferred in view of the indicated facies conditions. Huang (in Allen and Stephens 1971) described the Middle and Upper Devonian as comprising limestones, dolomites, shales and sandstones. No carbonates are mapped in the BHF although their presence is reported from Ma On Shan Mine where they occur in association with quartzites which may possibly (?) be correlated with the BHF. The lithologies of the BHF and the Middle Devonian deposits mapped in the Shenzhen Economic Zone are comparable (see Burnett 1983).

The assignment of a Lower Carboniferous age to the LMCF requires confirmation but the formation is contiguous with rocks considered to be of this age in the Shenzhen Economic Zone (Shenzhen Geological Bureau 1:50 000 scale geological map). Correlation with a Visean non-carbonate sequence of sandstones, shales, conglomerates and subordinate graphitic shales with minor coals can be suggested (see Burnett 1983). These rocks correspond in gross terms with the Zhongxin Formation of East Guangdong (Nan 1979). Anon. (1973) recorded two Lower Carboniferous formations, the Datangjie and Yanguanjie Formations, while in Central Guangdong Nan (op.cit.) recognised four members (of the Zhongxin Formation?), and a more precise correlation of the LMCF with the Ceshui Member or Formation is postulated by C.M. Lee (Circular, Hong Kong Geological Society visit to Shenzhen, November 1983).

Table 4. Provisional correlation; Hong Kong (1983) and southern Guangdong

PERIOD/SYSTEM	HONG KONG (1983 PROVISIONAL)	CENTRAL GUANGDONG	EAST GUANGDONG	MAIN LITHOLOGIES (GUANGDONG)	CORRELATN. RATING
L. CRETACEOUS	PORT ISLAND FM.		GUANCAOHU GP.	INTERMONTANE AND LACUSTRINE CLASTICS (RED BEDS) WITH VOLCANICS	H
U. JURASSIC	↑ ?	GAOJIPING GP.	GAOJIPING GP.	ACID VOLCANICS AND SEDIMENTARY INTERCALATIONS	H
M. JURASSIC	REPULSE BAY FM.	BAIZUSHAN GP.	ZHANGPING GP.	CONTINENTAL CLASTICS, PYROCLASTICS	
M. & L. JURASSIC	TAI O FM. ? }	JINJI FM.	JINJI FM.	NERITIC SANDSTONES, SHALES; CONTINENTAL CLASTICS AND COALS IN LOWER PART	M-L
L. JURASSIC	TOLO CHANNEL FM. }				M-H
PERMIAN	TOLO HARBOUR FM.	LONGTAN FM. OR GUFENG FM.	LONGTAN FM. OR GUFENG FM.	COAL-BEARING CONTINENTAL AND MARINE CLASTICS, NERITIC CARBONATES	M
CARBONIFEROUS	LOK MA CHAU FM. ?	CESHUI M. / FM.	ZHONGXIN FM.	cf. PERMIAN	H
DEVONIAN	BLUFF HEAD FM.	LAOHUAO FM.	LAOHUAO FM.	NERITIC SANDSTONES AND MUDSTONES	M-L
			GUITOU FM.	FLUVIATILE, LITTORAL AND NERITIC CLASTICS	M

NOTES:

1. CORRELATION CONFIDENCE RATING H-HIGH, M-MODERATE, L-LOW
2. INTERROGATION MARK (?) INDICATES UNCERTAIN AGE ASSIGNMENT
3. GUANGDONG DATA FROM HUANG (ALLEN AND STEPHENS 1971), NAN 1979 (IN NAU AND YIM 1983) AND BURNETT 1983.

No Permian deposits are reported in the Shenzhen Economic Zone (Burnett 1983) but Nan (1979) distinguished four formations in Guangdong, refining the earlier twofold breakdown of the succession into the Dalong and Longtan Groups (Anon. 1973). On lithological grounds it seems probable that the THF is represented in Guangdong by the Longtan Formation (Nan op.cit.), which is of early Late Permian age. The palaeontological evidence from the THF favours a somewhat older Late Carboniferous to mid-Permian age for these rocks (Nau 1980, Yim et al. 1981) although the younger end of the range is favoured. Correlation of the THF with the Maokou and/or the Gufeng Formations may, therefore, be considered but the neritic carbonates reported for the Gufeng Formation are not identified in the THF in Hong Kong. It should also be noted that Lai et al. (1982) proposed a more ambitious Permian stratigraphy for the THF than that noted above. They recognised Upper and Lower Permian members which they correlated respectively with the Cheung Hing and Lung Tam Formation and with the Mau Hou and Tsai Ha Formation (terminology after Shing, see Lai et al. (op.cit.), Table 1)*.

No Triassic deposits are known in Hong Kong. In southern Guangdong Lower and Upper Triassic formations are recognised (Nan 1979) but the Middle Trassic is not represented. In the Shenzhen Economic Zone rocks of Late Triassic and Early Jurassic age are grouped (Burnett 1983).

The TCF is considered to be of Early Jurassic (Liassic) age on the basis of limited palaeontological evidence. The formation comprises marine and continental/littoral sediments and is probably represented in Guangdong by the Jinji Formation (also known as the Lantang Formation, see Huang in Allen and Stephens 1971). The relative ages of the TCF and the TOF remain uncertain (see section 4.1). If Allen and Stephens' (op.cit.) interpretation of the TOF as an independent pre-volcanic formation of Jurassic age withstands further scrutiny their suggested correlation with Huang's Malung or Weiling Formation is acceptable. Huang's terminology, however,

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* Shing's formation names as listed above are taken to correspond with the Changsing (?), Longtan, Maokou and Qixia (?)Formations of Nan (1979).

is not used by other workers. Both Anon. (1973) and Nan (1979) referred the rocks of the same age to the Zhangping and Baizushan Groups, Nan restricting the former to East Guangdong and the latter to Central Guangdong.

The correlation of the RBF with the Gaojiping Group and of the PIF with the Yangshilan Formation, proposed by Allen and Stephens (1971) remains valid. The age difference of the volcanic rocks, as indicated in Tables 3 and 4 is considered to be more apparent than real. The volcanic activity reflects magmatism associated with the early Yenshanian orogeny and the gross relationship is one of granitoid bodies intruding a volcanic carapace. However, it is not unreasonable to assume that these two facets were, essentially coeval, one taking place under subaerial conditions, the other at a high level in the crust. The limited radiometric data support this. Two samples from the RBF yielded Rb/Sr ages in the range 170 to 130 Ma and 150 to 115 Ma (Chandy and Snelling in Allen and Stephens op.cit.). Biotite from a third sample gave a K/Ar age of 154±34 Ma. These results do not preclude a Late Jurassic age for the RBF and would permit a direct correlation with the Chinese results.

Both Anon. (1973) and Nan (1979) used the term Guancaohu Group in place of Huang's Yangshilan Formation, but Nan noted that rocks of the group were not represented in Central Guangdong. Correlation of the PIF with the Nanxiong Group may be justified in future if Upper and Lower Cretaceous representatives are confirmed. (See Section 3.8). It is worth recording here that the Upper and Lower Cretaceous formations in Guangdong and the Shenzhen Economic Zone are reported to contain volcanic rocks, and that granitoid clasts are described from the Upper Cretaceous beds in Shenzhen. No volcanic units are mapped in the PIF in Hong Kong nor are granitoid clasts reported.

The unconformity widely recognised in Guangdong beneath the Jurassic volcanic sequence accords with the regional break throughout the South China Sea region which coincided with the early Yenshanian event (Holloway 1982). Allen and Stephens (1971) did not recognise a major break in Hong Kong. There is now some evidence for it (e.g.

on Ma Shi Chau) but its magnitude and the significance attached to it depend on the stratigraphic assignment of the underlying units and careful attention to the base of the RBF will be merited during the remapping programme.

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