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Present understanding of the pre-Cenozoic stratigraphy of Hong Kong

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Abstract: Evidence has recently been obtained of the presence of Devonian and Carboniferous rocks in Hong Kong. Some new insights into the geology of the Mesozoic rocks which cover the greater part of the territory have been obtained from recent mapping. A new geological survey of Hong Kong begun in 1983 is expected to throw light on some of the numerous stratigraphic and structural problems and uncertainties which still remain.

INTRODUCTION

The most recent major publication on the geology of Hong Kong appeared 13 years ago. This was the report of a geological survey carried out by two geologists from Britain in 1967–69 (Allen and Stephens, 1971). The subject had up to that time received only sporadic attention, the principal published works being those of Williams (1943), Williams *et al.*, (1945), Davis (1952) and Ruxton (1960). There were numerous differences between these various authors' interpretations of the stratigraphy and structure of the territory, many of which remain unresolved to this day.

In 1977 the Hong Kong Government created a Geotechnical Control Office (G.C.O.) within the then Public Works (now Engineering Development) Department. By 1980 an engineering geology section was functioning as part of the G.C.O. As may be expected, this unit has been primarily engaged on work directly related to ground stability and land use, with emphasis on the engineering properties of rocks, rock weathering and superficial deposits. However, it was realized that there was a need for more detailed geological maps and a clearer knowledge of the distribution of the rock types, hitherto known in only broad outline. To rectify this situation Government approval was secured in 1982 for establishment of a Geological Survey Section within the GCO. The British Geological Survey (Natural Environment Research Council) was invited to advise and assist in setting up the new Survey and to initiate the systematic 1:20,000 scale geological remapping of the Territory. This mapping commenced in 1983 and will be continued by geologists belonging to the GCO. When completed in about 1991, a total of 28 colour-printed 1:20,000 maps (comprising 14 solid and 14 superficial geology sheets) and six accompanying area reports will be available. The results will be published and issued during the programme, as the work is completed.

The present paper gives an account of the current state of knowledge of the bedrock geology of Hong Kong, stemming from the published work, a limited amount of work done since publication of the Allen and Stephens report, some preliminary results of maping of the first sheet of the new geological map series, and initial contacts

in 1983 with geologists working adjacent to the Hong Kong border in the Shenzhen Special Economic Zone of Guangdong Province.

GENERAL GEOLOGY AND SUMMARY OF PRINCIPAL RECENT DEVELOPMENTS

The greater part of Hong Kong is covered by Jurassic igneous rocks, mainly granitic intrusions and siliceous volcanics.

There are many occurrences of sedimentary and meta-sedimentary rocks, but the areas of outcrop are generally small and separated. Macrofossils are scarce and microfossils unknown, so correlations remain essentially lithological and problematical.

One of the main recent developments regarding the stratigraphy of Hong Kong has been the assembly of evidence for the existence of pre-Permian rocks. Formations which were assigned to the Jurassic by Allen and Stephens (1971) now appear certainly to be Palaeozoic.

Another development has been progress in the delineation of the stratigraphy of the Jurassic volcanics and intercalated sedimentary units—the Repulse Bay Formation.

Devonian

Bluff Head Formation

Discovery of poorly-preserved "placoderm" fish fragments similar to fossils found at numerous localities in Guangdon (Lee, 1982) has led to provisional classification of the beds containing them (belonging to the so-called Bluff Head Formation previously thought to be Jurassic) as Devonian. The Bluff Head Formation consists essentially of pale-coloured orthoquartzites, in places micaceous, with associated quartz conglomerates, siltstones and mudstones. Finer beds have pinkish or purplish hues in places. Graded bedding, current bedding and rhythmic alternation of fine and coarse layers are common. Interlocking quartz grains and development of sericite in mudstones indicate a certain degree of low-grade metamorphism.

The main occurrence of the Bluff Head Formation is along the northern coast of Tolo Channel from Bluff Head (type locality) to Harbour Island (Fig. 1). Along this narrow belt the beds have consistently high dips, mainly towards the northwest, and are inverted in places. There is much small-scale folding and the structure is not known in detail.

Beds with broadly similar lithologies and structural attitudes on the southwest coast of Daya Bay, in China, some 30 km to the east-northeast along the regional strike, have been mapped as Devonian because of similarities with the Devonian succession elsewhere in Guangdong Province, thus providing rather tenuous support for the unconfirmed biostratigraphic age of the Bluff Head Formation (geologists of Shenzhen S.E.Z., pers. comm).

Lower Carboniferous?

Lok Ma Chau Formation

A belt of low-grade metamorphic rocks (the Lok Ma Chau Formation, orginally sediments possibly with minor tuffs) crosses the northern and north western New Territories from Tuen Mun to Lowu. (Fig. 1). The belt continues into China at Shenzhen, trending north-eastwards. In China the original beds are considered to be Lower Carboniferous; they underlie unmetamorphosed strata, including fusulinid-bearing limestones of late Carboniferous age. Principal outcropping rock types in Hong Kong and Shenzhen are soft sericitic quartzites and phyllites and some of the latter are graphitic. Extensive areas underlain by the Lok Ma Chau Formation in the New Territories are covered by recent superficial deposits. At Yuen Long, site investigations have revealed occurrences of marble beneath this cover. The assumption that the marble belongs to the Lower Carboniferous sequence is supported by similar occurrences (also not outcropping) in the Shenzhen Special Economic Zone.

The structure of the Lok Ma Chau Formation is complex. Evidence from recumbent folding is given in Allen and Stephens (1971) who supported earlier views that the metamorphism of the Lok Ma Chau Formation was a regional event which certainly occurred before the intrusion of the Jurassic granites. Some Chinese

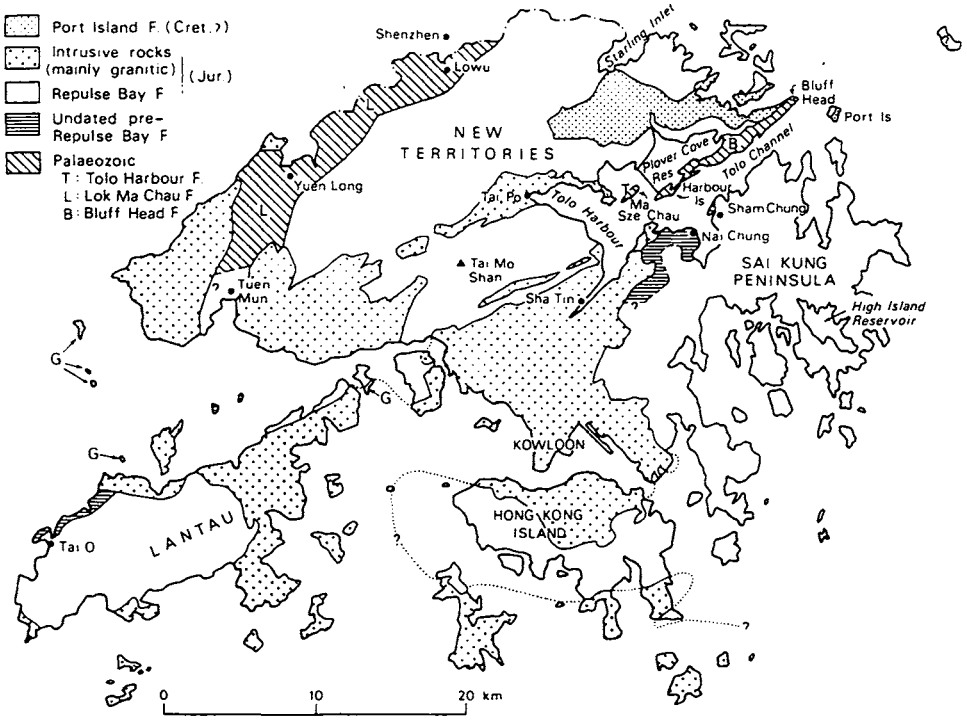


Fig. 1. Outline geological map of Hong Kong.

geologists maintain that the strong folding and metamorphism in south Guangdong Province can be explained in terms of Yenshanian (Mesozoic) tectonism. According to this view, the metamorphism, even where garnet and staurolite are developed (as in the area some 15 km northeast of Shenzhen), is essentially local and related to high-stress/moderate-temperate conditions along major fault zones, thus explaining the occurrence of unmetamorphosed and quite strongly metamorphosed Palaeozoic sequences in close juxtaposition. An alternative view, that there was earlier, truly regional deformation and metamorphism, pre-dating the Late Carboniferous, cannot be refuted at present.

Permian

Tolo Harbour Formation

Beds for which there is palaeontological evidence of a Permian age are found in the Tolo Harbour area (Ruxton 1960, Allen and Stephens, 1971, Yim *et al.*, 1981). They are strongly folded marine strata, mainly laminated grey to purple siltstones and mudstones with some sandstones. The principal occurrence is on the island of Ma Sze Chau (Fig. 1). The beds there have yielded a sparse fauna of corals, brachiopods, lamellibranchs, bryozoa and crinoid ossicles, generally not well preserved. The balance of evidence points strongly toward, but does not prove, a Permian age. If the identification of the corals as *Dictophyllum nikron* is accepted, then a middle Permian age is most likely (Yim *et al., op. cit.*).

UNDATED SEDIMENTARY ROCKS OLDER THAN THE JURASSIC VOLCANICS

Several isolated occurrences of generally unfossiliferous sedimentary formations, mainly sandstones and siltstones, directly underlie the Jurassic volcanics in Hong Kong; others which are not in contact with the volcanics can be correlated on lithological grounds. The principal of such occurrences are at Tai O on the north coast of Lantau island (the Tai O Formation) and at Nai Chung-Sham Chung on the south coast of Tolo Channel (un-named). The beds include conglomerates, orthoquartzites, micaceous sandstones, siltstones and mudstones, coarser horizons being mainly light grey or yellowish and finer beds often pink or purple-hued. Lithologically, all these occurrences bear a general similarity with the Bluff Head Formation, but they are less strongly folded and not so indurated. Unconfirmed palaeontological evidence suggests a Carboniferous-Permian age for the beds at Sham Chung (Atherton, 1983).

Jurassic

Tolo Channel Formation

For completeness, it may be noted that ammonite fragments were found at a locality on the north coast of the Tolo Channel on two occasions in the 1920s. Specimens sent to the well-known ammonite authority Buckman were identified as belonging to a new genus *Hongkongites*, of probable Lower Liassic age (Williams, 1943). The beds from which these fossils were obtained have been named the Tolo Channel Formation. No further specimens of *Hongkongites* have ever been recorded from the site. The Tolo Channel Formation has also been recognised and mapped on

Ma Sze Chau island, where a single unidentified ammonite has been found (Nau, 1981).

Repulse Bay Formation

The Repulse Bay Formation is some thousands of metres thick and consists mainly of tuffs with some lavas and intercalated sedimentary rocks. A sequence through part of the succession in the central New Territories, revealed during the current mapping, is shown in Table 1.

The volcanic activity is believed to have commenced in the Middle Jurassic. This is supported by limited radiometric data. The volcanic pile is intruded by Upper Jurassic granites but the age of the youngest volcanic rocks is not known and may be Cretaceous.

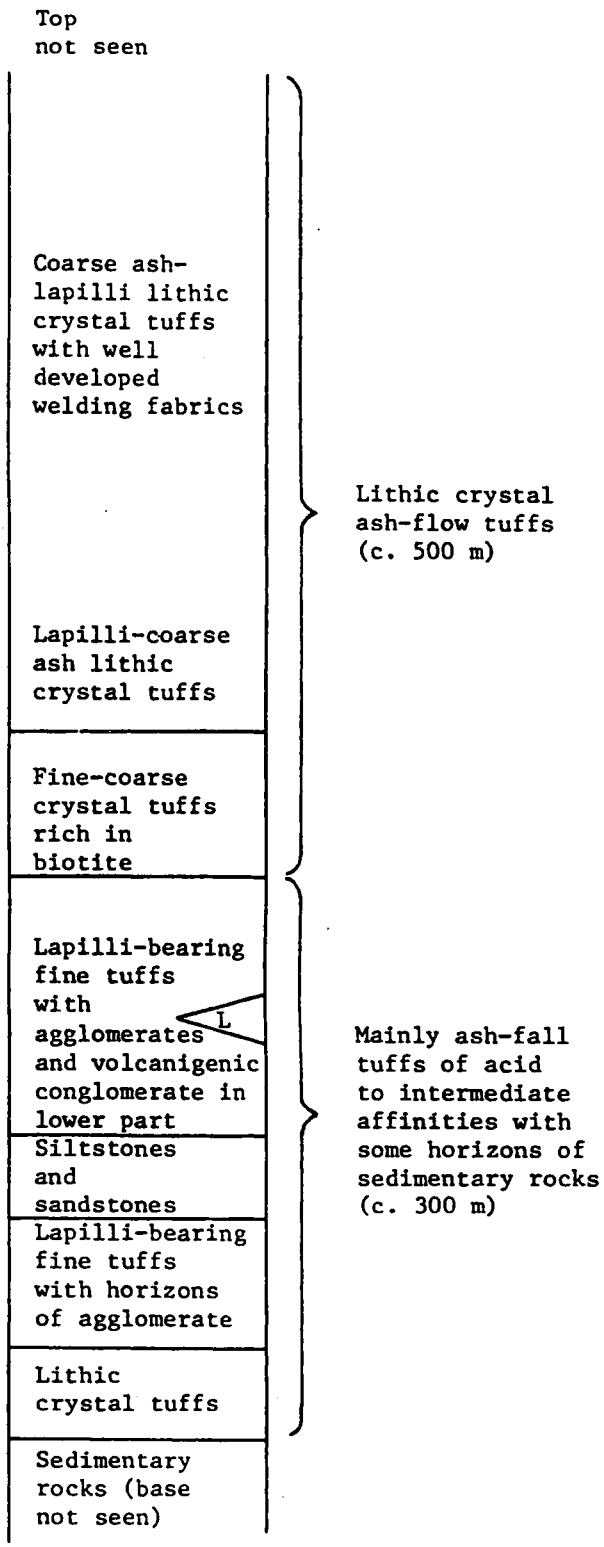
Most of the volcanic rocks in the Repulse Bay Formation are rhyolitic in composition, but some tuffs and lavas of intermediate (?andesitic) type occur in the lower part of the succession. The rhyolitic rocks comprise mainly ash and lapilli tuffs, with crystal pyroclasts generally predominating over lithic fragments. Block tuffs and bomb tuffs occur locally. Some of the rhyolitic tuffs are stratified and weather relatively easily; these are unwelded, mainly ash-fall types. Large sections, however, consist of hard, fresh crystal tuff and lithic crystal tuff which are essentially ignimbritic and originated as ash flows. There appears to have been a good deal of post-depositional re-crystallization in these rocks but signs of original volcanic glass and pumice are common in the upper part of the succession of ash-flow tuffs, as are other eutaxitic structures. The fresh crystal tuffs are generally massive rocks with no very clear layering, but banding, streaking and flow structures can be seen in many places, often showing conspicuously on weathered surfaces even when not visible in the fresh rock.

Within the Repulse Bay Formation discontinuous horizons of sedimentary rocks are found in many localities. They are especially extensive in W. Lantau, central New Territories and parts of the Sai Kung peninsula. Elsewhere, their scarcity may be more apparent than real, and due to a paucity of outcrops. They are of diverse types. Some are chaotic assemblages of volcanogenic debris which can be taken to represent contemporaneous landslide material, i.e. to be lahar-type paraconglomerates. Others are made up partly or entirely of particles of volcanic origin, but are clearly sorted and stratified by sedimentary processes; they are tuffaceous conglomerates, sandstones and mudstones. There are also many "cherty" sequences which may be the products of deposition of fine-grained siliceous ash or dust flowing or falling into water.

Some of the sediments however are not apparently of volcanogenic origin. This applies particularly to occurrences of grey and black mudstones (as opposed to the tuffaceous mudstones which are usually greenish) and shales, which are nevertheless generally interbedded with tuffaceous sediments. Some of these dark-coloured mudstones have yielded plant fossils. Paraconglomerates containing fossiliferous limestones clasts have also been discovered recently within the Repulse Bay Formation in the central New Territories.

TABLE 1

THE REPULSE BAY FORMATION AS DEVELOPED AROUND TAI MO SHAN AND SOUTH OF TAIPO.



L: Andesitic lava (amphibole and pyroxene phyric)

Intrusive rocks

All the intrusive rocks of Hong Kong are believed to belong to the Mesozoic. The most recent comprehensive study, and the only geochronological work to date, is contained in the report by Allen and Stephens (1971). The available evidence is that the main plutonic activity occurred in phases during the Late Jurassic, forming a single magmatic event which was associated in a general way with the volcanism responsible for the deposits which now comprise the Repulse Bay Formation. The intrusive rocks produced during this event are all granitoids but range from granites *sensu stricto* to quartz monzonites or quartz syenites and granodiorites. By far the most common rock type is granite, frequently coarse, but not conspicuously porphyritic, and quartz-rich, with perhaps as much as 35–40 per cent quartz, 50–60 per cent feldspar (usually dominant microperthite and a lesser amount of sodic andesine) and a few per cent of biotite.

The granitoid bodies are intrusive into at least the lower part of the volcanic succession of the Repulse Bay Formation which roofs, and is therefore (slightly) older than the intrusions. In general it may be said that the pluton rose into a roof formed largely of its own precursory volcanic ejecta and continued to provide a source for the upper part of the volcanic succession, but recent evidence indicates that the relationships between the plutonic rocks and the volcanics may be less simple than previously envisaged, notwithstanding their gross compositional similarities and close spatial association. Preliminary geochemical results indicate the possibility of two distinct phases of intrusion. The earlier, granodioritic phase possesses trace element similarities with and may have been the source of the volcanic rocks of at least the lower part of the Repulse Bay Formation. Later, more abundant granitic magmas with different trace element characteristics formed and rose to intrude the base of the overlying volcanic pile.

Cretaceous?

Port Island Formation

A large area in the northeast New Territories is covered by conglomerates, sandstones and mudstones which overlie at least part of the Repulse Bay Formation. The conglomerates contain boulders and pebbles of the volcanics and the sandstones seem to be partly volcanogenic, sometimes with greenish colouration. The beds are, however, commonly red or purple in colour, especially towards the east, with deep red colouration predominant on Port Island itself.

The Port Island Formation, which is approximately 450 metres thick, is taken as a fluvial or flood outwash deposit resulting from subaerial erosion, the main source of detritus being the Jurassic volcanics. No granite clasts have been found in the formation, and there is no direct evidence of its age. The Port Island Formation is overlain by siliceous volcanics similar to those underneath it. Ruxton (1960), followed by Allen and Stephens (1971), interpreted this rather complex contact as a large thrust. They concluded, but were not able to prove, that the volcanics overlying the thrust were in fact older than the Port Island beds (which are themselves sheared). There are other occurrences of clastic sedimentary rocks in the northeast New Territories, especially along the south coast of Starling Inlet. These have not yet been mapped in

detail. They could form part of the pre-volcanic sedimentary succession of early Jurassic or late Palaeozoic age. It is also conceivable that they may be part of a sequence of alternating sedimentary and volcanic rocks which includes the Port Island Formation. In other words, it is by no means certain that the Mesozoic acid volcanism (or plutonism) of Hong Kong was restricted to the Jurassic, or to a single major eruptive episode.

Age of Folding

Most of the formations which pre-date the Jurassic volcanics are strongly folded but because of the scattered nature of the outcrops there is no clear picture of the overall pattern of this folding, except that the regional strike of the beds and trend of axial traces of minor folds is mainly NE-SW to ENE-WSW.

The Repulse Bay Formation, on the other hand, is not so intensely folded, except locally. Over large areas, dips are moderate, often in the range 20–40°, with E-SE directions prevailing. It seems that the observed deformation of the volcanics can be explained as resulting from doming and warping by the rise of the underlying irregularly-surfaced granite batholith and from later faulting and tilting, but this is yet to be demonstrated.

Nothing is known at preset about any earlier period of folding. The Lower Carboniferous Lok Ma Chau Formation is regionally metamorphosed to greenschist facies, and northeast of Shenzhen the grade in ?Devonian rocks advances to epidote-amphibolite facies, with development of garnet and staurolite in pelites and tremolite-actinolite in impure limestones. However, there is apparently no direct evidence of a Palaeozoic tectonic event in southern Guang which could account for this metamorphism, which Chinese geologists generally seem to regard as localized and related to the Mesozoic tectonism, particularly the NE-SW faulting.

The youngest phase of folding affects the Early Cretaceous Port Island Formation. Folds are broad and dips are low, generally not exceeding about 20°. However, in the area south of Starling Inlet, the Port Island beds are locally sheared along a series of thrust faults trending NE-SW and overthrust towards the southeast (Ruxton, 1960). Elsewhere in the outcrop a penetrative cleavage is more extensively developed. The deformation of the Port Island Formation is presumed to be Cretaceous (late Yenshanian).

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