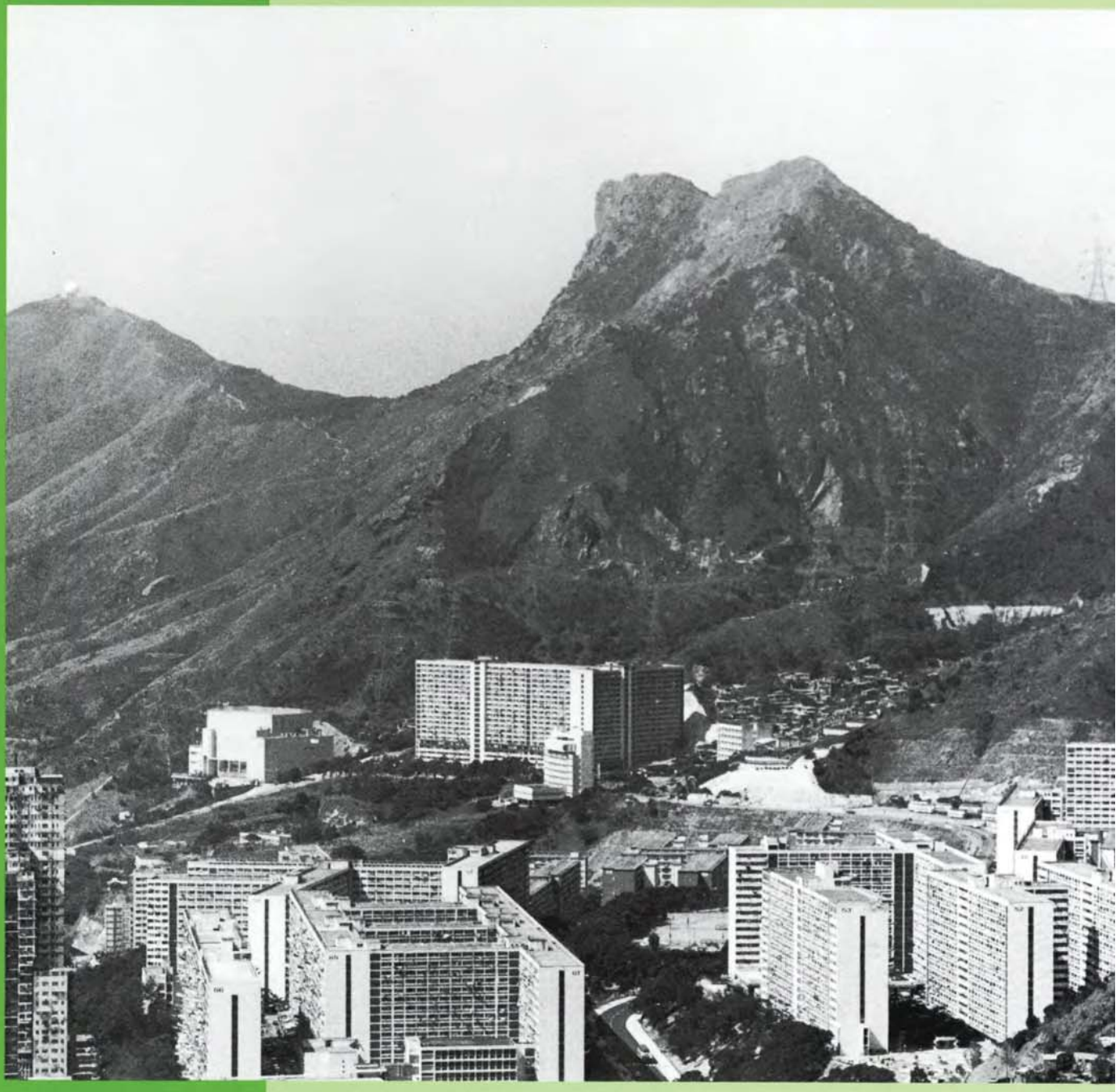
HONG KONG GEOLOGICAL SURVEY *MEMOIR No. 2*

Geology of Hong Kong Island and Kowloon



Geotechnical Control Office
Civil Engineering Services Department
HONG KONG

HONG KONG GEOLOGICAL SURVEY *MEMOIR No. 2*

Geology of Hong Kong Island and Kowloon

1:20 000 Sheets 11 & 15

P. J. Strange & R. Shaw

Geotechnical Control Office
Civil Engineering Services Department
HONG KONG December 1986

Published December 1986
Reprinted January 1997

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11/F Civil Engineering Building
101 Princess Margaret Road
Homantin
Kowloon
Hong Kong

Cover: Lion Rock from
Jat's Incline,
East Kowloon

This publication is available from:

Government Publications Centre
General Post Office Building
Ground Floor
Connaught Place
Hong Kong

Overseas orders should be placed with:

Publications (Sales) Office
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28/F Siu On Centre
188 Lockhart Road
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Price in Hong Kong: HK$78

Price overseas: US$13 (including surface postage)

Foreword

This Memoir describes the geology of Hong Kong Island and Kowloon as depicted on Sheets 11 and 15 of the 1:20 000 Geological Map Series of Hong Kong, and of Green Island and those parts of Lamma Island and the Po Toi Island Group beyond the boundaries of these sheets. It forms part of the published results of a programme of systematic geological mapping that is being undertaken by the Geotechnical Control Office (GCO). The programme involves the study of the geology of the Territory, both on land and offshore, in considerably greater detail than has been attempted previously. It is enhancing our understanding of Hong Kong's stratigraphy and structure, and is establishing a geological database necessary for the continuing economic development of the Territory. The mapping programme is being undertaken by the Geological Survey Section of the Planning Division of the GCO. The Section is led by Mr R. S. Arthurton and the Division is under the direction of Dr A. D. Burnett.

The Geological Survey of Sheets 11 and 15 was undertaken in 1984–85 by Mr P. J. Strange, who is the principal author of this Memoir. The marine geology was compiled by Dr R. Shaw, who also drafted the sections of the Memoir which deal with the offshore superficial deposits and with weathering. Fieldwork for parts of the Po Toi Island Group was carried out by Dr R. Addison, and detailed interpretation of geophysical traces by Dr C. D. R. Evans (British Geological Survey).

It should be noted that Hong Kong Island and Kowloon have also been the subject of a study carried out under the Geotechnical Area Studies Programme (GASP), the report on which will be published shortly by the Geotechnical Control Office (1987). That study, which was completed before the Geological Survey of Sheets 11 and 15 commenced, was based on the solid rock geology given on the 1:50 000 scale Geological Map produced by Allen & Stephens (1971), and the mapping of the superficial deposits was carried out independently. This Memoir and the two map sheets supersede both the solid rock geology and the mapping of superficial deposits presented in the GASP Report.

The survey of Sheets 11 and 15 benefitted from the generous co-operation of various organisations and many individuals. The Royal Hong Kong Auxiliary Air Force and the Marine Department helped in gaining access to remote areas, and the Mass Transit Railway Corporation arranged access to excavations and tunnels during the construction of the Island Line. The co-operation of Cable & Wireless Ltd, The Hongkong Electric Co Ltd, Ocean Park Ltd and Electronic & Geophysical Services Ltd is also acknowledged. The Charting Section of Port Works Division, Civil Engineering Services Department, made an important contribution to the compilation of the offshore geology. Many members of GCO staff were also involved in the mapping and compilation phases of the work.

This Memoir and its accompanying map sheets will be of interest and value to engineers and planners, to those concerned with resource investigations, to educationalists and earth scientists, and to interested members of the public. Additional physical resource information for the assessment of geotechnical limitations for outline and strategic planning purposes is available in the Geotechnical Area Studies Programme (GASP) publications prepared by the Geotechnical Control Office and obtainable from the Government Publications Sales Centre.

E. W. Brand
Principal Government Geotechnical Engineer
December 1986

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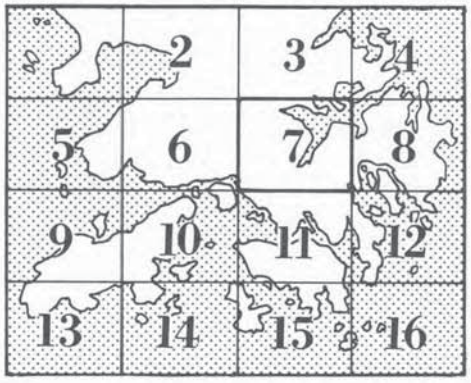
• This Memoir describes the geology of the Hong Kong Island and Kowloon areas and should be read in conjunction with the 1:20 000 Geological Map Sheets 11 (Hong Kong and Kowloon) and 15 (Hong Kong South and Lamma Island).

• The Memoir forms one of a series that records the findings of the Hong Kong Geological Survey. An index of the memoirs and the 1:20 000 geological maps to which the memoirs relate is shown below.



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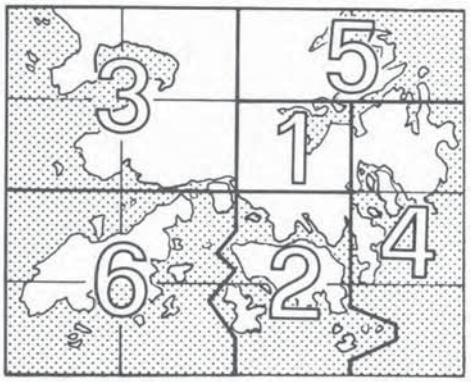


memoirs

• Individual superficial deposits less than 2 m thick are not generally considered mappable.

• Grid References cited in this account are those of the Hong Kong 1980 Metric Grid, as shown on the 1:20 000 Geological Maps. Eight-figure references indicate positions to the nearest 10 metres, with Eastings following by Northings, e.g. Stanley Fort (4019 0683). Six-figure references indicate positions to the nearest 100 metres.

• Hong Kong Principal Datum (PD) is 1.2 m below Mean Sea Level, and 0.15 m above Admiralty Chart Datum. The bathymetric contours shown on the 1:20 000 geological maps are based on Admiralty Charts, with supplementary data from surveys by Electronic and Geophysical Services (EGS) Ltd. EGS Ltd bathymetry relates to Principal Datum.

• Samples in the Territory-wide rock collection archived by the Hong Kong Geological Survey are referred to using the prefix HK followed by a serial number, e.g. (HK 4223). Additional samples, from a collection made by Mr B. P. Ruxton (GCO, 1982), are prefixed by the letter R, e.g. R216. Offshore borehole samples are archived using the contractor's reference number, e.g. Junk Bay JBS, Chek Lap Kok B and Victoria Harbour H.

• The system used in this Memoir for grain size description and classification is summarised in the table overleaf.

Table 1 – Grain Size Description and Classification of Rocks and Superficial Deposits in Hong Kong

Superficial Deposits		Grain Size mm	Solid Rocks									
			Sedimentary Rocks	Pyroclastic Rocks	Igneous Rocks							Foliated Metamorphic Rocks
					Acid					Inter-mediate	Basic	
Boulders		200	Conglomerate Sedimentary Breccia	Blocks, Bombs	Pegmatite							Gneiss
Cobbles		60										
Gravel	Coarse	20		Lapilli	Coarse	Granite	Granodiorite			Quartz Monzonite Quartz Syenite	* Gabbro	
	Medium	6										
	Fine	2			Med.							
Sand	Coarse	0.6	Sandstone	Coarse Ash Tuff	Fine							Schist
	Medium	0.2									* Basalt	
	Fine	0.06			Aplite							
Silt	Mud	0.002	Siltstone Mudstone	Fine Ash	Rhyolite		Rhyodacite	Dacite	Lamprophyre	Quartz Latite Quartz Trachyte Andesite		Phyllite Mylonite
Clay			Claystone									

* *Equivalent to Dolerite of Allen & Stephens (1971)*

Chapter 1
Introduction

Location and Physiography

This memoir describes the geology of the areas covered by Sheet 11 (Hong Kong and Kowloon) and Sheet 15 (Hong Kong South and Lamma Island); also Green Island (Sheet 10), those parts of Lamma Island on Sheet 14 and of the Po Toi Island Group on Sheet 16. The major urban areas of Kowloon and Hong Kong Island are included, as are Victoria Harbour and the East Lamma Channel. The area covered is referred to in this account as the district (Figure 1).

Urban Kowloon is partially ringed by a chain of hills that extends eastwards from Kwai Chung to the Lion Rock (495 m) and Tate's Cairn (577 m), then southwards to Fei Ngo Shan (602 m) and Tai Sheung Tok (419 m). Since 1860, reclamation of Victoria Harbour and Kowloon Bay has continued to the point that none of the predevelopment coastline of Kowloon is preserved. Expansion of the international airport at Kai Tak has been achieved by the reclamation of much of Kowloon Bay, and major reclamation projects are taking place for a new town centred on Junk Bay, and for an expansion of the container terminal at Kwai Chung in the northwest of the district.

The western part of Victoria Harbour, to the west of the Kowloon Peninsula, provides the main shipping anchorage in Hong Kong waters, and the principal access both to this anchorage and the Kwai Chung container terminal is the East Lamma Channel. Kowloon is linked with Central District of Hong Kong Island by an underground railway and a road tunnel under Victoria Harbour links Tsim Sha Tsui and Wan Chai; a new road and rail tunnel across the eastern part of the harbour is under construction.

The northern shores of Hong Kong Island are densely populated. Urban development is constrained inland by steep terrain culminating in a hill chain extending eastwards from Victoria Peak (554 m) to Mount Cameron (439 m) and Mount Parker (507 m). Successive phases of reclamation along the northern shores of the island have effectively doubled the land area available for development. Major housing estates continue around the western part of the island to the sheltered harbour at Aberdeen, where a large industrial estate has been established at Wong Chuk Hang. Much of the interior of Hong Kong Island is designated Country Park and serves as a water catchment, feeding reservoirs at Pok Fu Lam, Aberdeen and Tai Tam. Parts of the southern coast of Hong Kong Island have been developed for recreational and low density residential purposes.

Lamma Island is hilly, sparsely vegetated and largely unpopulated apart from the two main settlements of Yung Shue Wan and Sok Kwu Wan. The Po Toi Island Group forms rugged terrain, rising to 270 m at Lo Chau and 212 m on Po Toi Island.

Previous Work

The first geological survey of Hong Kong was undertaken by Brock, Uglow, Schofield and Williams between 1923 and 1927 under an agreement between the Colonial Office and the University of British Columbia. The resulting map (Brock et al, 1936) was published at the scale of 1:84 480, but no accompanying memoir was produced. Their findings were recorded in papers by Uglow (1926) and Brock & Schofield (1926), who defined the Repulse Bay Volcanics; and in Williams (1943) and Williams et al (1945), who recognized four volcanic units, and gave detailed descriptions of the intrusive igneous rocks.

The first memoir on the geology of Hong Kong was produced by Davis (1952), drawing extensively from the unpublished material of Brock, Uglow, Schofield and Williams. This was followed by a detailed description of the geology of the Territory by Ruxton (1960), who, with Berry (Ruxton & Berry, 1957; Berry & Ruxton, 1959; 1960) also addressed aspects of the superficial geology and weathering, especially in the vicinity of Victoria Harbour.

Figure 1 – Principal Topographic Features of the District

A systematic survey of the Territory by Allen & Stephens (1971) of the Institute of Geological Sciences, U.K. resulted in the publication of 1:50 000 geological maps and an accompanying memoir that have remained the definitive work on the geology of Hong Kong to-date. They made a lithological classification of the rocks of the Repulse Bay Formation, and recognized four phases of granite emplacement within a single episode of late-tectonic intrusive activity. In the present remapping programme by the Geological Survey in the Sha Tin district (Sheet 7), Addison (1986) established a detailed lithostratigraphic division of the Repulse Bay Volcanic rocks, and divided the granites using lithological criteria. His divisions have been extended southwards into this district (Sheets 11 & 15).

In 1979, the GCO commenced a programme to revise the delineation of superficial deposits including colluvium within the Territory. This investigation, known as the Geotechnical Area Studies Programme (Brand et al, 1982; Styles, 1983), used systematic terrain classification to collect physical land resource information at a scale of 1:20 000 for the Territory as a whole, and at 1:2 500 for much of the area covered by Sheet 11. The GASP report covering this district will be available to the public shortly (GCO, 1987).

A comprehensive review of the stratigraphy of Hong Kong and the South China region was given by Bennett (1984b). Bennett (1984c) also reviewed the Territory's tectonic history, structure and metamorphism, and (Bennett, 1984a) its superficial deposits and weathering.

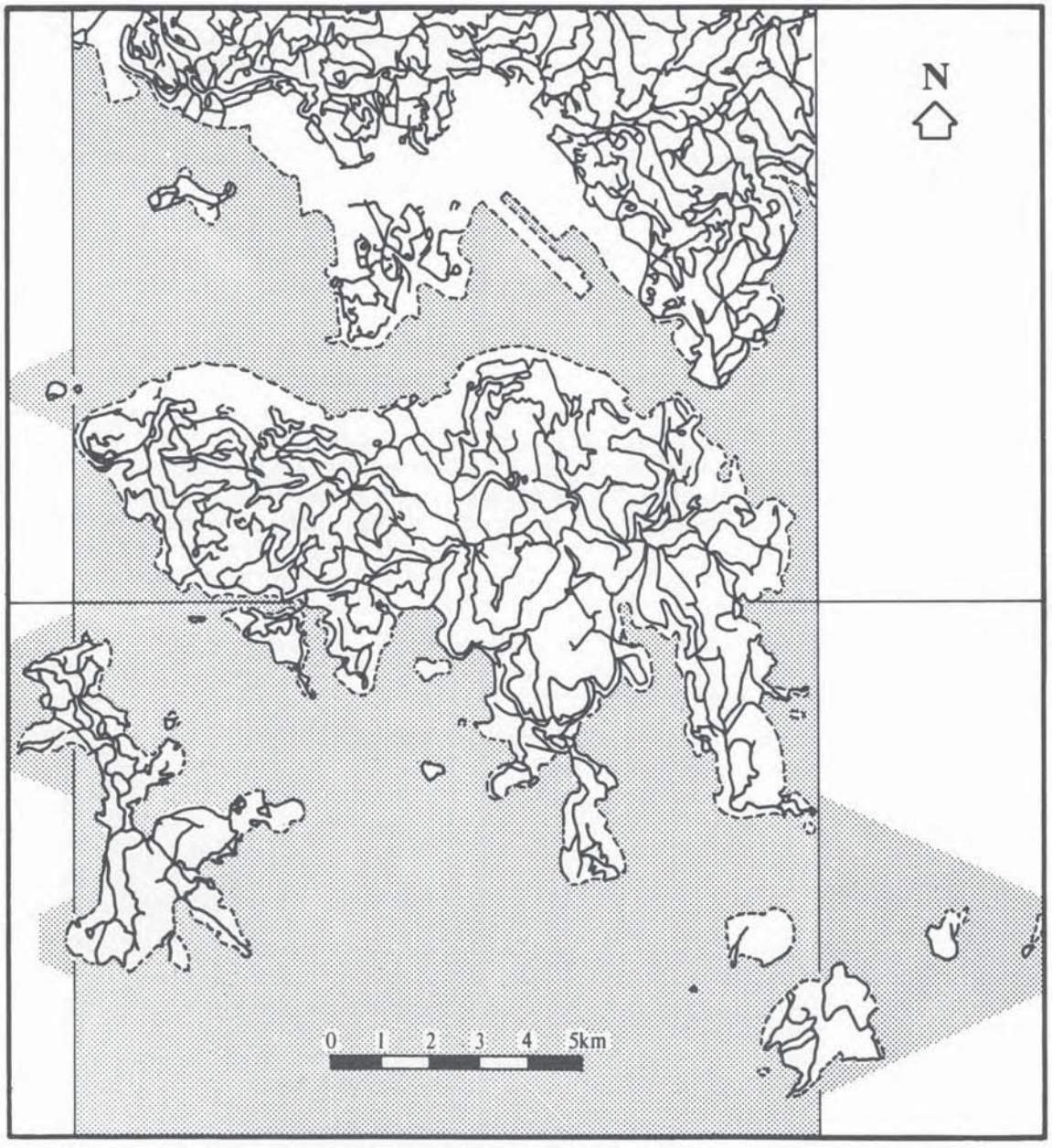


Figure 2 – Traverses Undertaken during Field Survey of the District

The Present Survey

Geological field mapping was undertaken between December 1983 and December 1985. Topographic base maps at 1:5 000 scale were used in all areas except Junk Bay – Ho Chung and the Po Toi Island Group, where geological information was plotted directly onto aerial photographs. The field survey entailed traverses along roads, footpaths and stream courses (Figure 2). Thick vegetation, particularly to the east of Fei Ngo Shan and on Hong Kong Island, restricted traverses away from well-defined footpaths. Most coastal sections were examined, but some stretches of rugged cliffs, notably on southern Hong Kong Island, southern Lamma Island and the Po Toi Island Group, proved inaccessible. The old-established urban areas, such as the Mong Kok District of Kowloon, yielded little or no useful field data, and traverses there were more widely spaced. Temporary sections were examined as available; these were particularly important, often the only source of information in areas of old urban development.

A desk study involved the examination of over 2 000 borehole records, mostly from site investigation for major engineering projects such as the construction of the Mass Transit Railway. These records were used especially to determine the subsurface geology of areas covered by fill, including reclamation. Other archival data consulted included the Lion Rock Road Tunnel investigations, record drawings of Housing Authority site formations and pre-development topographic maps. The latter two were used to determine extents of fill, the natural coastline and the extents of the various phases of reclamation. The maps of 1845 and 1863 covering Hong Kong Island, and the 1904 series covering Kowloon and the New Territories were particularly useful. Similarly, aerial photograph sets from 1949 and 1963 provided information on the pre-development topography and geology, mainly in the more recent urban developments of East Kowloon, Chai Wan and Aberdeen.

Mapping of the superficial deposits of the district was aided by reference to the Engineering Geology maps produced by the GCO for the Geotechnical Area Studies Programme (Brand et al, 1982; Geotechnical Control Office, 1987).

A photogeological interpretation of the district was conducted using 1982–1985 photographs, but in some areas covered by recent developments it was necessary to refer back to the excellent 1949 set (scale 1:5 000). The extent of reclamation shown on the maps is based on data supplied by Survey Division, Buildings and Lands Department.

From a total of 1 047 rock samples collected, 18 were sent to the Analytical Chemistry Research Group of the British Geological Survey for geochemical analysis of major and trace elements.

The offshore survey was accomplished by reference to approximately 1 600 borehole records and to the traces of shallow seismic records from geophysical surveys carried out for the Harbour Reclamations and Urban Growth Study (Harbour Area Consultants, 1983), major offshore engineering works and also specifically for this Geological Survey. An appreciation of the stratigraphic complexities of the offshore Quaternary deposits was gained through detailed logging of several continuously sampled marine boreholes, drilled both within and outside the limits of the district. These studies facilitated the interpretation of commercial borehole records and the stratigraphic assessment of seismic traces.

The geological information gathered from all sources was transferred onto 1:10 000 scale base maps. Provisional geological maps were prepared at this scale, and these formed the basis for the published 1:20 000 scale geological map sheets.

All records from the survey, including rock samples, thin sections, field notes, manuscript maps and analytical data are held by the Geological Survey Section, Geotechnical Control Office.

Chapter 2
Outline of Geology

The solid geology of the district is dominated by Mesozoic volcanic and intrusive igneous rocks (Table 2, Figure 3). The volcanic rocks are those of the Upper Jurassic Repulse Bay Volcanic Group. The oldest rocks of this group exposed in the district are tuffs of the Yim Tin Tsai Formation. These are lithologically uniform, consisting of massive coarse ash tuff. The overlying Shing Mun Formation is variable, containing interlayered tuff-breccia, tuffite and tuff, and minor epiclastic bands. The dominant rock type is poorly sorted, lapilli-bearing, coarse ash crystal tuff. The Shing Mun Formation is overlain by up to 1 800 m of Ap Lei Chau Formation, composed of welded fine ash vitric tuff with well-defined eutaxite layers that form positive topographic features. The uppermost unit of the volcanic rocks within the district is the Tai Mo Shan Formation, formed of coarse ash to lapilli crystal tuff and impersistent layers of tuffaceous sandstone and siltstone.

The Repulse Bay Volcanic Group is intruded by granitoid rocks of Upper Jurassic to Lower Cretaceous age. Granodiorite and the highly modified coarse-grained granites forming the plutons of northern Lamma Island and Lai Chi Kok – Sha Tin are the oldest intrusions. The younger plutons forming southern Lamma Island and Kowloon – northern Hong Kong island include fine-, fine- to medium-, and medium-grained granite varieties. In northern and eastern Lamma Island, and in the King's Park area of Kowloon, the granites are markedly megacrystic (Strange, 1985). Quartz syenite forms a small plutonic body on the D'Aguilar Peninsula of Hong Kong Island, as well as impersistent dykes extending across the island from Aberdeen to Chai Wan. The granites are cut by minor acidic intrusions, mostly dykes of feldsparphyric rhyolite and quartzphyric rhyolite. Several feldsparphyric rhyodacite dykes are present on southern Lamma Island. Basaltic dykes of probable Tertiary age occur throughout the district, cutting volcanic rocks and granite plutons alike.

Thermal metamorphism around the granitic intrusions has altered tuffs and epiclastic rocks to hornfels. Late stage emanations of hydrothermal fluids from the granite plutons have resulted in greisenisation of the granite and the metasomatism of adjoining volcanic rocks in southeastern Kowloon and in northern Lamma Island.

A regolith, or mantle of weathered rock, forms much of the outcrop, effectively masking the fresh rock solid geology. The effect of weathering upon the different rock types is broadly reflected in the topographic relief. Volcanic rocks, especially the finer grained tuffs, tend to form higher and sharper peaks with few surface boulders, whereas granites form lower and more rounded hills with abundant surface boulders (exhumed corestones). In general, the fine-grained granites are more resistant to weathering than the coarser grained varieties.

Superficial deposits of Quaternary age conceal solid rock, in various states of weathering, over much of the district, particularly in low-lying areas and offshore (Table 2). In the hilly areas, for example on the slopes of Fei Ngo Shan, debris flow deposits (colluvium) are common, older deposits mantling interfluves and younger ones lining present-day valleys. Alluvium is widespread on the low ground of Kowloon and the Ho Chung Valley. Beach deposits fringe the natural coastline.

The offshore Quaternary deposits are laterally extensive and generally comprise Holocene marine mud (Hang Hau Formation) overlying a complex stratified alluvial sequence (Chek Lap Kok Formation) of presumed Late Pleistocene age. These older alluvial deposits comprise clay and silt as well as sand and gravel; some of them are mottled yellow and red, while others are dark grey and organic. Around most of the Kowloon peninsula, in Junk Bay and along the northern shores of Hong Kong Island, the Quaternary deposits have been disturbed and concealed by reclamation.

Table 2 – Solid Rocks and Superficial Deposits of the District

Superficial Deposits (Onshore)			
Age		**Genetic Classification**	
Quaternary	Holocene	Fill (made ground) Beach deposits	
Quaternary	Holocene and Pleistocene	Alluvium Terrace deposits Debris flow deposits Talus (rockfall) deposits Mixed debris flow and talus deposits } colluvium	
Superficial Deposits (Offshore)			
Age		**Named Divisions**	**Principal Materials**
Quaternary	Holocene	Hang Hau Formation including East Lamma Channel Member and Telegraph Bay Member	Mainly mud
Quaternary	Pleistocene	Chek Lap Kok Formation	Clay, silt, sand and gravel
Solid Rocks			
Age		**Named Volcanic Divisions**	**Principal Rock Types**
Mesozoic	Upper Jurassic	Repulse Bay Volcanic Group: Tai Mo Shan Formation	Coarse ash crystal tuff
		Repulse Bay Volcanic Group: Ap Lei Chau Formation	Fine ash vitric tuff with eutaxite
		Repulse Bay Volcanic Group: Shing Mun Formation	Lithic and crystal tuffs, tuff-breccia and tuffite
		Repulse Bay Volcanic Group: Yim Tin Tsai Formation	Coarse ash crystal tuff
Major Intrusive Igneous Rocks			
Mesozoic	Upper Jurassic—Lower Cretaceous	Fine-grained granite Fine- to medium-grained granite Medium-grained granite Coarse-grained granite Quartz syenite and quartz monzonite Granodiorite	
Minor Intrusive Igneous Rocks			
Tertiary	Palaeocene	Basalt Lamprophyre	
Mesozoic	Upper Jurassic—Lower Cretaceous	Quartzphyric rhyolite Feldsparphyric rhyolite Feldsparphyric rhyodacite Quartz trachyte Aplite Pegmatite	

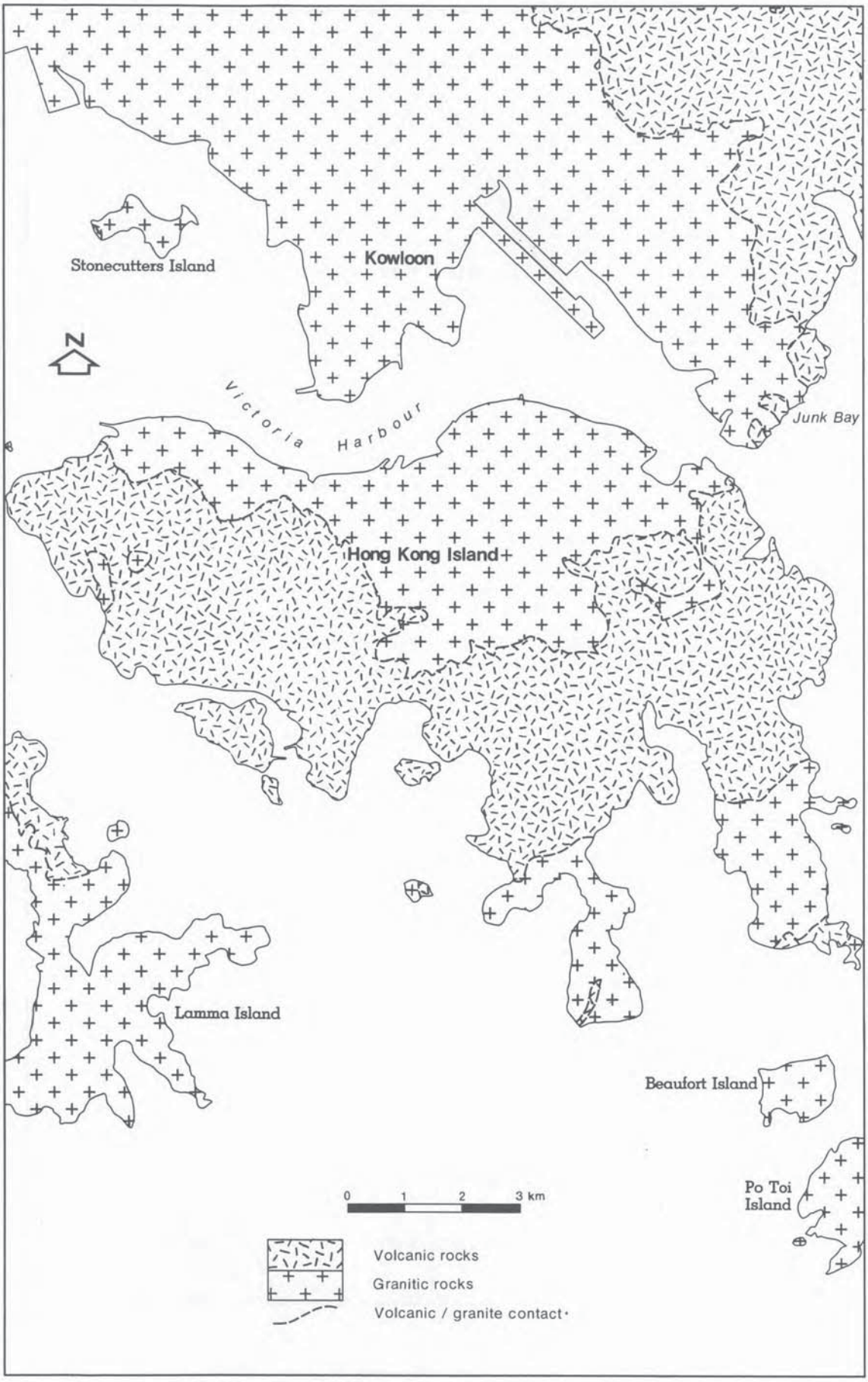


Figure 3 – Generalized Solid Geology of the District

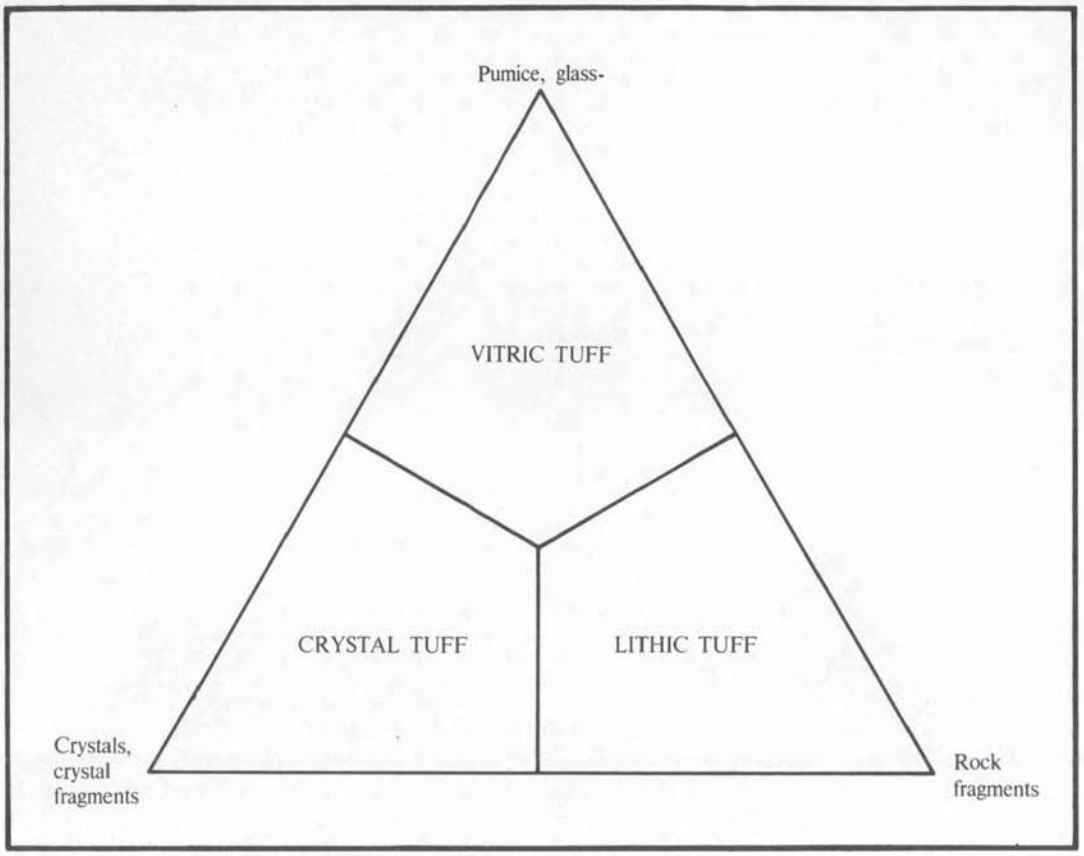


Figure 4 – Classification of Pyroclastic Rocks Based on Composition (after Schmid, 1981)

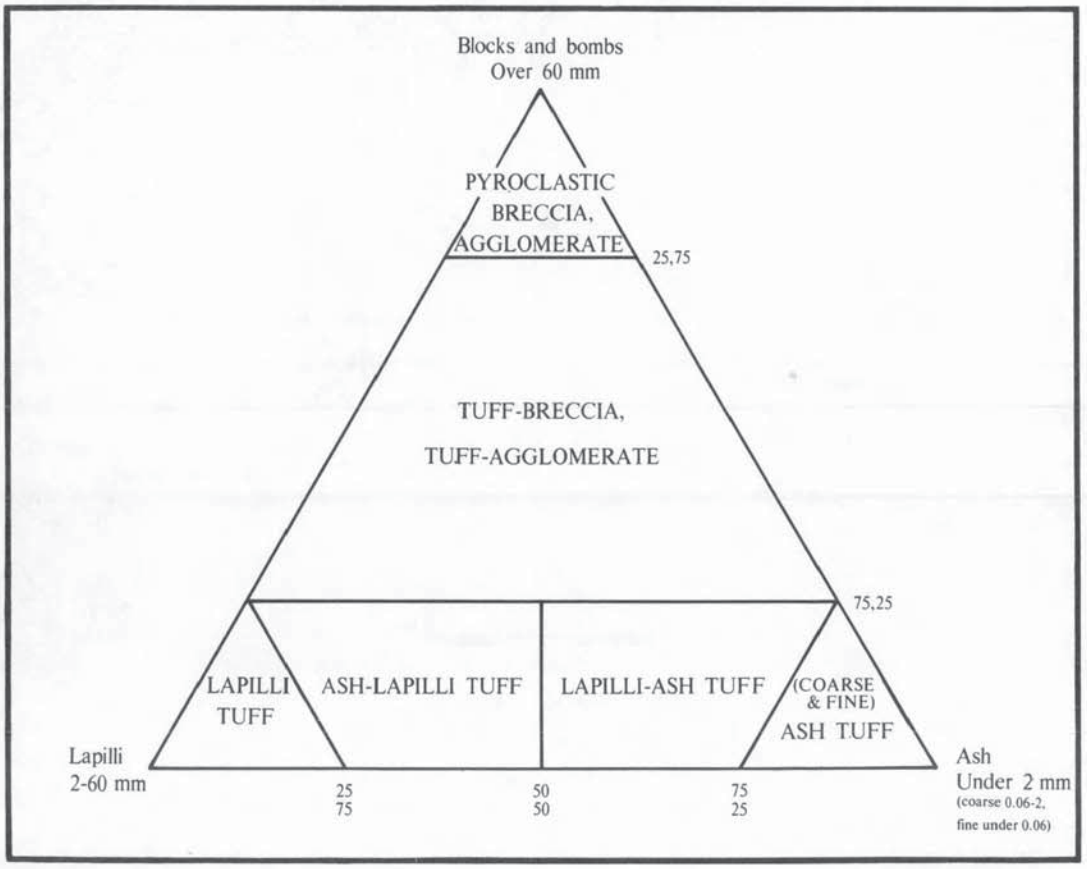


Figure 5 – Classification of Pyroclastic Rocks Based on Grain Size (adapted from Schmid, 1981; Fisher & Schmincke, 1984)

Chapter 3
Mesozoic Volcanic and Sedimentary Rocks – Repulse Bay Volcanic Group

Classification and Distribution

The earliest work on the detailed stratigraphy of the volcanic rocks of the Territory was undertaken by Uglow (1926), and Brock & Schofield (1926), who first used the term Repulse Bay Volcanics. Williams et al (1945) recognized four volcanic units comprising the Repulse Bay Volcanics, the Rocky Harbour Volcanics, the Shelter Volcanics and the Tai Mo Shan Porphyry, although they considered the latter to be an intrusive formation within the Volcanics. Ruxton (1960) proposed a revised succession, with these units forming part of the Plover Cove Formation of acid volcanic rocks. Allen & Stephens (1971) adopted the term Repulse Bay Formation for a unit comprising all the volcanic rocks of the Territory, with the type section along the coast between Repulse Bay and South Bay on Hong Kong Island.

Addison (1986) established the first detailed lithostratigraphy of the volcanic rocks in the Sha Tin district (Sheet 7) and recognized four formations there within the Repulse Bay Volcanic Group. These four formations can be traced southwards from Sha Tin through East Kowloon to Hong Kong and Lamma islands. They comprise the Yim Tin Tsai Formation at the base of the sequence, followed in turn by the Shing Mun, the Ap Lei Chau and the Tai Mo Shan formations (Table 2). Type localities for the Yim Tin Tsai, Shing Mun and Tai Mo Shan formations are situated in the Sha Tin district. The type locality for the Ap Lei Chau Formation is on the south-western side of Ap Lei Chau Island near Aberdeen.

The nomenclature and classification of the pyroclastic rocks used in this survey are based on the recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks (Schmid, 1981), and the work of Fisher & Schmincke (1984), which are summarized in figures 4 and 5.

The Repulse Bay Volcanic Group is dominated by tuffs. Each of the four formations displays specific, distinctive characteristics that have allowed the recognition of individual formations even where stratigraphic relationships with the other volcanic rocks are unknown. There are minor epiclastic sedimentary units throughout but these are laterally impersistent. The present survey has delineated these epiclastic rocks, as well as mappable units of tuff-breccia and pyroclastic breccia, and the distinctive, eutaxitic banded, welded tuff (eutaxite). Generalised sequences within the district are illustrated in Figure 6.

C. M. Lee (Anon, 1985) considered the Repulse Bay volcanics to be equivalent to the Upper Jurassic Gaojiping Group of Guangdong Province. No fossil-bearing horizons have been located during the present survey of this district.

Yim Tin Tsai Formation

Stratigraphy

The Yim Tin Tsai Formation is considered to be the oldest widespread tuff division within the Repulse Bay Volcanic Group (Addison, 1986). The type section is at Yim Tin Tsai in Tolo Harbour (Sheet 7), where a basal sedimentary breccia has been recognized resting on the Lower Jurassic Tolo Channel Formation. In this district the formation has isolated outcrops, separated from other sedimentary or volcanic formations, at Cape D'Aguilar, and on Stanley Peninsula, Round Island and Lamma Island.

Although its stratigraphic relationships are unclear, the lithologies at all localities are uniform and are consistent with the Yim Tin Tsai Formation as described in the Sha Tin district (Addison, 1986) and on Tsing Yi Island (R. L. Langford, oral communication).

The dominant lithology is a light grey to grey coarse ash crystal tuff, with scattered blocks of porphyritic lava with distinctive diffuse margins (Plate 1). The crystal matrix consists of feldspar and quartz with primary magmatic hornblende usually present in minor amounts, and with scattered secondary biotite crystals common (Plate 2).

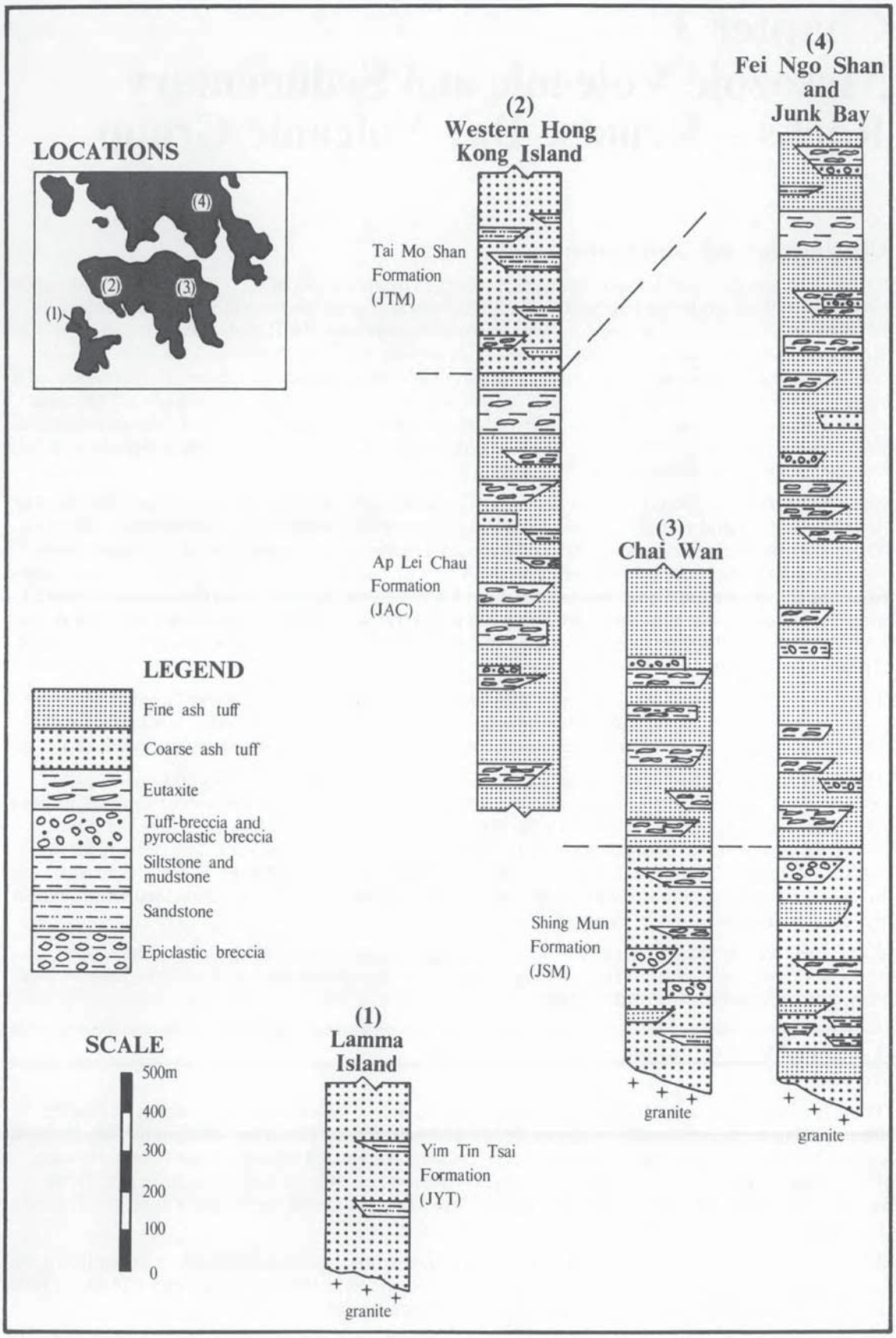


Figure 6 – Generalized Sequences of Repulse Bay Volcanic Group Rocks

On Lamma Island, several epiclastic units consisting of siltstone and fine-grained sandstone have been mapped, but these are laterally impersistent. Also on this island there has been considerable hydrothermal alteration along several clearly defined bands running through the formation; the alteration has been so intense that the original lithology and character of the rock has been obscured, but it is possible that preferential alteration and metasomatism has taken place along a band of calcareous tuffaceous sandstone that would be particularly susceptible to such chemical changes (See Chapter 7).

The Yim Tin Tsai Formation tuffs are intruded by granodiorite at Cape D'Aguilar, Stanley and Round Island, and by the older calcium rich granites on Lamma Island.

Details

D'Aguilar Peninsula. Coarse ash to lapilli crystal tuff is exposed in the coastal sections south of the old lighthouse at Cape D'Aguilar (4480 0772), where it weathers to a uniform, light grey rock. No blocks were noted in these sections, but in a nearby road cutting (4466 0766) exposures of dark grey fresh rock reveal the presence of blocks of leucocratic porphyritic lava 0.15 to 0.25 m across, displaying characteristic diffuse margins (Plate 1). The lava blocks consist of white feldspar megacrysts up to 8 mm in length, set in light grey to grey aphanitic groundmass. The tuff matrix contains abundant quartz crystals up to 5 mm across and feldspars to 4 mm across, but the average grain size is between 1 and 2 mm. Fresh, single black biotite flakes are visible in hand specimen. In thin section (HK4223, 4449 0790) biotite is also seen to occur as minute crystal aggregations concentrated in small patches. Quartz is dominant among the larger crystals. Smaller plagioclase crystals are ubiquitous, and some are zoned. Near the Wireless Station (4413 0782) there are exposures of weathered fine ash tuff. The Yim Tin Tsai Formation has been intruded by a syenite pluton to the north, by granodiorite in the southeastern part of D'Aguilar Peninsula, and by basalt dykes and numerous leucocratic quartzphyric rhyolite dykes.

Stanley Peninsula. From the coastline at Wong Ma Kok (3998 0628), inland to the summit of Stanley Fort (4019 0683), coarse ash to lapilli crystal tuff forms a wedge-shaped outcrop surrounded and metamorphosed by granodiorite. In thin section (HK4240, 3998 0628) the matrix is almost entirely recrystallised as a result of the thermal metamorphism. The equigranular quartz matrix surrounds less altered, larger quartz crystals up to 2 mm across; occasional zoning of plagioclase crystals was noted.

Round Island. Coarse ash to lapilli crystal tuffs are continuously exposed in the coastal sections around the eastern half of the island. As with the Cape D'Aguilar exposures, the cliff sections show a remarkable lithological uniformity. In thin section (HK4030, 3738 0864) crystals of broken quartz, alkali feldspar and zoned plagioclase averaging 1 to 2 mm are set in a very fine matrix of roughly equigranular recrystallised quartz grains. Hornblende is also present and the rock is speckled with iron oxides. There is no sign of any welding fabric.

Lamma Island. The Yim Tin Tsai Formation crops out over approximately 2.5 sq km of northern Lamma Island, forming a smooth, rounded topography with few surface exposures apart from scattered corestones and blocks on hill summits. Apart from the main outcrop, which extends from Pak Kok southwards to Luk Chau Village, there are some small isolated inliers less than 100 m across, surrounded by the granitic rocks. The bulk of the outcrop consists of uniform coarse ash tuff containing scattered small blocks and lapilli of porphyritic lava. When fresh, the tuff has a bluish grey colour with light grey or brown quartz crystals prominent against a dark matrix containing abundant biotite. This usually occurs as fresh, shiny black crystals, occasionally up to 3 mm (Plate 2).

A distinctive thin fine ash tuff band, exposed in a temporary cutting near Pak Kok (3030 1110), strikes roughly E–W and dips to the south at about 30°. In thin section (HK5096, 3030 1110) the matrix is fine-grained and recrystallized, and muscovite and secondary biotite are abundant. Scattered crystals of quartz and microperthite average 2 mm across. A similar fine ash tuff band was noted near Tai Peng (3042 1010). A strong feature-forming band of brecciated, intensely hydrothermally altered rock strikes roughly E–W across the hill 500 m south of Pak Kok (3030 1095). The rock is iron-rich and contains abundant quartz, both as discrete crystals and as anastomosing veins. The original lithology of the rock cannot now be determined and the brecciated appearance may be a result of the metasomatism. Large fallen blocks of this material are found on the beach at Pak Kok Tsui (3012 1114). Similar hydrothermally altered zones 50 to 70 m wide, striking ENE, were mapped north-northeast of Hung Shing Ye (3051 0957 & 3058 0937).

A light brown fine-grained sandstone band is exposed at Lo Tik Wan (3097 0927) where it appears to dip towards the south. This sandstone is about 10 m thick but is laterally impersistent. In the vicinity of Lo Tik Wan, numerous minor intrusions of quartz syenite are exposed, and the irregular nature of the contacts are well seen in the coastal sections (3106 0945). Farther south, larger bodies of quartz syenite intrude the tuffs, and in places appear to have infiltrated and modified them. Some 300 m east of Hung Shing Ye (3068 0905), fine-grained quartz syenite has percolated through the tuffs and large secondary crystals of alkali feldspar have grown within the coarse ash tuff. A similar modification was noted in excavations at Tai Wan Kau Tsuen (3023 0949) where the coarse ash tuff has been thermally metamorphosed and subsequently infiltrated by syenitic fluids. Although the original texture and character of the tuff remain, the quartz syenite has produced a distinctive overprint of aligned alkali feldspar megacrysts.

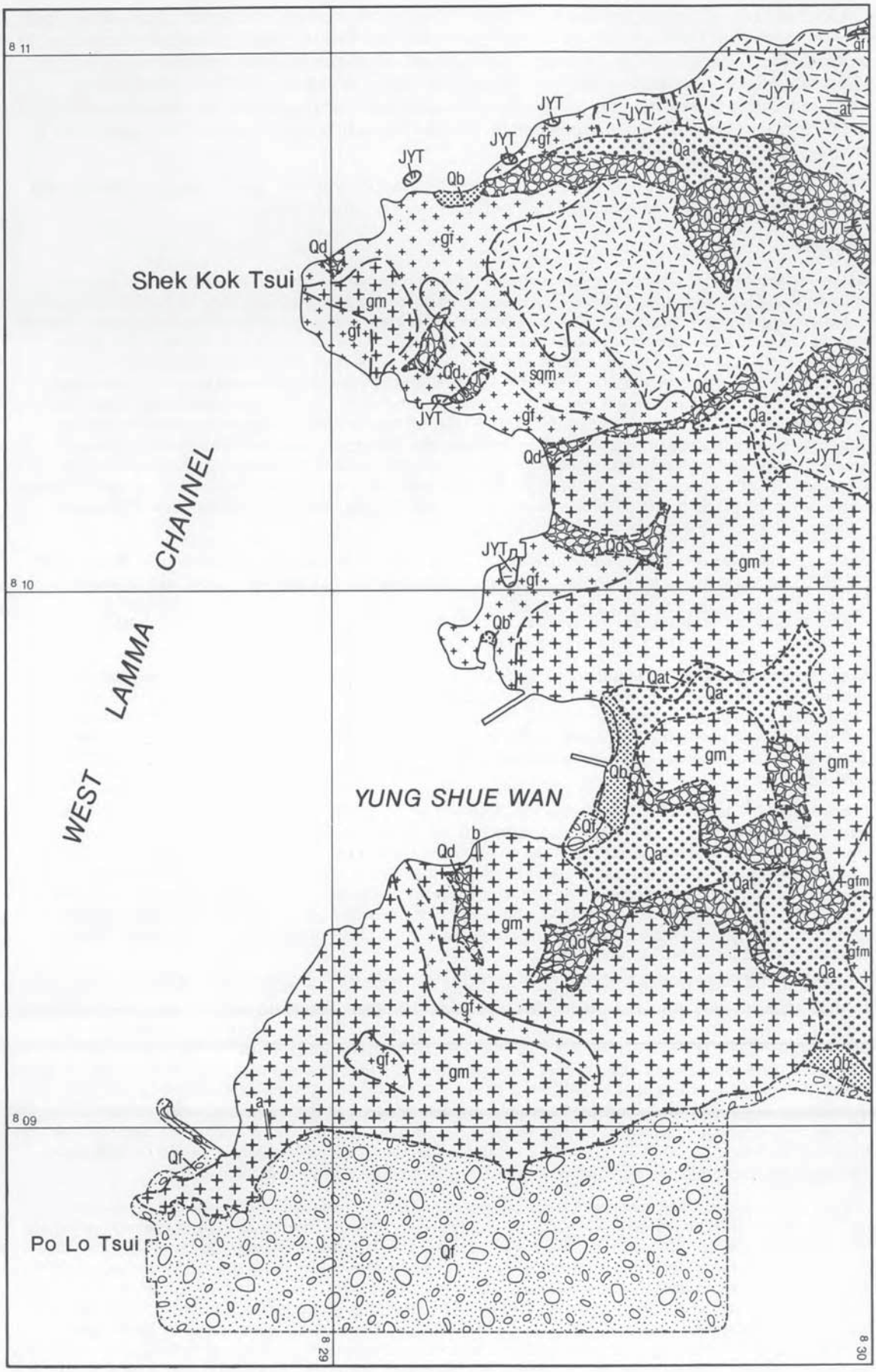
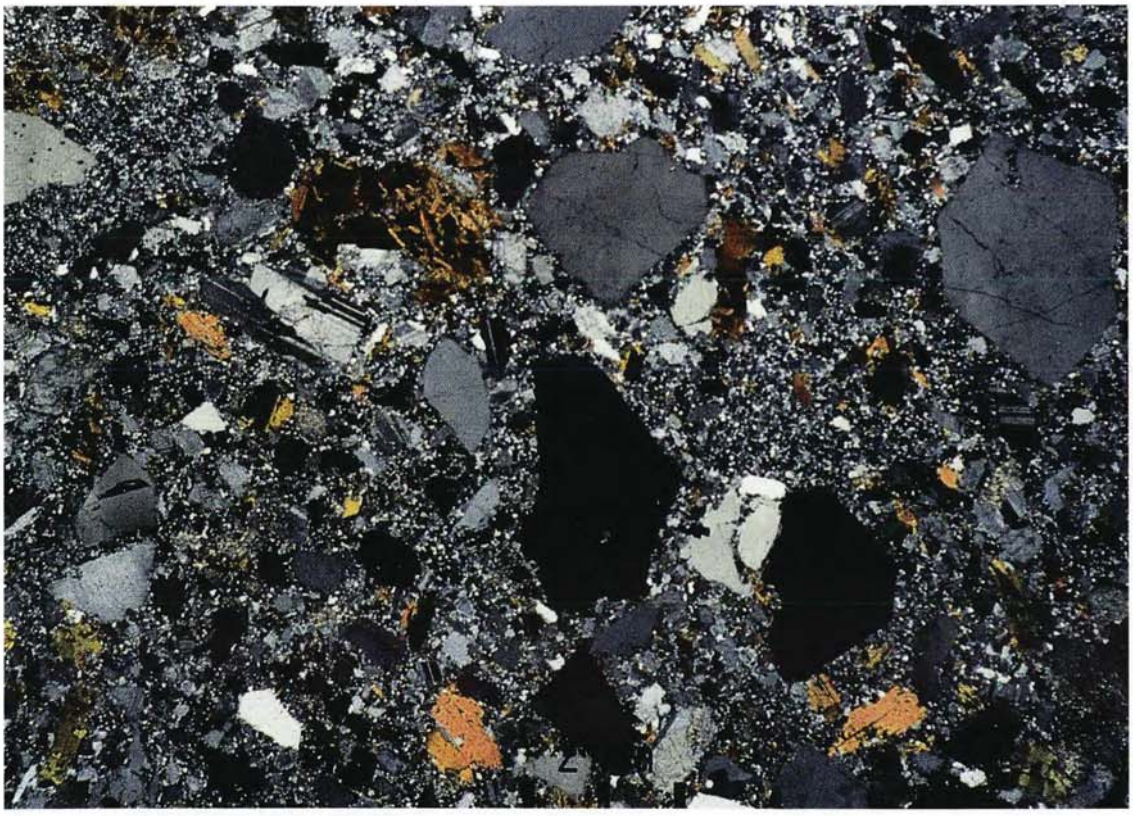


Figure 7 – Geological Map of Northwestern Lamma Island (Sheet 14)

Plate 1 – Coarse Ash Tuff in Yim Tin Tsai Formation (HK 5322) from Cape D'Aguilar (4466 0766); Natural Scale

Plate 2 – Thin Section of Coarse Ash Tuff in Yim Tin Tsai Formation (HK 5095) from Northern Lamma Island (3010 1098); XPL × 10



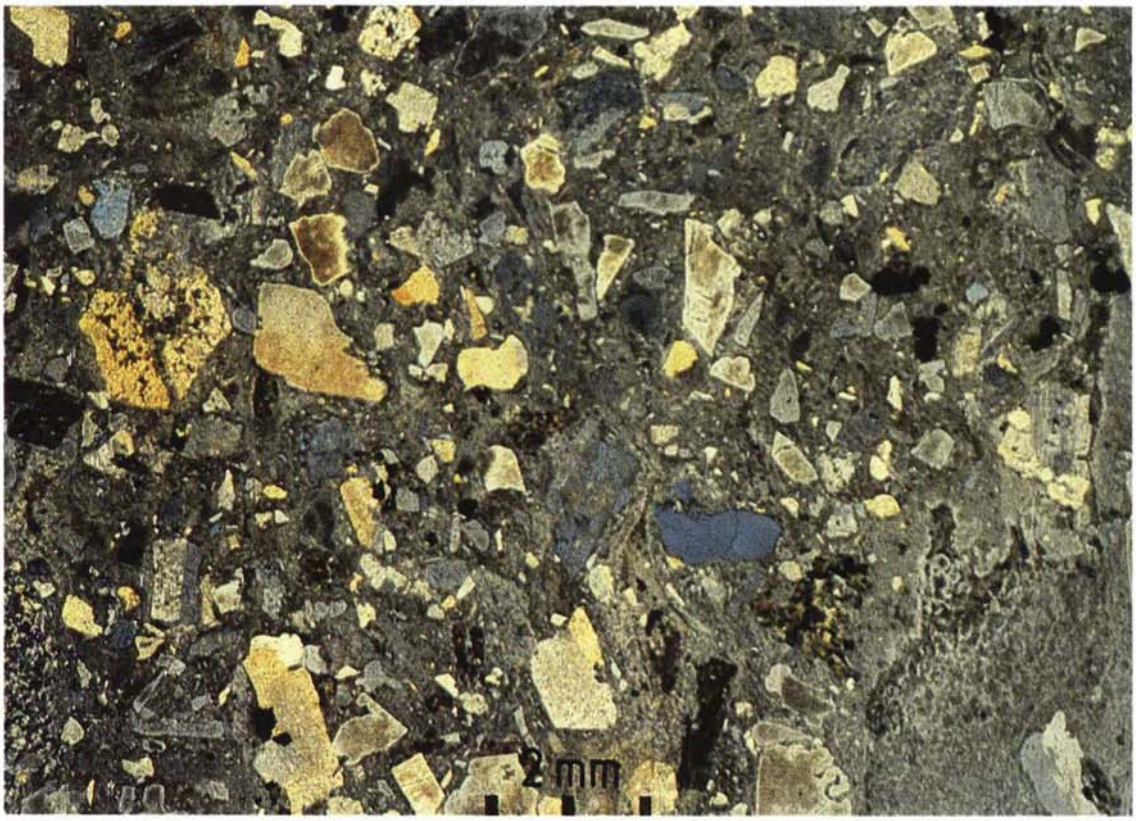


Plate 3 – Thin Section of Lapilli-bearing Coarse Ash Tuff in Shing Mun Formation (HK 2884) at Cape Collinson, Chai Wan (4401 1326); XPL plus $\frac{1}{4}\lambda$ plate × 10

Plate 4 – Thin Section of Fine Ash Vitric Tuff in Ap Lei Chau Formation (HK 2466) from Victoria Peak (3398 1379); XPL × 10

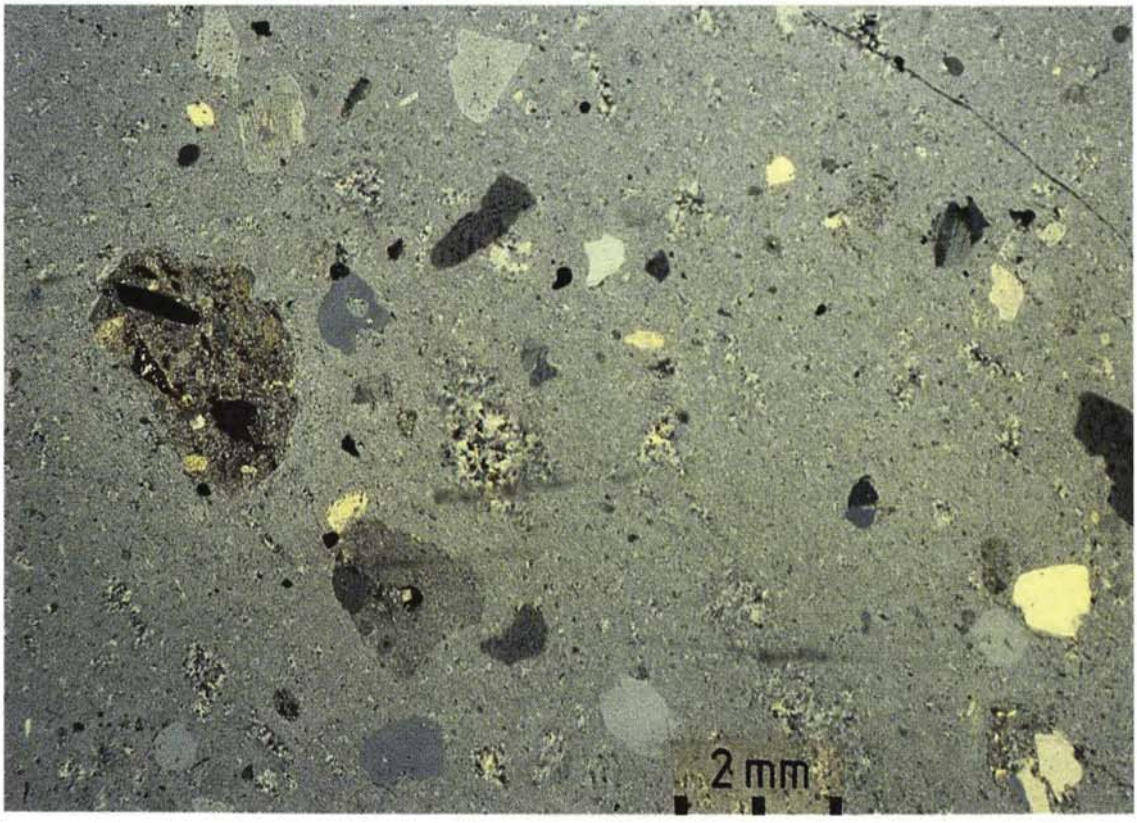


Plate 5 – Eutaxite in Ap Lei Chau Formation (HK 5117) from Ap Lei Chau (3393 1086); Natural Scale

Plate 6 – Thin Section of Eutaxite in Ap Lei Chau Formation (HK 1215) from Hebe Hill, Clear Water Bay Road (4268 2239); XPL × 10

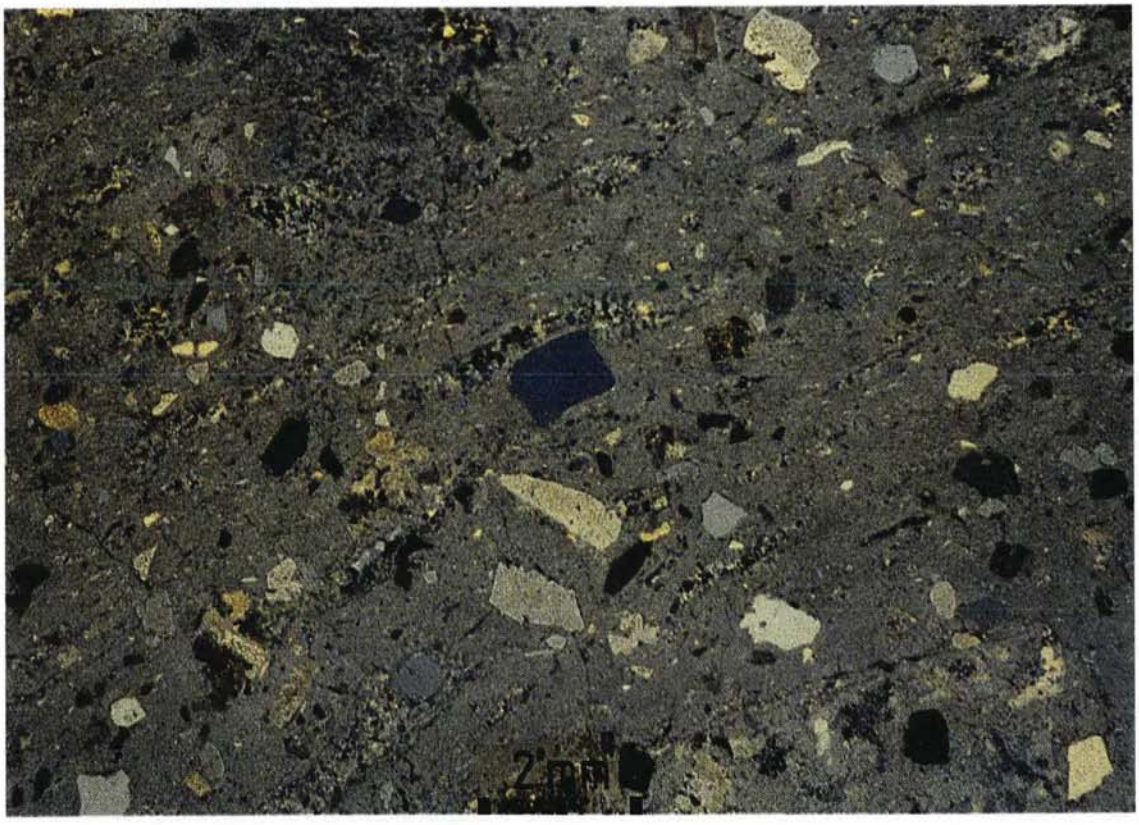
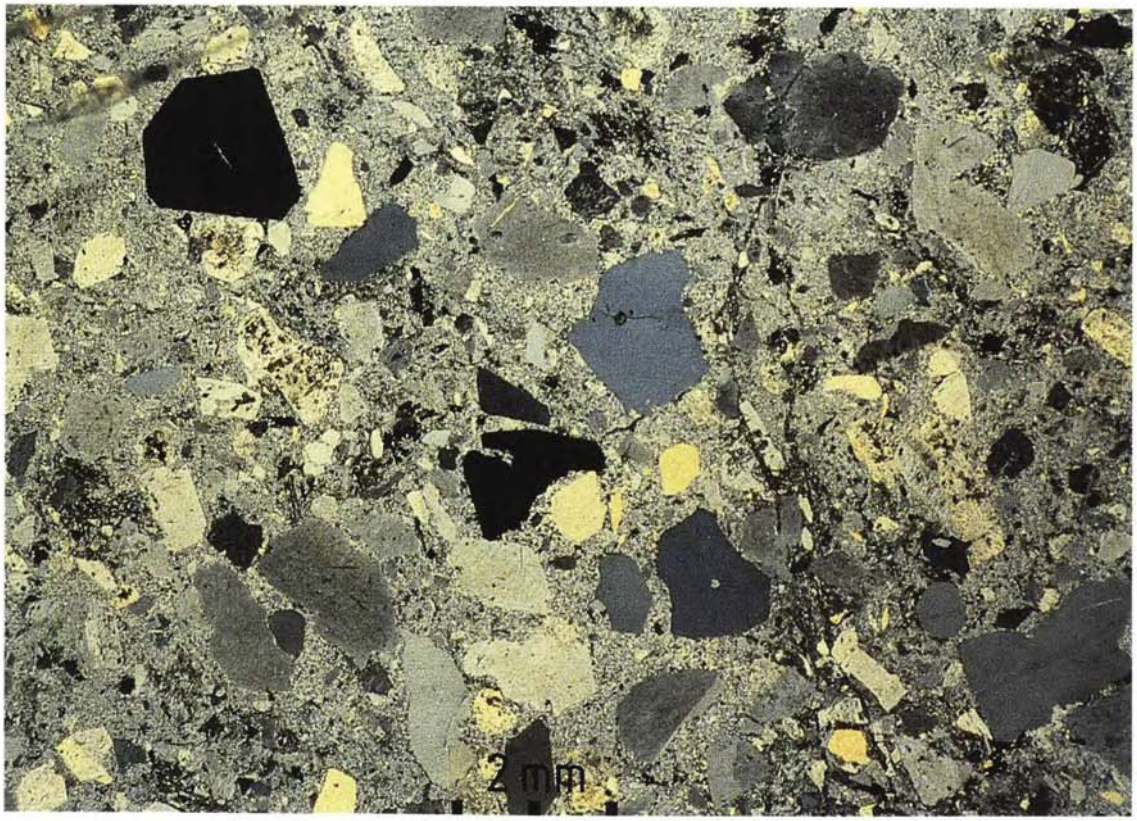


Plate 7 – Coarse Ash Tuff in Tai Mo Shan Formation (HK 2857) from Mount Davis, Hong Kong Island (3076 1497); Natural Scale

Plate 8 – Thin Section of Coarse Ash Tuff in Tai Mo Shan Formation (HK 2472) from Shek Pai Wan, Aberdeen (3435 1250); XPL plus $\frac{1}{4}\lambda$ plate × 10



South of Hung Shing Ye (3047 0855) a body of highly altered tuff, measuring 25 m across is present within granite; it is probably a large xenolith of the country rock. Along the coastline, to the north of Yung Shue Wan (Figure 7), five small areas of coarse ash tuff have been mapped, all occuring as isolated bodies within the granite mass. The tuff bodies vary from 30 to 80 m across and it is not known whether they are giant xenoliths of country rock within the granite or roof pendants.

Shing Mun Formation

Stratigraphy

The Shing Mun Formation is the most variable formation within the Repulse Bay Volcanic Group, and this variability is the dominant character of the formation, with any one outcrop displaying several markedly different lithologies. These include eutaxite, fine ash, coarse ash and lapilli lithic and crystal tuffs, tuff-breccia, pyroclastic breccia, mudstone, siltstone, sandstone, tuffite and epiclastic breccia (Plates 3, 9, 10 & 11). In some places particular lithologies have been delineated, and these areas are shown on the 1:20 000 maps. Mostly, however, lack of exposure and lateral impersistence of the lithological units have made such divisions impractical and hence there are no named lithostratigraphic members within the formation.

The type locality lies to the northeast of Tsuen Wan (Sheet 7) and was defined by Addison (1986). In this district the Shing Mun Formation crops out from Tate's Cairn southwards to Fei Ngo Shan, and as two isolated occurrences near Lei Yue Mun. Across the Lei Yue Mun passage, on eastern Hong Kong Island, the formation covers 6 sq km between Shau Kei Wan and Big Wave Bay (Tai Long Wan). A small outcrop of tuff-breccia on the western side of Stonecutters Island is also placed in this formation (Plate 9).

The boundary between the Shing Mun Formation and the underlying Yim Tin Tsai Formation is not seen in this district. To the east of Fei Ngo Shan, and in the eastern part of Hong Kong Island, the Shing Mun Formation passes upwards into fine ash vitric tuffs of the Ap Lei Chau Formation. Near the mapped boundary the lithologies of the two formations are intercalated and no clear dividing line can be defined.

Plate 9 – Tuff-breccia in Shing Mun Formation at Stonecutters Island (3160 1996)

Details

Tate's Cairn to Fei Ngo Shan. Lapilli-bearing fine ash lithic and crystal tuffs are found to the east of Grasscutter's Pass (4040 2400), but these have been altered in the vicinity of the granite intrusions. Eastwards to Tate's Cairn the tuffs are variable from fine ash to coarse ash tuffs, and contain scattered lithic blocks. Near Tate's Pass (4066 2383), mudstone bands have been mapped. The black mudstones are finely laminated and have been thermally metamorphosed; they are impersistent and dip steeply towards the southeast. From Middle Hill (4100 2317) to Fei Ngo Shan (4102 2220) the strata strike approximately north-south, and fine ash to coarse ash tuffs at Middle Hill display a crude bedding dipping towards the east at about 30°. In thin section (HK572, 4093 2329) the rock has a very fine vitric matrix enclosing large broken quartz crystals up to 2.5 mm. There are a few wispy shards and concentrations of small equigranular quartz grains along preferred planes indicating that the tuff is welded.

On the southeastern slopes of Fei Ngo Shan a tuff-breccia and pyroclastic breccia layer has been exposed in excavations for a new service reservoir (4153 2222). This polymictic rock contains angular to sub-rounded lithic blocks, mainly dark greenish grey aphanitic lava, averaging 0.35 m but with some up to 3 m across. Some of the smaller blocks are almond-shaped with a tail, and resemble volcanic bombs. The matrix is a coarse ash crystal tuff. Overlying the tuff-breccia is a thick lapilli-bearing fine ash tuff layer. At Fei Ngo Shan summit (4110 2230) a prominent, vertical, N–S striking rhyolite is present. This rock displays distinctive highly contorted flow-banding in exposures 50 m east of the transmitting tower (4110 2241). The rhyolite closely resembles the quartzphyric dyke varieties, which are intrusive. Although this rock unit parallels the strike of the volcanic strata, it is assumed that it is a dyke rather than an extrusive body. Feldsparphyric rhyolite dykes, striking NW–SE, intrude the tuffs to the northwest of Fei Ngo Shan (4054 2334 and 4055 2286). Above Jat's Incline (4034 2297) a light pink grey, fine-grained, banded sandstone, approximately 15 m in thickness, has been thermally metamorphosed by the nearby granite.

Southeastern Kowloon – Devil's Peak. Two isolated outcrops of Shing Mun Formation, surrounded by granite, have been mapped between Yau Tong and Junk Bay. Much of the rock has been thermally metamorphosed by the granite. There is also hydrothermal alteration (greisenisation) of the granite that, to a lesser extent, has affected the volcanics lying within 20 m (thickness) of the easterly dipping contact.

In thin section (HK677, 4311 1713) the matrix of equigranular quartz grains is entirely recrystallised and encloses corroded quartz and microperthite crystals, which average 1 mm. Some muscovite is present and small secondary biotite crystals are scattered throughout the matrix. Along the coastline immediately northeast of Lei Yue Mun Point (4314 1636), subangular lithic blocks up 0.6 m across are present in the fine to coarse ash tuffs.

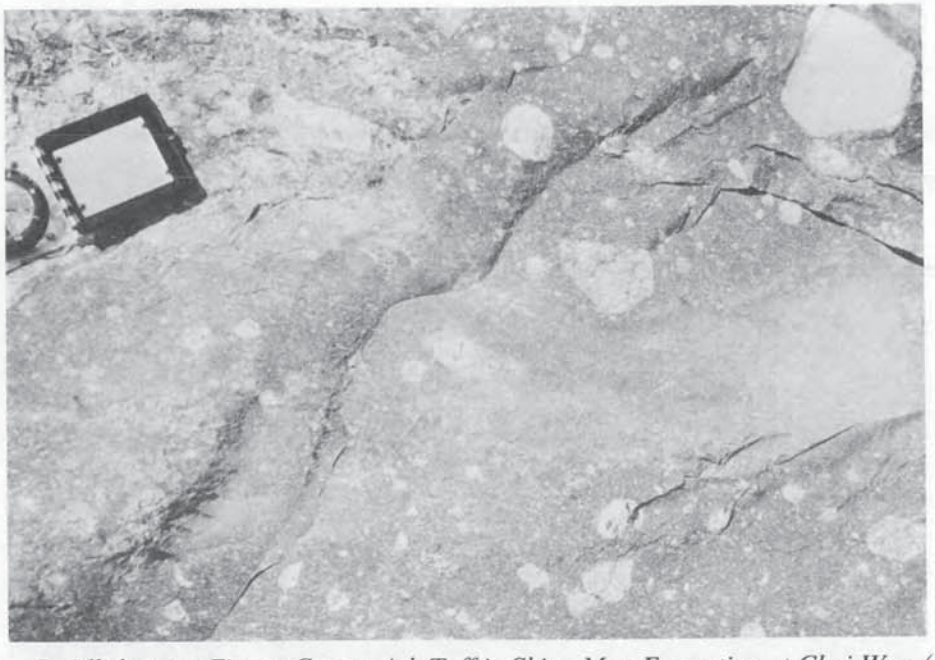


Plate 10 – Lapilli-bearing Fine to Coarse Ash Tuff in Shing Mun Formation at Chai Wan (4240 1453)

Hong Kong Island – Shau Kei Wan to Chai Wan. There are excellent exposures of the Shing Mun Formation along the western side of Lei Yue Mun Bay (now reclaimed) and southwards to Chai Wan. Near Pak Sha Wan at the railway tunnel portals (4259 1558), an irregular contact with the granite is well exposed, with little visible alteration of the tuffs. The tuffs are fairly uniform fine ash to coarse ash lapilli- and block-bearing crystal tuffs with no sign of stratification. Nearby, the tuffs have been intruded by quartz syenite and in turn by the main granite pluton.

On the hill summit at Lei Yue Mun Fort (4225 1488), pyroclastic breccia is present, interlayered with fine to coarse ash tuff bands apparently dipping eastward at about 10°. Angular to sub-rounded lithic blocks up to 1.5 m across are common and lie on an irregular load-casted tuff surface. A similar breccia crops out on the hill top 400 m to the west (4180 1488), above Aldrich Village. Here, the breccia layer is roughly horizontal and forms a flat capping to the hill. Block-bearing tuff is present in cuttings (4252 1528) east of the old fort, and this may be equivalent to the breccia on the hill summit. Southwards, along this cut slope, the tuff becomes coarser until a considerable thickness of coarse ash tuff is exposed (4267 1491). In thin section (HK 2949) the crystal matrix is fine but abundant plagioclase and quartz crystals averaging 1 mm are present, with some of the plagioclase showing distinct zoning. Chlorite and iron oxide patches are common in the matrix. Similar dark purplish grey fine ash to coarse ash tuff has been exposed in excavations for the new Eastern Hospital (e.g. 4240 1453), where scattered black aphanitic lapilli are also present (Plate 10). On this site (4246 1462) volcaniclastic rocks, consisting of laminated, brown and grey, mudstone and tuffite have been noted in temporary exposures (Plate 11). These display graded-bedding and appear to dip northeast at 35°. Some 50 m to the north, the volcanics have been cut by a 50 to 100 m wide quartz syenite dyke, and within 3 m of the contact the tuffs have been bleached light grey and are closely jointed. On the northern slopes of Mount Parker (4086 1451) a layer of light brown, tuffaceous sandstone and siltstone crops out but is laterally impersistent. The surrounding rocks are fine ash tuffs weathered to light grey. Dark grey coarse ash tuffs form the hill summit at the western radar station (4085 1432).

In the vicinity of Hing Wah Estate, Chai Wan, there are exposures of fresh, dark grey to black, lapilli-bearing fine ash vitric tuffs in roadside cuttings (4208 1359). A thin section (HK 2926) shows a welded, faintly eutaxitic fabric present in the fine ash tuff. Scattered quartz, microperthite and plagioclase crystals are also present, with some flow structure in the matrix visible around the larger crystals. Some 150 m farther west-northwest, across a major fault line, the tuffs are highly altered close to the granite. In thin section (HK 2924, 4193 1361) the rock has a recrystallized matrix consisting of equigranular quartz and muscovite grains averaging 0.5 mm.

Plate 11 – Contorted Mudstone and Tuffite in Shing Mun Formation, Chai Wan (4246 1462)

Siu Chai Wan to Big Wave Bay. New excavations at Siu Chai Wan (HK 578, 4361 1391) have revealed bluish grey fine to coarse ash welded tuff with abundant subhedral, often corroded, plagioclase crystals 1 to 2 mm in length, and more altered microperthite crystals, 2 to 3 mm across. On slopes forming the eastern side of Siu Chai Wan (4413 1385) scattered dark-grey lava lapilli stand out on the white weathering tuff surface. Southwards to Cape Collinson Training Centre these tuffs are bluish black when fresh and are well exposed along the Cape Collinson Road. There (e.g. 4421 1301), a black tuff with a very fine matrix contains abundant angular to sub-angular black aphanite lapilli up to 40 mm across (see also Plate 10). In the road cutting 120 m north of the Training Centre gate (4420 1260) the lapilli become so abundant that the rock becomes a lapilli tuff. In thin section many of these tuffs show evidence of welding. In particular, HK 3311 (4422 1270) shows a streaky parataxitic fabric; in thin section the vitric matrix is very fine, but abundant 0.5 to 1 mm quartz crystals are present. Sample HK3314 (4402 1308) is a welded tuff that contains large angular lapilli of parataxitic banded tuff.

A strong feature-forming welded tuff layer can be traced across Pottinger Peak, and dips steeply towards the south (4385 1279). At this location large boulders of welded tuff, many displaying a crude eutaxitic fabric, are strewn along the ridge. A similar, roughly horizontal layer of eutaxite forms a scarp along the catchwater east of the cemetery (4314 1367), but appears impersistent. Along the catchwater that skirts Mount Collinson a thick band of coarse ash tuff forms a strong feature striking NW–SE (4277 1257). 200 m farther southwest along this catchwater, greenish grey fine ash tuffs of the Ap Lei Chau Formation crop out.

Between Cape Collinson Training Centre (4416 1250) and Big Wave Bay (4362 1197) the volcanics are very variable, with layers of eutaxite typical of the Ap Lei Chau Formation interlayered with fine ash to coarse ash lapilli and block-bearing crystal tuffs more characteristic of the Shing Mun Formation. Large sub-rounded blocks of aphanitic lava up to 3 m across are enclosed by variable tuff. Occasional very fine chert lenses, 3 to 4 m in length, are also present (4364 1194). Abundant lithic fragments are found in the fine ash to coarse ash tuffs at the southern end of Tso Tui Wan (4386 1212), and in places the rock becomes a polymictic tuff-breccia. On the southern side of Big Wave Bay fine ash vitric tuffs and thick eutaxite layers typical of the Ap Lei Chau Formation are present.

Ap Lei Chau Formation

Stratigraphy

The type locality of the Ap Lei Chau Formation is the southwestern foreshore of Ap Lei Chau, near Aberdeen, where there are excellent exposures mainly of welded tuffs with prominent eutaxitic banding. Although the formation is characterized by fine ash vitric tuffs (Plate 12) with interlayered eutaxite bands, there are also tuff-breccias, pyroclastic breccias, tuffites and coarse ash tuffs, as well as thin lavas and epiclastic debris occurring as impersistent layers in many parts of the sequence. The present survey found that Allen & Stephens' (1971) type locality of the Repulse Bay Formation between Repulse Bay and South Bay clearly falls within the Ap Lei Chau Formation.

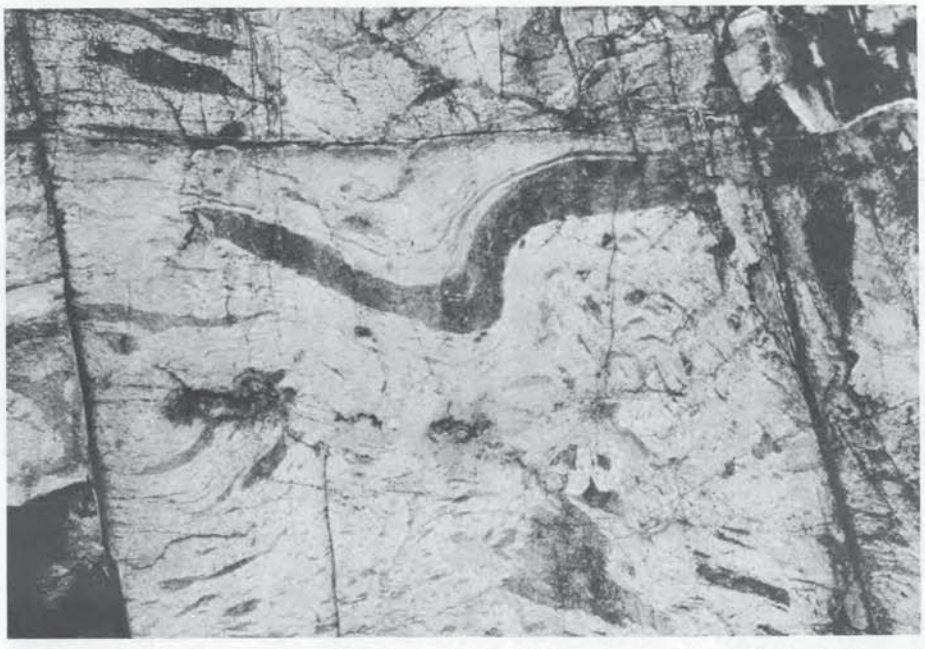


Plate 12 – Eutaxite, Displaying Flow-fabric, in Ap Lei Chau Formation at Ap Lei Chau (3400 1075)

The Ap Lei Chau Formation crops out over a wide area of Hong Kong Island and to the east of Kowloon in the vicinity of Junk Bay, where a maximum calculated thickness of almost 2 000 m is reached. There is no clearly defined boundary between the Shing Mun and Ap Lei Chau formations, and an arbitrary line has been taken where, in upward sequence, the dominant lithology becomes a persistent uniform fine ash vitric tuff. The top of the formation has been drawn at the base of the massive, uniform, coarse ash tuff (Tai Mo Shan Formation).

Much of the formation is considered to be welded tuff interlayered with distinctive pyroclastic flow deposits called eutaxites, which contain fiamme; flattened and stretched, pumice and lithic fragments (Plates 4, 5 & 6). Fritsch and Reiss (in Ross & Smith, 1961) first used the term Eutaxite in 1868 to describe such pyroclastic flow deposits from Tenerife. In these rocks the prominent eutaxitic fabric may be stretched out to the point when it becomes a parataxitic structure, that is it consists of finely colour-banded, streaky layers. With dense welding of the tuffs, all grain boundaries disappear and a new glassy matrix is formed. Later devitrification of this groundmass produces a homogeneous fine ash tuff with no visible evidence of welding, even in thin section. Slender vitric shards are occasionally found in these rocks; the shards are broken fragments of walls of tiny bubbles developed by vesiculation of silicic magma (Fisher & Schmincke, 1984). The eutaxitic fabric provides a guide to the attitude of the strata, but care should be taken as such fabrics can become contorted, by viscous flow, so a number of measurements are necessary to determine structural attitudes.

Details

East Kowloon, Ho Chung and Junk Bay. The Ap Lei Chau Formation occupies a wide area to the east of Fei Ngo Shan and Anderson Road. The Shing Mun Formation seen along Fei Ngo Shan Road passes imperceptibly upwards into a thick sequence of fine ash vitric tuffs that weather homogeneously to a white rock containing scattered dark aphanitic lapilli. To the east of the Pak Kung Au – Ho Chung valley (4185 2385) the strata dip fairly consistently to the east, and impersistent, feature-forming eutaxite layers produce north-south striking ridges, well seen on Tsim Fung Shan. There (4268 2239) the eutaxite is a dark greyish blue fine ash vitric tuff containing abundant flattened pumice lapilli, and fiamme are commonly visible in hand specimen. The thin section (HK 1215, Plate 6) shows the fiamme clearly and also the characteristic, slender, wispy glass shards. The matrix is extremely fine and is most probably devitrified glass debris. Angular to sub-rounded quartz crystals, 0.5 to 1 mm across, are common, and there are occasional altered microperthite and plagioclase crystals. Wavy flow patterns in the matrix around the larger crystals show stronger compaction near the crystal edges. HK 1216 (4287 2286) in thin section shows less prominent flow structures but a welding compaction fabric is faintly visible. More abundant crystals of quartz and microperthite, averaging 0.4 to 0.6 mm, are present in this sample. Nearby (4297 2292), a 15 m thick monomictic pyroclastic breccia crops out and forms a discontinuous feature extending for about 200 m diagonally across the ridge. The breccia consists of angular ot sub-rounded lava blocks 0.2 to 1.5 m across. A similar breccia crops out at Nam Wai (4450 2364), enclosed by eutaxite. Abundant pyrite is scattered throughout the eutaxite and breccia matrix.

The thickest eutaxite layer and strongest associated topographic feature in the area strikes north-northwest along Razor Hill. Eutaxite blocks are present along the ridge crest but natural rock exposure is poor. The feature is broken and displaced by several faults (4440 2161 & 4448 2152) but can still be traced over a distance of at least 2.5 km. In the cuttings along Clear Water Bay Road, 400 m northeast of Pik Uk Prison (4378 2266), the rock is very hard, brittle and black in colour. No eutaxitic fabric was discernible in fresh outcrop but the thin section (HK 1199, 4378 2266) clearly possesses a welded fabric in the very fine vitric groundmass. Larger quartz crystals, 0.5 to 1 mm across, are angular to sub-rounded and unaltered.

White, fine-grained sandstone is exposed in roadside cuttings on Hiram's Highway (4423 2325). This epiclastic layer is about 25 m thick, with several metres of pale cream siltstone present in the lower part.

The tuffs are well exposed in the upper levels of the Anderson Road Quarries near Tai Sheung Tok (4273 2036), where they have been intensely baked close to the irregular granite contact. Small scattered lapilli are visible but the matrix has been completely recrystallized within 30 m of the contact. A prominent eutaxite band crosses Tai Sheung Tok (4251 2069) and, in thin section (HK 1211, 4263 2056), its eutaxitic fabric is very clear. Quartz and alkali feldspar are present as larger crystals, 0.4 to 0.7 mm across, and smaller plagioclase grains are scattered throughout. The collapse of porous pumice has formed dense, glassy fiamme. Minute quartz veinlets cut the rock and probably originate from the nearby granite, but no thermal metamorphism is apparent.

East of Anderson Road and Ma Yau Tong (4322 2017), fine ash vitric tuff with scattered crystals and lapilli predominates, with discontinuous north-south striking eutaxite bands forming characteristic ridge features. At Ma Wu Tsai the eutaxite has a prominent flow fabric dipping variably to the east. In thin section (HK 1473, 4400 1951), black glassy fiamme are present and roughly parallel to a faint flow fabric that waves around the randomly scattered, 0.75 to 1.25 mm quartz crystals. On the coast 500 m to the east (4447 1928) a roughly horizontal polymictic, matrix-supported breccia is exposed. Nearby (4454 1942), chert lenses several metres in length occur within crystal-bearing fine ash tuff, which contains scattered rounded bombs with tails up to 0.45 m in length. Near the foundry (4445 1991) an exposure of breccia with clasts 20 mm to 0.2 m across is interlayered with fine ash tuff. Across Junk Bay (4494 2043) a similar rock passes laterally southeastwards into a thick pyroclastic breccia (Sheet 12).

South of Rennie's Mill (4410 1760), crystal-bearing fine ash vitric tuffs are exposed in the coastal sections where occasional larger lapilli and blocks were noted. Some rounded blocks, with tails, are visible in coastal exposures 1 km south of Rennie's Mill (4413 1756), and these are probably volcanic bombs.

Mount Parker to Shek O. Crystal-bearing fine ash vitric tuff crops out on the hill 300 m southwest of the Mount Parker western radar station (4065 1400). The strata are fairly flat-lying in this area. A series of eutaxite bands form strong features around the southerly part of the hill, with distinctive crags of eutaxite at 4082 1356. Several eutaxite bands contain pyroclastic breccia and tuff-breccia horizons, similar to the pyroclastic breccias enclosed by eutaxite in the northeast of the district at Ho Chung. It is possible these blocks have been transported by the pyroclastic flow; Fisher & Schmincke (1984) cited several examples of this phenomenon. Between the strong eutaxite features, fine ash vitric tuff predominates, often with abundant aphanitic lithic lapilli. These lapilli are locally concentrated, and the rock appears almost a breccia, as for example along the catchwater, 550 m northwest of Boa Vista (4067 1318). Southwards to Mount Collinson, crystal-bearing fine ash tuff is present over a wide area. A discontinuous eutaxite layer crops out at Mount Collinson (4229 1247). Road cuttings along the Tai Tam and Shek O roads contain excellent exposures of lapilli-bearing fine ash vitric tuff. These are black when fresh but have a characteristic greenish grey colour where slightly weathered, and white where moderately to highly weathered. The lapilli content appears to increase towards the D'Aguilar Peninsula.

Along the coast south of Big Wave Bay, variably dipping eutaxite is interlayered with homogeneous fine ash tuff. Inland it has not been possible to trace the eutaxite bands beyond a north-south fault (4339 1163). The contact with the granite is exposed in the road cutting east of Ngan Hang Village (4272 1012), where it dips 50° to the north.

Tai Tam, Repulse Bay and Stanley. Apart from a capping of eutaxite on the summit of Violet Hill (3846 1228), much of the area of volcanic rocks cropping out in the Tai Tam Country Park consists of homogeneous fine ash tuff displaying little variation between exposures. A roughly horizontal fine-grained sandstone band about 15 m thick skirts the hill 500 m southeast of Wong Nai Chung Gap (3833 1272). The thin section of this sandstone (HK 3531) shows that considerable thermal metamorphism has taken place, with abundant muscovite and recrystallised quartz present.

Between Repulse Bay and Tai Tam Tuk Reservoir the Ap Lei Chau Formation displays a monotonous lithology of crystal-bearing fine ash vitric tuff with varying amounts of lithic lapilli scattered through the rock. In thin section most samples show a very fine vitric matrix with a faint welding fabric and containing a scatter of 0.5 to 1.5 mm crystals. These are usually subangular quartz grains, but smaller plagioclase and iron oxide grains may be present.

On Red Hill (4150 1075) the tuffs are welded, but lack the large-scale eutaxitic fabric. Sample HK 3643 (4129 1090) is packed with welded glass shards and a good compaction fabric is seen under plain light. In polarised light the shardic fabric is less clear, but much of the glassy material is seen to be devitrified. Other nearby samples, for example HK 3644 (4116 1058), show a similar lithology and fabric. In hand specimen and outcrop, however, these rocks appear as fairly uniform, crystal-bearing fine ash tuff without any visible evidence of welding.

A thick development of eutaxite crops out around Ma Hang Shan (4000 1000), dipping gently to the northeast. Lower down the hill, towards Stanley, another eutaxite layer some 40 m thick roughly follows the Stanley Gap Road (3922 0957), where there are good exposures in roadside cuttings. A gentle anticlinal fold crosses the Chung Hom Kok Service Reservoir hill, and the feature-forming eutaxite is exposed in the nearby road cutting (3903 0950). This can be traced northwestwards to the coast between South Bay and Middle Bay (3838 1007). On Tau Chau, fine ash tuffs are interlayered with fine-grained sandstone (3775 0954) and a breccia containing abundant chert fragments in a glassy matrix (3790 0953). From the tip of the peninsula opposite Tau Chau, as far east as South Bay beach, quartzphyric rhyolite has been noted. Near the point (3803 0950), flow-banding is visible, but it has not been possible to determine whether the rhyolite is extrusive or intrusive. Allen & Stephens (1971) referred to this area as rhyolite lava in the text but it is not delineated as such on their map. This is the southernmost part of their Repulse Bay Formation type section, which extends northwards along the coast to Repulse Bay beach (3850 1062). North of South Bay beach (3831 0950), fine ash tuffs predominate, but several prominent eutaxite bands are present around Middle Bay. Although there are grain size variations in the tuffs at several localities, the entire section falls clearly into the Ap Lei Chau Formation.

Deep Water Bay, Middle Island and Ocean Park. On Middle Island and the neighbouring coastline at the eastern end of Deep water Bay, excellent exposures of eutaxite are found in the cliffs. On the southern coastline of Middle Island (3714 1041), the eutaxite contains large, partially flattened vesicular pumiceous blocks that are less compressed than is usual in these deposits (Plate 13). Fine ash vitric tuffs are interlayered with the eutaxite to the west of Deep Water Bay beach, and these are intruded by a small body of quartz syenite near the Victoria Recreational Club (3717 1186).

Along the coast immediately to the southeast of the main Ocean Park development (3643 1167), fine ash tuff contains coarse ash lenses 0.2 to 0.3 m thick and 0.5 to 1.5 m long. The tuff is locally brecciated. Mudstone crops out nearby (3645 1168), and extends inland where old clay workings in this layer (3626 1184) are now part of the ornamental ponds of Ocean Park. This was the site of the Green Island Brick and Tile Works

described by Davis (1952), who considered the clay deposit to be part of the Tolo Formation occurring as a large inclusion in the volcanics. It seems certain, however, that the mudstone is simply an epiclastic lens within the tuffs.

On Brick Hill and southwards to the peninsula at Sham Shui Kok (3580 1020), eutaxite predominates. Numerous exposures along Nam Long Shan Road and at the peninsula end of Ocean Park display excellent eutaxitic structures, and a series of roughly east-west striking anticlines and synclines has been recognised. The road skirting the coast from Po Chung Wan to Tai Shue Wan provides good sections through the folded, predominantly eutaxite sequence. Intercalations of uniform, lapilli-bearing coarse ash tuff (3505 1108) and a tuff-breccia (3507 1091) are associated with a welded fine ash vitric tuff that lacks a eutaxitic fabric.

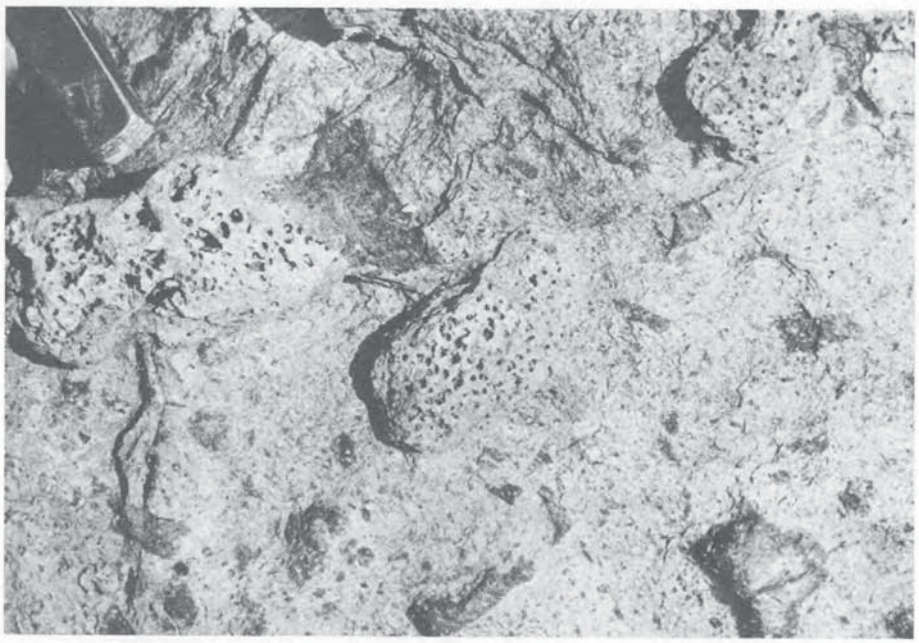


Plate 13 – Pumice Blocks within Eutaxite in Ap Lei Chau Formation on Middle Island, Deep Water Bay (3714 1041)

Ap Lei Chau. This island provides the type locality of the Ap Lei Chau Formation, with excellent exposures along the southwestern coastline and on the eastern coastline.

On the coast west of Yuk Kwai Shan (3400 1075) the eutaxite is well exposed in the cliffs, with the weathered surface of the rock showing the strong colour contrast between the fiamme and flattened discontinuous blocks and the vitric tuff matrix (Plate 12). The pumice fragments have been flattened, stretched out and often contorted by the pyroclastic flow process. The darker areas are completely collapsed pumice fragments, but occasional unflattened non-pumice lithic lapilli are present. Nearby (3393 1084), tuff-breccia 50 to 70 m thick occupies the core of a syncline. All the blocks are of sub-angular pumice averaging 0.5 m across, but with occasional blocks up to 2 m across set haphazardly in a coarse ash matrix.

Around much of southern Ap Lei Chau, Ap Lei Pai and the small islands of Fo Yeuk Chau (3254 1165) and Lung Shan Pai (3283 1134), eutaxite predominates. Along the eastern shoreline of Ap Lei Chau a fine-grained, pink to brown sandstone, approximately 25 m in thickness, underlies a thick eutaxite development (3460 1108), and is in turn underlain by about 10 m of uniform coarse ash tuff containing scattered dark aphanitic lithic lapilli (3462 1108). Discontinuous sandstone and mudstone layers have been exposed during the excavations for the new Housing Authority estate (3405 1138). In Ap Lei Chau Bridge Road (3396 1154) a fine-grained sandstone grading upwards into mudstone forms a 5 m thick unit within fine ash tuff. In the fresh rock cuttings at the new housing estate (3389 1132), and in the road cuttings near the oil depot (3335 1139), the eutaxite is fresh and dark bluish black with little or no sign of the eutaxitic fabric seen so clearly on weathered surfaces.

Victoria Peak to Aberdeen, Mount Cameron and Mount Nicholson. The Ap Lei Chau Formation crops out over a wide area of western Hong Kong Island. The strata consists predominantly of crystal-bearing fine ash vitric tuff with interlayered eutaxite bands, folded into a series of northwest-trending anticlines and synclines. The eutaxite forms strong positive topographic features, for example High West and Mount Kellett.

In the vicinity of Victoria Peak the tuffs and minor sediments have been thermally metamorphosed by the Kowloon – Hong Kong granite pluton. Eutaxite is present as an impersistent layer on the summit of the Peak at the radio station (3299 1522). Nearby, fine-grained sandstone forms a strong ridge feature striking NW–SE (3312 1512). Between the Peak and Pok Fu Lam the alternating eutaxite and fine ash tuff sequence is repeated at outcrop by the folding. Tai Mo Shan Formation coarse ash tuffs occupy the synclinal core extending from the col between High West and Victoria Peak (3252 1500), southeastwards to Aberdeen (3545 1222). The transition to the dominantly coarse ash tuff of the Tai Mo Shan Formation is obscured by superficial deposits in the valleys to the northeast of Pok Fu Lam Reservoir. The thickest eutaxite development extends from High West to Aberdeen, and crops out on both limbs of the anticline. On the eastern limb it is well exposed in the Mount Kellett area, where it has been described in detail by Workman (1985). Here, the eutaxitic structure is displayed in the road cuttings near Matilda Hospital (3340 1345), where some fiamme are so stretched out that the texture is parataxitic. The rock is extremely hard and brittle when fresh. On the western limb of the anticline on the southern side of Pok Fu Lam Reservoir the eutaxite outcrop was mapped by Allen & Stephens (1971) as a rhyolite lava. Although spherulitic in part (HK 2435, 3235 1406), the eutaxitic fabric and lapilli fragments present suggest it is a pyroclastic flow deposit. No lava has been recognised in the present survey of the Ap Lei Chau Formation on Hong Kong Island. Coarse ash tuffs and thin lenticular mudstone layers (3260 1246, 3277 1228) were seen in cuttings along Shek Pai Wan Road, and a finely laminated volcaniclastic mudstone was noted along the catchwater north of Tin Wan Estate (3339 1274), where it appears to occupy a channel a few metres wide cut into fine ash tuff.

In the vicinity of Mount Gough, eutaxite layers become laterally impersistent, and homogeneous fine ash vitric tuff containing scattered dark aphanitic lapilli is dominant. Within the Aberdeen Country Park, to the south of Magazine Gap, a number of eutaxite bands form strong features, displaced by faulting. Such eutaxites are seen on Mount Cameron (3610 1371), with a prominent eutaxitic fabric dipping steeply to the west. A similar eutaxite band forms the sharp ridge feature striking southeastwards from near Wan Chai Gap (3600 1420) to Middle Gap (3625 1376). This layer can be traced to the east of Middle Gap, striking eastwards across the summit of Mount Nicholson (3720 1340).

Cut slopes to the north of the Wong Chuk Hang factory area, around Tong Bin Lane (3534 1236), have exposed fresh, homogeneous fine ash vitric tuff which, in thin section (HK 2479, 3534 1236), is seen to have a welded fabric. The matrix is devitrified glass, and contains scattered angular to sub-angular quartz crystals averaging 1 mm.

Tai Mo Shan Formation

Stratigraphy

Brock & Schofield (1926) and Uglow (1926) named the Tai Mo Shan Formation as a division within their Repulse Bay Volcanics, but considered it to be an intrusive porphyry. Ruxton (1960) concluded it was not an intrusive rock and Allen & Stephens (1971) mapped the rock as coarse tuff. Addison (1986) has defined the Tai Mo Shan Formation with the type locality in the vicinity of Tai Mo Shan (Sheet 7), where it overlies a thin development of the Ap Lei Chau Formation.

On Hong Kong Island the Tai Mo Shan Formation is present, occupying the core of a syncline extending from Wong Chuk Hang and Aberdeen northwestwards to near Victoria Peak, and also cropping out over a wide area north of a major east-northeast striking fault, between Green Island (Figure 8), Mount Davis and Hong Kong University. In the northeast corner of the district, the formation is present in the Ho Chung Valley, but exposure is poor due to a widespread cover of superficial deposits.

The rock is essentially a coarse ash crystal tuff which displays a remarkable uniformity throughout the outcrops (Plate 7). Occasional scattered lapilli are present, and these aphanitic fragments often show a degree of flattening. Close examination with a hand lens reveals signs of welding (usually black glassy shards and fiamme) and in thin section, welding fabric is common. The abundant quartz crystals are usually stained brown, and can reach 3 mm. Biotite is often present, scattered as single flakes in the matrix (Plate 8). When weathered the coarse ash tuff often resembles a weathered fine-grained granite, with which it has often been misidentified, particularly in site investigations on western Hong Kong Island.

Epiclastic layers appear to be a common characteristic of the formation in this district. These take the form of sandstone lenses up to 25 m in thickness, extending laterally for 100 to 300 m. They are prevalent in the vicinity of Mount Davis, on Green Island and near Belcher's Street, Kennedy Town. In the latter two localities the sandstone has been particularly susceptible to

thermal metamorphism, and abundant muscovite is scattered throughout the rock. Away from the granite contact the sandstone is fine-grained and light yellowish brown, and in places displays evidence of current-bedding.

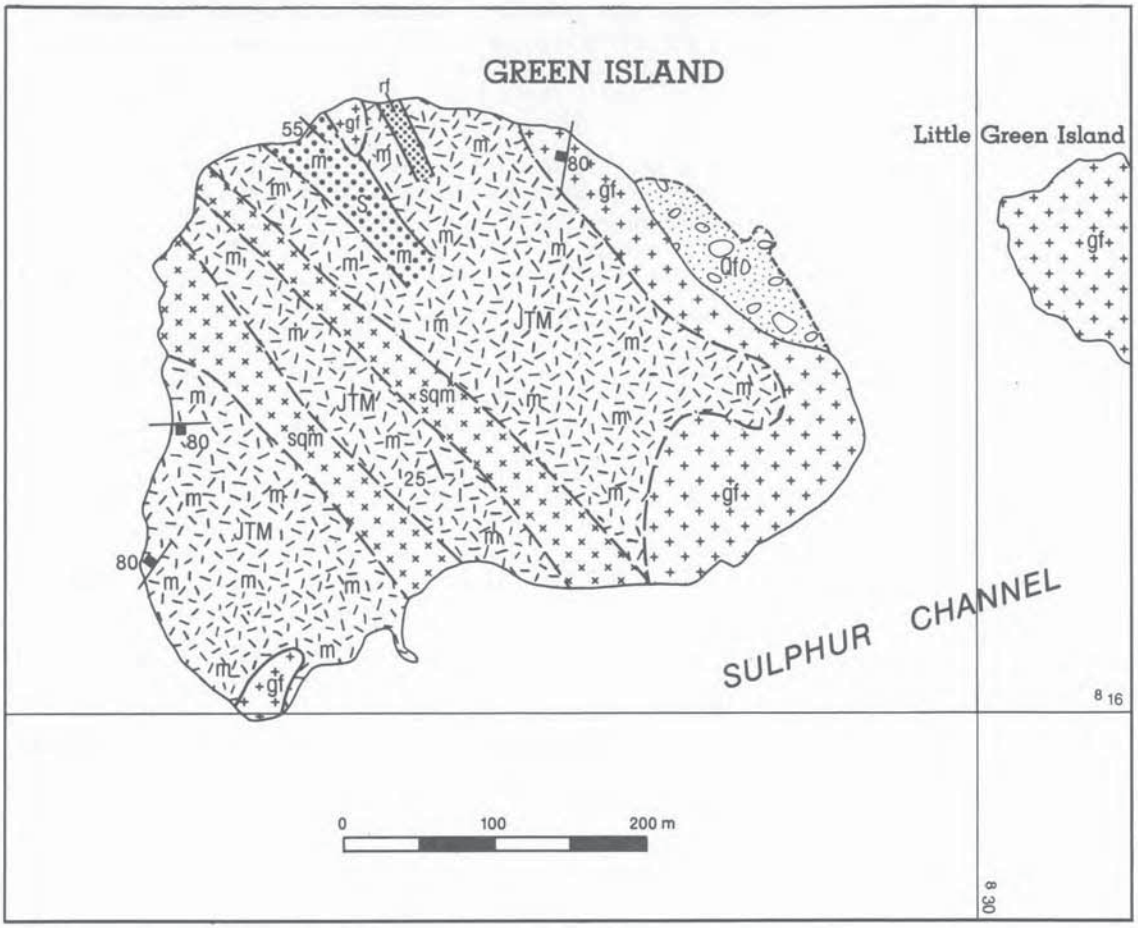


Figure 8 – Geological Map of Green Island (Sheet 10)

Details

Ho Chung Valley. In the stream courses of the Ho Chung Valley there are isolated exposures of massive, uniform coarse ash crystal tuff which, at Yuen Ling (4333 2393), have been intruded by fine-grained granite. When fresh the tuff is dark grey with abundant biotite, and contains occasional flattened lithic fragments.

Western Hong Kong Island. The Tai Mo Shan Formation occurs as an isolated faulted block of coarse ash crystal tuff immediately to the east of the Wong Chuk Hang Housing Estate (3550 1205). At the western end of the Wong Chuk Hang Industrial Estate (3454 1222) the formation is exposed in roadside cuttings and can be traced northwestwards through the Shek Pai Wan Estate, occupying the core of the north-west striking syncline. Here (HK 2472, 3435 1250, Plate 8), the rock is dark grey, massive coarse ash tuff, containing occasional dark streaks of flattened pumice, and scattered black, subangular, aphanitic lapilli. Nearby (3427 1215), the coarse ash tuff passes abruptly downwards into eutaxitic structured rocks of the Ap Lei Chau Formation.

The syncline can be traced northwestwards through the Aberdeen Country Park, and coarse ash tuff again crops out between Mount Kellett and Peak Road (3360 1400), with very fresh uniform, dark bluish grey coarse ash tuff exposed in small cuttings along Mount Kellett Road (3363 1404). In the headwaters of the Pok Fu Lam Reservoir valley, isolated exposures of coarse ash tuff are highly weathered. In the col between High West and Victoria Peak (3237 1493) similar uniform coarse ash tuff prevails. Coarse ash tuff is exposed along the coastline between Telegraph Bay and Sandy Bay, dipping towards the west (3100 1395). In this area an arbitrary boundary with the Ap Lei Chau Formation has been drawn due to lack of exposure.

An extensive outcrop of Tai Mo Shan Formation occurs to the north of a major fault that extends east-northeastwards from Sandy Bay to the Mid-levels. The formation also occurs on nearby Green Island (Figure 8). The rocks are predominantly coarse ash crystal tuff, as exposed in the extensive cut slopes behind the Mount Davis High Level Service Reservoir (3076 1506). They are dark grey when fresh, with biotite flakes visible in the matrix. Quartz and feldspar crystals up to 3 mm are common, but average around 1 to 1.5 mm. Lithic lapilli fragments and small blocks are occasionally present. In thin section (HK 2856, 3098 1502) the crystals are subangular to sub-rounded, and set in a very fine but subordinate matrix. Nearby, exposures in Mount Davis Road (3081 1490) and Victoria Road (3087 1485) have revealed an almost vertical, white quartzitic sandstone layer which, in thin section (HK 2227, 3088 1486), is seen to be completely recrystallised. Near the summit of Mount Davis, four impersistent light yellowish brown micaceous sandstone bands have been mapped. Similar sandstone, thermally metamorphosed near the granite contact, is well exposed on the northern side of Green Island (2913 1767). Here the rock shows distinctive banding produced by preferential quartz recrystallisation along certain sedimentary layers.

A thick eutaxite layer, dipping westwards at 40 to 65°, appears to overlie the coarse ash tuff on the western flanks of Mount Davis. It is exposed in roadside cuttings at the junction of Mount Davis Road and Victoria Road (3017 1514), where a prominent parataxitic fabric is developed. The eutaxite is seen along the coast north of Sandy Bay, where it is thermally metamorphosed in the proximity of the granite. The small irregular granite intrusions exposed at Sandy Bay (3032 1481) may represent the roof of a much larger granite pluton.

Uniform, massive coarse ash tuff predominates in the Kennedy Town area, but, in Belcher's Street (3167 1627), sandstone is developed as a thick lens, up to 50 m in thickness and extending southwards over a distance of 400 m. Sandstone, dipping eastwards at 75° and part of the same horizon, is exposed in roadside cuttings along Pok Fu Lam Road (3174 1607). These light yellowish brown sandstone lenses have been thermally metamorphosed by the Kowloon-Hong Kong granite pluton, and contain abundant muscovite mica.

Between Pok Fu Lam Road (3155 1558) and the Hill Above Belcher's (3195 1565), weathered fine ash tuff alternates with coarse ash tuff, and on the summit (3196 1565) the tuff has been intruded by a 30 to 50 m wide feldsparphyric rhyolite dyke.

Depositional Environment of the Repulse Bay Volcanic Group

The Yim Tin Tsai Formation is remarkably uniform throughout its outcrop and was most likely deposited from large volume incandescent ash flows. No possible vents or sources for this tuff have been identified. The Shing Mun Formation is extremely variable, with ash flow and air fall tuffs associated with block-bearing deposits. As with the Yim Tin Tsai Formation, no vent or fissures have been located, but, from the large size of many blocks and bombs, the source is considered to have been within a few kilometres, possibly in an area now occupied by granite intrusions, such as, for example, central Kowloon. Addison (1986) suggested that some of the Shing Mun Formation may be laharic debris flow deposits. Epiclastic layers within the Shing Mun Formation indicate water-lain deposition in fluvial or lacustrine environment. However, no fossils were found in these rocks.

The Ap Lei Chau Formation is distinguished by the thick layers of welded tuff laid down from large volume incandescent flows. These fine ash vitric tuffs characteristically display eutaxitic flow fabrics, but it has not proved possible to determine any direction of origin for these flows. Such flows might have travelled many tens of kilometres. A possible source is the Pyramid Hill area of the Sha Tin district, where Addison (1986) recognized a large body of flow-banded intrusive rhyolite that forms a plug-like mass at least 300 m high.

The Tai Mo Shan Formation was probably deposited in a manner similar to the Ap Lei Chau welded tuffs, possibly from a separate fissure or vent. The uniform coarse ash tuff commonly displays evidence of welding, but there are a number of intercalated sedimentary layers, suggesting quiet periods allowing water-lain deposits to accumulate in hollows or along stream channels.

Chapter 4
Major Intrusions

Classification

The major intrusions described in this chapter are the granodiorite, the quartz syenite and the granites. The nomenclature of the granitoid rocks used by Allen & Stephens (1971) was based on the system proposed by Streckeisen, whose updated nomenclature (Streckeisen, 1974) has been adopted here for the principal rock types (Figure 9). However, the classification devised by Allen & Stephens, consisting of twelve named units defined partly by lithology and partly by mutual age relationships, has not stood the test of the detailed remapping and has not been adopted in this survey.

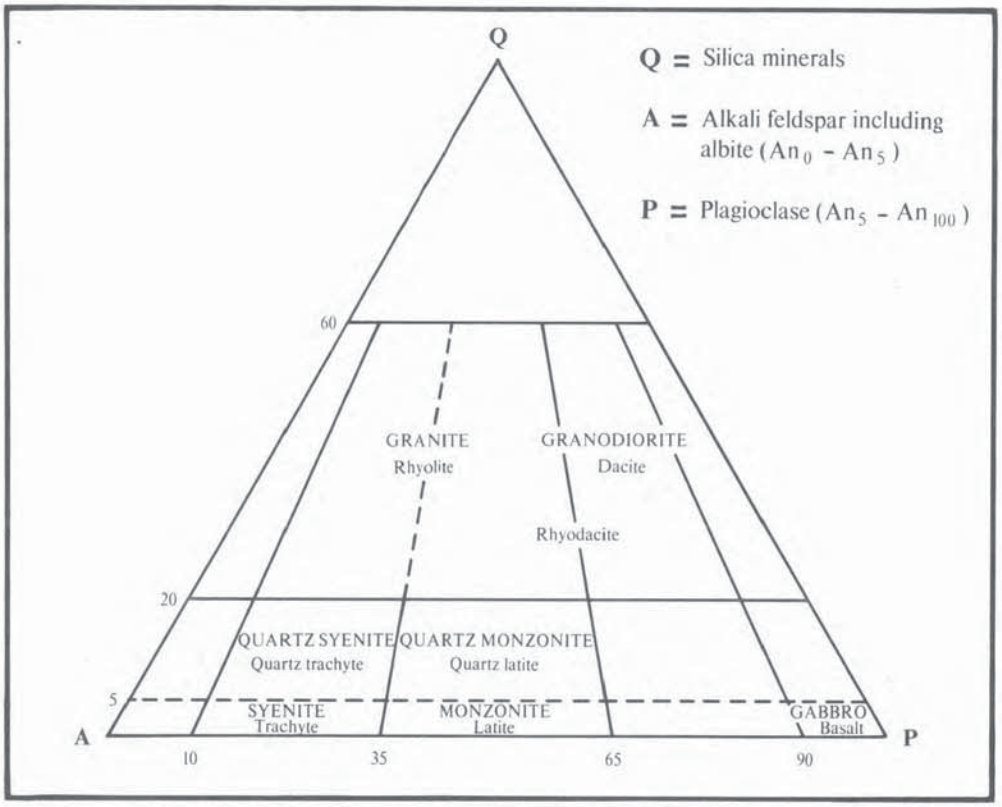


Figure 9 – General Classification and Nomenclature of Major and Minor Intrusive Rocks (after Streckeisen, 1974)

Allen & Stephens recognized four phases of granitoid intrusion forming a single episode of late tectonic intrusive activity of Upper Jurassic to Lower Cretaceous age. For most units a geographical name and a rock name were combined, for example, Sung Kong Granite; the rock unit so named being regarded as a stratigraphic unit. The present survey has found this system to be impractical because many of the named granites are similar both lithologically, in hand specimen and thin section, and chemically. For example, some specimens of Allen & Stephens' Cheung Chau Granite and Hong Kong Granite appear to be identical in all respects.

The field criteria used by Allen & Stephens for separating their named granites have not proved wholly satisfactory; for instance, the principal criterion for distinguishing Cheung Chau Granite from Hong Kong Granite was the respective presence or absence of 'porphyry dykes'. Thus they found it necessary to draw an arbitrary line across northeastern Kowloon, separating a medium-grained granite cut by these dykes from an identical granite that contained no dykes. The resurvey of this area has found these dykes present in both of their mapped units.

The revised classification of the granites (Strange, 1985) centres primarily on grain size (Table 3). An estimation of the average grain size of the principal mineral types in the rock groundmass allows the placing of most granites of the Territory into one of the three main classes; fine-, medium- and coarse-grained granites. Where the grain size clearly straddles a class boundary, a hybrid term is used, for example, fine-to medium-grained granite. There are no internationally accepted grain size categories for the granitic rocks, but a compromise between the divisions commonly used in engineering practice, namely 0.06, 2 and 6 mm (BSI, 1981), and the boundaries used by Allen & Stephens (1971), namely 1 and 5 mm, has been adopted by this survey.

Where megacrystic or porphyritic textures are distinctive mappable features of the rock, they are shown by overprints on the published 1:20 000 map sheets.

Table 3 – Grain Size Classification of Granitic Rocks (after Strange, 1985)

Grain Size	*Rock Name*
> 20 mm	*Very coarse-grained (pegmatitic) granite*
6 to 20 mm	*Coarse-grained granite*
2 to 6 mm	*Medium-grained granite*
0.06 to 2 mm	*Fine-grained granite*
<0.06 mm	*Rhyolite*

Granodiorite

Distribution and Lithology

Outcrops of granodiorite delineated in this survey conform approximately with those mapped by Allen & Stephens (1971) as the Tai Po Granodiorite. The main outcrops are in central Lamma Island, on Round Island, Stanley Peninsula and Cape D'Aguilar. Exposure is generally poor and, even on coastlines, granodiorite boulders are usually the only indication of insitu rock nearby.

The granodiorite includes both fine- and medium- and coarse-grained varieties but, because of limited exposure, it has not been feasible to distinguish these on the map. The rock is composed of roughly equal amounts of light and dark coloured constituents (mesocratic), with abundant biotite scattered throughout the inequigranular groundmass (Plates 15 & 16). Occasional megacrysts of white feldspar occur and, as Allen & Stephens (1971) noted, a distinctive character is the presence of dark grey or green xenoliths. When weathered the granodiorite may easily be confused with coarse ash or lapilli tuff. In its completely weathered state it forms a thick, reddish brown soil.

Details

Round Island, Stanley Peninsula and Cape D'Aguilar. Exposures of fresh rock in these outcrops are seen only along the coastal cliffs. In every case, the granodiorite intrudes coarse ash crystal tuff of the Yim Tin Tsai Formation. The rock is mesocratic and commonly variable in grain size, ranging from fine- to coarse-grained. It is also megacrystic. The average grain size of the groundmass is between 1 and 2.5 mm, and microperthite feldspar megacrysts average 10 mm in length while some reach 25 mm. Quartz is fairly abundant as subrounded megacrysts 6–10 mm in diameter. Patches of fine felty biotite, as aggregations of minute laths, are ubiquitous in the groundmass and give the rock its dark colour. In thin section (HK4225, 4492 0775, Plate 16) the abundant biotite crystals are associated with light green amphibole and chlorite. Subhedral plagioclase includes zoned and altered crystals and forms an interlocking texture. Subhedral quartz grains fringe some of the larger microperthite megacrysts. The granodiorite contains conspicuous xenoliths of a dark, aphanitic rock, and blocks of coarse ash tuff up to 0.4 m across have been noted (3715 0835). At Wong Ma Kok Point (3995 0630) the granodiorite has a 0.25 m wide chilled margin against coarse ash tuff. Nearby, the rock is intruded by dykes of quartz syenite, basalt and quartzphyric rhyolite. On the northwestern part of the Stanley Peninsula (3990 0786), close to the granite pluton, small dykes of fine-grained granite intrude the granodiorite. Much of this western shoreline of Stanley Peninsula is covered by large boulders of granodiorite,

up to 5 m across, which generally conceal the bedrock. A distinctive feature of the granodiorite in the cliffs at Cape D'Aguilar is the presence of epidote, both as light green patches and as haphazard veins. Here, the granodiorite is cut by a number of quartzphyric rhyolite dykes, and by several smaller basalt dykes.

Lamma Island. Granodiorite boulders are abundant on the shore between Lo So Shing Beach (3060 0740) and Tit Sha Long Bay (3050 0772), but there are no exposures of fresh rock. On the nearby slopes vegetation is sparse and the soil is dark reddish-brown. In hand specimen the rock is medium-grained with grey quartz and feldspar crystals highlighted by abundant interstitial small black biotite crystals. The average grain size of feldspars and quartz is between 2 and 3 mm, and there are scattered alkali feldspar megacrysts to 10 mm in length. In thin section (HK3858, 3051 0744) subhedral hornblende is common, and present alongside fresh biotite. Plagioclase forms at least 80% of the total feldspars, and quartz makes up 25 to 30% of the rock. Inland from Lo So Shing the granodiorite is flanked by megacrystic, medium-grained, biotite-rich granite, similar in appearance to the granodiorite. It is possible that the two rocks may have been intruded penecontemporaneously, the granodiorite representing the calcium-rich fraction of the pluton.

Coarse-grained Granite

Distribution and Lithology

The coarse-grained granite approximately covers the area mapped by Allen & Stephens (1971) as Sung Kong Granite. It crops out in the northwest of the district between Lai Chi Kok and Beacon Hill; also on central and eastern Lamma Island and the Po Toi Island Group (Figure 10).

The coarse-grained granite of northwestern Kowloon and the Po Toi Island Group consists of an inequigranular rock with feldspar and quartz grains averaging 6 to 8 mm in length (Plates 17 & 18). Biotite is present, though commonly chloritised, and tends to occur as aggregations of minute crystals, creating the appearance of randomly scattered felted black blotches. Megacrysts are not prominent. In the coarse-grained granite on Lamma Island, however, euhedral megacrysts of alkali feldspar up to 40 mm long are common, set in a groundmass averaging 6 mm.

In places the granite displays a distinctive microcrystic texture, with interstitial patches of fine-grained granite. In hand specimen the fine material has diffuse margins and often appears to surround the larger alkali feldspar crystals, producing a texture in which the megacrysts are the sole remnants of the mother rock (Strange 1985), similar to the textural variants described by Cobbing et al (1986) in granites of the Southeast Asian Tin Belt.

Details

Northwestern Kowloon. Coarse-grained granite crops out in the northwest of the district, between Lai King, Lai Chi Kok, the Kowloon Reservoirs and Beacon Hill. Exposures of fresh rock are few but can be seen in recent excavations for housing estates and roads around Lai King (313 232) and Lai Yiu (315 236). There the granite is inequigranular, with average grain sizes of between 6 mm and 8 mm (Plate 17). Biotite, as chloritised blotches, makes up less than 3% of the rock. Around Ha Kwai Chung (312 235) east-northeast-trending dykes of rhyolite are common, and younger basalt dykes are also present. In places the rock is porphyritic, with randomly scattered euhedral alkali feldspars up to 20 mm. The coarse-grained granite is intruded by fine-grained granite in many places, with a very irregular contact well exposed in road cuttings at Lai Yiu Road (3161 2358) and Cho Yiu Chuen (3134 2327). In both cases the contacts are sharp, with small tongues of fine-grained granite intruding several metres into the coarse-grained rock. Around Byewash Reservoir (3337 2327) the coarse-grained granite is faulted against the fine-grained granite by the Lai Chi Kok – Tolo Channel Fault (Figure 15). Here, the coarse-grained granite is characterised by large quartz pools, pink alkali feldspars and very little visible biotite. Nearby at Piper's Hill (3347 2280), the coarse-grained granite is markedly inequigranular and displays distinctive interstitial fine-grained patches (Plate 18).

Between Piper's Hill (338 230) and Beacon Hill (356 234), fine-grained granite intrusions are common, and these form the topographic high points, for example, the summit of Beacon Hill (3558 2343). On the southern slopes of Beacon Hill (3534 2267), just north of Beacon Heights, the contact between the coarse-grained and the younger medium-grained granite is seen. Here, for several metres from the contact, the coarse-grained granite takes on a dark bluish grey appearance, with chlorite abundant. Smilar alteration is seen in the road cuttings at the Butterfly Valley – Castle Peak Road interchange (3258 2241), but there the rock has a distinctive pinkish brown colouration, similar to the coarse-grained granite around Amah Rock in the Sha Tin District which Addison (1986) regarded as a quartz-poor syenitic variety. It is probable that the widespread alteration of these rocks results from hydrothermal action in this heavily faulted area. Large isolated blocks (at least 5 m by 5 m) surrounded by younger medium-grained granite at Ching Cheung Road (3414 2264) and at Caritas Hospital (3381 2249) are probably xenoliths.

Lamma Island. Although there are patches of coarse-grained granite within the main mass of inequigranular medium-grained granite that crops out over much of central and northern Lamma Island, it has not been feasible to delineate them on the 1:20 000 scale map. The main outcrops of coarse-grained granite are found south and east of Mo Tat Wan, and at Yuen Kok in the southeast. Around Mo Tat Wan the coarse-grained granite has an average groundmass grain size of 6–7 mm, a distinctive grey colour, and is biotite-rich. The rock is similar in appearance to the mesocratic granodiorite, but contains much less plagioclase. Abundant euhedral alkali feldspar megacrysts averaging 15 mm in length are present, and these are highlighted by the

dark biotite-rich groundmass. Biotite is present as minute laths which tend to cluster to form distinctive black blotches up to 10 mm in diameter. Fine-grained basaltic xenoliths up to 1 m across are enclosed by the granite (3314 0694). Inland, it weathers deeply to form a dark reddish brown soil containing large rounded corestones. It has been intruded by fine- to medium-grained granite, the irregular contact being well exposed in the cliffs 500 m east of Yung Shue Ha (3317 0684, Plate 24). Basalt dykes intrude the granite nearby (3315 0693). At Yuen Kok (3318 0530) the coarse-grained granite has an average grain size of between 7 and 10 mm, with scattered prominent euhedral or subhedral alkali feldspar megacrysts. Seen in thin section (HK 5100) the megacrysts are generally microperthitic. The rock is intruded by fine- and fine- to medium-grained granites, and intrusive contacts are sharp. At the extremity of Yuen Kok (3337 0474), dykes of quartzphyric and feldsparphyric rhyolite cut the coarse-grained granite.

Po Toi Island Group. The coarse-grained granite is well exposed on Po Toi and Sung Kong islands (Figure 10); the latter being the type locality for Allen & Stephens' (1971) Sung Kong Granite. The granite on Po Toi Island is intruded by fine-, fine- to medium, and medium-grained granites, all intrusive contacts being sharp. Quartzphyric rhyolite, aplite and basalt dykes cut the coarse-grained granite, and pegmatite patches are recorded.

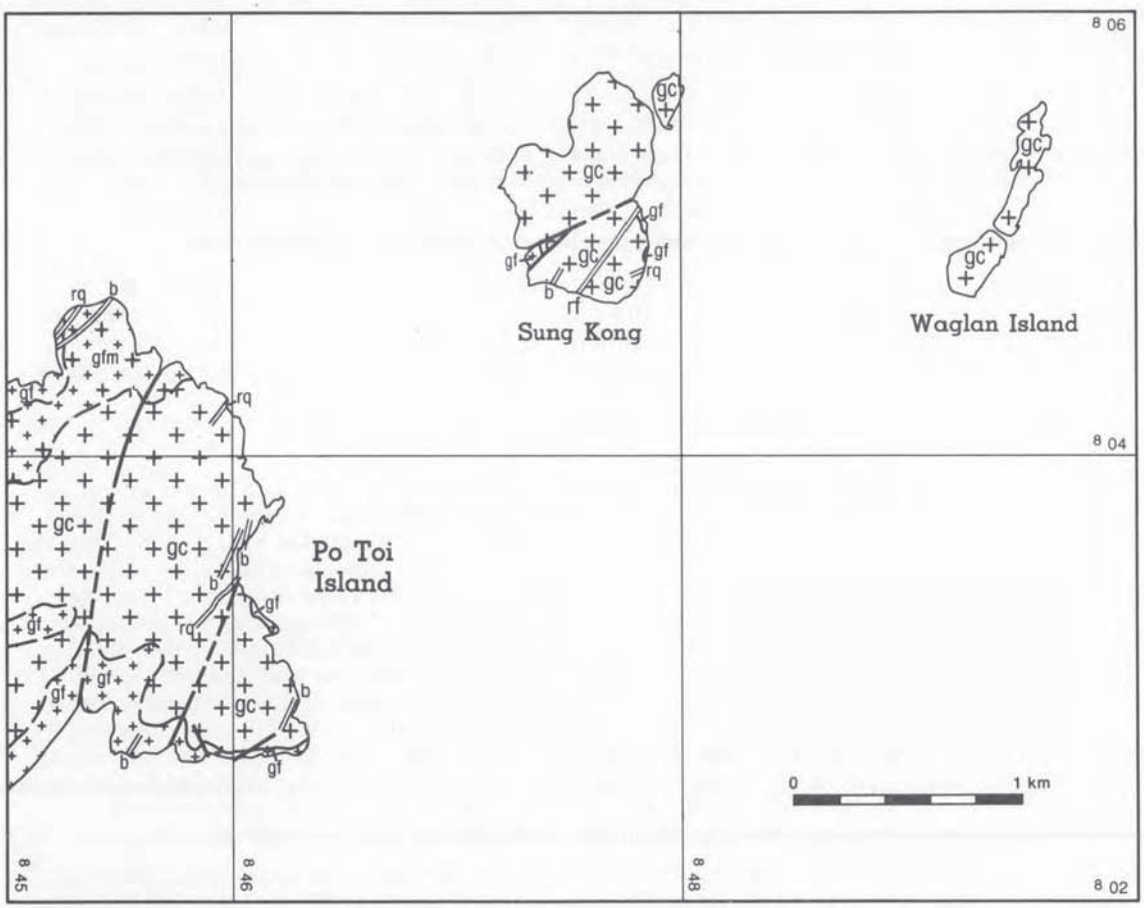


Figure 10 – Geological Map of the Po Toi Island Group on Sheet 16

Medium-grained Granite
Distribution and Lithology

The medium-grained granite of this district can be divided into two distinct types; an equigranular variety and a markedly inequigranular, megacrystic rock. The latter occurs exclusively on Lamma Island and is related to the coarse-grained granite.

The major outcrops of medium-grained granite around Kowloon, Stonecutters Island, northern Hong Kong Island, Stanley and Shek O consist of equigranular granite with no significant variation between samples collected several kilometres apart. The medium-grained granite of Kowloon, Stonecutters Island and northern Hong Kong Island appears to form an almost circular pluton approximately 10 km in diameter. It is not known how this body relates to the intrusions at Stanley and Shek O, although the latter may form parts of an entirely separate pluton.

Unfortunately, the original plutonic boundaries have been interrupted by later intrusions of fine- and fine- to medium-grained granites, a feature particularly obvious around Braemar Hill on Hong Kong Island, and in East Kowloon. Allen & Stephens (1971) assigned most of these outcrops to their Hong Kong Granite, an exception being that in northeastern Kowloon which they mapped as Cheung Chau Granite. The present survey found no differences between the medium-grained granite of northeastern Kowloon and those of the other outcrops.

The main constituents are alkali feldspar (generally microcline or microperthite), plagioclase and quartz, all with average grain sizes of 3 to 5 mm (Plates 19 & 20). Biotite is generally present as a scatter of black, shiny, single flakes. This granite appears to have been particularly prone to weathering and forms the extensively gullied foothills of Beacon Hill and Lion Rock, as well as much of the Kowloon Peninsula and the northern shores of Hong Kong Island. Corestones of fresh rock, and tors of only slightly weathered rock are, however, seen in many parts of the district.

The light pink colouration of the granite is typical of the Kowloon and Hong Kong Island outcrops; Allen & Stephens (1971) suggested that this was caused by iron oxide weathering. This colouration has been noted, however, in fresh rock in deep excavations, and does not appear to be a weathering effect. It seems more likely that the colour, found only in the alkali feldspar grains, is a primary character.

The medium-grained granite of Lamma Island is extremely variable in appearance, markedly inequigranular and has distinctive euhedral megacrysts of alkali feldspar up to 45 mm long (Plate 23). This rock grades variously into fine- and coarse-grained varieties, and appears to be a product of multiple intrusion, causing infiltration to the extent that the character of the original rock is unrecognizable.

Details

Kowloon and Stonecutters Island. The medium-grained granite intrudes the coarse-grained granite close to the northern boundary of the district, with a roughly vertical contact following the southern slopes of Butterfly Hill (332 224), Eagle's Nest (344 229) and Beacon Hill (352 230). Eastwards from Beacon Hill this contact is interrupted by a younger intrusion of fine-grained granite in the vicinity of the Lion Rock (370 236). At Lai Chi Kok (3284 2229) the contact is sharp and vertical, with a chilled margin of fine-grained granite up to 10 m wide. Exposure is poor in western and northern Kowloon except in roadside and housing estate cuttings. At Pak Tin, Shek Kip Mei (3493 2191) the granite shows its typical uniformity; a non-megacrystic rock with an equigranular groundmass comprising subhedral interlocking grains of quartz light pink alkali feldspar and subordinate, slightly smaller, white plagioclase grains. Biotite, which makes up 3 to 5% of the rock, consists of single, fresh, shiny black flakes. The average grain size of the granite is 4 mm. A chemical analysis of a sample (HK2180) collected from this locality, which can be regarded as the type location for the equigranular medium-grained granite, is given in Table 4. Pegmatite patches, 0.5 to 0.7 m across, were observed in the fresh granite at Nam Shan Estate, Shek Kip Mei (3580 2185). This pegmatite consists entirely of large quartz and pink alkali feldspar crystals.

The average grain size of the medium-grained granite in the Kowloon Tong and Diamond Hill areas is 5 mm, with biotite generally making up only 2 to 3% of the rock. At Diamond Hill Quarry (3886 2277) the granite is light grey and uniform, but is cut by small aplite dykes, and by a 7 m wide basalt and fine-grained gabbro dyke (3906 2275). Medium-grained equigranular granite may be traced up the hill slopes north and east of Diamond Hill to its contact with the volcanic country rock, where no appreciable chilled margin was observed. This granite, and the volcanic rocks in the vicinity of Sha Tin Pass and Grasscutter's Pass (3931 2398), are cut by prominent feldsparphyric rhyolite dykes trending approximately northwest. The Lion Rock (371 237) is composed of medium-grained granite, with fine-grained granite forming both a thin capping and dykes intruding the prominent overhanging 'Lion's Head' (3707 2361). The presence of these finer grained intrusions may explain the resistance of this feature to erosion.

Near Hung Hom Power Station (3762 1972) layers of pegmatite are abundant within the medium-grained equigranular granite. These are 2 to 4 m wide but only 50 to 100 mm thick, occurring on joint surfaces dipping 25° to the east-northeast. Some 800 m to the north of this site a prominent medium-grained granite tor (Plate 61) formed To Kwa Wan Island (3785 1950), now joined to the Kowloon Peninsula by reclamation. Most of the Tsim Sha Tsui peninsula is underlain by uniform medium-grained granite except for a younger intrusion of fine- and fine- to medium-grained granite around King's Park (360 188) and Gun Club Hill (362 183).

The only occurrence of medium-grained granite east of Kwun Tong is found between Yau Tong (428 175) and Lei Yue Mun Point (431 163). Here, the granite has been extensively quarried, and the contact with the volcanic rocks of the Shing Mun Formation is seen in the quarry face as an irregular surface with an average dip of 25° to the east. The chilled margin of the granite is only 0.3 to 1.5 m thick. Pegmatite patches are common, usually as lenses parallel to the contact or at the contact. The granite of this area is uniform, equigranular and has an average grain size just over 2 mm. It appears identical to the medium-grained granite cropping out at Shau Kei Wan (419 159) southwest of the Lei Yue Mun channel.

On Stonecutters Island the rock is uniform, equigranular and medium-grained, with an average grain size of 3 mm. Single, fresh, black biotite crystals are common, and the rock is light grey or light pink. It has been quarried for building stone on the western side of the island (3174 2022). Near the western tip of the island (3159 1998), where volcanic rocks of the Shing Mun Formation have been mapped, the granite becomes finer grained and probably represents a chilled margin. To the northeast of Stonecutters Island, towards Sham Shui Po, granite formed a chain of small islands that are depicted on the early maps of the Territory. These islands were later removed by blasting to provide a safe passage for shipping. Similar rocky islets were present in Hung Hom Bay prior to its reclamation.

Northern Hong Kong Island. Medium-grained granite crops out along the northern shores of Hong Kong Island between Kennedy Town and Shau Kei Wan. The outcrop is bounded by the overlying volcanic rocks in the western half of the island, and by younger intrusions of fine- and fine- to medium-grained granite to the east of Happy Valley. Small areas of medium-grained granite have been mapped in the vicinity of Mount Nicholson and Shouson Hill. In Belcher Street, Kennedy Town (3170 1638), medium-grained granite is found to within a few centimetres of the volcanic country rock contact, with only a very narrow chilled zone. This contact may be traced through the disused, wartime tunnels under Belcher's Gardens (3173 1622), where the contact dips about 25° west and strikes 010°. Thin tongues of fine-grained granite intrude several metres into the contact metamorphosed tuffs and associated sandstones. Between Hong Kong University and Central District the granite is light grey to light pink, uniform, equigranular and medium-grained, with an average grain size of 3 to 4 mm. Tunnelling operations under Statue Square (3456 1583) revealed two chloritic zones within this granite, each about 15 m wide and associated with shear zones, with the biotite completely altered to chlorite. Railway tunnel excavations under Sheung Wan (3383 1644) exposed a northeast-striking zone of banded greisen, 7 to 10 m wide, cutting the medium-grained granite, and probably formed by late-stage hydrothermal fluids and gases infiltrating a fracture zone (Plate 14).

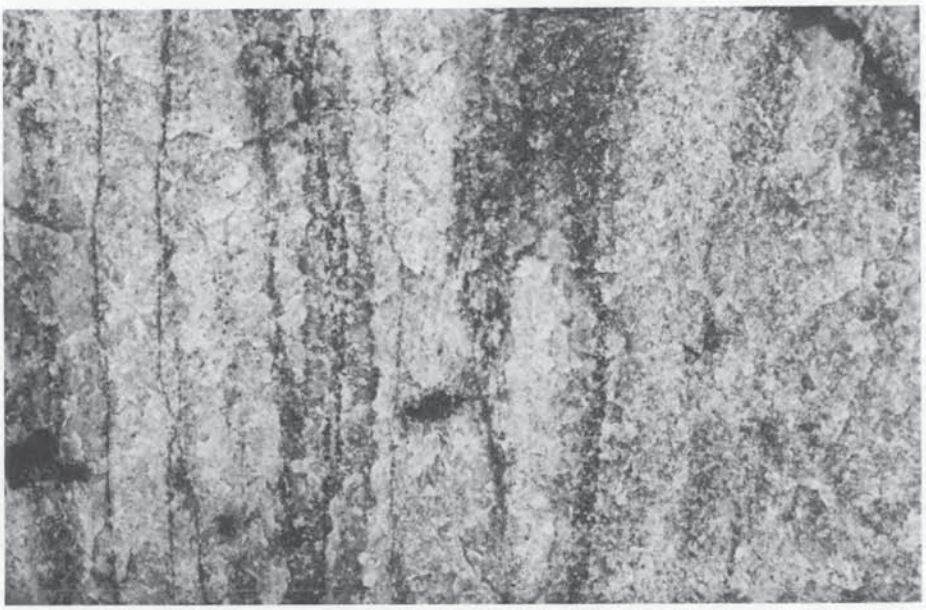


Plate 14 – Banded Greisen (HK 3853) from Underground Excavations at Sheung Wan, Hong Kong Island (3383 1644); Natural Scale

There are few exposures of fresh medium-grained granite between Central and Causeway Bay except in temporary building site excavations. A 30 m deep section into the hillside at the Ruttonjee Sanitorium (3611 1522) revealed completely weathered granite with fresh equigranular medium-granite occurring as isolated corestones at the base. The granite there is pale pink, uniformly equigranular and non-megacrystic with an average grain size of 4 mm (Plates 19 & 20). The biotite occurs as shiny, black, single flakes. White plagioclase grains are subordinate to the larger light pink alkali feldspars. A geochemical analysis for a sample (HK 4237) collected from this locality is given in Table 4. Some 200 m to the east, at Morrison Hill (3635 1518), the medium-grained granite is inequigranular in appearance, perhaps a consequence of textural modification by infiltration of fine-grained granite. Similar modification was noted at Kellett Island (3677 1618), where pegmatite lenses are also present. Uniform, equigranular medium-grained granite is exposed on the western side of Leighton Hill (3688 1527), and southeastwards along Happy Valley to Tai Hang Road. 150 m south of the Tai Hang Drive – Tai Hang Road junction (3787 1478) molybdenite crystals up to 8 mm

Plate 15 – Granodiorite (HK 5321) from Cape D'Aguilar (4487 0768); Natural Scale

Plate 16 – Thin Section of Granodiorite (HK 4225) from Cape D'Aguilar (4492 0775); XPL × 10

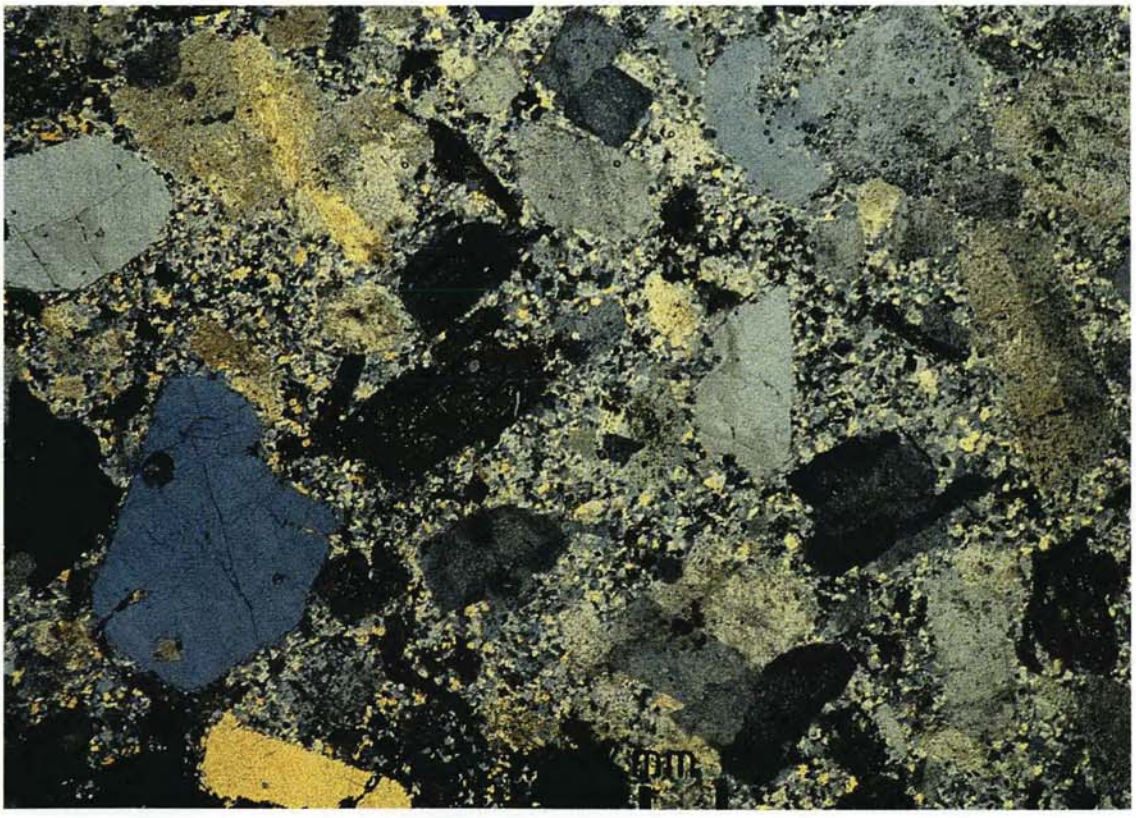
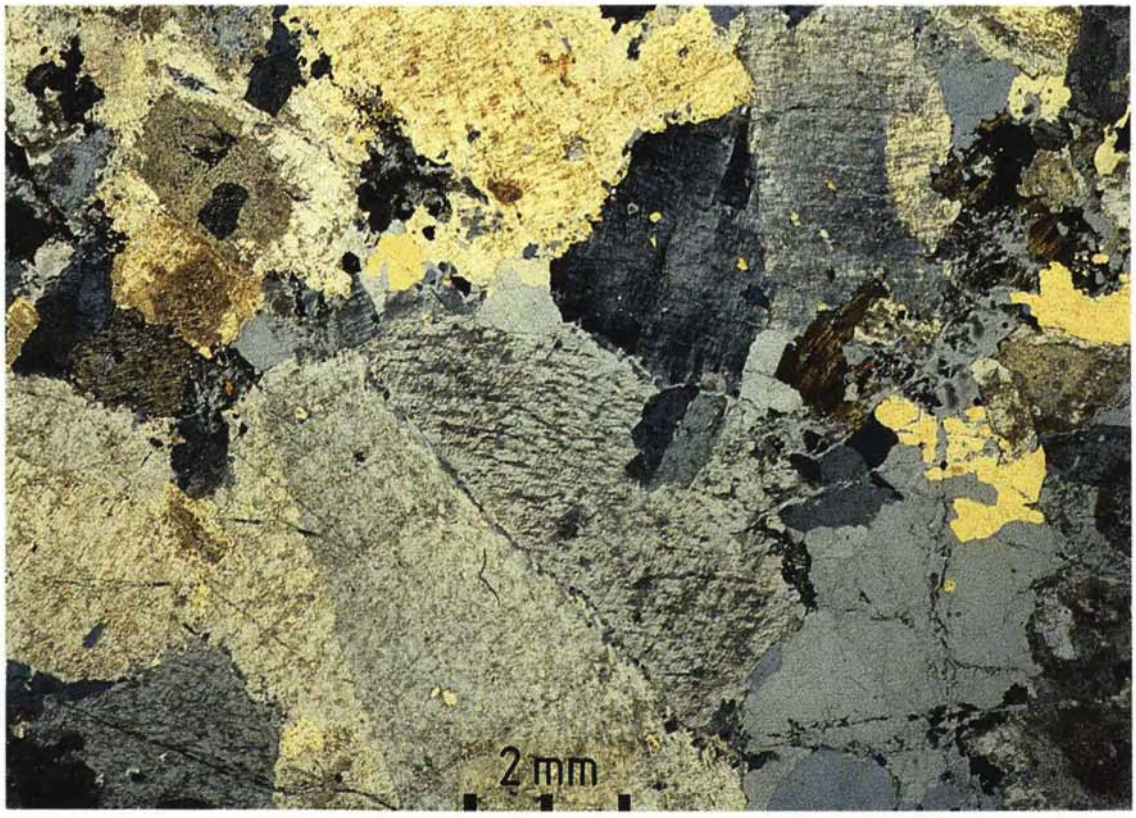


Plate 17 – Coarse-grained Granite (HK 2183) from Lai King, Northwestern Kowloon (3141 2370); Natural Scale

Plate 18 – Thin Section of Coarse-grained Granite (HK 441) from Caldecott Road, Piper's Hill, Northwestern Kowloon (3347 2280), XPL × 10



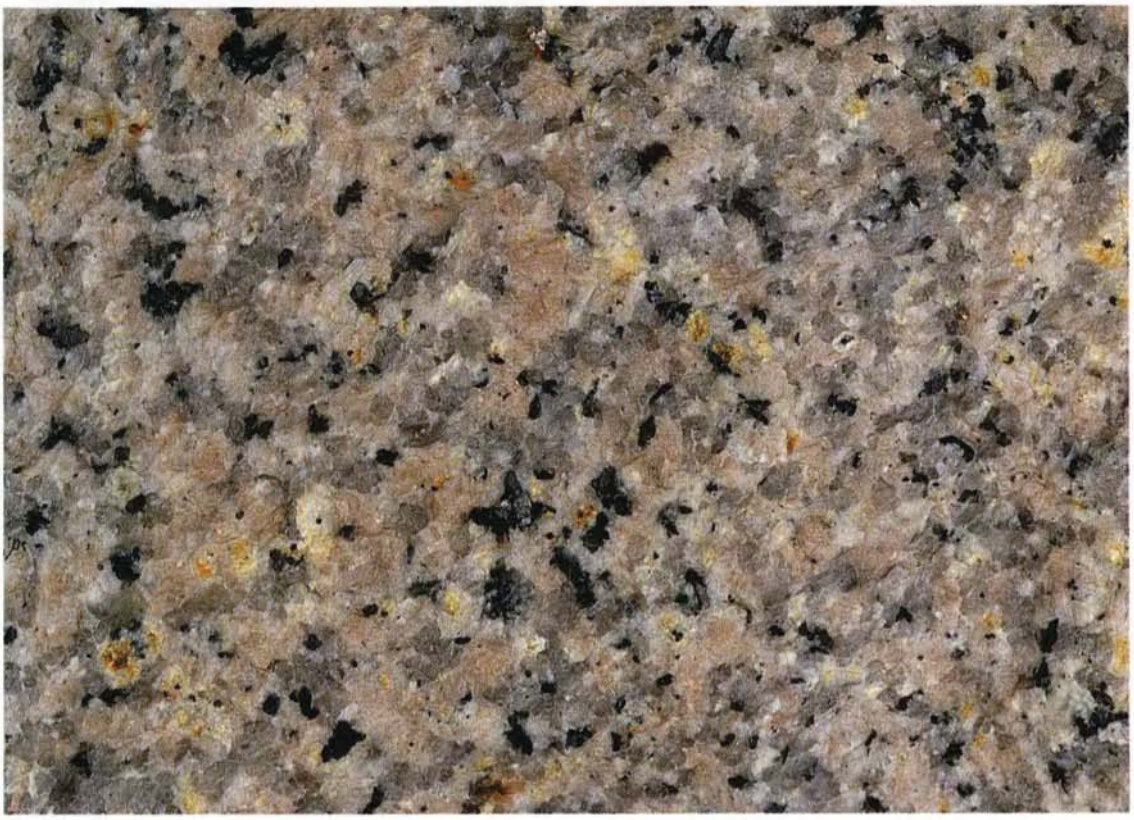
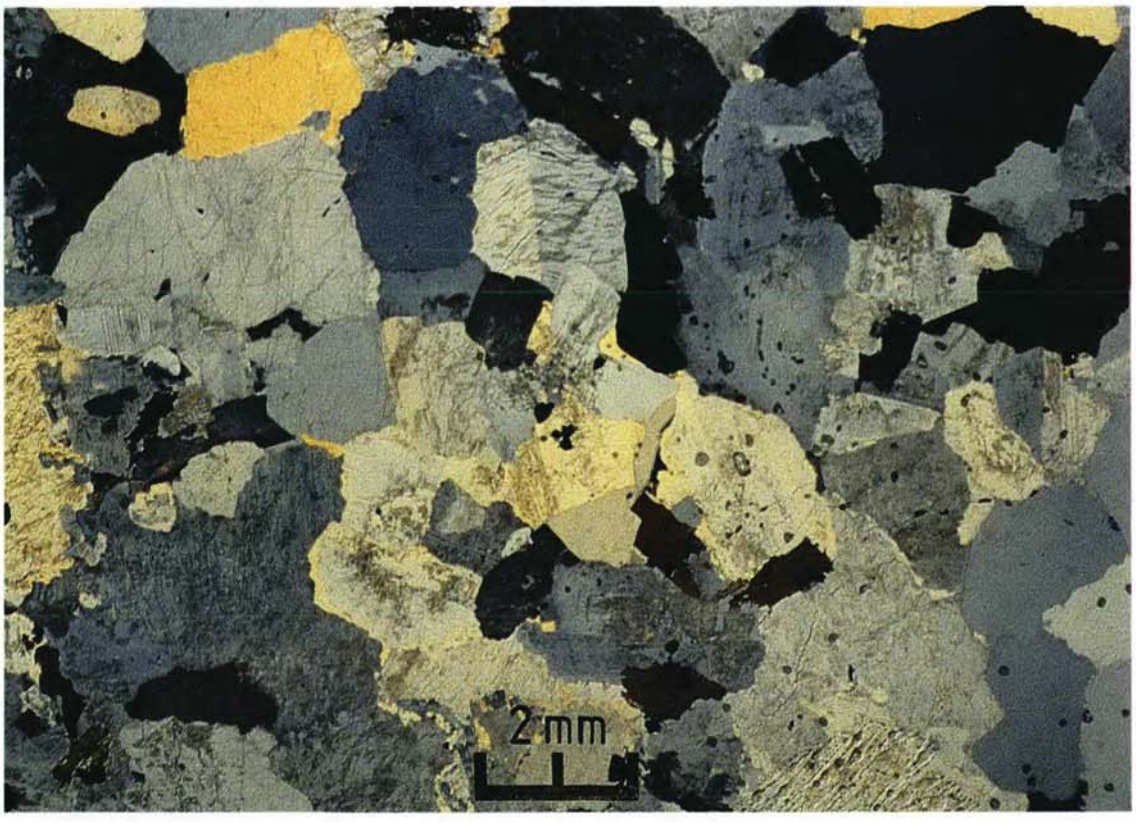


Plate 19 – Medium-grained Granite (HK 4237) from Ruttonjee Sanitorium; Wan Chai (3611 1522); Natural Scale

Plate 20 – Thin Section of Medium-grained Granite (HK 4237) from Ruttonjee Sanitorium; Wan Chai (3611 1522); XPL × 10



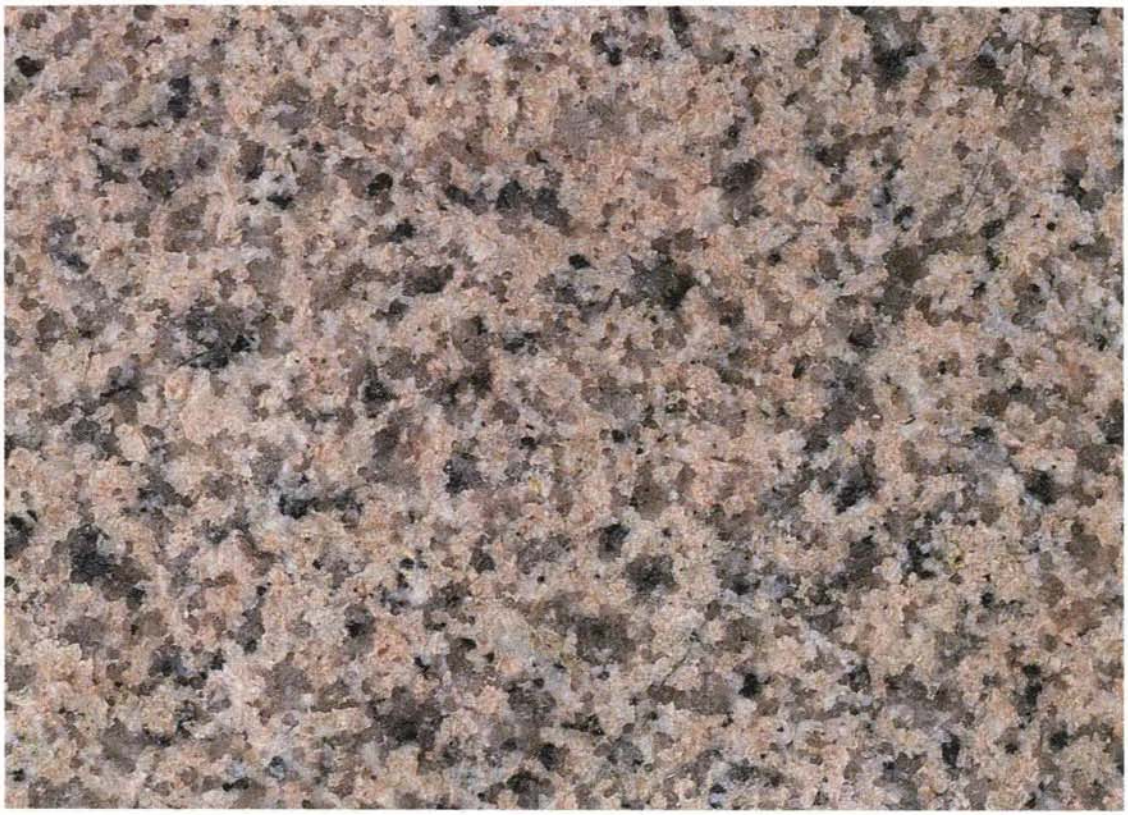
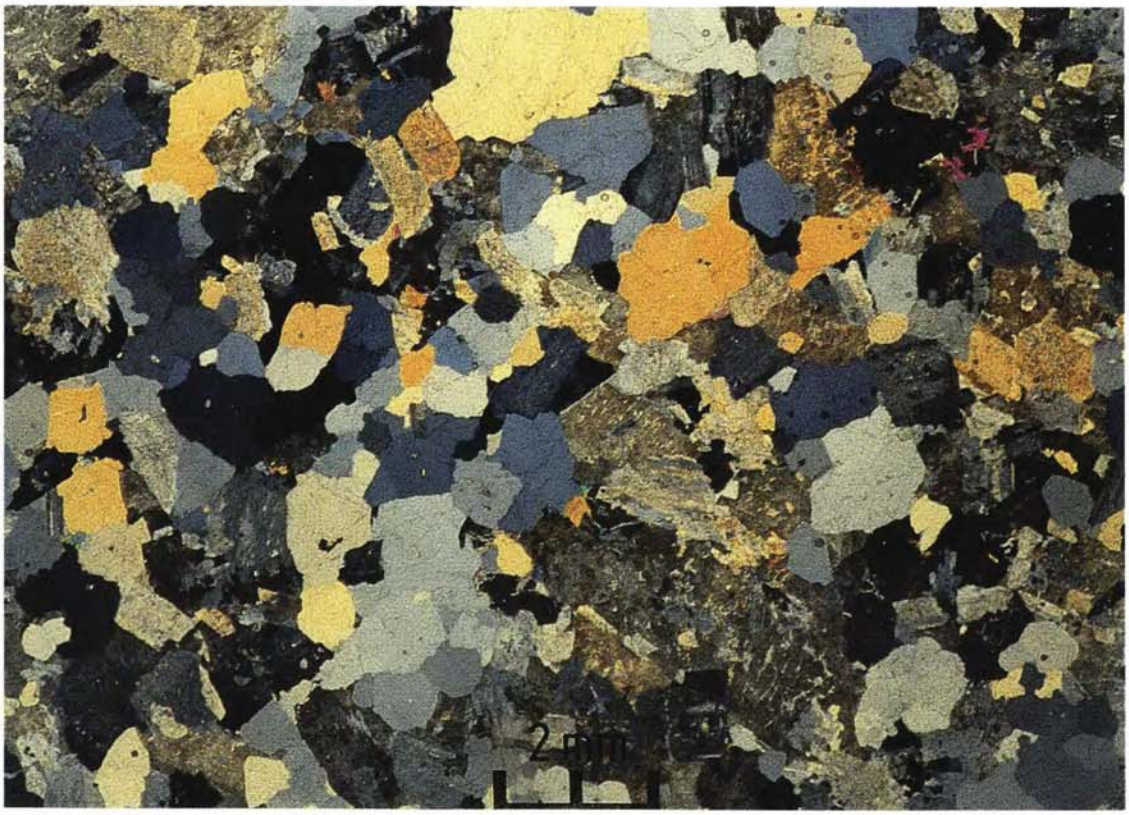


Plate 21 – Fine- to Medium-grained Granite (HK 2185) from Junk Bay Road, East Kowloon (4288 1947); Natural Scale

Plate 22 – Thin Section of Fine- to Medium-grained Granite (HK 2185) from Junk Bay Road, East Kowloon (4288 1947); XPL × 10



long were noted, scattered throughout recently excavated fresh granite. The boundary between the medium- and fine-grained granites is sharp in the Jardine's Lookout area, and was seen as a vertical contact in temporary exposures at the new Mount Butler Government Quarters (3798 1485). However, the contact between the medium- and the fine- to medium-grained granites in the vicinity of Bowen Road and Stubbs Road (364 143) is poorly defined and the mapped boundary there is approximate.

From Victoria Park eastwards to Quarry Bay, medium-grained granite occurs close to the original coastline, with later, finer grained granites occupying the higher ground southwards to Braemar Hill. Along King's Road (3791 1612), fresh, equigranular medium-grained granite is exposed, and the contact with the fine-grained granite is well seen close to the Tsing Fung Street flyover (3790 1626). The best exposures of medium-grained granite are those in the rock cuttings at Healthy Village Estate, North Point (3916 1677), where the rock displays its characteristic uniformity. Major excavations at Kornhill – Taikoo Shing (403 157) have revealed a sharp vertical contact between the fine- and medium-grained granites. There appears to have been some infiltration of the medium-grained granite by fluids emanating from the intruding fine-grained granite, and within 30 m of the contact (4021 1584) there is some textural modification shown by a marked inequigranularity of the medium-grained rock. Eastwards towards Aldrich Bay the granite grain size diminishes to an average of 2 to 3 mm, as seen in old quarries behind Shau Kei Wan Road (4105 1559). This granite is separated from the fine-grained granite at A Kung Ngam Road (4187 1524) by a 0.2 m wide pegmatite zone. At A Kung Ngam (4188 1593) some diffuse, fine-grained patches were observed in the otherwise uniform, equigranular medium-grained granite.

Medium-grained granite crops out on the slopes between Mount Nicholson Road and Black's Link (366 135). Corestones of fresh equigranular medium-grained granite in highly to completely weathered granite are exposed in cuttings at Black's Link (3656 1349). The medium-grained granite grades into fine-grained granite within 2 m of the contact with the volcanic country rock (3660 1347). Small areas of medium-grained granite occur on the southwestern slopes of Mount Nicholson (3651 1310) and along Deep Water Bay Road close to its junction with Nam Fung Road. There (3722 1278), the granite is equigranular and averages 2 to 3 mm in grain size, and contains distinctive pegmatitic patches surrounded by 0.1 m wide biotite concentration haloes (Plate 39). This granite grades imperceptibly into fine- to medium-grained granite towards Shouson Hill (3707 1261). The valley slopes southeast of Deep Water Bay Road are covered by superficial deposits, but medium-grained granite is again exposed in the stream bed (3761 1275), where quartz syenite is also seen, probably forming a dyke.

Stanley and Shek O. On the Chung Hom Kok and Stanley peninsulas the granite is uniformly equigranular, non-megacrystic medium-grained, with an average grain size of 3 mm. The rock is usually deeply weathered and exposures of fresh rock are rare except along the coast and in roadside cuttings. On the coast the granite forms cliffs of pink to light brown, slightly to moderately weathered rock. Inland, tors form hilltop features at Chung Hom Kok (387 084), and on the Stanley Peninsula (403 076).

Aplite dykes, averaging 150 mm in width, are common along the cliffs east of Stanley Prison (4076 0806 & 4062 0789). Wider dykes of aplite were noted on the western side of the Stanley Peninsula (4000 0805) where a 0.8 m wide vertical dyke strikes north-south. On the southern side of Stanley Bay the granite contains scattered granodiorite xenoliths (3992 0790); thin stringers of granite intrude the granodiorite, but the contact between the two rock types was not exposed. At Stanley Fort an area of fine- to medium-grained granite cuts the granodiorite and syenite, and this probably represents a chilled margin of the medium-grained granite pluton. On the D'Aguilar Peninsula, medium-grained granite crops out from the west coast at Shek O Quarry northeastwards to Shek O Village (437 102). On both coasts it is bounded gradationally by fine- to medium-grained granite. It is probable the fine- to medium- and the medium-grained granites were derived from the same magma; except for grain size there is no difference in composition or appearance.

Lamma Island. The medium-grained granite occupies much of the central part of Lamma Island between Lo So Shing (310 074) and Hung Shing Ye (305 110). It also occurs on the northern tip of the island at Pak Kok (302 113). The granite is extremely variable in grain size, composition and general character. Grain size varies abruptly from fine- to coarse-grained, and diffuse-bounded patches of both fine- and coarse-grained granite may occur within a dominantly medium-grained groundmass, as seen in coastal exposures near the jetty at Pak Kok (3010 1123). Alkali feldspar megacrysts are common, up to 45 mm long, and stand out clearly, particularly on weathered surfaces. Megacrysts are prominent at Pak Kok (3030 1124, Plate 23). In the same area (3028 1120), a chilled margin only 50 mm thick was seen at the irregular contact with the volcanic country rock. Nearby, fine-grained granite appears to have infiltrated the medium-grained rock, producing a patchwork pattern with biotite prominent in the darker, coarser grained patches. South of Hung Shing Ye beach (3043 0873), biotite-rich, megacrystic medium-grained granite is exposed in the cliffs. Here, a feldsparphyric rhyolite dyke is seen cutting the granite, and, 200 m further south, a large body of highly altered tuff 25 m across and surrounded by the medium-grained granite is probably a large xenolith (3047 0855). There are few exposures inland, most of the granite outcrop being deeply weathered. At Sok Kwu Wan Quarry, medium-grained granite is surrounded by fine- and fine- to medium-grained granite. The finer varieties have infiltrated the medium-grained rock, in particular close to the contact in a zone 25 to 30 m wide (3185 0842). Biotite is abundant in the medium-grained granite and the rock is megacrystic in part, with prominent euhedral alkali feldspar megacrysts. Sometimes they are roughly aligned and similar in appearance to the tabular feldspars that characterise the quartz syenite intrusions. Another feature of the granites exposed in this quarry is the presence of numerous basaltic xenoliths 0.6 to 1.0 m across and commonly very angular (3164 0837).

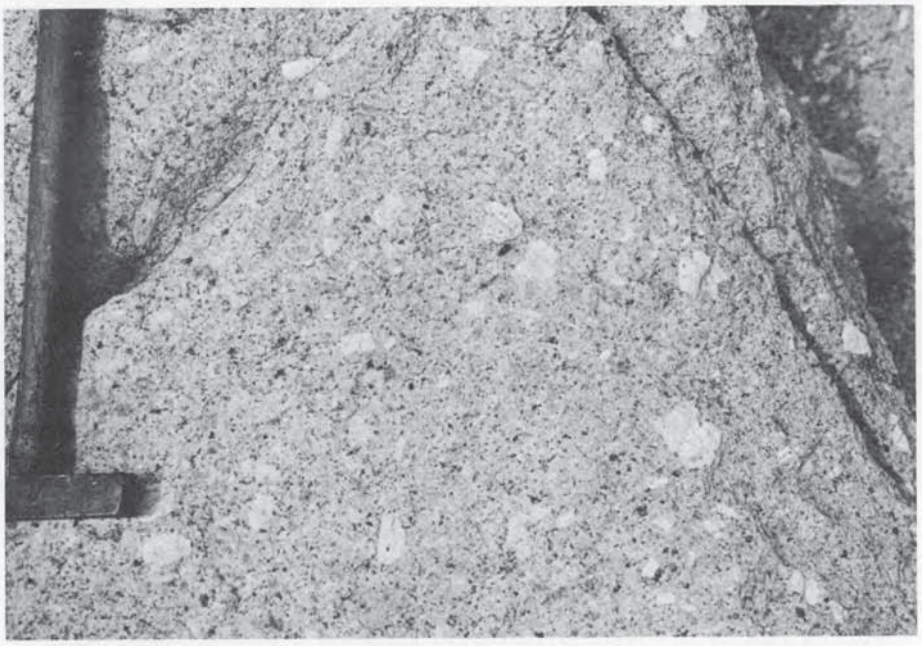


Plate 23 – Megacrystic Medium-grained Granite on Pak Kok, Lamma Island (3030 1124); Megacrysts of Alkali Feldspar up to 45 mm in Length

Po Toi Island Group. Medium-grained granite is found in several places on Po Toi Island, where it intrudes coarse-grained granite, and is in turn intruded by fine-grained granite (4462 0244). Dykes of quartzphyric rhyolite cut the granite near Tai Wan Village (4420 0300). The medium-grained granite is essentially equigranular, non-megacrystic and similar in appearance to the granite cropping out at Stanley and Shek O. The medium-grained granite forming the western side of Beaufort Island (Lo Chau) is roughly equigranular, with an average grain size of 2 to 3 mm. Biotite, as shiny black flakes, makes up about 1% of the rock. Quartz crystals form aggregates up to 8 mm across giving the impression of a coarse-grained rock. There are scattered euhedral alkali feldspar megacrysts up to 7 mm in length. A mineral vein 0.5 m wide and rich in haematite is present in this granite (4331 0501). The contact with the fine-grained granite is sharp (4327 0490).

Fine- to Medium-grained Granite

Distribution and Lithology

This granite occurs mainly in association with the fine-grained variety, with which it has close affinities. It crops out in East Kowloon, around Mount Butler and Wong Nai Chung, on the D'Aguilar Peninsula, and on the Po Toi Island Group; it is also widespread over much of southern Lamma Island. The fine- to medium-grained granite and associated fine-grained granite forms small plutons, the most prominent cropping out at Kwun Tong, on Mount Butler, and on Mount Stenhouse on Lamma Island. These post-date the larger plutons of Kowloon – northern Hong Kong Island and Sha Tin – Lai Chi Kok, both of which have been intruded, partially digested by the younger, finer grained phase.

The fine- to medium-grained granite is generally equigranular and uniform in appearance and character, and in places is megacrystic (Plates 21 & 22). With an average grain size of about 2 mm, the granite falls between the two main categories; fine- and medium-grained granites (Strange, 1985). The fine- to medium-grained variety forms a clear mappable unit distinct from the fine-grained granite (in the order of 1 mm grain size of less) and the medium-grained granite (predominantly 3 to 4 mm).

The fine- to medium-grained granite of central and northern Lamma Island, like the medium- and coarse-grained varieties, is distinctive and markedly different from its counterpart in other outcrops of the district. This rock has a highly modified texture and consists of an older medium-grained granite, intensely infiltrated by later intrusion of fine-grained granite. The resulting rock is highly inequigranular and variable in appearance, and contains abundant pseudoporphyritic megacrysts; remnants from the original granite. The fine- and fine- to medium-grained granites are

the most extensively quarried rocks in the Territory, most of the active quarries being located within this district.

Allen & Stephens (1971) assigned the granite here mapped as fine- to medium-grained granite to various units; the East Kowloon and Hong Kong Island outcrops were shown as Hong Kong Granite, the southern Lamma Island outcrop as Cheung Chau Granite, and the Po Toi Island and Beaufort Island outcrops as Ma On Shan Granite. All are similar in character and have similar cross-cutting relationships, and it is not considered feasible to attempt any sub-division.

Details

East Kowloon. This granite crops out from Choi Wan (4040 2144) southwards to Yau Tong (4265 1716), covering an area of approximately 6 sq km. The exposures at Junk Bay Road (4280 1952) are regarded as typical, with the fine- to medium-grained granite passing gradationally into fine-grained granite over a distance of some 10 m. Geochemical analyses of a fine-grained sample (HK 2184) and a fine- to medium-grained sample (HK 2185) show close similarities (Table 5). The fine- to medium-grained granite is roughly equigranular, having an average grain size of 1.8 to 2 mm. Biotite occurs as single, shiny black flakes (Plates 21 & 22). There are scattered quartz crystals up to 4 mm, but these megacrysts are not prominent in hand specimen and the main character of this light pink granite is its uniformity. At this Junk Bay Road locality, basalt dykes cut the granite.

Fresh granite has been extensively quarried in the past; there are large disused quarries with almost vertical faces to 80 m in height at Choi Wan (4040 2135), Ngau Tau Kok (4028 2107) and Jordan Valley (4065 2094). The rock is at present quarried at Anderson Road (4200 2100) and Cha Kwo Ling (4200 1800). At both locations the fine- to medium-grained granite consists of an equigranular, non-megacrystic rock, with an average grain size just under 2 mm. At Cha Kwo Ling Kaolin Quarry (4170 1821) a 50 m wide vertical zone of kaolinized rock is excavated for its kaolin content. Quartz is rare and the kaolin most probably results from hydrothermal alteration of a syenitic dyke. Some of the surrounding fine- to medium-grained granite cropping out in these workings is bleached white by hydrothermal alteration. Basalt dykes are common in the East Kowloon area, as are thin aplite dykes and pegmatitic patches. North of Jordan Valley (4060 2116), two sub-parallel, quartzphyric rhyolite dykes cut the granite. These stand out on the deeply weathered surface, and an adit (4061 2118) has been driven into the dyke, presumably as a trial mineral working.

Hong Kong Island. Fine- to medium-grained granite crops out from the flanks of Mount Nicholson and the Tai Tam Country Park, northwards to Braemar Hill. There are small outcrops at Lei Yue Mun Bay (4253 1577) and Chai Wan (4192 1376). The granite has close affinities with the fine-grained granite and, in many places, infiltration by the fine-grained granite has produced a modified texture. Between Stubbs Road and Wong Nai Chung Gap (3740 1363), fine- to medium-grained granite is present, but its relationship with the medium-grained granite to the north is unclear. At Stubbs Road (3647 1413) the fine- to medium-grained granite has a microcrystic texture; very fine-grained granite infiltrating the fine- to medium-grained groundmass, producing a markedly inequigranular rock. At Deep Water Bay Road (3720 1273) the fine- to medium-grained granite passes gradationally into medium-grained granite, with both rocks similar in character apart from grain size. Fine- to medium-grained granite predominates between Wong Nai Chung Gap (3823 1320) and Tai Tam Reservoir (3968 1313). In places, for example 450 m southeast of the main dam at Tai Tam Reservoir (4010 1289), infiltrations of fine-grained granite are common, and diffuse patches of fine-grained granite up to 0.5 m across also occur. At Mount Butler Quarry (3900 1440) the granite is light grey to light pink, slightly inequigranular and appears to be medium-grained. This appearance, however, is due to clotting of quartz crystals, creating the impression of a coarser grained rock. Closer inspection reveals a dominant groundmass of 1.5 to 2 mm average grain size. Quartz crystals form aggregations up to 5 mm. Biotite as single flakes stands out clearly in this leucocratic granite, but makes up less than 2% of the rock. Outcrops have been distinguished on the map where the average grain size reaches 2 mm, for example, 200 m southwest of the Country Park Management Centre (3883 1330) and on the eastern shore of the Tai Tam Reservoir (3992 1333).

In the vicinity of Shek O, fine- to medium-grained granite is well exposed in coastal sections between the golf club (4410 1090) and the village. The granite is fairly uniform and equigranular, with an average grain size in the order of 1.5 to 2 mm. In places the rock becomes slightly coarser, verging on medium-grained. Westwards from Shek O Village (4380 1013) to the Shek O Quarry (4270 0930) the granite is coarser and has been delineated as medium-grained; it is, however, regarded as belonging to the same intrusive phase. Thin aplite dykes are common in the fine- to medium-grained granite, as are quartz veins. Greisenisation associated with several parallel quartz veins is visible in the cliff section 200 m south of the golf club (4410 1054), where greisen bands are present for 0.1 to 0.15 m each side of the thin quartz veins. On Tai Tau Chau (4480 1020), fine-grained granite has intruded fine- to medium-grained granite. Nearby, on Shek O Headland (4443 0996), similar infiltration of the fine- to medium-grained granite has taken place.

Southern Lamma Island. Uniform fine- to medium-grained granite crops out over a wide area of southern Lamma Island. There is little lithological variation between the area southwest of Mount Stenhouse (3050 0550) and that to the east of Sok Kwu Wan (3270 0770). The rock is roughly equigranular, with a uniform groundmass and average grain size bordering on 2 mm. It is usually light pink and non-megacrystic, and is intruded by numerous feldsparphyric and quartzphyric rhyolite dykes as well as basalt dykes. In the coastal section east of Yung Shue Ha (3317 0684) the fine- to medium- grained granite has a very irregular contact

with the older coarse-grained granite (Plate 24). The younger light pink granite appears to have intruded the older dark grey granite along cooling joints, producing an unusual trellis pattern extending over many metres. On the coast south of Mount Stenhouse (3080 0470), fine-grained granite has intruded the fine- to medium-grained granite without any apparent infiltration of the latter. Instead, the existence of pegmatite concentrations along the contact suggests that the older granite was already cool at the time of the later intrusion.

Plate 24 – Fine- to Medium-grained Granite Intruding and Partly Digesting Darker Coarse-grained Granite near Yung Shue Ha, Southern Lamma Island (3317 0684)

Central and Northern Lamma Island. The fine- to medium-grained granite of this area is closely related to the intensely modified medium- and coarse-grained granites. All these varieties have close affinities and are intermixed, making their distinction on the map difficult. Fine- to medium-grained areas have been mapped at Sok Kwu Wan Quarry (3170 0860), Luk Chau (George Island) (3180 0960) and north of Hung Shing Ye (3040 0920). There are isolated areas of finer grained granite within the medium-grained granite in inland parts of central Lamma Island, although these cannot be delineated through lack of exposure. The Sok Kwu Wan Quarry (3175 0856) affords the best fresh rock exposures of this granite. The rock here is variable, but characterized throughout by abundant biotite. The average grain size is about 1.5 mm, but alkali feldspar megacrysts to 10 mm and quartz megacrysts to 5 mm are common. The granite is grey and particularly dark in places due to the biotite concentrations. Patches of fine-grained granite pervade this inequigranular rock and have modified the megacrystic medium-grained granite with which it is closely related. Large, angular basalt xenoliths (3180 0833) are recorded in the quarry face (Plate 25).

On Luk Chau (3183 0959) the fine- to medium-grained granite has been infiltrated by syenite. The inequigranular granite has a quartz-poor, microcrystic fabric invading a rock which appears to have already undergone some modification from granitic fluids. The resulting fine- to medium-grained granite is very variable and markedly inequigranular. Patches of syenitic rock displaying the characteristically aligned euhedral feldspar megacrysts can be seen in places (3182 0939). In the vicinity of Hung Shing Ye (304 092) the fine- to medium-grained granite is markedly inequigranular, but has a distinctive biotite-rich groundmass, with an average grain size of about 1.5 mm. The rock has abundant megacrysts of quartz up to 6 mm across, as well as sparse feldspar megacrysts.

Po Toi Island Group. There are extensive outcrops of fine- to medium-grained granite on Beaufort Island (Lo Chau), where the rock shows similarities with the granites of Shek O and Stanley. The rock is fairly uniform and roughly equigranular, with an average grain size between 1.5 and 2 mm. The groundmass is light pink to

Plate 25 – Basalt Xenoliths within Fine- to Medium-grained Granite at Sok Kwu Wan Quarry, Lamma Island (3180 0833)

white, with scattered single black biotite flakes throughout. In places, however, the biotite flakes form clusters averaging 4 to 5 mm across. Euhedral alkali feldspar megacrysts reaching 5 mm are randomly distributed. Similar granite occurs at Castle Rock (Lo Chau Pak Pai, 425 048) where quartzphyric rhyolite and aplite dykes intrude the rock. Thin quartz veins with associated 0.8 m wide zones of greisenisation affect the granite on the southeastern coast of Beaufort Island (4411 0464), similar to the greisen and quartz veins noted at Shek O. Fine-grained granite intrudes the fine- to medium-grained granite on the southern coast of Beaufort Island (4390 0458), with pegmatite concentrations as a series of parallel subhorizontal layers near the contact (Plate 38). In northwestern Po Toi Island (Figure 10), fine- to medium-grained granite is well exposed, with extensive unvegetated rock surfaces. The granite is light pink and equigranular, with an average grain size of just under 2 mm. There are scattered tabular alkali feldspar megacrysts 5 mm by 3 mm, and pools of quartz crystals to 7 mm across.

Fine-grained Granite

Distribution and Lithology

Fine-grained granite is found in many parts of the district and generally occurs as later stage intrusions. It is most widespread in northern and northwestern Kowloon, in East Kowloon and in the Mount Butler and Braemar Hill areas of Hong Kong Island. It also forms numerous smaller isolated outcrops on Lamma Island (Figure 7), across Hong Kong Island and on the Kowloon peninsula; also on the Po Toi Island Group (Figure 10).

The fine-grained granite is commonly associated with the fine- to medium-grained variety, and both may be megacrystic. The rock is usually equigranular, with subhedral crystals of alkali feldspar interlocking with grains of quartz and subordinate plagioclase (Plates 28 & 29). Biotite generally occurs as single flakes but makes up less than 3% of the rock. Biotite may not be visible in hand specimen, particularly if the rock is weathered. The fine-grained granites of northwestern Kowloon are usually light grey in colour, whereas those of East Kowloon and Hong Kong Island have a pinkish colouration.

The fine-grained granite of the isolated outcrops on western Hong Kong Island, and Green and Little Green islands (Figure 8) has a distinctive granophyric texture in thin section, although it appears similar in hand specimen to the fine-grained granites of other outcrops.

In places the fine-grained granite may be seen to have intruded the coarser grained granites by a process of infiltration and digestion. This modification can progress to the point when only a few crystals of the original primary granite remain, preserved as megacrysts surrounded by a fine groundmass in a pseudoporphyritic texture. It seems probable that this modification process was most effective where the fine-grained granite intruded granite that was still hot, possibly in a

semi-liquid state. Near the contact with the volcanic rocks in East Kowloon, fine-grained granite has been extensively hydrothermally altered to greisen, consisting largely of quartz and muscovite, and forming a distinctive sacharroidal textured equigranular rock, usually purple or reddish brown when weathered (Plate 26).

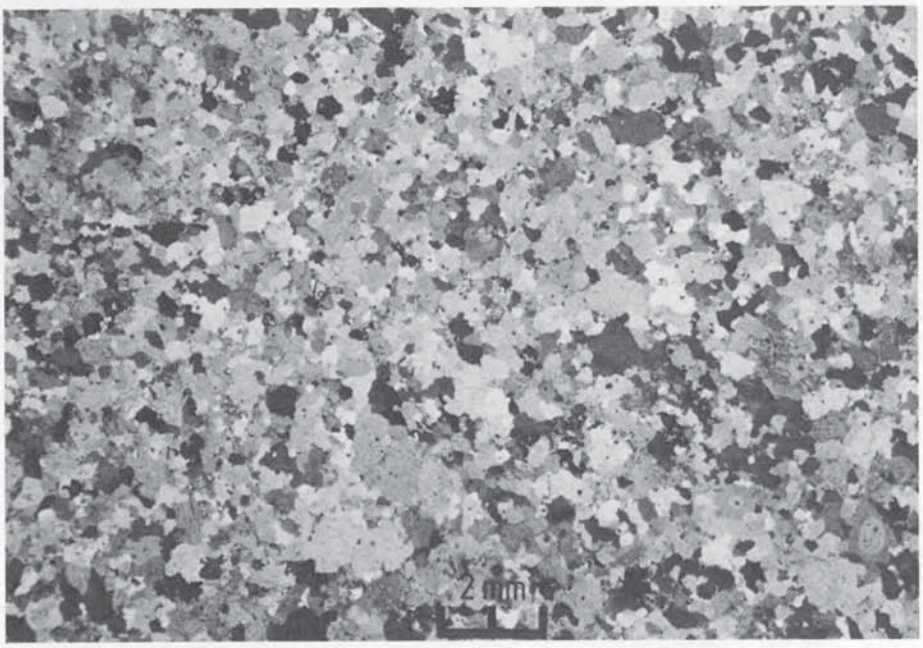


Plate 26 – Thin Section of Greisenised Fine-grained Granite (HK 1620) from Rennie's Mill (4377 1828); XPL × 7

Details

Northwestern and Northern Kowloon. Much of the fine-grained granite cropping out in this area was mapped by Allen & Stephens (1971) as Needle Hill Granite. The granite is younger than the other granites of the area, and is seen intruding coarse-grained granite north of Lai Chi Kok. Fine-grained granite forms a vertical dyke-like body in the Lai King and Cho Yiu estates (3126 2329 & 3138 2331), with sharp margins against the coarse-grained granite. Average grain size is less than 1 mm, although there are scattered megacrysts of quartz. Similar rock forms a roughly horizontal contact with the coarse granite, well exposed in fresh rock cuttings in Wah Yiu Road (3160 2358). Here, several very fine-grained aplitic dykes cut both the coarse- and the fine-grained granites. The contact between the fine- and coarse-grained varieties is sharp everywhere, with no sign of any significant infiltration or modification of the intruded rock. At the main entrance to Princess Margaret Hospital (3158 2272), parallel zones of biotite concentration, striking 060°, are prominent in the fine-grained granite. Associated pegmatite patches 0.3 to 0.5 m across are also present, and 200 m to the south (3161 2251) a 50 m wide N-S striking zone of pegmatite concentration has been mapped. The surrounding fine-grained granite contains 5 mm quartz megacrysts.

Fine-grained granite is widespread in Kam Shan Country Park, and is seen faulted against the coarse-grained granite in the stream bed immediately below the Byewash Reservoir dam (3337 2326). At Piper's Hill (338 230) and Beacon Hill (356 234) the fine-grained granite occurs on the topographic high points, and appears more resistant to weathering and erosion than the surrounding coarser grained granites. The Piper's Hill granite is almost very fine-grained and equigranular, with only scattered quartz and feldspar megacrysts visible. Fine-grained granite associated with the chilled margin of the medium-grained granite intrusion crops out in Butterfly Valley Road (3283 2228) where it forms a 10 m wide zone against the sharp, vertical contact. A similar fine-grained margin to the medium-grained intrusion is seen near the Carlton Hotel in Tai Po Road (3386 2275).

It is probable that the fine-grained granite cropping out between Beacon Hill (3600 2348) and the Lion Rock (3704 2372) occurs as a sheet-like intrusion, dipping gently towards the north.

East Kowloon. Fine-grained granite crops out from Pik Uk (4311 2208), southwards and roughly parallel to the volcanic contact, to Rennie's Mill and Lei Yue Mun. Smaller areas occur at Ping Shek (4007 2137), north of Jordan Valley (4092 2134), and between Shun Lee (415 215) and Sau Mau Ping (419 206). The granite is light pink, uniform, equigranular and occasionally megacrystic. Average groundmass grain size is 0.5 to 1 mm,

with quartz megacrysts up to 5 mm (Plates 28 & 29). Megacrysts of feldspar are not common. Biotite occurs as single flakes, and constitutes less than 3% of the rock. There is a gradational margin with fine- to medium-grained granite, the transition occuring over a distance of several metres. This is well seen at Junk Bay Road (4288 1947) and in the Anderson Road Quarries (4222 2082). Geochemical analyses from samples collected each side of the boundary (4288 1949) give almost identical results, and it is probable that the fine- and fine- to medium-grained granites are parts of the same intrusion. Pegmatite patches are common, usually consisting of large crystals of alkali feldspar and quartz; these are well seen at or near the granite-volcanic contact, for example, near the Clear Water Bay Road (4275 2160) at Tseng Lan Shue Village. Nearby (4311 2208), a borehole in the fine-grained granite showed considerable amounts of pyrite present as discrete crystals scattered throughout the rock. Thin mineral fissure veins crop out above Anderson Road Quarries (4225 2100), where wolframite was seen in the quartz vein rock. A number of parallel fissure veins containing mainly quartz, but with small amounts of beryl, fluorite and wolframite, cut the fine-grained granite between Rennie's Mill and Lei Yue Mun, and have been extensively prospected in the past. (Details of this mineralisation are given in Chapter 9).
The fine-grained granite of this area is extensively hydrothermally altered, and a sheet of greisenised fine-grained granite, probably up to 100 m thick, lies parallel to the gently dipping volcanic contact. The greisenisation is considered to result from infiltration of late-stage hydrothermal fluids and gases contained within the granite by the overlying impervious fine ash tuffs of the Ap Lei Chau Formation. Ruxton (1957) regarded the volcanics as having been greisenised and not the granite. Evidence from this survey suggests, however, that the greisen has developed mainly in the granitic rocks. The greisenised granite has a sacharroidal texture, is equigranular, and has an average grain size of 1 mm (Plate 26). It is composed largely of quartz and light coloured micas; mainly muscovite, but also some light purple lepidolite. At the surface the rock is extensively weathered and takes on a reddish brown or purple coloration, as seen on the top of Chiu Keng Wan Shan (4338 1789). In trial adits nearby (4319 1807), the fresh rock is fairly soft, white to light brown, with abundant quartz and muscovite. The alteration here is patchy, and in places relatively unaltered fine-grained granite occurs. The outcrop of greisenised fine-grained granite is delineated on 1:20 000 map Sheet 11.

Basalt dykes intrude fine-grained granite at many localities; these were formerly well exposed in Junk Bay Road (4291 1945), where three prominent vertical dykes cut both the fine- and the fine- to medium-grained granite. Similar dykes were noted along the coast from Lei Yue Mun Point, northeastwards to Junk Bay, including a lamprophyre dyke following a fault trace striking 010° (4327 1660).

Southern Kowloon and Tsim Sha Tsui. Distinctive, megacrystic fine-grained granite crops out between Observatory Hill (360 181), Gun Club Hill (363 182) and King's Park (351 191), the best exposures being those behind Queen Elizabeth Hospital (3588 1892) and at the Nathan Road – Gascoigne Road Junction (357 189). The granite is grey and equigranular, with a fine groundmass of less than 1 mm average grain size and distinctive feldspar megacrysts averaging 8 to 10 mm in length. Biotite occurs as single flakes and in places as clusters of single crystals. This rock grades into a fine- to medium-grained granite with similar characters, but with a groundmass averaging 1.5 to 2 mm. The boundary between these megacrystic rocks and the equigranular medium-grained granite was not seen, but it is probable that the fine-grained megacrystic granite represents a later intrusion. Small bodies of fine-grained granite are intruded into medium-grained granite in Hung Hom (3710 1903 & 3760 1873). They are light pink and sparsely megacrystic, dissimilar to the fine-grained granite of King's Park described above, and their contacts are sharp and steeply dipping.

Northern and Eastern Hong Kong Island. Fine-grained granite crops out over wide areas on the hills between Happy Valley and Chai Wan. It is quarried at Mount Butler (390 144), where a gradational boundary with the fine- to medium-grained granite runs through the northern part of the workings (3905 1453). Mount Butler can be regarded as the type locality of the fine-grained granite of the district. The rock is leucocratic, light pink to light grey and roughly equigranular, with a groundmass grain size between 0.5 and 1 mm. It is sparsely megacrystic, with quartz grains up to 4 mm and occasional alkali feldspar crystals to 5 mm in length. In places, finer diffuse patches occur up to several metres across, with an average grain size of less than 0.5 mm. Biotite, in the form of fresh black shiny crystals, is scattered throughout but constitutes less than 2% of the rock. Pegmatite is common, usually as irregular shaped pods 0.1 to 0.3 m across. In the light grey granite, small specks of pyrite are visible in hand specimen.

The contact between the fine- and medium-grained granites is clearly defined between Tai Hang Road, King's Road, North Point and the Kornhill site at Quarry Bay. In this area, centred on Mount Butler, the fine-grained granite and associated fine- to medium-grained granite have an almost circular outcrop of some 9 sq km. Cross-cutting relations, as seen at Kornhill (4031 1565), demonstrate that the fine-grained body forms a younger intrusion into the medium-grained granite pluton of Kowloon and northern Hong Kong Island. Much of the area covered by this younger intrusion is designated as country park (Tai Tam and Quarry Bay country parks), and there are few exposures except in road cuttings around the fringe. At Jardine's Lookout, Mount Butler Drive (3797 1418), the granite contains scattered large feldspar megacrysts and is similar in appearance to the fine-grained granite at King's Park in Kowloon. The section along Mount Butler Drive and Price Road (3782 1402) shows variation from a non-megacrystic, markedly fine-grained granite with a sacharroidal texture (3795 1412) to a fine-grained granite containing diffuse patches of medium-grained granite (3782 1402). Pegmatite pods are common in these sections. Similar variation is seen

along Tai Hang Road near its junction with Mount Butler Road (3766 1404), southwards to the Tai Tam water tunnel portal (3774 1375). Thin aplite dykes are common, and these stand out as ribs on the highly weathered granite surfaces, for example, along Sir Cecil's Ride (3852 1531) and at Braemar Hill (3868 1600).

Between Victoria Barracks (3462 1542) and Bowen Road, Wan Chai (3594 1469), fine-grained granite crops out as a margin to the main medium-grained granite pluton. It is usually equigranular, and only sparsely megacrystic. A similar chilled margin is recorded at Middle Gap (3649 1362). Fine-grained granite intrusions into the main medium-grained pluton body occur at Morrison Hill (3642 1544) and at the Hong Kong Stadium (3739 1481), where a weathered basalt dyke (3738 1488) cuts the fine-grained granite. Here, the granite is equigranular with an average grain size of 0.5 to 1 mm. It is sparsely megacrystic, with scattered megacrysts of quartz, alkali feldspar and biotite up to 4 mm. The rock is light grey when fresh, with small, diffuse pink patches, probably resulting from iron staining of the alkali feldspar. Fine-grained granite crops out to the north, east and southeast of Mount Parker. The granite outcrop at the latter location forms a 150 to 200 m wide body with steeply dipping sides. Exposures near the junction of Chai Wan Road and Tai Tam Road (4207 1458) show the typical rock. It has a light pink colouration and is roughly equigranular, with an average grain size of 0.8 to 1 mm. There are quartz megacrysts up to 2 mm, but these are not prominent. Biotite is present as scattered fresh, single, black flakes. In places, however, the flakes have clustered to form clots of crystals 2 to 3 mm across. Pyrite also occurs, as crystals up to 3 mm across, with a 2 to 3 mm surrounding halo of dark green to black mineral, probably chlorite.

The fine-grained granite grades imperceptibly into a fine- to medium-grained granite at Hing Wah Estate, Chai Wan (4200 1386). The only intrusions cutting the fine-grained granite of this area are thin aplite (4197 1377) and basalt (4198 1391) dykes.

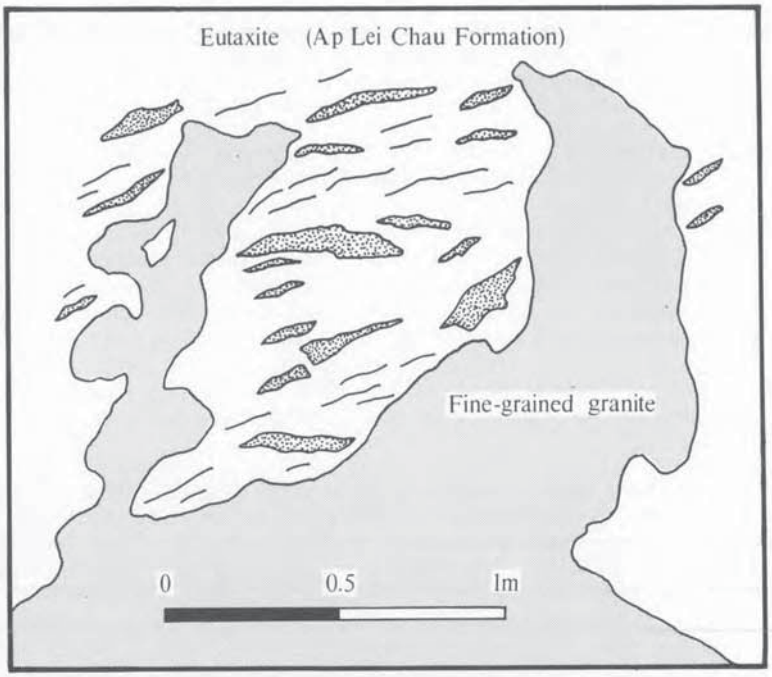


Figure 11 – Sketch Showing Irregular Granite/Volcanic Rock Contact at Sandy Bay (3031 1481)

Western Hong Kong Island. Isolated outcrops of fine-grained granite occur in the Pok Fu Lam area and also on Green and Little Green islands (Figure 8). The largest lies between Pokfulam Road and Baguio Villas, where the fine-grained granite grades into fine- to medium-grained granite (3167 1349). It is probable that all the isolated outcrops form parts of a single intrusive body at depth. The contact with the volcanics is very irregular, as seen in the small granite intrusions at the northern end of Sandy Bay (3031 1484, Figure 11). Everywhere the granite is light pink or light brown and characterized by its fine grain size, less than 0.5 mm. It appears equigranular, with a few scattered quartz megacrysts up to 2 mm. In thin section these granites possess a granophyric texture not apparent in hand specimen (Plate 27). No dykes were seen intruding this fine-grained granite, but pegmatite lenses were noted on Little Green Island (3013 1628), and on the western side of Telegraph Bay pegmatite concentrations occur at the granite-volcanic contact (3131 1367). In the grounds of Grantham Hospital, Wong Chuk Hang (3583 1247), fine-grained granite very similar to the variety at Pok Fu Lam occurs. This small body is bounded to the north by quartz syenite and to the south by volcanic rocks, but its precise relationship with the syenite is not clear.

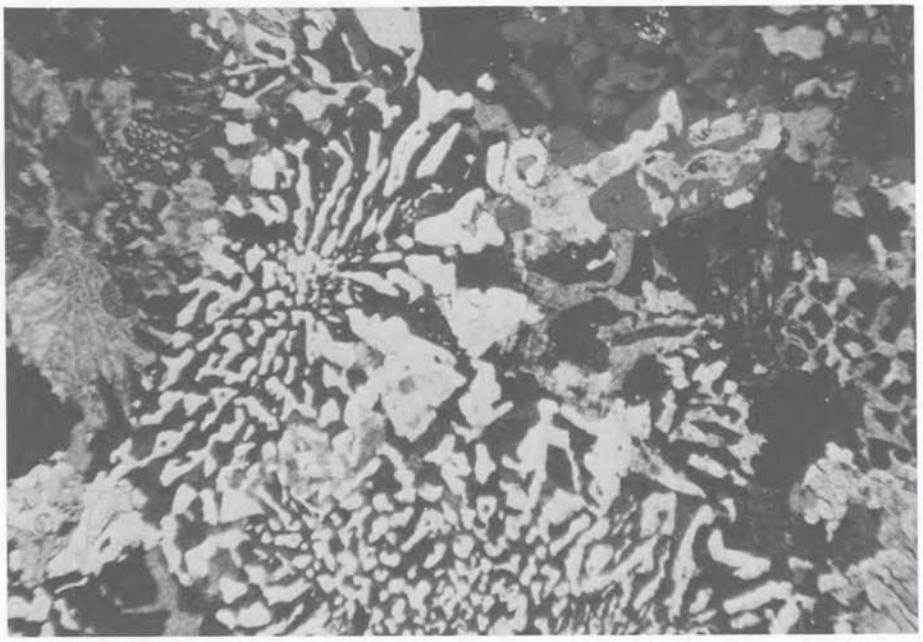


Plate 27 – Thin Section of Fine-grained Granite Displaying Granophyric Texture (HK 2459) from Pok Fu Lam (3129 1412); XPL × 50

Stanley and Shek O. Fine-grained granite marginal to the medium-grained granitic intrusions at Stanley and Shek O has been delineated on the map. On D'Aguilar Peninsula, fine-grained granite bordering an older quartz syenite intrusion consists of a fine equigranular groundmass with an average grain size of the about 0.5 mm. The rock is pink, and no biotite is visible. Rounded quartz megacrysts up to 4 mm across are scattered throughout. There are also sparse alkali feldspar megacrysts up to 3 mm. Quartz veining is common (4355 0917), and close to the contact with the syenite a wide quartzphyric rhyolite band parallels the contact (4373 0900). This is presumed to be a dyke, but it could possibly represent an extremely fine-grained chilled margin to the granite.

Quartz Syenite

Classification, Distribution and Lithology

The D'Aguilar Syenite rock unit was defined by Williams et al (1945), and its outcrop on the D'Aguilar Peninsula was shown on the 1936 geological map. Davis (1952) and Ruxton (1957) retained the term, but Allen & Stephens (1971) grouped the unit into their Quartz Monzonite category, based on the detailed examination of one thin section from a sample collected along the Cape D'Aguilar road (4320 0880). Allen & Stephens considered all rocks previously mapped as syenite to be quartz monzonite. However, detailed modal analyses of eight thin sections of samples collected from various localities on Hong Kong Island (Figure 12) during the present survey have revealed that all these rocks fall into the Quartz Syenite category (Streckeisen, 1974). This survey has thus reinstated the term Quartz Syenite (Figure 9).

In appearance the rock is fine- or medium-grained, with abundant, commonly aligned, alkali feldspar megacrysts averaging 8 to 10 mm in length (Plates 30 & 31). Quartz is present in minor amounts, and biotite forms approximately 5% of the rock. The groundmass is roughly equigranular in the Cape D'Aguilar and Stanley outcrops, but inequigranular in some bodies, notably those at Wong Chuk Hang and Mount Butler.

Quartz syenite intrudes and occasionally modifies the granites of central and northern Lamma Island, and this is best seen at Luk Chau (George Island), where infiltration of syenitic fluids into the fine- to medium-grained granite has produced a distinctive, modified rock, more syenitic than granitic in composition.

Details

D'Aguilar Peninsula and Stanley. Quartz syenite crops out over approximately 1.5 sq km, centred on D'Aguilar Peak (4370 0870), and apart from a wide fine-grained zone along its southern margin it is remarkably uniform in texture and appearance. It is a leucocratic medium-grained rock with abundant, prominent euhedral alkali

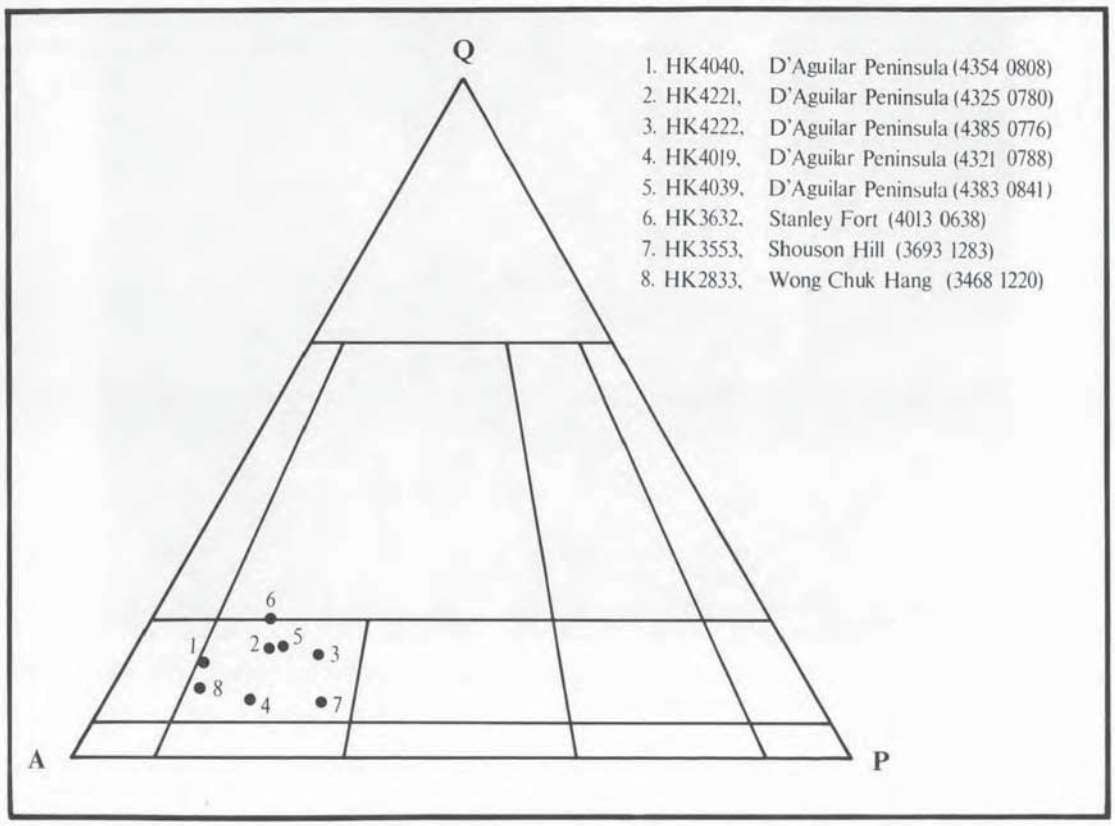


Figure 12 – QAP Diagram (after Streckeisen, 1974), Showing Plots of Quartz Syenite Samples from Hong Kong Island

feldspar megacrysts (Plates 30 & 31). These average 7 mm in length and are white or light pink in colour. In places these megacrysts are aligned. Quartz makes up less than 15% of the rock and does not occur as megacrysts. In thin section the groundmass is roughly equigranular, with interlocking subhedral alkali feldspar dominant. Biotite makes up 5 to 6% of the rock, and accessory minerals include minor amphibole, orthite and apatite. The very fine-grained chilled margin of the pluton around Hok Tsui Wan (4370 0785) has alkali feldspar megacrysts set in an indeterminate aphanitic groundmass. It is presumed that the chemical composition is roughly similar to the main pluton, thus placing this fine-grained rock into the Quartz Trachyte category (Streckeisen, 1980).

Quartz syenite is found on the Stanley Peninsula, where it intrudes granodiorite and tuffs of the Yim Tin Tsai Formation, and it is in turn intruded by fine- to medium- and medium-grained granites. Northwest of Stanley Village an almost circular outcrop of quartz syenite (3945 0920) is surrounded by younger granite. This syenite closely resembles that of the D'Aguilar Peninsula pluton. A similar but smaller outcrop of quartz syenite is found (3874 0915) in the northeastern corner of Chung Hom Wan Bay, where it intrudes Ap Lei Chau Formation tuffs. It is possible that, in view of the medium-grained nature of this rock, the outcrop represents a much larger pluton at depth.

Aberdeen, Wong Chuk Hang and Shouson Hill. Both fine- and medium-grained phases of quartz syenite are present in this area, and these crop out as impersistent elongate bodies intruding both granite and volcanic rocks. Behind the Technical School at Wong Chuk Hang (3770 1223) the quartz syenite grades into a chilled margin with an aphanitic groundmass and a few scattered feldspar megacrysts. Quartz syenite excavated from temporary trenches nearby (3470 1219) is medium-grained and has a distinctive bluish grey colour. Some feldspar crystals display a schiller effect, and in hand specimen the rock resembles larvikite (a syenite that grades to monzonite).

Although quartz syenite intrudes medium-grained granite, for example along Deep Water Bay Road (3747 1308), it is in turn intruded by fine- to medium-grained granite; this is well seen along the stream bed east of Shouson Hill (3745 1288). Here, the granite has a chilled margin against the medium-grained quartz syenite, and thin discontinuous dykes of fine-grained granite extend several metres into the quartz syenite. Small patches of granite pegmatite were noted at the contact.

Mount Butler and Chai Wan. Fine-grained quartz syenite forms a prominent ridge extending from Mount Parker westwards to Mount Butler (3980 1431). Its relationship with the surrounding granite is unclear, with no exposures of the contact, but a contact between chilled quartz syenite and tuff is exposed (4000 1428). It is

possible that the quartz syenite is older than the surrounding granite at Mount Butler, as is the case at Lei Yue Mun Barracks (4220 1552). In this outcrop the quartz syenite forms a sill cutting tuffs of the Shing Mun Formation; these in turn are intruded by granite, the contact having been well exposed in slope remedial works at A Kung Ngam Road (4194 1558).

Lamma Island. Quartz syenite is found as a number of small intrusive bodies in northern and eastern Lamma Island. To the north and east of Yung Shue Wan, quartz syenite intrudes both the volcanics and granites. Generally, the groundmass is fine-grained, but abundant alkali feldspar megacrysts are present, and these are commonly aligned. Excavations near Tai Peng (3014 0986) have revealed quartz syenite at the granite-volcanic contact, with some infiltration of syenite into the coarse ash tuffs. On Luk Chau (George Island), quartz syenite intrudes the fine- to medium-grained granite, and infiltration and modification of this granite by syenitic fluids is common. Syenitic patches several metres across are present in the granite near the summit at the centre of the island (3194 0956). The weathered quartz syenite produces rounded corestones that are common on the sparsely vegetated hill slopes east of Hung Shing Ye (3084 0874).

Megacrystic medium-grained quartz syenite crops out immediately southeast of Mo Tat Wan (3316 0756) in eastern Lamma, where it intrudes coarse-grained granite as a northwesterly striking dyke-like body some 250 to 300 m in width.

Geochemistry

Two samples of coarse-grained granite, both from northwestern Kowloon, have been analysed for major and minor elements. The analyses show a trend similar to that found in the coarse-grained granites of the Sha Tin district (Addison, 1986), having a higher calcium content than the surrounding finer grained varieties. The silica content of the coarse-grained granite is also slightly lower, whereas the titanium oxide percentage is roughly double that found in the medium- and fine- to medium-grained granites. The analyses of these coarse-grained granites show certain affinities with the granodiorite of the Sha Tin district, but, unfortunately, none of the granodiorite samples obtained from Hong Kong and Lamma islands were suitable for analysis.

The fine-grained granites are low in titanium and calcium, but slightly higher in their sodium content. The trends are summarized in an ACF diagram (Figure 13) in which the plot of analyses

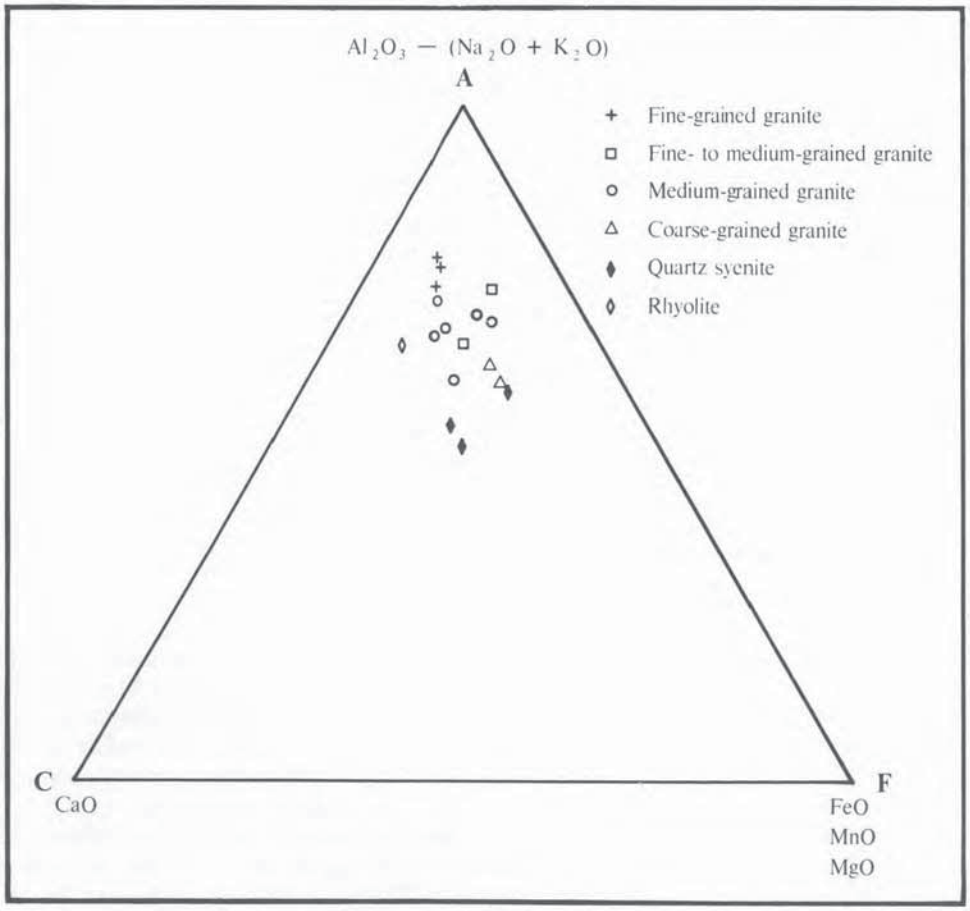


Figure 13 – ACF Diagram Showing Relative Proportions of Alumina Minus Alkalis, Lime and Combined Ferrous Manganese Oxide and Magnesia in Samples of the Major Intrusive Rocks

follows the observed emplacement sequence; older coarse-grained granite, richer in calcium and ferromagnesium minerals, grading into medium- and fine- to medium-grained granites and finally to the youngest of the granites, the fine-grained variety which is deficient in CaO, FeO, MnO and MgO.

Table 4 – Major Element Analyses of Coarse- and Medium-grained Granites

Element	Coarse-grained Granite		Medium-grained Granite					
	Lai King (3146 2366) HK 2181	Lai King (3141 2370) HK 2183	Hung Hom (3760 1882) HK 1608	Pak Tin (3493 2191) HK 2180	Shek O Quarry (4259 0930) HK 3635	Chung Hom Kok (3894 0832) HK 3851	Wan Chai (3611 1522) HK 4237	Sok Kwu Wan (3186 0848) HK 4808
SiO_2	71.85	73.19	74.24	74.75	75.83	77.89	77.01	73.30
TiO_2	0.29	0.20	0.13	0.13	0.06	0.06	0.13	0.18
Al_2O_3	13.56	13.01	12.34	12.71	12.23	11.87	12.09	14.08
Fe_2O_3	0.64	0.56	0.38	0.56	0.31	0.18	0.42	0.53
FeO	1.84	1.44	1.07	1.01	0.81	0.91	0.99	1.41
MnO	0.05	0.05	0.06	0.07	0.09	0.07	0.07	0.08
MgO	0.29	0.17	0.15	0.11	0.10	0.04	0.11	0.07
CaO	1.37	1.19	0.82	0.89	1.13	0.66	0.90	0.96
Na_2O	3.03	3.01	3.13	3.15	4.33	2.92	2.77	3.55
K_2O	5.45	5.42	5.12	5.34	4.80	4.81	4.76	5.19
H_2O+	0.59	0.44	0.28	0.13	0.33	0.48	0.52	0.65
H_2O-	0.15	0.22	0.10	0.11	0.09	0.12	0.09	0.09
P_2O_5	0.07	0.04	0.02	0.02	0.00	0.01	0.02	0.02
Total	99.18	98.94	97.84	98.98	100.11	100.02	99.88	100.11

The quartz syenite forms a separate group of analyses, markedly different from the granites. The silica content is low, whereas calcium, titanium, aluminium and the ferromagnesium oxides are much higher than found in the granite. The analyses have been plotted as % $Na_2O + K_2O$ against % SiO_2, and these plots fall clearly into the syenite field (Cox, Bell & Pankhurst, 1979).

Age Relations

There is no evidence for any plutonic rocks within the district older than the granodiorite. The granodiorite is intruded into the Yim Tin Tsai Formation, the lowest part of the Mesozoic volcanic pile of the Repulse Bay Volcanic Group, on the Stanley and Cape D'Aguilar peninsulas, and on Round Island. The coarse-grained granites, which display textural and chemical affinities with the granodiorite, may be of similar age or possibly slightly younger. The coarse-grained granite has been modified, apparently by infiltration of later granitic and syenitic fluids, producing a particularly variable rock. In some exposures, fine-, fine- to medium-, medium- and coarse-grained varieties can be seen grading into each other. Quartz syenite appears to have been intruded in several phases, but the larger plutons at Stanley and on D'Aguilar Peninsula pre-date the medium-grained granite, in which large xenolith blocks of quartz syenite have been found.

The fine- to medium-grained granite pluton that occupies much of southern Lamma is clearly younger than the coarse-grained granite, which is found as isolated outcrops along the southeastern

Table 5 – Major Element Analyses of Fine- and Fine- to Medium-grained Granites, Quartz Syenite and Feldsparphyric Rhyolite

Element	Fine- to Medium-grained Granite		Fine-grained Granite			Quartz Syenite			Feld-spar-phyric Rhyolite
	Shouson Hill (3708 1261)	Kwun Tong (4288 1947)	Mount Butler Quarry (3910 1440)	Kwun Tong (4284 1953)	Sok Kwu Wan (3154 0845)	Wong Chuk Hang (3476 1225)	Shouson Hill (3693 1283)	Ap Lei Chau (3333 1175)	Lai King (3142 2367)
	HK 3614	HK 2185	HK 214	HK 2184	HK 4806	HK 3552	HK 3553	HK 3636	HK 2182
SiO_2	76.51	76.56	75.49	75.26	77.29	59.06	58.74	65.74	73.91
TiO_2	0.10	0.02	0.03	0.02	0.04	0.46	0.60	0.33	0.19
Al_2O_3	11.86	12.41	12.52	12.45	12.51	19.17	18.67	16.74	12.63
Fe_2O_3	0.45	0.10	0.24	0.22	0.26	1.32	1.77	0.73	0.60
FeO	0.89	0.86	0.69	0.65	0.88	2.36	2.91	2.02	1.39
MnO	0.05	0.09	0.05	0.08	0.11	0.10	0.14	0.12	0.08
MgO	0.10	0.02	0.03	0.02	0.01	1.02	1.40	0.33	0.17
CaO	1.02	0.55	0.45	0.45	0.58	3.97	4.36	1.40	0.63
Na_2O	3.10	3.89	3.95	3.82	3.15	3.25	3.27	3.98	3.05
K_2O	5.02	4.55	4.52	4.82	5.06	7.55	6.80	7.55	5.39
H_2O+	0.56	0.28	0.46	0.31	0.47	1.02	1.12	0.96	0.97
H_2O-	0.06	0.14	0.08	0.17	0.01	0.00	0.04	0.20	0.23
P_2O_5	0.00	<0.01	<0.01	<0.01	0.01	0.25	0.31	0.07	0.04
Total	99.72	99.47	98.51	98.27	100.38	99.53	100.13	100.17	99.28

coastline, but a swarm of E–W rhyodacite and rhyolite dykes cuts the fine- to medium-grained granite pluton. Elsewhere, on the Po Toi Island Group and southern Hong Kong Island, the fine- to medium-grained granite is of similar age to that of the Lamma Island pluton. On the D'Aguilar Peninsula the granite is seen intruding the quartz syenite pluton, and similar relationships have been noted at Stanley. Chemically the fine- to medium-grained granite is closely similar to the medium-grained granites of Stanley, Shek O and the large Kowloon – northern Hong Kong Island pluton. All are equigranular and texturally similar. It is suggested that these granite bodies were intruded at about the same time and that they post-date some, but not all, of the rhyolite and quartz syenite dykes. The medium-grained granite displays chilled contacts with the coarse-grained granite in northern Kowloon. Fine- and fine- to medium-grained granites intrude the eastern part of the medium-grained Kowloon – northern Hong Kong Island pluton, cropping out over Braemar Hill and Mount Butler on Hong Kong Island, and in the Kwun Tong – Anderson Road area of East Kowloon. A small circular body of megacrystic fine- and fine- to medium-grained granite intrudes the medium-grained granite in the King's Park area of the Kowloon peninsula. Granophyric fine-grained granite, occurring as isolated outcrops in the Pok Fu Lam area, and on Green and Little Green islands, may represent the youngest of the granitic intrusions. Late stage emanations from the cooling granite bodies have produced quartz and mineralised fissure vein deposits, pegmatite lenses and small aplite dykes.

The geochronology of the granites has been discussed by Chandy & Snelling (in Allen & Stephens, 1971). The potassium: argon age determinations indicated that the age of the granite micas ranged from 117 to 143 ma, with a tendency to cluster about 135 ma. Chandy & Snelling noted that there was no convincing correlation between the ages and the sequence of emplacement of the intrusive rocks as deduced from the field studies. The circa 135 ma date probably represented the cooling point of the last major granitic intrusion. Whole rock rubidium: strontium age determinations indicated the intrusion age of the granodiorite, coarse-grained granite and quartz monzonite (sic) to be 163 ± 35 ma, with the medium-grained granite (Hong Kong Island) and the fine- to medium-grained granite (southern Lamma Island) at 140 ± 7 ma.

Chapter 5
Minor Intrusions

Classification

The minor intrusions of this district occur as dykes varying from a few centimetres to as much as 150 m wide, and consist of feldsparphyric rhyolite, quartzphyric rhyolite, feldsparphyric rhyodacite, quartz syenite, quartz trachyte, basalt or lamprophyre. The rhyolite, rhyodacite, syenite, and trachyte intrusions are related to the Mesozoic granitic emplacement, whereas most of the basalt and lamprophyre is considered to be of Tertiary age (Allen & Stephens, 1971).

The rhyolite, rhyodacite and trachyte correspond to the porphyry dykes of Allen & Stephens (1971), and the basalt corresponds to their dolerite (Table 1). Hatch et al (1972) recommended use of the terms rhyolite, trachyte and basalt on non-genetic grounds for the minor intrusives and volcanics alike. Streckeisen (1974, 1980) made recommendations for the classification of these rocks to the IUGS Subcommission on the Systematics of Igneous Rocks, and his divisions are used in this survey (Figure 9). Thus it is possible to correctly identify a rock from thin section or hand specimen even though field relationships may be uncertain and mode of occurrence unknown.

Feldsparphyric Rhyolite

Distribution and Lithology

This rock comprises the majority of dykes within the district. They crop out mainly in three areas; along the northern margin of the district between Lai Chi Kok and Tate's Cairn, across southern and central Lamma Island, and through the Po Toi Island Group. In each of these areas the dykes occur as sub-parallel steeply dipping or vertical bodies, trending in most cases roughly ENE or E–W, and varying in thickness from 2 to 50 m.

The rhyolite is characterized by a very fine, often aphanitic, grey green to dark grey groundmass containing prominent subhedral to euhedral feldspar megacrysts (Plates 32 & 33). These megacrysts are mainly of alkali feldspar, usually light grey but in places light pink in colour. Smaller megacrysts of quartz and plagioclase feldspar are generally present, and scattered fresh black biotite flakes are not uncommon. The average megacryst size varies greatly from dyke to dyke, but in an average sized body of 10 m width megacrysts between 10 and 15 mm in diameter are typical. The greatest concentration of megacrysts is present in the centre of the dyke, in contrast to the 5 to 50 cm wide chilled margins where megacrysts are sparse. Evidence from fresh rock outcrops suggests that some of the dykes are composite intrusions, with possibly three or more phases of fluid injection. The presence of broken and rounded megacrysts in some dykes suggests they may have crystallised elsewhere and have been transported by the liquid groundmass fluids.

Details

Kowloon. Feldsparphyric rhyolite occurs as dykes 2 to 10 m wide in the Lai King area of northwestern Kowloon, where they intrude both the fine-grained and coarse-grained granites. They form part of a wide dyke swarm extending east-northeast from Lantau Island through Tsing Yi into the Sha Tin district. The rhyolite is invariably composed of a greyish green, very fine groundmass containing minute black specks of biotite, megacrysts of alkali feldspar averaging 12 mm across, and smaller quartz and plagioclase megacrysts of 3 to 4 mm. Biotite crystals tend to aggregate into felty blotches in a similar manner to those in the coarse-grained granite of this area. At Wah Yiu Road, Lai King (3144 2367), a 3.2 m wide dyke shows evidence of multiple phases of intrusion (Figure 14). The feldspar megacrysts are commonly rounded and broken, especially where most abundant in the central part of the dyke. A chemical analysis of this dyke rock (HK 2182) shows that the composition is granitic (Table 5) and very similar to the coarse-grained granite host. In the vicinity of Grasscutter's Pass (3930 2400) and Fei Ngo Shan, prominent NW–SE trending feldsparphyric rhyolite dykes cut both the granite and the volcanic rocks. The largest of these is 120 m wide at Grasscutter's Pass and 90 m wide west of Middle Hill (4057 2318). In the Ho Chung Valley (4258 2334) an isolated outcrop of feldsparphyric rhyolite was noted in the stream bed, but its relationship with the country rock was obscured by superficial deposits.

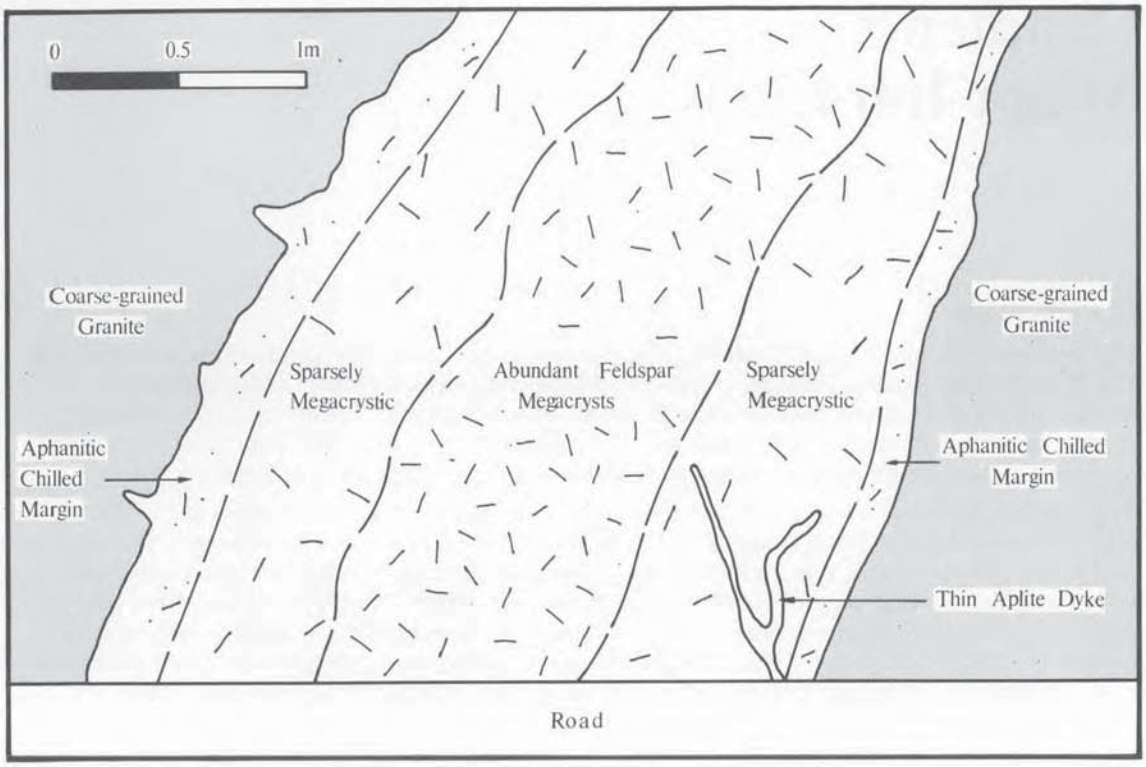


Figure 14 – Dyke of Feldsparphyric Rhyolite at Lai King, Northwestern Kowloon (3142 2367), Showing Multiple Phases of Intrusion

Hong Kong Island. Feldsparphyric rhyolite dykes were mapped in only two locations, at the Hill above Belcher's and northwest of Mount Cameron. The rhyolite forms a prominent N–S ridge named the Hill Above Belcher's (3196 1566), where the dyke is approximately 25 m wide and cuts coarse ash tuffs of the Tai Mo Shan Formation. The rock is highly weathered, but distinct alkali feldspar megacrysts can be seen, often more weathered than the groundmass. A crude flow-banding was noted in places. A similarly trending N–S dyke, approximately 10 m wide, crops out in the stream bed 200 m northwest of Mount Cameron summit. Here, the groundmass is almost aphanitic, and the megacrysts average 5 mm.

Lamma Island. Numerous feldsparphyric rhyolite dykes striking roughly east-west cut the granites of central and southern Lamma Island. Most average 20 to 30 m wide and extend over distances varying from 100 m to 2 km. The largest dyke attains a width of 100 m west of Shek Pai Wan (3200 0635), and further west this dyke divides into two branches (3169 0632). A similar branching of a feldsparphyric dyke occurs northwest of Mount Stenhouse (3070 0618). The dyke rock is characterised by a dark grey to greenish-grey, very fine-grained groundmass, with prominent abundant light grey and light pink alkali feldspar megacrysts averaging 10 mm across. Quartz and plagioclase are found as smaller, less common megacrysts reaching 6 mm across. Biotite is present, usually as individual flakes up to 5 mm in length. On the weathered surfaces, the alkali feldspar megacrysts stand proud of the surface.

Po Toi Island Group. A composite feldsparphyric rhyolite dyke, 20 m in width, with basalt margins, strikes northeast across the southeastern part of Sung Kong Island.

Quartzphyric Rhyolite

Distribution and Lithology

Although of similar chemical composition to the feldsparphyric rhyolites, the quartzphyric rhyolites have a remarkably dissimilar appearance. In hand specimen they are light grey or pinkish white and very fine-grained, with a few scattered quartz megacrysts usually only to 2 or 3 mm across. The rock is uniform, but near the margins of the dykes distinctive flow-banding parallels the contact (Plate 36).

Quartzphyric rhyolite occurs throughout the district as dykes that do not appear to be confined to distinct swarms or geographical areas, unlike the dykes of feldsparphyric rhyolite and rhyodacite. On Lamma Island some quartzphyric rhyolite dykes trend parallel to the principal feldsparphyric rhyolite dykes, but often they trend in different directions; this is well demonstrated at Ngau Tai (3353 0744), where a feldsparphyric rhyolite dyke striking E–W is cut by a NW trending quartzphyric rhyolite dyke.

Plate 28 – Fine-grained Granite (HK 2184) from Junk Bay Road, East Kowloon (4284 1953); Natural Scale

Plate 29 – Thin Section of Fine-grained Granite (HK 580) at Shun Lee, East Kowloon (4190 2120); XPL × 10

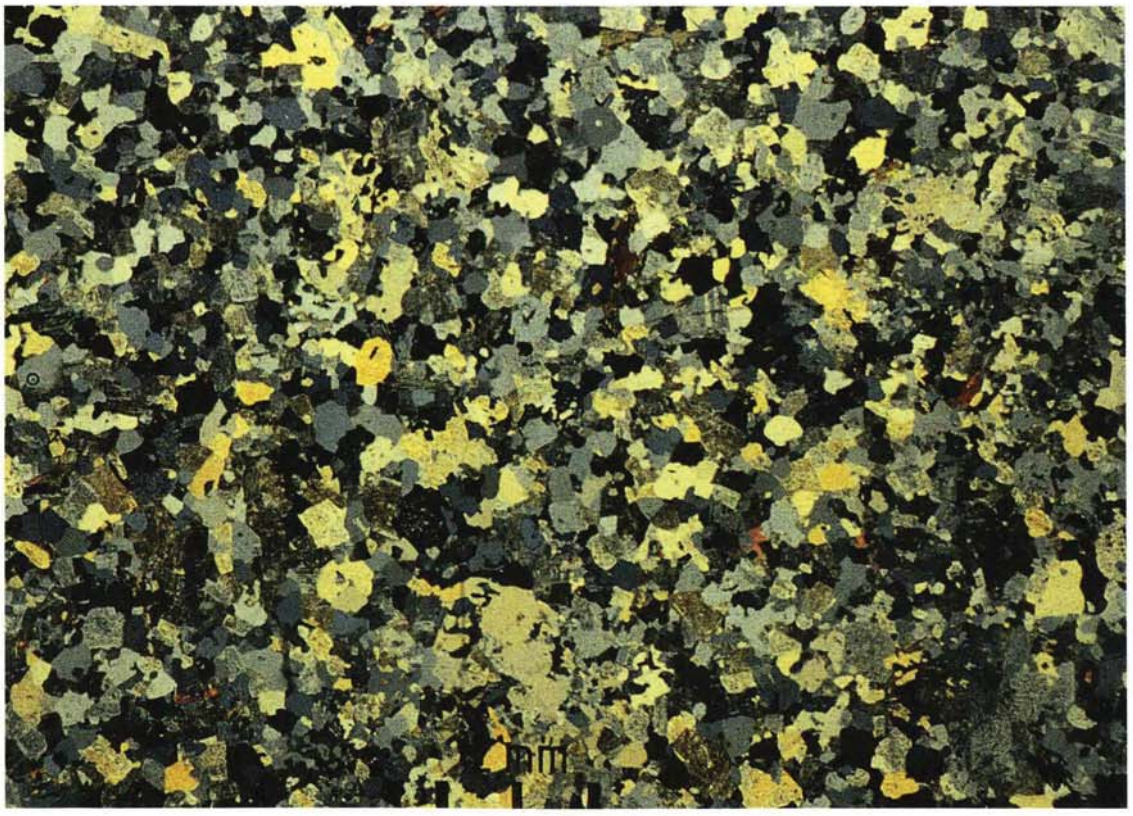


Plate 30 – Quartz Syenite (HK 4019) from D'Aguilar Peninsula (4321 0788); Natural Scale

Plate 31 – Thin Section of Quartz Syenite (HK 4019) from D'Aguilar Peninsula (4321 0788); XPL plus $\frac{1}{4}\lambda$ plate × 10

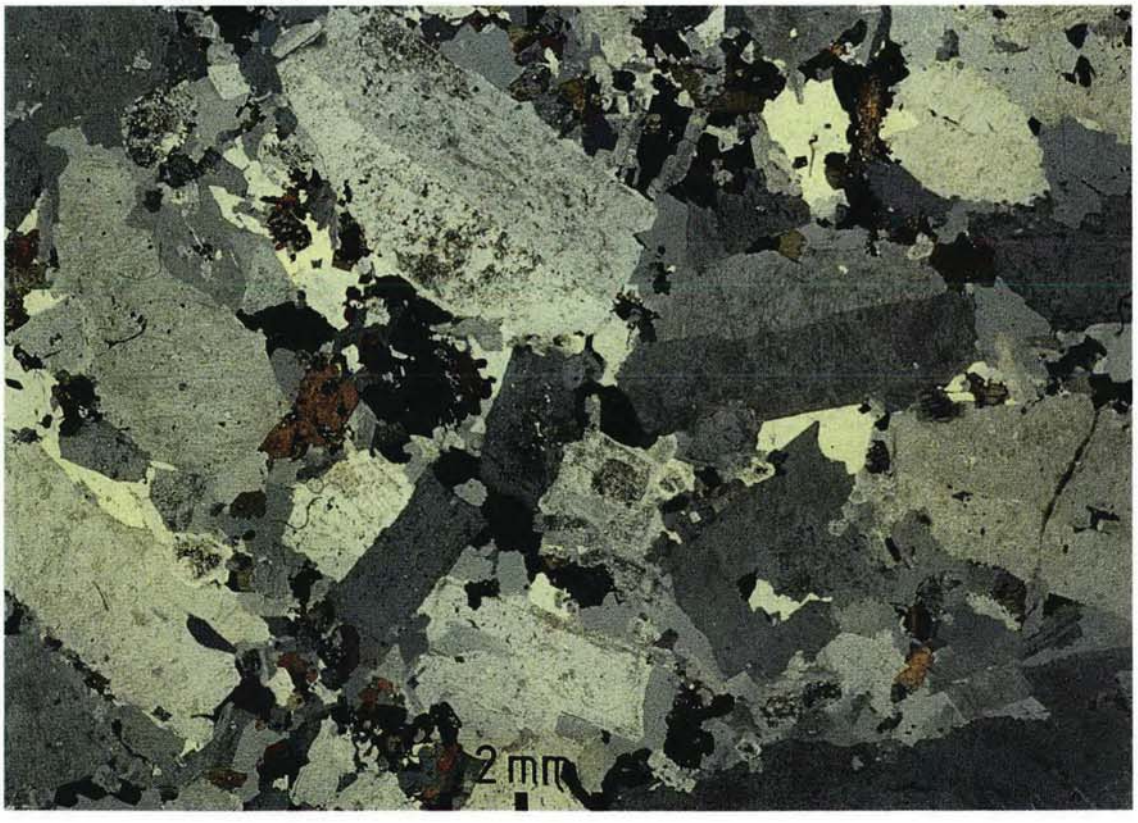
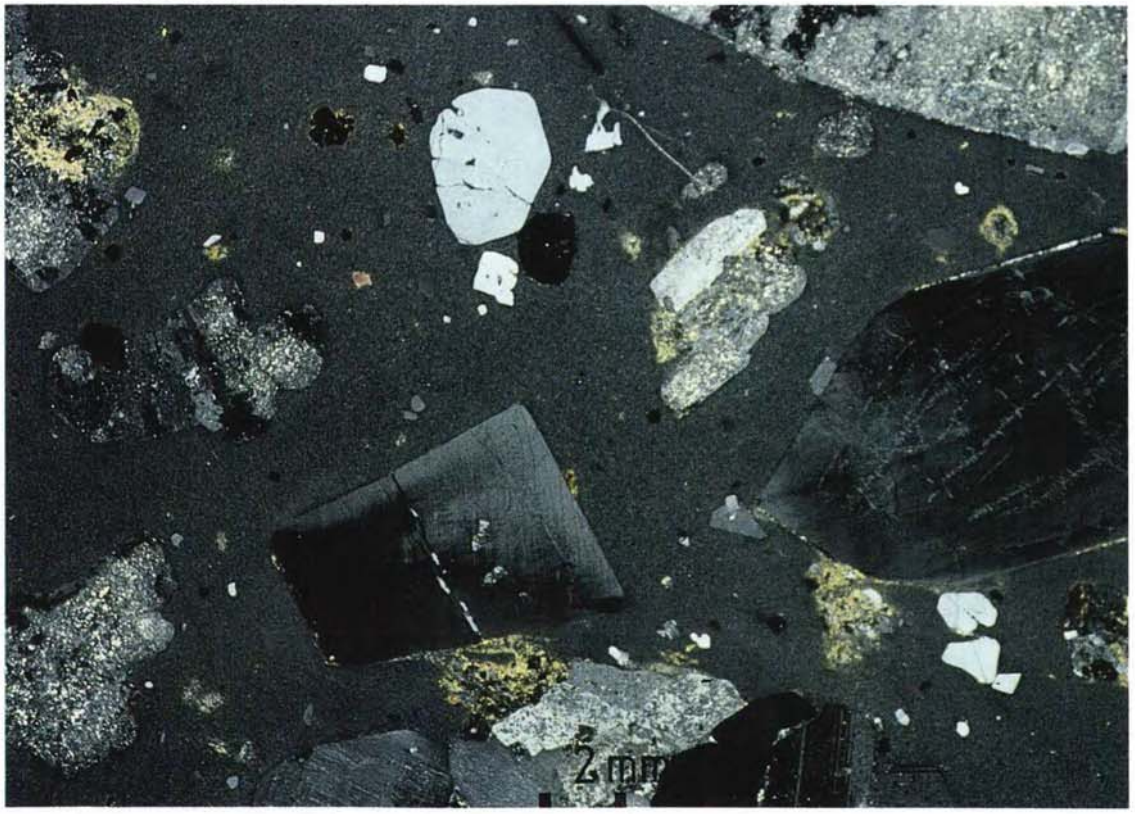


Plate 32 – Feldsparphyric Rhyolite (HK 5115) from Sok Kwu Wan, Lamma Island (3165 0700); Natural Scale

Plate 33 – Thin Section of Feldsparphyric Rhyolite (HK 3846) from Yuen Kok, Lamma Island (3337 0474); XPL × 10



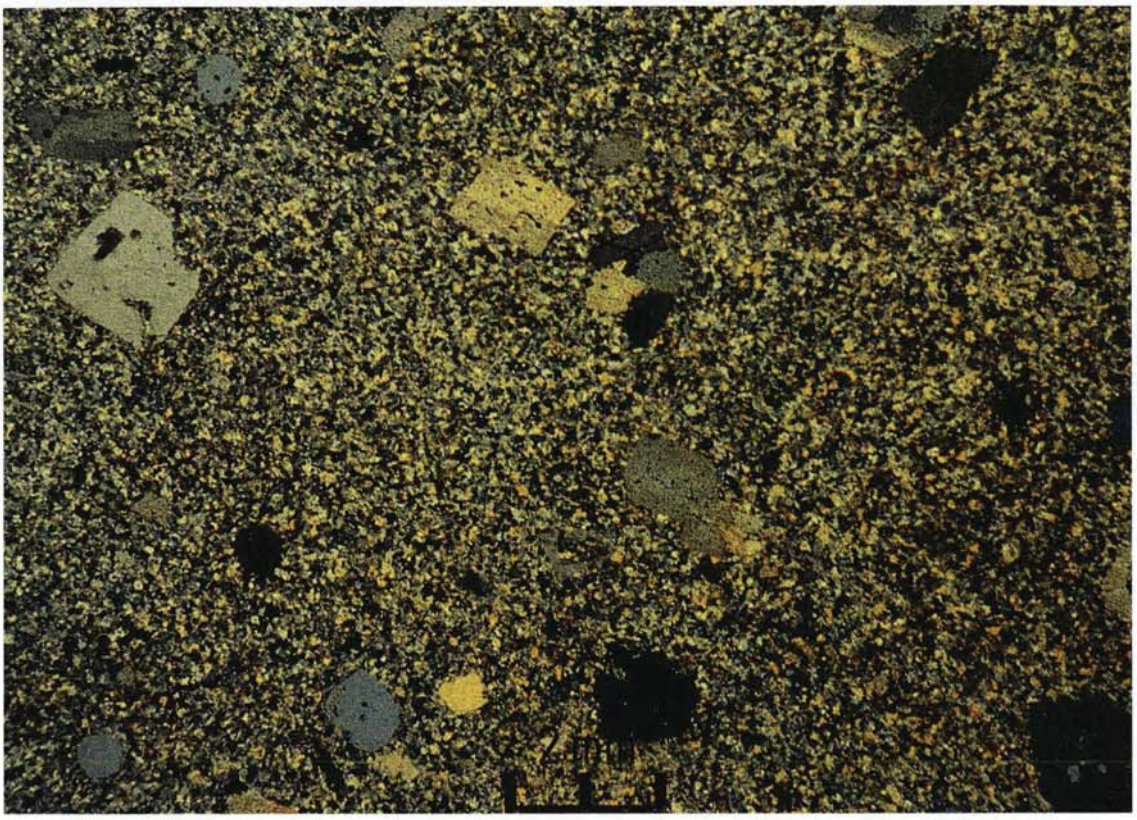


Plate 34 – Thin Section of Quartzphyric Rhyolite (HK 2879) from Shouson Hill (3660 1230); XPL × 10

Plate 35 – Thin Section of Basalt (HK 424) in Dyke At Diamond Hill (3906 2275); XPL plus $\frac{1}{4}\lambda$ plate × 10

Quartzphyric rhyolite dykes are most commonly found cutting the granitoid bodies, but they have also been noted in many places intruding the volcanic rocks. The latter, especially the fine ash tuffs of the Ap Lei Chau Formation, weather in a manner similar to the dykes and, unless fresh rock is exposed, it is not always possible to distinguish the dykes from the country rock.

Details

Kowloon. A vertical quartzphyric rhyolite dyke, 10 m wide, cuts the coarse-grained granite at Ha Kwai Chung (3118 2336) and parallels nearby feldsparphyric rhyolite and basalt dykes. Elsewhere in central, northern and western Kowloon, quartzphyric rhyolite has not been mapped, but in East Kowloon there are isolated occurrences. The most prominent is a N–S vertical dyke 60 m wide, cutting volcanic rocks of the Shing Mun Formation on Fei Ngo Shan (4110 2237). The rhyolite displays distinctive flow-banding, well exposed 50 m east of the radio transmitter tower (4113 2240), where the flow-fabric is highly contorted. Between Ngau Tau Kok and Shun Lee (4062 2114), two roughly parallel quartzphyric rhyolite dykes intrude the fine- to medium-grained granite. Trial adits have been dug into the larger of the dykes, presumably in an exploration for metalliferous minerals.

Hong Kong Island. Quartzphyric rhyolite has been exposed in temporary excavations at Queen Mary Hospital (3151 1468), where it forms a NNW-trending dyke several metres wide. Similar trending dykes occur at Shouson Hill (3660 1230, Plate 34) and on the southern flanks of Mount Nicholson. There (3678 1317), one dyke is 40 m wide and cuts both fine-grained granite and Ap Lei Chau Formation volcanic rocks. Prominent vertical flow-banding parallel to the dyke trend is seen on weathered surfaces. At Bennet's Hill (3527 1300) a quartzphyric rhyolite dyke up to 60 m wide strikes N–S. Some flow-banding was observed, but the rock is deeply weathered. Feldspar megacrysts have been eroded out, leaving euhedral hollows often stained purple, but the quartz megacrysts, up to 3 mm across, are unaffected by the weathering. The best exposures of quartzphyric rhyolite in the district are found at Cape D'Aguilar (4490 0560), where a number of dykes cut both the dark grey coarse ash tuff and the granodiorite, and are in turn cut by basalt dykes. The rhyolite dykes are light pink to white in colour, but darker grey to greenish-grey when fresh. Distinctive flow-banding parallel to the irregular dyke margins is common. The dykes are approximately vertical, but their attitude varies greatly along the strike from northerly dips of only 35° to southerly dips of 80°. The rock has a very fine-grained groundmass, with scattered quartz and a few feldspar megacrysts usually less than 2 mm

Plate 36 – Dyke of Flow-banded Quartzphyric Rhyolite Intruding Granodiorite on Cape D'Aguilar (4489 0765)

in diameter. Biotite is present as tiny specks throughout the rock. In thin section, the groundmass is a microcrystalline aggregate of quartz and feldspar, with some granophyric texture around feldspar crystals. A 0.2 m wide quartzphyric rhyolite dyke cuts the granodiorite on the western side of the Stanley Peninsula (3985 0773), while near South Bay (3803 0951) a 30 m wide flow-banded rhyolite forms a prominent coastal rib. This dyke has sharp contacts with the fine ash tuffs of the Ap Lei Chau Formation, and both rocks weather to a very similar appearance.

Lamma Island. Light grey, sparsely megacrystic quartzphyric rhyolite crops out as a dyke almost 200 m wide northeast of Mo Tat Wan (3360 0805) on eastern Lamma. This dyke intrudes both the fine- and the coarse-grained granites, and appears to be cut by a thin feldsparphyric rhyolite dyke. Locally (3374 0808), the central part of the dyke consists of a monomictic breccia and has the appearance of a tuff-breccia. This zone, some 10 m wide, may be an auto-brecciated core to the dyke; brecciation in dyke intrusions has not been observed elsewhere in the district. The dyke can be traced along the coast on the eastern side of the bay as far as Wong Chuk Kok (3449 0786). Along this coast the southern margin of the dyke crops out in the cliffs, with the rhyolite part of the cliffs being particularly resistant to erosion by the sea. 500 m ESE of Mo Tat Wan (3354 0744) a 20 m wide quartzphyric rhyolite dyke cuts obliquely across a feldsparphyric rhyodacite dyke, suggesting that at least some of the quartzphyric rhyolite intrusions post-date the feldsparphyric varieties. South of Lo So Shing, several 20 to 30 m wide quartzphyric rhyolite dykes crop out on the coast (3056 0685 & 3049 0603) striking 070 to 090°, parallel to the main feldsparphyric rhyolite dyke swarm. Inland, one quartzphyric rhyolite dyke (3100 0643) reaches a width of 100 m and consists of light pink very fine-grained rock that forms a clear positive feature on the more readily eroded granite landscape.

Po Toi Island Group. A number of quartzphyric rhyolite dykes are found on Po Toi and Sung Kong islands (Figure 10). One dyke (4442 0344) forms a strong negative photogeological lineament north of Tai Wan Village on Po Toi. Flow-banded margins to the dykes are common and particularly well seen on Lo Chau Pak Pai (Castle Rock, 4244 0407).

Feldsparphyric Rhyodacite

Distribution and Lithology

Feldsparphyric rhyodacite has been distinguished only on central and southern Lamma Island, where it occurs as dykes 50 to 150 m wide paralleling the feldsparphyric rhyolite dykes with an approximately east-west trend. The rock is characterized by a roughly equigranular groundmass containing felty biotite patches. These patches are aggregations of minute biotite crystals, and appear similar to those in the granodiorite and the coarse-grained granite. Quartz megacrysts up to 6 mm and white plagioclase megacrysts averaging 7 mm by 5 mm make up the bulk of the megacryst content, but large alkali feldspar crystals averaging 10 mm in length are also present (Plates 40 & 41).

In thin section many of the alkali feldspar grains in the groundmass display a granophyric texture, and crystal intergrowth obscures many of the original grain boundaries, making accurate grain size measurements difficult.

The dykes always possess a chilled aphanitic margin ranging in width from 0.1 to 1.5 m, and the centre of the dyke is usually characterised by a slightly coarser groundmass and an abundance of the larger alkali feldspar megacrysts. Unlike the quartz syenite intrusions, no sign of megacryst alignment has been noted in these dyke rocks.

No chemical analyses have been undertaken. However, this rock is placed in the rhyodacite class because of the higher estimated percentage of plagioclase present compared with the feldsparphyric rhyolite. Exposures of these dykes are not common, and their outcrop is characterised by smooth slopes, low vegetation and a red soil strewn with rounded iron-stained boulders, usually with pitted surfaces.

Details

Lamma Island. A prominent dyke crossing southern Lamma is composed of feldsparphyric rhyodacite and is the largest continuous dyke mapped in this district. It averages 100 m in width and in places exceeds 150 m. The dyke is roughly vertical and has been displaced by a major fault at Sham Wan (3180 0520). A similar dyke rock occurs on the eastern side of Sham Wan, where it crosses the Yuen Kok peninsula (3283 0543). Samples collected along this outcrop over a distance of several kilometres show uniformities of texture and appearance. The rock has a fine groundmass with abundant felty biotite patches. In the centre of the dyke (3286 0542) the rhyodacite shows a remarkable similarity to the granodiorite cropping out at Lo So Shing (3050 0744). A similar feldsparphyric rhyodacite dyke occurs 200 m south of the summit of Mount Stenhouse (3132 0566), but there the dyke is only 50 m wide and megacrysts are less prominent (Plates 40 & 41). On the Ngau Tai peninsula, east of Mo Tat Wan (3414 0766), a 75 to 100 m wide dyke of feldsparphyric rhyodacite trends east-west, cutting coarse-grained granite. A parallel rhyodacite dyke crops out on the coast 600 m east of Mo Tat Wan (3360 0747). There, the dyke is at least 75 m wide and cuts the coarse-grained granite. It is in turn cut by a NW–SE trending quartzphyric rhyolite dyke. The rhyodacite dykes in the Ngau Tai area have a groundmass similar to that of the dykes on southern Lamma Island, but alkali feldspar megacrysts appear to be more common at Ngau Tai.

Quartz Syenite, Quartz Trachyte and Quartz Monzonite
Classification, Distribution and Lithology

Apart from the plutons of quartz syenite, described in detail in Chapter 4, a number of discontinuous dyke-like bodies of this rock occur on Hong Kong Island, especially along a line extending from Aberdeen to Chai Wan.

Quartz trachyte is the very fine-grained equivalent of quartz syenite (Figure 9). Williams et al (1945) referred to samples of quartz trachyte from the D'Aguilar Peninsula as quartz syenite porphyrite, and Allen & Stephens (1971) grouped these intrusions under their more general porphyry dykes category.

Minor dykes associated with the quartz syenite intrusions are considered in this survey to be quartz trachytes, although in many cases, a detailed modal analysis is not feasible due to the very fine, almost aphanitic nature of the groundmass. As most megacrysts are composed of alkali feldspar, a modal analysis of megacrysts alone would not reveal the true nature of the rock composition. Quartz trachyte dykes occur on Hong Kong Island, in the Aberdeen, Chai Wan and Stanley areas, but all are small and impersistent.

Quartz monzonite dykes in the southern part of the adjoining Sheet 7 extend just into the district, along the northern Flanks of Beacon Hill. Isolated poor exposures were seen along the catchwater, 500 m east of the Tai Po Road (3467 2380).

Basalt and Lamprophyre
Distribution and Lithology

The term dolerite, as used by Allen & Stephens (1971), referred to a basic dyke rock without necessarily possessing an ophitic (doleritic) texture or a defined grain size. In the present survey the classification adopted is that recommended by Streckeisen (1980), and the terms basalt and fine-grained gabbro are used for these minor basic intrusions (Figure 9). Most basalt dykes are less than 2 m wide and impersistent; only in exceptional cases, for example at Diamond Hill, do they exceed 5 m in width and extend over more than 300 m (Plate 37).

The basalt is a very fine-grained black rock with a groundmass of euhedral laths of plagioclase and abundant amphibole, biotite and magnetite. Phenocrysts of plagioclase and olivine are sometimes present (Plate 35). Alteration products are common and include chlorite and sericite, often in abundance.

Lamprophyre, a dyke rock characterised by plagioclase feldspar and a high percentage of mafic minerals, was recognized by Ruxton (1957) in Junk Bay, and by Allen & Stephens (1971) on Lamma, Po Toi and Hong Kong islands. The lamprophyre dykes are usually highly altered, and samples collected during the present survey have generally been altered and weathered, and were therefore unsuitable for thin sectioning.

Potassium: argon age determinations were conducted on four dolerite (sic) samples (Allen & Stephens 1971) and these produced dates of 76 ± 2, 63 ± 6, 62 ± 2 and 57 ± 2 ma, placing the age of intrusion as the early Palaeocene (Tertiary).

Details

Kowloon. Basalt dykes have been mapped in several localities, especially in the Lai King (e.g. 3100 2341) and Kwun Tong areas. One large dyke cuts medium-grained granite at Diamond Hill, and this can be traced over 1.4 km striking ENE. The roughly vertical dyke is best exposed in Diamond Hill Quarry (3906 2275, Plate 37), where it can be seen as a series of sub-parallel dykes which merge and divide, enclosing screens of granite. The total dyke width amounts to about 7 m. The margins are chilled for several centimetres, and the central part of the dyke is coarser grained and is classified as fine-grained gabbro. An unusual characteristic of the basalt at Diamond Hill is the vesicular nature of part of the dyke. The thin section (HK424, 3906 2275, Plate 35) shows a very fine, equigranular groundmass dominantly of plagioclase crystal laths, with partially altered mafic minerals and much chlorite. The dyke follows a dominant joint trend, as do the basalt dykes mapped in the Junk Bay Road area of Kwun Tong (4200 1908 & 4288 1941). There, a number of basalt dykes less than 1 m wide cut fine- and fine- to medium-grained granite and strike in a similar direction to the Diamond Hill dyke. Other basalt dykes in the Jordan Valley and Yau Tong area have a dominant northwesterly strike. In some places, dykes have been noted cutting volcanic rocks, but these are usually less obvious due to lack of colour contrast with their host rock. On the western shores of Junk Bay, near Lei Yue Mun Point (4328 1659), a lamprophyre dyke about 2.5 m wide follows a N–S striking fault zone. This dyke rock was named a diorite-lamprophyre or spessartite by Ruxton (1957).

Hong Kong Island. Basalt dykes usually less than 1.5 m wide have been noted intruding granite near the Hong Kong Stadium (3738 1488), the Kornhill development at Quarry Bay (4023 1568), at Sai Wan Ho (4060 1608) and in Chai Wan (4197 1390). In all cases the dykes are impersistent and seldom extend more than 300 m.

Basalt dykes have also been noted intruding the volcanic rocks in the Aberdeen Country Park (3547 1328) and near the Cape Collinson Training Centre (4419 1259). Basalt dykes cut volcanic rocks, granodiorite and quartzphyric rhyolite on the D'Aguilar Peninsula (4410 0770, 4450 0804 & 4470 0768). Allen & Stephens (1971) recognized vogesite lamprophyre at Cape D'Aguilar, but in this survey the separation of lamprophyre and basalt dykes, both very similar in appearance when weathered, has proved impractical. Where these dykes are exposed in the shoreline, deep erosion has taken place along the dyke, producing caves and in one case (4481 0774) a spectacular blowhole feature.

Lamma Island. Basalt dykes have been noted at several localities on Lamma Island, and in many cases the intrusions appear to be related to and follow faults. Southwest of Mount Stenhouse (3072 0476) a 3.5 m wide basalt dyke follows a major N–S striking fault, and 1 km to the east (3162 0496) another basalt dyke, 1.5 m wide, follows an important NNE striking fault. At Sok Kwu Wan Quarry (3180 0832) large, angular and sub-angular xenoliths of basalt are found in the granite, suggesting that at least some basalt predates the Upper Jurassic to Lower Cretaceous granites (Plate 25).

Po Toi Island Group. Dykes of basalt extending less than 200 m and less than 2 m wide cut granites on Lo Chau and Po Toi Island; they generally trend between ENE and NE. At Tai Pai (4605 0358) a number of basalt dykes cut the coarse-grained granite and fine-grained granite as well as faults and a quartzphyric rhyolite dyke.

Plate 37 – Basalt Dykes Cutting Medium-grained Granite at Diamond Hill Quarry (3906 2274)

Pegmatite
Classification, Distribution and Lithology

Pegmatite consists of very coarse-grained granite, with crystals over 20 mm across (Table 3). It usually occurs as lenticular patches or nests within the granite, but also in thin dykes or veins. Pegmatite is commonly concentrated at or close to the granite-volcanic contact.

Pegmatites represent the last and most hydrous part of the granite magma to crystallise, and may contain high concentrations of minerals present only in trace amounts in the surrounding granite. Alkali feldspars, usually pink in colour, and quartz make up the bulk of the pegmatite, with occasional biotite and small plagioclase crystals present in some bodies. The alkali feldspar and quartz crystals often attain 100 mm in length but average 30 to 40 mm.

Pegmatite is least common in the coarse-grained granite, but widespread in the medium-, fine- to medium-, and fine-grained granites, being most abundant in the latter.

Plate 38 – Pegmatite Layers parallel to Contact between Fine- and Fine- to Medium-grained Granites on Southern Coast of Beaufort Island (Lo Chau, 4390 0458)

Details

Near the entrance to Princess Margaret Hospital (3164 2268) a 50 m wide zone of fine-grained granite abundant in pegmatite extends roughly N–S over a distance of 400 m. Elsewhere, isolated pegmatite patches or nests within the granite were commonly encountered during the survey. The most significant occurrences, however, were those at or near the granite-volcanic contact in southeastern Kowloon. Pegmatite is exposed as a pavement along the stream bed (4382 1829) south of Rennie's Mill, forming a widespread layer 0.15 to 0.2 m thick, sandwiched between the fine-grained greisenised granite and the fine ash tuffs of the Ap Lei Chau Formation. It includes some euhedral quartz crystals up to 0.2 m. Similar outcrops of pegmatite dipping 15 to 25° seaward occur along the coast northeast of Lei Yue Mun Point (4321 1647); as at Rennie's Mill, the pegmatite has crystallized at the volcanic country rock contact. In the Lei Yue Mun Granite Quarry (4312 1637), 0.2 to 0.3 m wide nests of pegmatite are common within 20 m of the irregular granite-volcanic contact. At Hung Hom (3772 1873), sheets of pegmatite up to 4 m by 4 m and 0.1 m thick occur on low-angle joint surfaces. Nests of pegmatite surrounded by biotite-rich haloes are present in the medium-grained granite south of Mount Nicholson around the Deep Water Bay Road (3722 1278, Plate 39). Layered pegmatite zones paralleling the contact between fine- and fine- to medium-grained granite are prominent on the southern coast of Lo Chau (4390 0458, Plate 38). Pegmatite is developed at the contact of the fine- to medium-grained granite and coarse-grained granite on northeastern Po Toi Island (4595 0424).

Aplite
Classification, Distribution and Lithology

Aplite is a light-coloured, hypabyssal igneous rock characterised by a fine-grained sacharroidal or allotriomorphic-granular texture (Bates & Jackson, 1980). Aplite may range in composition from granitic to gabbroic, but the term used with no modifier is generally understood to mean granitic composition. This term has been adopted here for the minor intrusions of equigranular very fine-grained granite that are insufficiently fine to be classed as rhyolites.

Aplite occurs exclusively as dykes or sills generally less than 2 m wide, with 0.2 to 0.5 m wide dykes most common. These dykes seldom extend continuously for more than 50 m, although a few outcrops have been traced for 100 m. Aplite dykes and sills are believed to be late-stage, high level intrusions emanating from cooling granite plutons. They are not exclusive to any one grain size class of granite, but are found throughout the pluton. They are, however, more abundant close to the margins of the granite bodies. No aplite dykes or sills have been observed intruding the volcanic country rocks.

Plate 39 – Pegmatite Nest Surrounded by Biotite-rich Halo in Medium-grained Granite. Deep Water Bay Road, Hong Kong Island (3722 1278)

Details

Kowloon. Aplite dykes are common cutting the coarse-grained granite between Lai Chi Kok (3290 2245) and Beacon Hill (3535 2337). Only the more extensive dykes have been shown on the 1:20 000 map, and these have widths varying from 0.5 to 3 m, with one exceptional dyke on Beacon Hill (3511 2369) 7 m wide and producing a prominent ridge feature striking roughly E–W. A number of parallel ENE trending aplite dykes 0.3 to 0.7 m wide cut the medium-grained granite north of Diamond Hill Crematorium (3976 2352). The aplite is more resistant to erosion, and stands out as ribs on the weathered granite landscape. Aplite dykes 50 to 400 mm wide are exposed in the railway cuttings (3613 1943) and intrude medium-grained granite. None of these dykes is believed to extend laterally over more than 50 m, and most are less than 30 m in length.

Hong Kong Island. Aplite dykes are common in the fine-, fine- to medium-, and medium-grained granites on Hong Kong Island, but they are usually less than 0.2 m wide and impersistent. Aplite dykes averaging 0.15 m wide are common along the coast near Stanley Prison (4076 0806 & 4062 0789). On the western side of the Stanley Peninsula (4000 0805) a N–S trending vertical aplite dyke is 0.8 m wide, cutting medium-grained granite.

Chapter 6
Structure

The rocks of the Repulse Bay Volcanic Group in the central and northern parts of the district form a broad NW–SE trending anticline plunging to the southeast (Figure 15). The core of the structure is intruded by granites, mainly those of the Kowloon—northern Hong Kong Island pluton. The volcanic rocks preserved on the northeastern limb of the fold are those of the Shing Mun and Ap Lei Chau formations of the Fei Ngo Shan—Junk Bay area. These are inclined generally to the east or ENE at 20 to 30°.

The structure of the southwestern limb is more complex. The Shing Mun Formation of the Chai Wan area dips to the south, but its outcrop is faulted against the relatively flat-lying Ap Lei Chau Formation of Tai Tam. In the western part of Hong Kong Island the regional dip of the volcanic rocks in the Magazine Gap area is steep to the southwest, while southwestwards from there both the Ap Lei Chau and the Tai Mo Shan formations are folded along NW–SE axes (Figure 15).

The structural relationships of the Repulse Bay Volcanic rocks cropping out on Lamma Island, on Round Island, and also on the Stanley and D'Aguilar peninsulas are unclear. All these outcrops are classified as being of Yim Tin Tsai Formation. This being so, it is likely that a major fault along the East Lamma Channel (East Lamma Channel Fault) separates the Lamma Island outcrop from Hong Kong Island. Whether similar faulting separates the other outcrops from the Ap Lei Chau Formation in the eastern part of Hong Kong Island is a matter of speculation.

In this account of the structure of the district, folds, faults and photo-lineaments, and joints are treated in separate sections.

Folds

Allen & Stephens (1971) noted folding in the volcanic strata of western Hong Kong Island, but their mapping was not sufficiently detailed to allow delineation of the fold axes. Although most volcanic rocks possess no visible stratification, the presence of eutaxitic banding within the Ap Lei Chau Formation and the sedimentary layers within the Shing Mun and Tai Mo Shan formations have provided good indications of the structural attitude of these strata. The distinctive flow fabric of the eutaxites gives a general impression of attitude of the strata (Workman, 1985), but care must be taken as the eutaxites commonly display convolute structures and marked local irregularities in flow-fabric. Similarly, some of the mudstone layers may include slump-folds with contorted bedding of sedimentary rather than tectonic origin. Figure 15 portrays the main fold pattern that dominates the volcanic strata of western and southwestern Hong Kong Island. Equal area point plots and density contours for strata and flow fabric in the volcanic rocks are illustrated in Figure 16 and discussed below.

Details

The equal area point plots and density contours for the strata and flow-fabric in the volcanic rocks (Figure 16) indicate no folding in the north-eastern quarter of Sheet 11, but show a mean bedding of strike 010°/24°S dip. The eigenvalue ratio graph (ERG) (Woodcock & Naylor, 1983) indicates a fairly strong cluster. The eutaxite layers, which are reasonably planar, dip consistently eastward, away from the Kowloon—northern Hong Kong Island pluton. To the south (quarter map sheet areas 11SE & 15NE) the strata are dominantly flat-lying, but the equal area point plots imply a broad flexing around an E–W axis. In places, as for example in coastal sections around Big Wave Bay, a series of E–W folds have been recognised in the eutaxitic banded volcanics. In the Aberdeen, Ap Lei Chau and Deep Water Bay areas (15NW) the widespread occurrence of eutaxitic banded rocks has revealed a series of WNW–ESE and E–W striking anticlinal and synclinal axial traces. Most of these folds can be considered gentle and open.

The fold axes on western Hong Kong Island (11SW) strike roughly NW–SE. The eastern limb of a major anticline extending from High West southeastwards to Aberdeen has been recognized as a prominent structural feature, and data from this limb have been shown as a separate plot. This shows a constant orientation (single point cluster) with a mean bedding of strike 136°/71°N dip. The data from the rest of 11SW have been combined. The ERG indicates a weak girdle, confirmed by the contours. The inter-limb angle of 108° indicates open folding. The data can be summarized as follows; a near vertical axial plane, open folding, a near horizontal axis, western anticlinal limbs of strike 160°/45°W dip and eastern limbs of strike 177°/27°E dip. The folding has a conical element and is best described as noncylindrical.

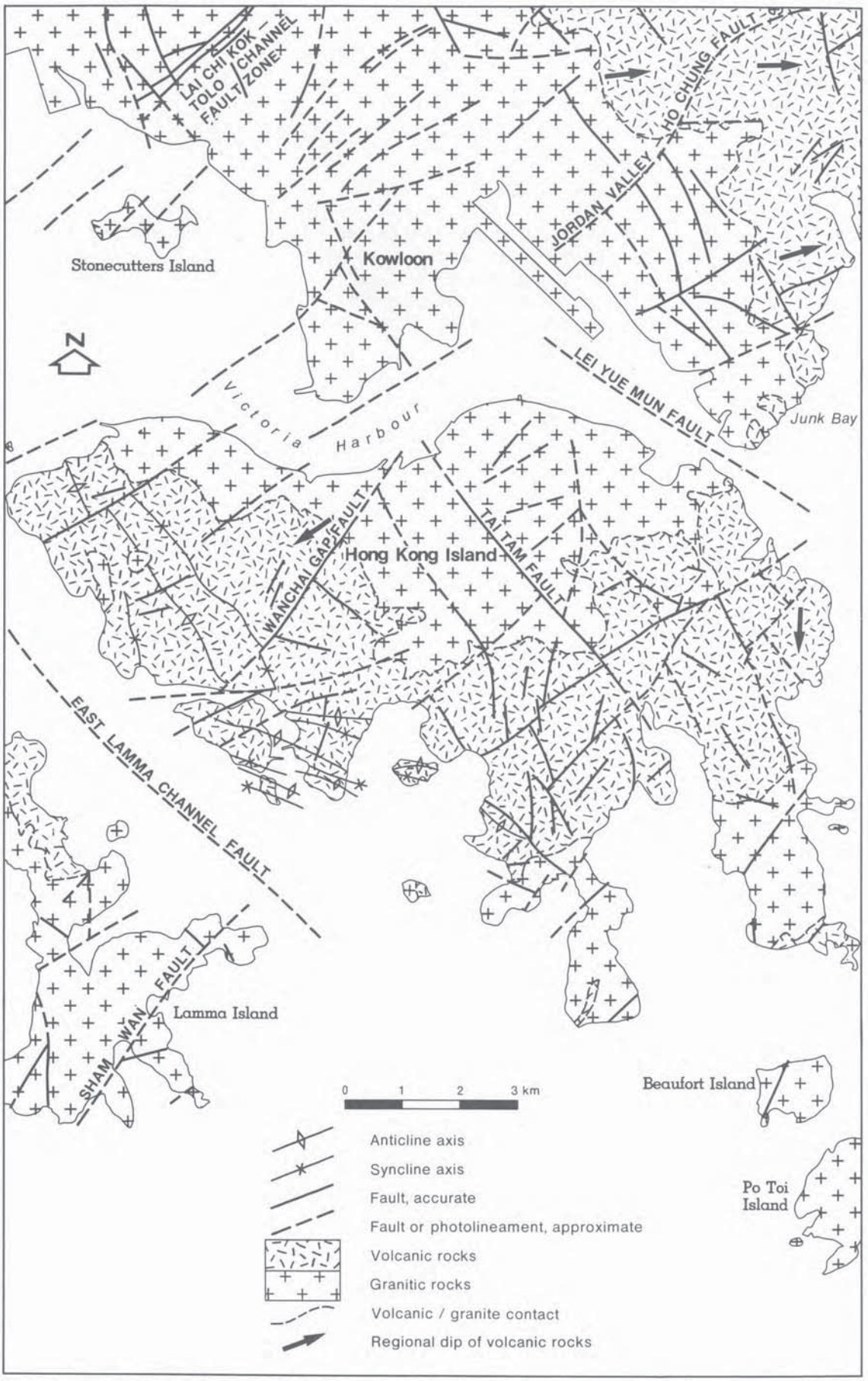


Figure 15 – Principal Structural Features of Sheets 11 and 15

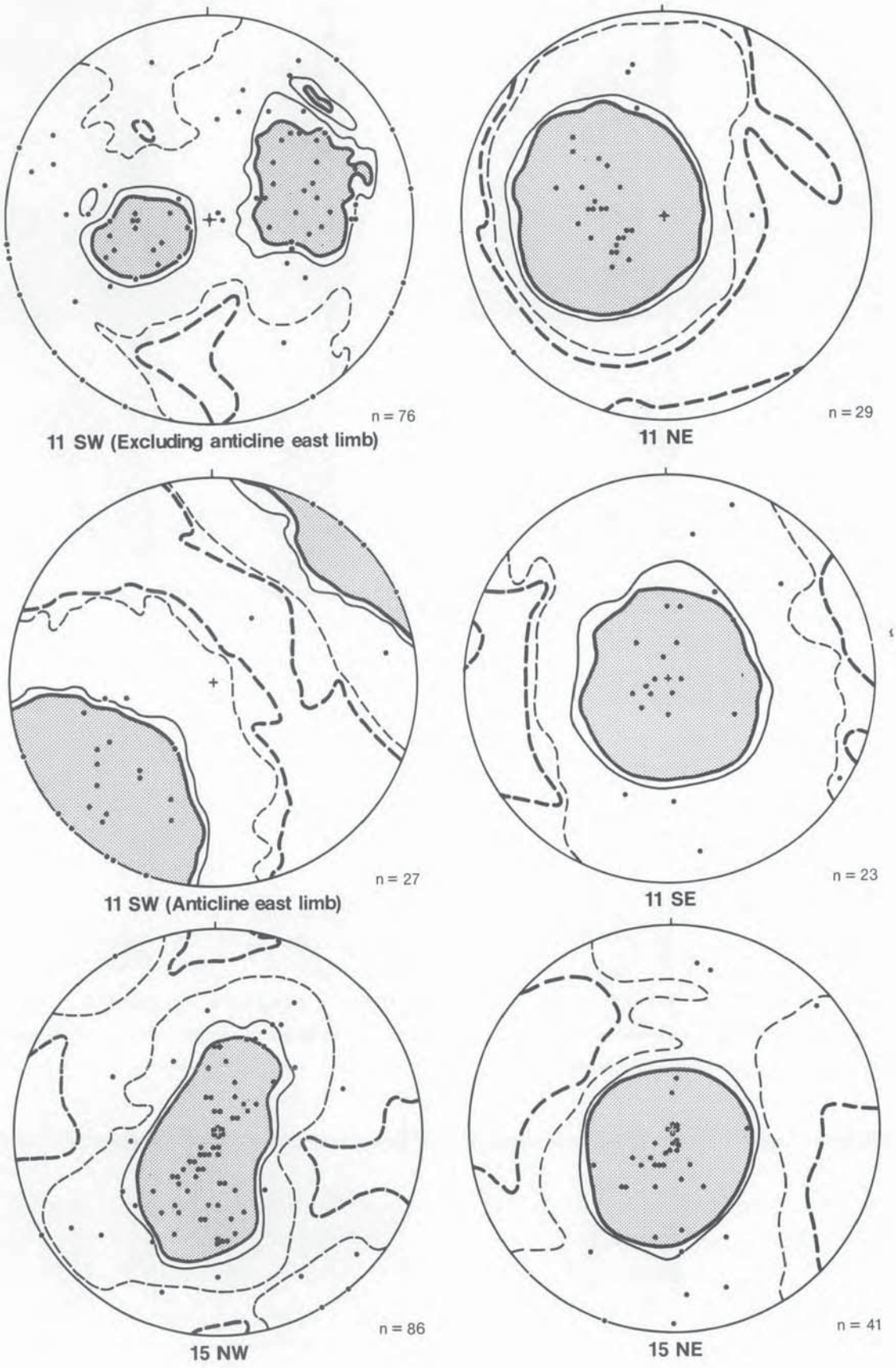


Figure 16 – Equal-area Point Plots and Density Contours for Strata and Flow-fabric in the Volcanic Rocks of Sheets 11 and 15. Concentration (solid lines) and dispersion (broken lines) of 5% and 1% significance levels (Langford & Adlam, 1985)

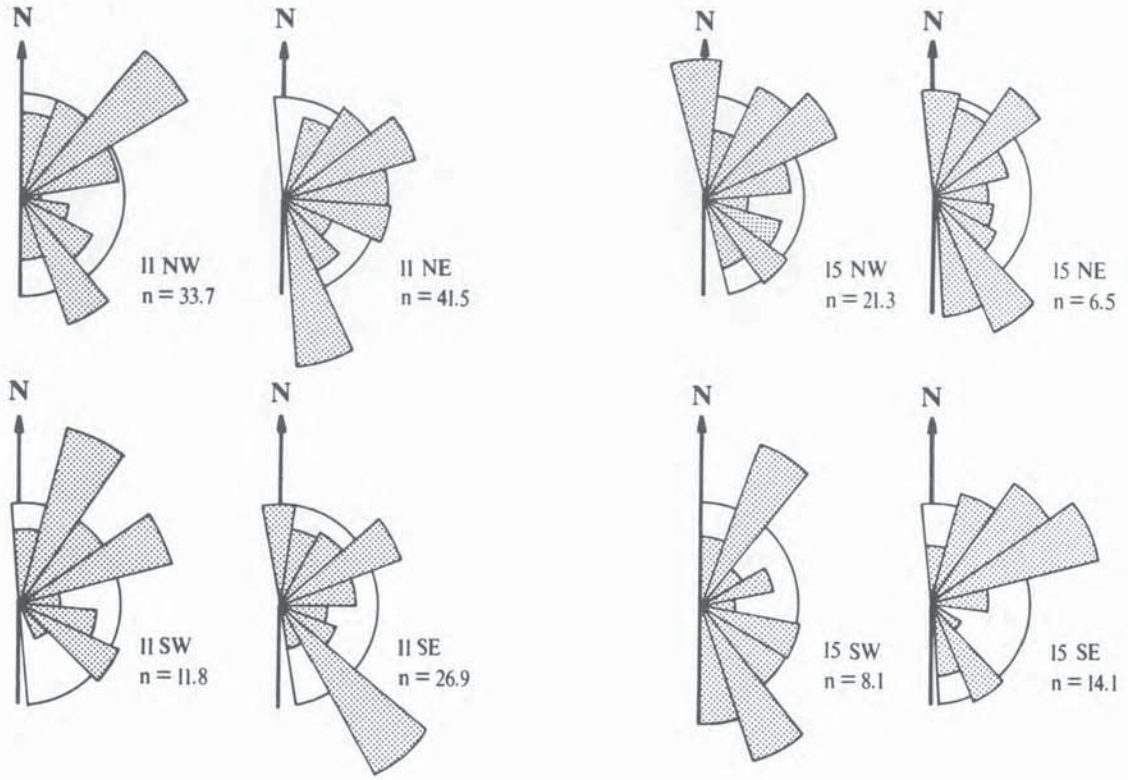


Figure 17 – Circular Histograms of Faults and Photolineaments on Sheets 11 and 15. Total length measured. km = n.

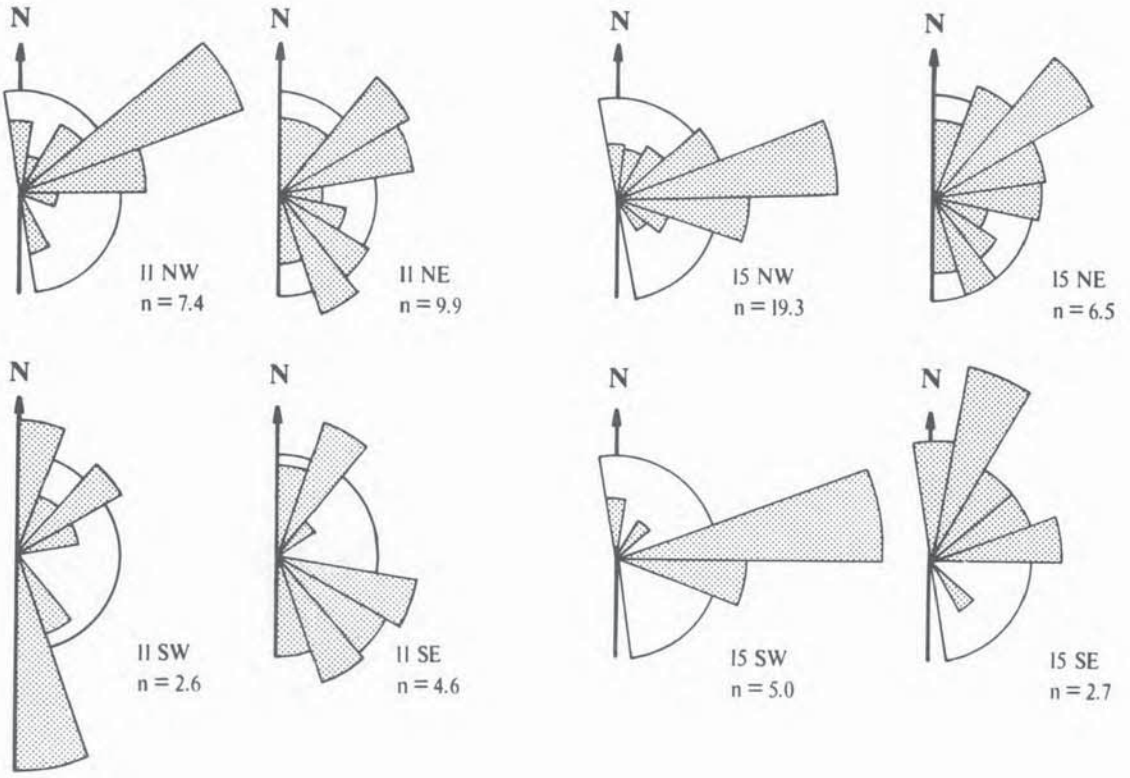


Figure 18 – Circular Histograms of Dykes on Sheets 11 and 15. Total length measured. km = n.

Faults, Photolineaments and Dykes

Figure 15 illustrates the main faults and photolineaments affecting the solid rocks of the district. These traces appear on the published 1:20 000 geological mapsheets only where they are not covered by superficial deposits, however, the statistical analysis of trends includes the logical extrapolation of these features beneath superficial deposits. The present survey has found no evidence of active faults within the district, and no visible effects of faulting in the Quaternary deposits.

The main trends in the faults and photolineaments are NW–SE and NE–SW. The larger dykes tend to occur in swarms, and these are concentrated in southern Lamma Island and northwestern Kowloon. The dykes of Lamma Island are predominantly of rhyolitic composition and strike E–W, whereas the dykes of northwestern Kowloon strike ENE–WSW to NE–SW, and are of variable composition from rhyolite to monzonite. These rhyolitic dykes are associated with the Late Jurassic to Early Cretaceous phase of granite emplacement. Younger basic dykes, of Palaeocene age, are widely scattered but tend to follow the main fault pattern, with a number of basalt dykes clearly intruded along faults.

The regional geological lineaments and fault systems, and their proposed classification, have been described by Burnett & Lai (1985). They class the Lai Chi Kok—Tolo Channel Fault as a major fault, and the Po Toi—Sanmen Islands Fault (an inferred structure striking NE–SW several kilometres south of Po Toi Island) as a deep-seated fault extending over a distance of more than 1 000 km. This postulated fault is named the Haifeng Fault Zone by Liu & Zhuo, 1983. Other faults within the district have been classed by Burnett & Lai as moderate or minor faults.

Circular histograms of faults and photolineaments, and of dykes, have been drawn for each map sheet quarter (Figures 17 & 18), and will be discussed by quarter sheet areas.

Details

Western and northwestern Kowloon (11NW). The major fault zone associated with the Lai Chi Kok—Tolo Channel Fault passes through the Kowloon Reservoirs area in the northwestern corner of the district. Several parallel faults can be traced from the Sha Tin valley through the reservoirs area as far as the coast at Lai Chi Kok. Fine-grained granite is faulted against coarse-grained granite immediately below the Byewash Reservoir dam (3337 2326), and recent excavations near the junction of Ching Cheung Road and Castle Peak Road (3265 2243) have exposed a fault dipping southeast at 45°. The surrounding granite appears hydrothermally altered and closely jointed. Later NW–SE striking faults have produced some displacement of the NE–SW faults, as seen at Butterfly Valley (3285 2281). A similar NW-trending fault is well exposed at Kau Wa Keng (3192 2311), where an intensely pulverised mylonite zone 0.7 m wide marks the fault plane. Numerous NE-striking negative photolineaments have been identified on the aerial photographs, particularly on the 1949 set, pre-dating the urban development. Geophysical traverses across the western Victoria Harbour have located the positions of drainage channels in the Pleistocene Chek Lap Kok Formation under a cover of Holocene Hang Hau Formation. Channels to the northwest of Stonecutters Island are aligned with a seaward extension of the Lai Chi Kok—Tolo Channel Fault. Similarly, channels to the west of Yau Ma Tei and Tsim Sha Tsui lie parallel to the dominant NE trend of the onshore photolineaments. The circular histogram of faults and photolineaments indicates the dominant NE trend, and also a less significant NW trend. The histogram of dykes clearly reflects the main Lai Chi Kok—Tolo Channel trend, with the dyke swarm roughly paralleling this fault zone.

East Kowloon, Junk Bay and Ho Chung (11NE). The most significant fault within this area extends from Jordan Valley (4075 2073) northeastwards to Ho Chung, but superficial deposits obscure the fault trace north of Shun Lee Estate (4151 2160). In the vicinity of Clear Water Bay Road (4165 2180), mapping evidence suggests that the volcanic-granite contact has been displaced about 300 m to the northeast by this fault. NW- and NE-striking faults cutting the granites in the Kwun Tong area have associated zones of deep weathering which produce distinctive linear topographic hollows. Basalt dykes, for example along Junk Bay Road (4200 1910), parallel these valley features. The circular histogram shows a dominant SSE trend for the faults and photolineaments, and a less well-defined ENE trend (Figure 17). Similarly, the dyke pattern shows two dominant trends; ENE to NE, and SE (Figure 18).

Western Hong Kong Island (11SW). NE-trending faults, for example the Aberdeen—Wanchai Gap Fault, have displaced the granite-volcanic contact (3574 1459). Smaller faults appear to have no preferred trend; in many cases these produce no negative topographic features but have been delineated from the recognition of displacement of the volcanic strata. It is possible that the East Lamma Channel follows a major discontinuity striking NW–SE. The circular histogram of faults and photolineaments shows a strong NNE trend, with less prominent ENE and ESE trends (Figure 17). The histogram of dykes (Figure 18) gives a dominant N–S alignment, but the total length of dykes measured in this quarter amounted to only 2.6 km.

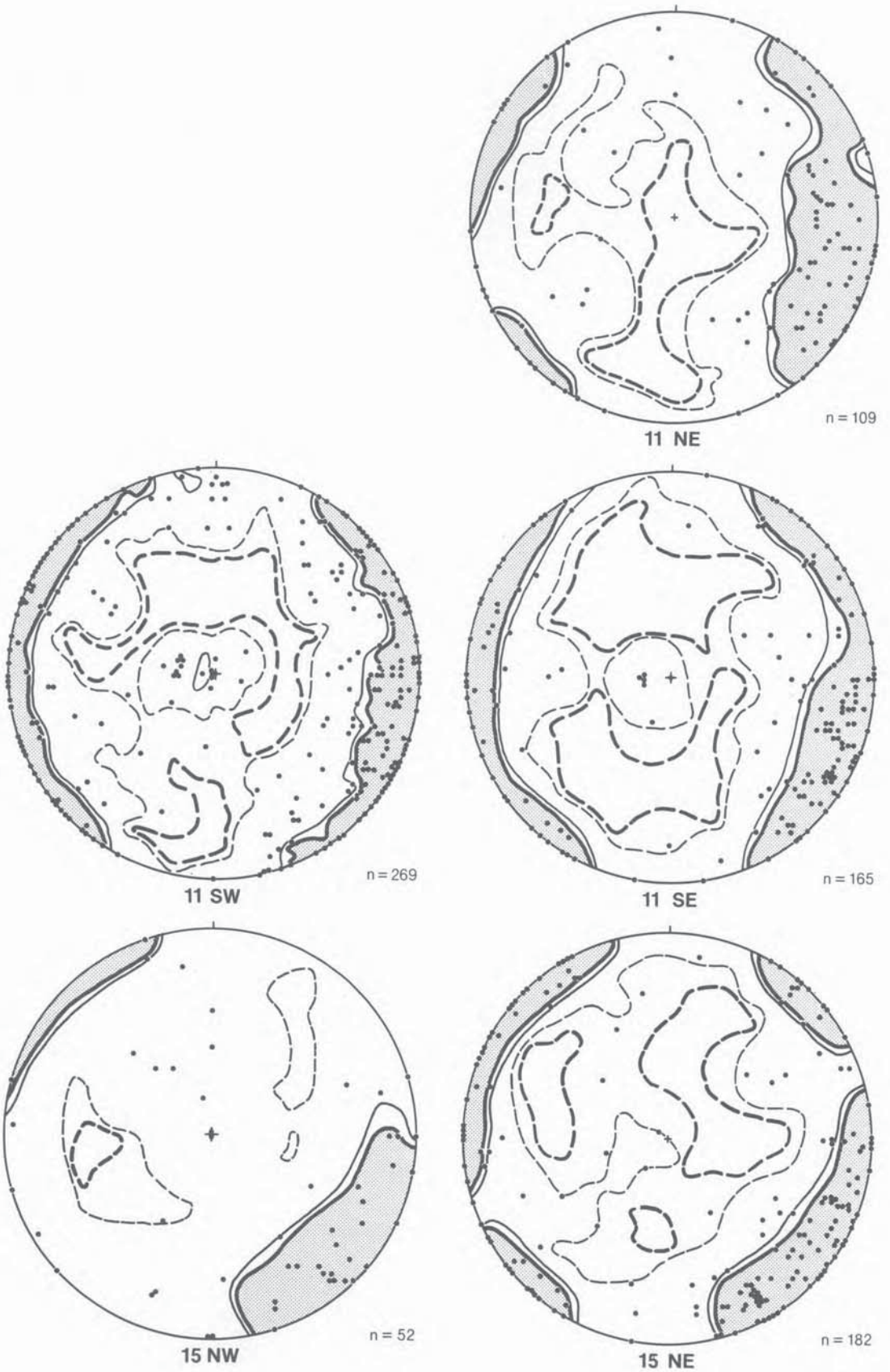


Figure 19 – Equal-area Point Plots and Density of Contours for Joints in the Volcanic Rocks of Sheets 11 and 15. Concentration (solid lines) and dispersion (broken lines) at 5% and 1% significance levels (Langford & Adlam, 1985)

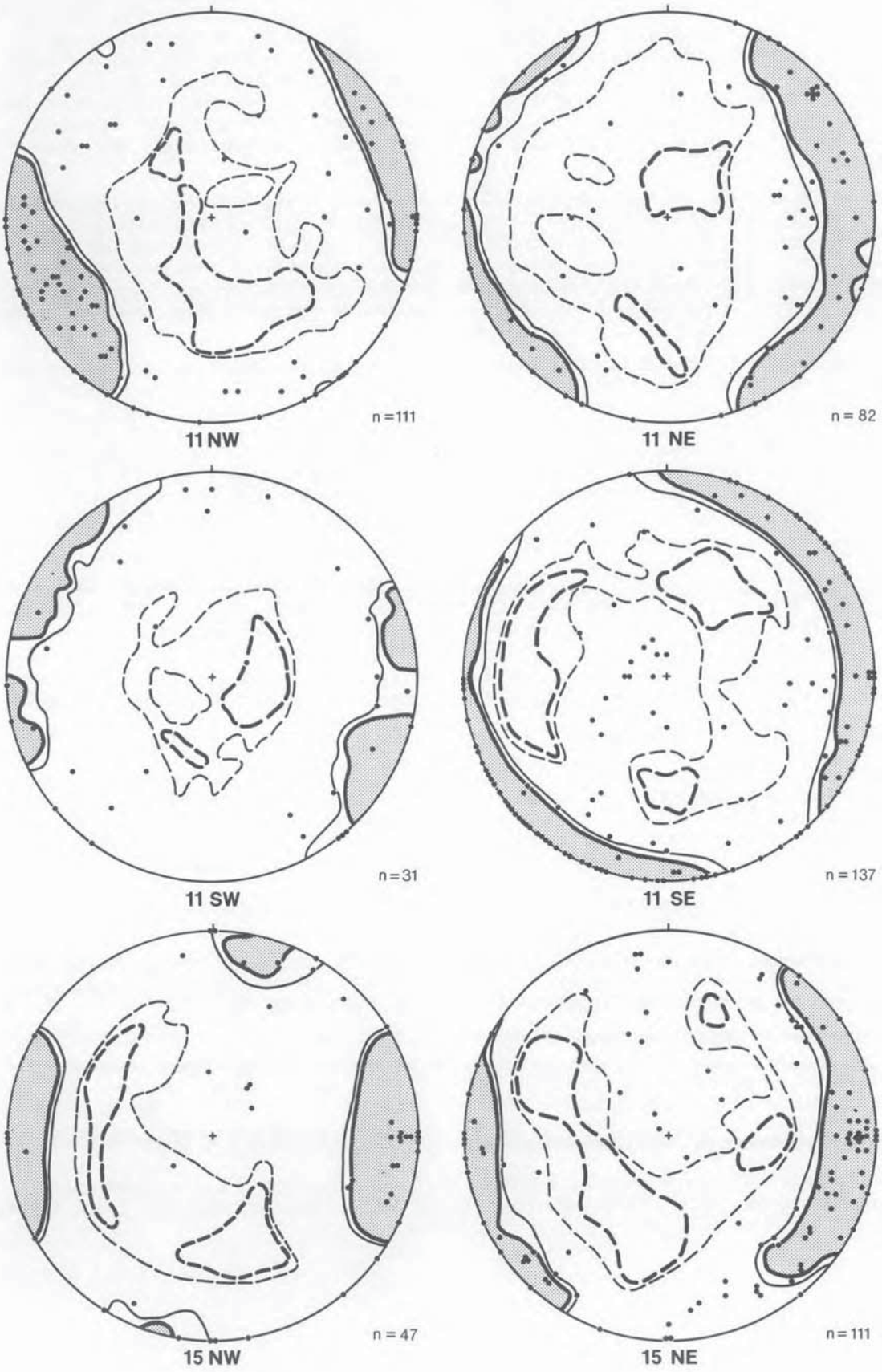


Figure 20 – Equal-area Point Plots and Density Contours for Joints in the Granites of Sheets 11 and 15. Concentration (solid lines) and dispersion (broken lines) at 5% and 1% significance levels (Langford & Adlam, 1985)

East Hong Kong Island (11SE). A prominent straight fault trace extends southeastwards from Causeway Bay through Tai Tam Country Park to Tai Tam Harbour. In Mount Butler Quarry (3893 1435) the rock face contains very close, vertical, parallel joint planes with a strike direction of 150°. An ENE-striking fault extending from Repulse Bay to Chai Wan is displaced horizontally 100 m by the NW–SE fault (4048 1255). Numerous photolineaments have been recognized in the granites of eastern Hong Kong Island, and many of these may be fault traces. The Lei Yue Mun passage follows a marked NW–SE trending topographic feature, but geophysical traverses across the passage have revealed no evidence for faulting. The NW–SE trending faults dominate the circular histogram (Figure 17), the ENE trend being less well developed. The dykes are widely dispersed, but no easterly trend is indicated (Figure 18).

Lamma Island, Ap Lei Chau and Ocean Park (15NW & SW). Significant lineaments trend NE through Sok Kwu Wan (Picnic Bay) and Shek Pai Wan (3280 0677) on Lamma Island. ENE-trending lineaments cut Ap Lei Chau and join an E–W feature that forms Aberdeen Harbour and the Wong Chuk Hang valley. This lineament may represent an early fault, and is marked by dyke-like intrusions of quartz syenite at intervals along the valley. The histogram of faults and photolineaments (Figure 17) does not readily identify dominant trends, but the histogram of dykes (Figure 18) shows a marked E–W alignment corresponding to the rhyolite dyke swarm of central and southern Lamma Island.

Stanley, D'Aguilar Peninsula and the Po Toi Island Group (15NE & SE). Faults and photolineaments in this area are dominated by N–S and SSE trends on Hong Kong Island, and NE and ENE trends in the Po Toi Island Group. Dyke trends are widely dispersed but are most commonly NE to NNE. The Po Toi—Sanmen Islands Fault (Burnett & Lai, 1985) is inferred to pass several kilometres south-southeast of Po Toi Island, striking in an ENE direction, but the present survey has found no evidence to support the existence of this fault zone. On the southern part of Waglan Island faults with approximate strikes of 55° (4939 0497) show minor sinistral displacements; other faults striking 175° have minor dextral displacements.

Joints

The equal area point plots and density contours for the joints of the district (Figures 19 & 20) give only general indications of trends, and do not necessarily represent the joint trends at any specific locality. Only systematic joints were measured, i.e. those that are planar and parallel or sub-parallel and form joint sets. However, the density of sampling has been inconsistent because of lack of exposure in some areas, for example inland on Lamma Island, and abundant exposure in other areas, for example in East Kowloon, where numerous fresh cut slopes were available for examination during the field survey.

Details

Granite outcrops, excluding Lamma Island. In all areas a girdle pattern of joint poles is developed, although on 11SW this is resolved into two maxima, strike 170°/90° dip and strike 030°/90° dip. The joints are mostly near vertical, and a break in the girdle at the north and south of the net indicates a marked absence of E–W striking joints. In all cases the girdle is around the perimeter of the diagrams, indicating no significant deviation from vertical. The weakest girdle development is found in the area of 11NW, where there is a marked concentration around strike 160°/80°E dip. Only in 11SE is there a significant number of roughly sub-horizontal joints.

Granite of Lamma Island. Two concentrations (strike 005°/85°W dip and strike 105°/85°S dip) are possibly a conjugate set of shears, indicating the main compression direction as NE–SW. Few sub-horizontal joints are present, but the sample is small. A girdle distribution is not developed in this area.

Volcanic rocks, excluding Lamma Island. In all areas girdles are well-developed, but unlike the granite areas where joints are dominantly vertical, there is a marked deviation combined with a marked concentration. The concentration of poles is consistently strike 010° to 030°/80°W dip. In all areas the contours can be resolved into two clusters; a strong one strike 030°/80°W dip, and a weak one strike 120°/90° dip. In 11SW & 11SE a near-horizontal joint set is developed, which is absent elsewhere. The complex girdle pattern, particularly in 11SW, may indicate a predominance of polygonal jointing (Whiteside, 1986).

Volcanic rocks on Lamma Island. Only a limited area of volcanic rocks occurs on Lamma Island, and the marked joint concentration indicates joints striking 040°/80°N dip, i.e. similar to other areas. Neither a girdle nor any sub-horizontal jointing is present on a very simple plot pattern.

Chapter 7
Metamorphic Rocks

The metamorphic rocks of the district are restricted to those formed by the metasomatic and thermal alteration of the country rock in contact with or adjacent to granitic plutons. No dynamically metamorphosed rocks have been recognized in the district apart from small developments of mylonite in fault zones. Regional metamorphism, developed in the northern New Territories, does not affect the rocks of this district.

Allen & Stephens (1971) described thermally metamorphosed volcanic rocks collected close to a granite contact, but it was Ruxton (GCO, 1982) who first attempted a detailed examination of the thermal metamorphic products. Ruxton produced a thermal metamorphic isograd map of the Victoria Peak area of Hong Kong Island, and recognized four grades of thermal metamorphism.

Thermal (Contact) Metamorphism

The bulk of the pyroclastic volcanic rocks that constitute the country rock surrounding the granitic intrusions are rhyolitic or rhyodacitic tuffs, possessing mineral assemblages stable at temperatures as high as those of the intruding molten granite. Rocks within a few metres of the contact usually show mesoscopic signs of thermal metamorphism, but away from this zone the evidence of metamorphism is apparent only from the examination of thin sections. The fine and coarse ash tuffs are metamorphosed to a lesser extent than the tuffaceous sandstone layers.

The area around Victoria Peak has been examined in detail, and the findings correspond approximately to Ruxton's metamorphic zonation (GCO, 1982). The study of 72 thin sections in this area by A. Lai (written communication, 1986) has enabled the division of the thermally metamorphosed tuffs into four zones (Figure 21); Low-grade A (slightly metamorphosed), Low-grade B (albite-epidote hornfels facies), Medium-grade (hornblende hornfels facies) and Contact rock (pyroxene hornfels facies).

Low-grade A (slightly metamorphosed facies). In the rocks of this facies the original pyroclastic texture is preserved. Feldspar is commonly sericitized and the matrix recrystallised. Incipient growths of muscovite and biotite are present interstitial to quartz in the matrix. In places there are traces of garnet. These rocks are widespread and occur more than 500 m from the nearest granite contact outcrop. Sample HK2225 (3149 1523) is typical; originally a coarse ash crystal tuff, some recrystallization of the ground-mass has taken place, with quartz intergrown with biotite and muscovite. Randomly oriented biotite aggregates are associated with garnet.

Low-grade B (albite-epidote-hornfels facies). The rocks of this facies are characterised by an abundance of fine-grained sericite in the groundmass. Quartz is abundant and there are variable amounts of garnet and biotite. The original pyroclastic texture is still visible, and in hand specimen the thermally metamorphosed character is not readily apparent. Lack of available thin sections covering the area south of the Peak and the Mount Gough area has prevented an accurate southward delineation of this zone.

Medium-grade (hornblende-hornfels facies). The rocks whose outcrops are represented on the 1:20 000 maps as thermally metamorphosed rock (hornfels) fall mainly within this category. They are characterised by complete recrystallization of the matrix and the presence of higher grade metamorphic minerals, such as andalusite. The original pyroclastic texture is not usually preserved, apart from scattered larger quartz crystal fragments. Muscovite is abundant, and clinozoisite and garnet are also common. Ruxton (GCO, 1982) considered this zone to be about 100 m thick in the area northeast of Victoria Peak. An example of this facies is seen in a sample (HK 2447, 3192 1590) from near Hong Kong University that was probably originally a tuffaceous sandstone (Plate 42). In thin section this rock consists mainly of inequigranular, interlocking quartz crystals. Anhedral muscovite occurs interstitially to the quartz. Andalusite is present as aggregates enclosed by quartz crystals up to 3 mm across.

Contact rock (pyroxene-hornfels facies). Rocks of this facies are found only at, or within a few metres of, the granite contact. The incipient growth of sillimanite together with annealed

quartz crystals in a preferred orientation produces a schistose appearance. The original rock texture has been destroyed. Thin section R216 (3336 1552) (Plate 43) from a sample collected at the granite contact north of Victoria Peak consists of recrystallized quartz crystals in a granoblastic-polygonal texture, intergrown with biotite and sillimanite. In places cordierite and andalusite are present, apparently replacing the felted fibres of sillimanite. Muscovite is found, but often broken down to scaly aggregates of sericite and chlorite. In hand specimen the contact rock is recognized as a brittle, very hard rock with a hackly fracture. Similar metamorphosed tuffs are well seen in the upper levels of the Anderson Road Quarries in East Kowloon.

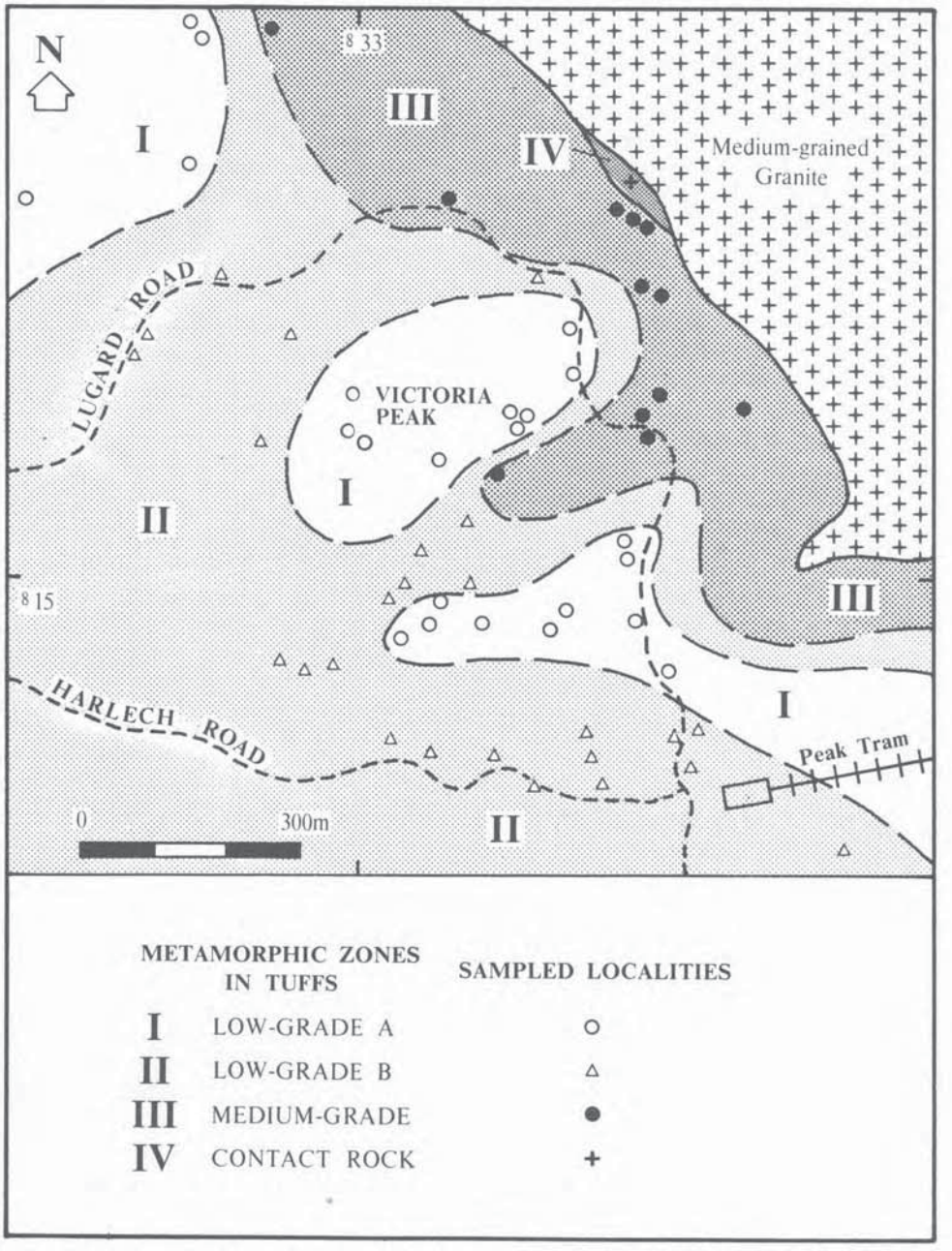
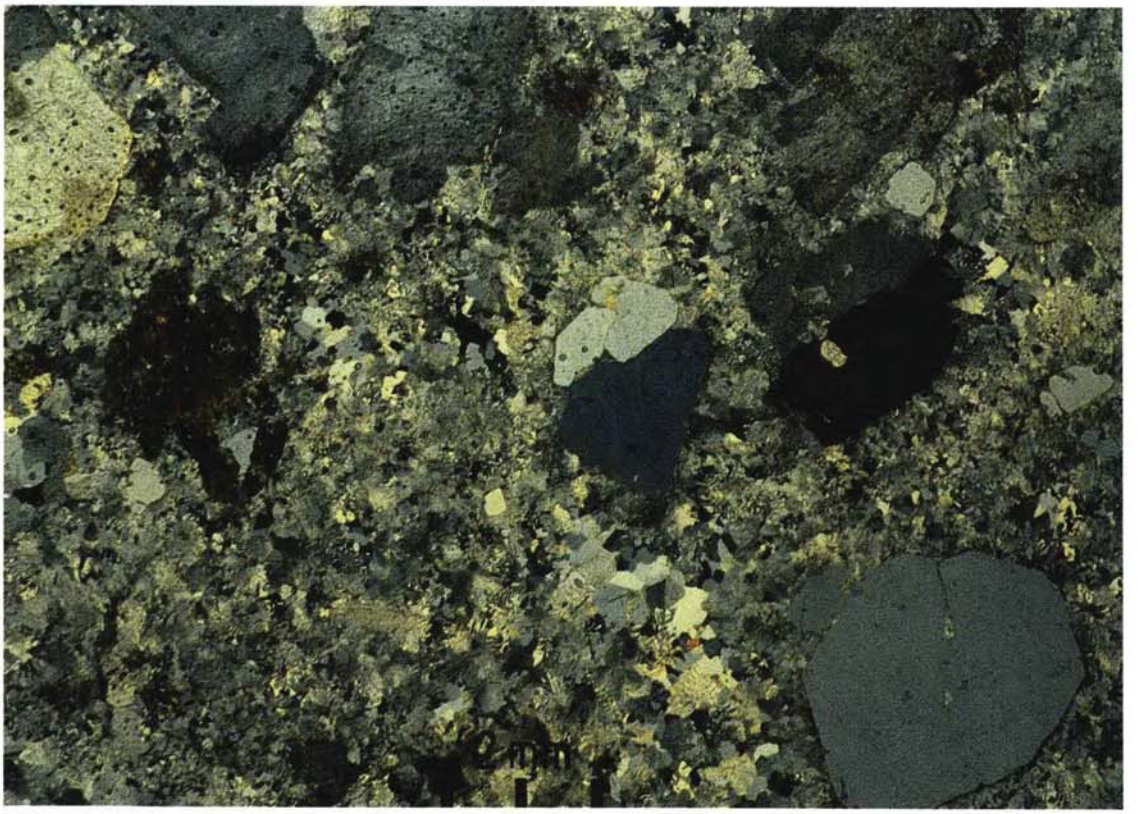


Figure 21 – Metamorphic Zones in the Tuffs around Victoria Peak, Hong Kong Island

Plate 40 – Feldsparphyric Rhyodacite (HK 4300) from Mount Stenhouse, Lamma Island (3132 0566); Natural Scale

Plate 41 – Thin Section of Feldsparphyric Rhyodacite (HK 4298) from Mount Stenhouse, Lamma Island (3120 0498); XPL plus $\frac{1}{4}\lambda$ plate × 10



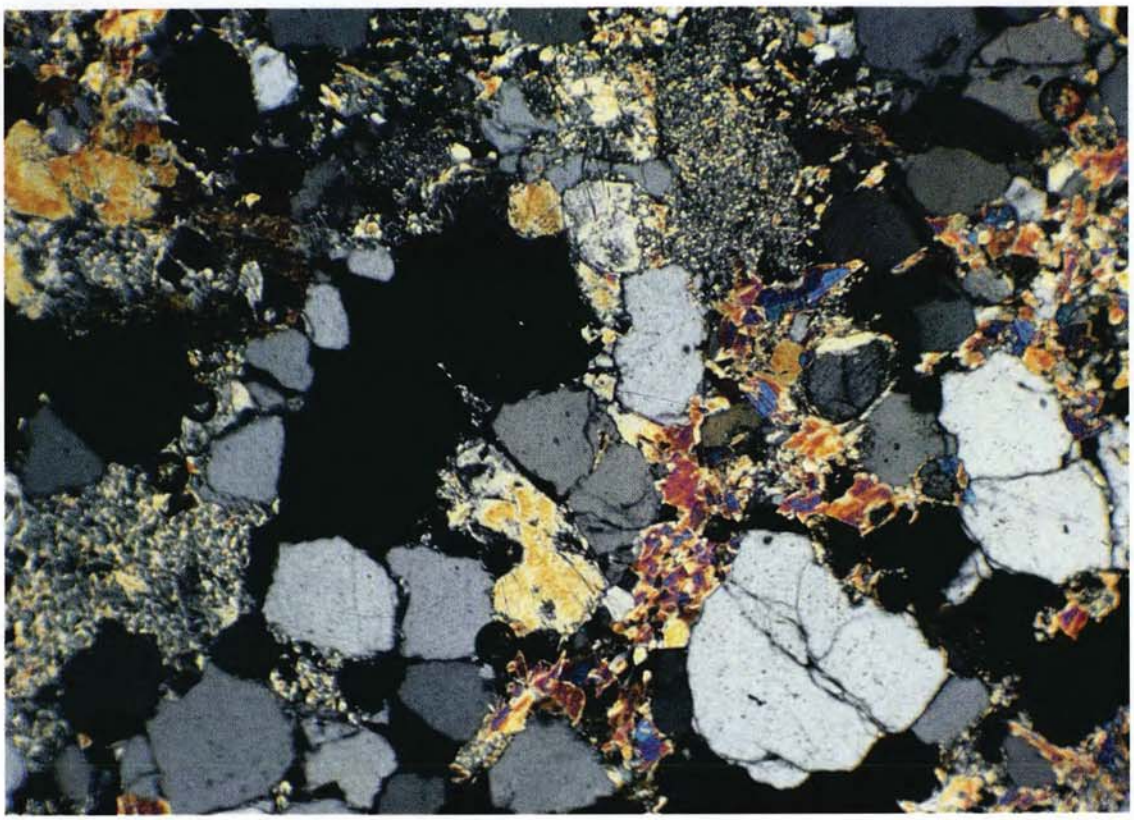
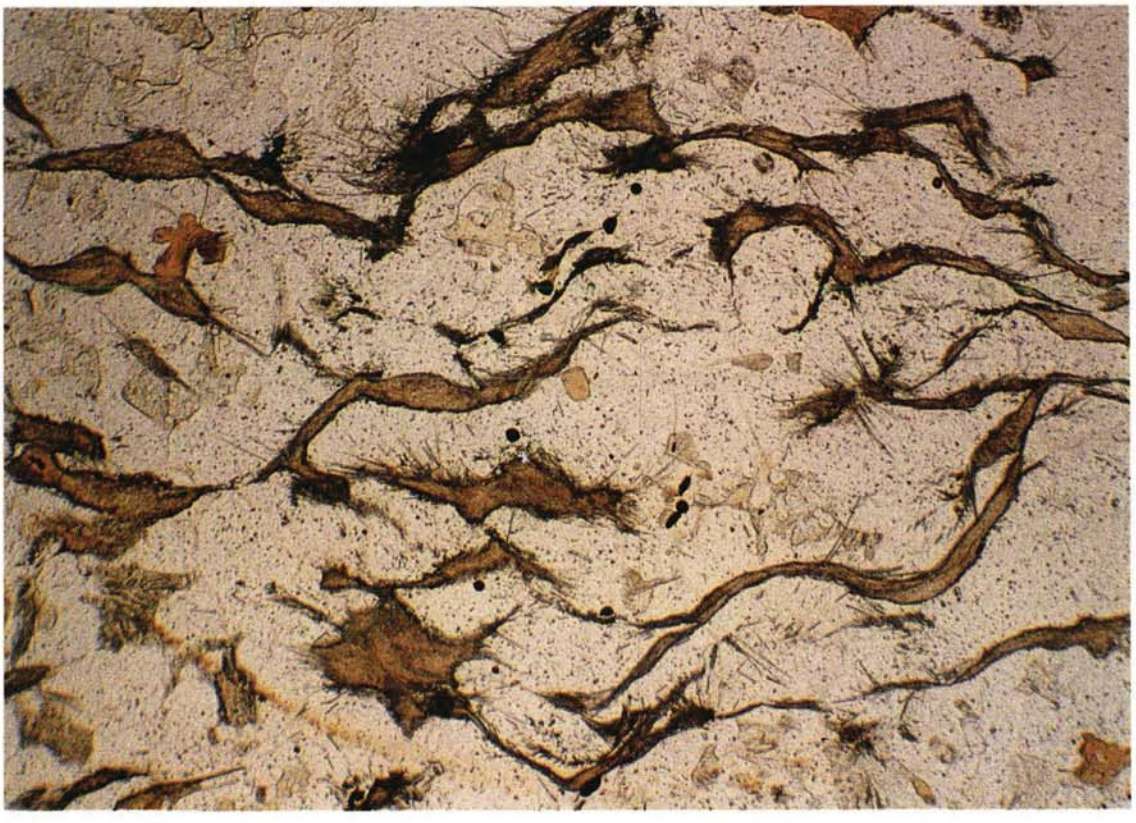


Plate 42 – Thin Section of Medium Grade Thermally Metamorphosed Rock (HK 2447) from Kennedy Town, Hong Kong Island (3192 1590); XPL × 65

Plate 43 – Thin Section of High Grade Thermally Metamorphosed Rock (R216) from Victoria Peak (3336 1552); XPL × 65



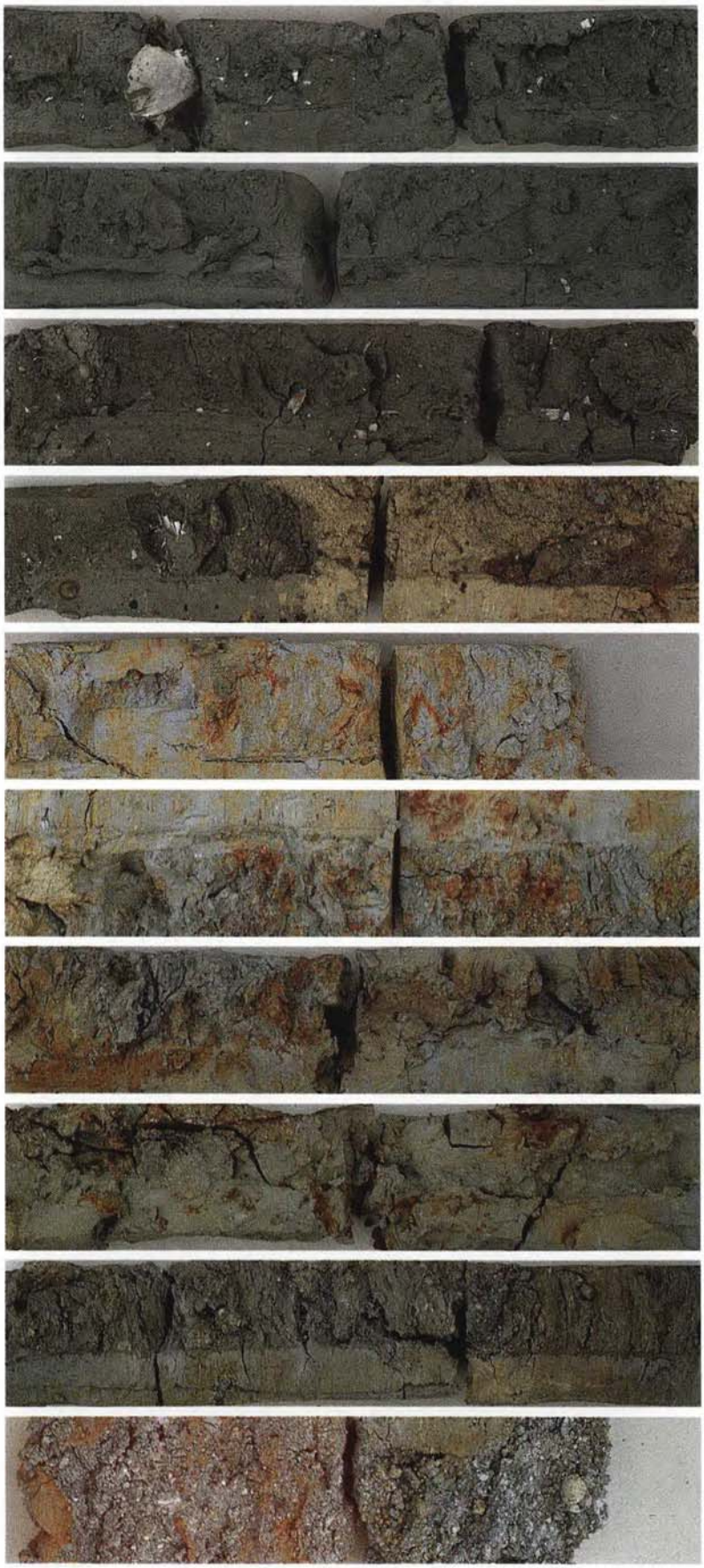


Plate 44 – Split Piston and Mazier Samples from the Hang Hau and Chek Lap Kok Formations in the Junk Bay Borehole, JBS 1/1A (Appendix); Hang Hau Formation to Unconformity at 13.22 m. Depths in Metres Below Sea-bed.

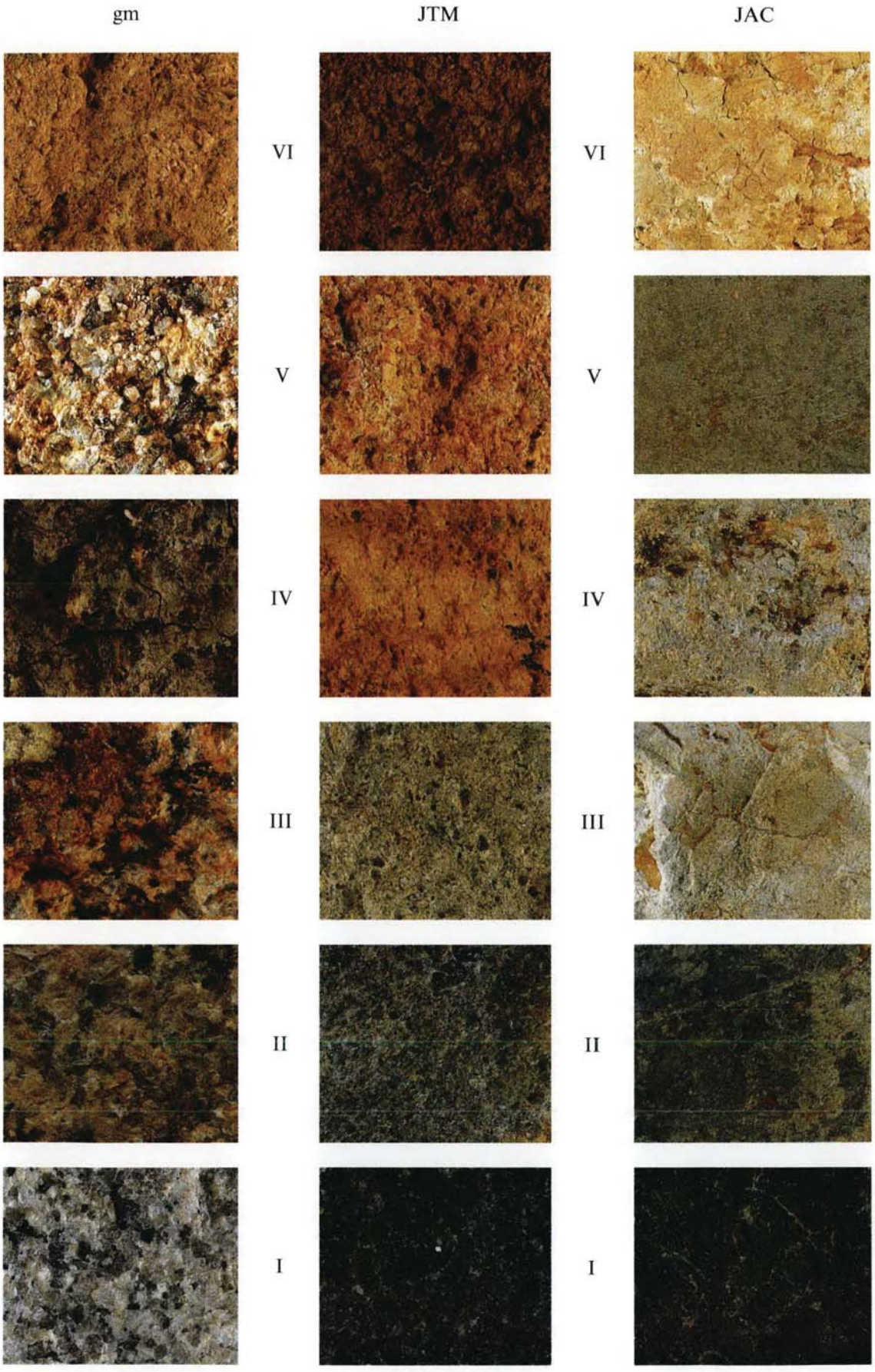


Plate 45 – Samples of Medium-grained Granite, Coarse Ash Crystal Tuff of the Tai Mo Shan Formation and Fine Ash Vitric Tuff of the Ap Lei Chau Formation. Showing Progressive Weathering from Fresh Rock (I) to Residual Soil (VI).

Metasomatism

Metasomatism is the chemical alteration of the country rock by fluids that have emanated from a granitic intrusion. Hydrothermal alteration of the main body of a granite pluton by late-stage magmatic fluids, producing kaolinisation and greisenisation, has been dealt with in Chapter 4. This section concentrates solely on the metasomatism of the country rock surrounding the granite plutons.

In places along granite contacts the thermally metamorphosed volcanic rocks display unusual patches of alteration which may represent hydrothermal infiltration and metasomatism. The greisenised fine-grained granite of East Kowloon has in places only a vaguely discernible contact with the fine ash tuffs of the Ap Lei Chau Formation. Indeed, Ruxton (1957) considered much of the greisen present in the Devil's Peak—Rennie's Mill area to be greisenised volcanics. It is possible that some of the volcanic rocks have been greisenised near the contact, but most of the greisen is considered to be the result of hydrothermal alteration of the granite. Along a stream bed 200 m south of Rennie's Mill (4380 1825), apparently unaltered fine ash tuff is separated from greisenised fine-grained granite by a 0.15 m thick layer of pegmatite extending laterally over at least 100 m. Such pegmatite concentrations at the intrusive contact are common in East Kowloon.

Several linear features consisting of hard quartz and iron-rich rock up to 50 m across, and extending up to 600 m, affect the coarse ash tuff of the Yim Tin Tsai Formation on northern Lamma Island. The rock is markedly altered and characterised by its dark brown colour and abundant quartz, infilling vughs and criss-crossing the rock in an haphazard pattern. Much of the rock appears highly brecciated, and the original character and texture has been completely obliterated. The roughly east-west strike of these features (delineated as altered tuffs and sediments on the 1:20 000 map) is approximately parallel to the bedding of thin layers of sandstone within the tuffs, and it is possible these altered rocks were formed by the preferential hydrothermal alteration of such a layer, composed perhaps of a calcareous tuffaceous sediment.

Chapter 8
Superficial Geology

The superficial deposits of the district are broadly divisible into the widely distributed, stratified units that characterise the offshore and some coastal areas; and the restricted, commonly isolated and usually irregular deposits that are typical of the land. These two divisions are treated separately in this account, their boundary being taken arbitrarily at the pre-reclamation coastal low water line. All the deposits are believed to have formed during the Quaternary period.

The deposits of the land area are classified according to their inferred mode of formation. The offshore deposits are sufficiently extensive and regular to be classified lithostratigraphically in terms of named formations and members. The relations between the deposits of the onshore and offshore divisions are illustrated in Figure 22. The deposits of both divisions consist, with a few exceptions, of transported material only. They do not include the insitu materials produced as a result of the weathering of rocks. Such weathered materials are described later in this chapter and also in the chapters dealing with the respective solid rocks.

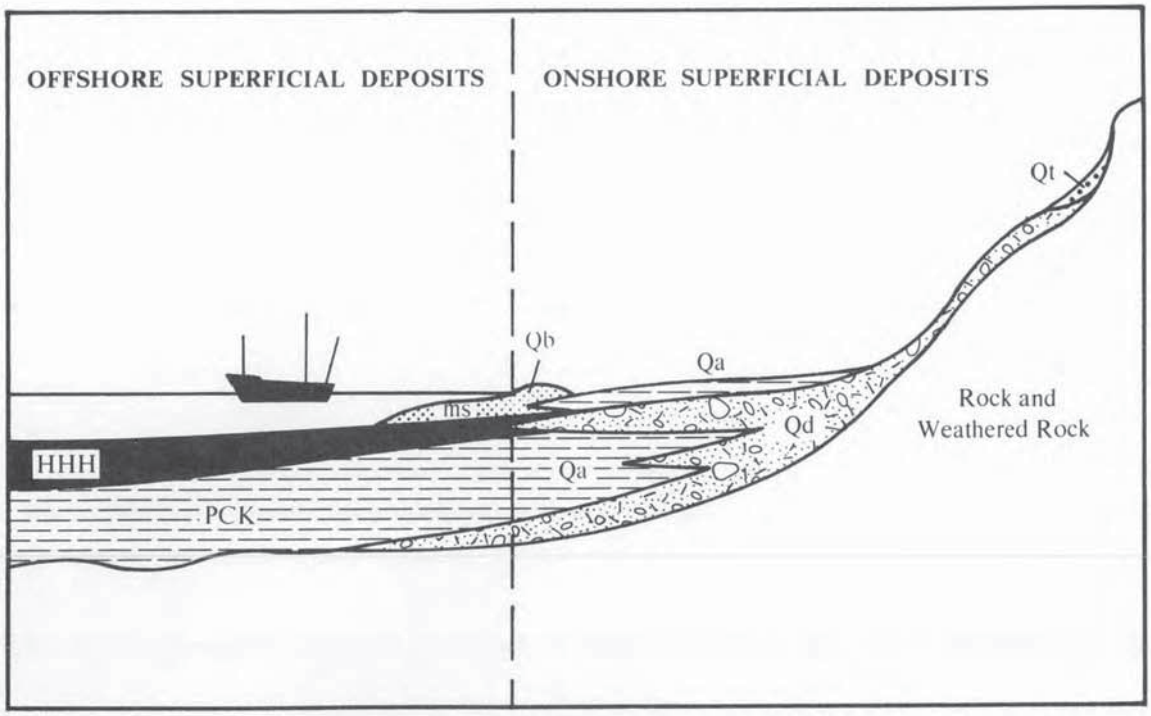


Figure 22 – Schematic Section Showing the Relationship between the Offshore and the Onshore Superficial Deposits

Onshore Superficial Deposits
Classification

Bennett (1984a) reviewed the previous work in detail. He recommended the division of transported superficial deposits for onshore geological mapping purposes into a layered, fluviatile sequence that includes alluvium and associated river terrace deposits, and the deposits of mass wasting (colluvium) that, in turn, may be subdivided into slightly transported and substantially transported categories. The slightly transported category can generally be regarded as insignificant

and unmappable at the mapping scale of this survey, and includes such features as small-scale landslips and almost insitu boulder fields. The substantially transported mass wasting deposits have been divided into debris flow and talus (rockfall) deposits. Occasionally the two are so closely associated that they have been delineated on the map as mixed debris flow and talus deposits.

Beach deposits have been mapped, and these include beach material extending inland from the low water mark and blown sand that forms deposits occuring up to 10 m above present day sea level. In places, deposits of boulders accumulated by storm action are sufficiently large to be delineated as deposits on the 1:20 000 scale maps. Localised patches of cemented beach material (beach rock) have been noted (Strange, 1986).

Extensive reclamation has been undertaken around Victoria Harbour, Kowloon Bay, Junk Bay and Aberdeen. Inland, large areas of fill underlie many of the major housing developments, and over much of the urban area between 1 and 4 m of fill is commonplace.

Alluvium and River Terrace Deposits

Widespread deposits of alluvium border Kowloon Bay and occupy river valleys in Shek Kip Mei, Kowloon Tong and the Ho Chung areas of Kowloon, and at Happy Valley and Wong Chuk Hang on Hong Kong Island. Smaller patches are common in upland valleys, for example, along Clear Water Bay Road, east of Kowloon. In places along the coast there are valleys that have been dammed either by sand bars as at Shek O, or by beach boulder barriers as seen on eastern Lamma. In these valleys, lacustrine sediments have filled the lagoons formed behind the seaward obstructions. The extensive, flat or very gently sloping alluvial areas within the district have been largely covered by building developments, the only notable exception being the Ho Chung Valley and Happy Valley. For the purposes of this survey it has been necessary in many cases to refer to pre-development aerial photographs to accurately ascertain the alluvium boundaries.

The alluvium consists mainly of well-sorted to semi-sorted clay, silt, sand and gravel, generally grey to yellowish brown in colour. In the Kowloon area most of the alluvial material is derived from the completely weathered granite, and sand-size quartz grains are abundant.

Although older terraced alluvium is extensive in the northern and central parts of the New Territories (Allen & Stephens, 1971), its extent in Kowloon is very limited, and it has not been recognized on Hong Kong, or Po Toi islands. It is possible that river terrace deposits or older alluvium did previously exist in East Kowloon, Junk Bay and Ho Chung, but they would have been obliterated by agricultural terracing and subsequent building developments.

The river terraces depicted in the present survey lie 3 to 7 m above the present alluvium surface. They have been delineated solely from pre-development aerial photographs (1949) as they are now totally obscured by fill and covered by housing estates. The terraces were noted in the So Uk, Lei Cheng Uk and Shek Kip Mei areas of northwestern Kowloon, and at Yung Shue Wan on Lamma Island.

Details

Kowloon. Extensive, flat alluvial tracts fringe the Kowloon Bay reclamation, and alluvial valleys extend northwards into the foothills of the Lion Rock ridge. In the vicinity of Kai Tak International Airport terminal building, very close to the pre-reclamation coastline (3870 2177), borehole logs record up to 20 m of alluvium consisting of yellowish brown silt with gravel layers. This alluvium thins northwards. In the San Po Kong Industrial Estate (3835 2205) it averages 10 to 15 m and is recorded to depths of -10 mPD, resting on weathered granite. Borehole records in the areas of Kowloon Walled City (378 214) and Tung Tau Estate (381 216) show alluvium in excess of 20 m. Alluvium up to 10 m thick is recorded from boreholes in the former valleys underlying the Wong Tai Sin Estate, now covered by up to 8 m of fill.

Alluvium fringes the former coastline from Lai Chi Kok eastwards to Shek Kip Mei and Sham Shui Po. This alluvium extends inland along the larger stream courses at Shek Kip Mei (352 216), Tai Hang (357 216) and Kowloon Tong (364 212). At the latter location, boreholes in Boundary Street (3601 2080) show up to 14.5 m of alluvium resting on granite, and along Waterloo Road near the junction with Lancashire Road (3643 2121), 13 m of alluvium on granite. A narrow alluvial tract extends eastwards from Mong Kok (3549 2004), where 3.5 m of alluvium is recorded in boreholes underlying 6 m of marine sands, as far as Ho Man Tin (3660 1979), where the alluvial valley has now been entirely covered by fill.

River terraces lie approximately 3 m above the alluvium in northwestern Kowloon, which, in the area of Lei Cheng Uk, is about 4 m above present day sea level. At Lei Cheng Uk (3453 2209), a Han Dynasty tomb was discovered in 1955 in the river terrace deposits during construction works. Watt (1970) reported that the tomb was built into a raised marine bench lying about 22 m above present day sea level. The tomb site is actually at 6.8 m above sea level, and there is no evidence to support a marine origin for the terrace.

Clear Water Bay Road and Ho Chung. Small alluvial pockets occur close to the Clear Water Bay Road, 1 km east of the Shun Lee Estate. The largest area is at Tseng Lan Shue (4260 2170), where 2 m of brown silt is exposed in the stream banks. Alluvium is widespread but generally thin in the Ho Chung Valley. At Yuen Ling (4332 2395), where the stream banks are less than 3 m high, granite is exposed in the stream bed (4337 2395); coarse ash tuff is exposed beneath the alluvium (4312 2388) 250 m to the west. Around Ngau Pui Wo (4255 2330), feldsparphyric rhyolite was noted in the stream floor, with less than 2 m of alluvium in the stream banks. Most of the alluvium of the Ho Chung Valley supports intensive market gardening; the original alluvial tract has, in many places, been modified by the construction of agricultural terraces.

Hong Kong Island. A wide, flat alluvial tract is developed at Happy Valley (368 149), centred on the race course, and a similar area of alluvium is present some 500 m farther east, in the vicinity of the Hong Kong Stadium (375 151). No details of the thickness of the alluvium are available for these areas. Alluvium is also present between Wong Chuk Hang and Shouson Hill, an area formerly covered by extensive agricultural terraces. Recent building developments and major road works have considerably modified the local topography there. Flat areas of lacustrine alluvium are present behind beach sand barriers at Deep Water Bay (3730 1156), Shek O (4385 1032) and Big Wave Bay (4340 1205). Elsewhere, small patches of coastal alluvium have been mapped at Chai Wan and Siu Chai Wan, and small scattered pockets of upland valley alluvium are present in the uplands of the Tai Tam Country Park.

Lamma Island. Alluvium is common in many low-lying valleys on Lamma Island, and is particularly well developed around Yung Shue Wan (Figure 7), where most of the alluvial tract is used for market gardening. Similar alluvial tracts are found at Lo So Shing, where the seaward end of the valley is blocked by extensive deposits of beach sand. Between Sham Wan (3225 0590) and Tung O (3253 0626) on the southeastern coast, a straight valley has been blocked at both ends by beach sand. At the Sham Wan end (3216 0587) the sand reaches 10 m above sea level, and the small streams draining into this valley have deposited in excess of 5 m of clay with organic material in a swampy environment (Meacham, 1978). Radiocarbon dating has indicated an age of 6 600 yr BP for the lower part of the deposit (Meacham, 1978), which may be partly intertidal. Large storm beaches consisting entirely of boulders have been thrown up across the valley mouths east of Mo Tat (3330 0722 & 3346 0746). In both cases the boulder dam is 10 to 11 m above present-day sea level, and lacustrine alluvial sediments have accumulated on the landward side. The resulting valleys are flat and between 10 and 12 m above sea level. Agricultural plots on their generally clayey and partly swampy surface are now abandoned.

Beach Deposits

These deposits are defined as unconsolidated material formed by marine action, extending landwards from the low-water line to a cliff-line or storm beach limit. They form a narrow fringe around the natural coastline of Victoria Harbour, but on southern Hong Kong Island, Lamma Island and the Po Toi Island Group they are present only in sheltered bays. They usually consist of clean sand, and the majority of beaches on southern Hong Kong are gazetted for recreational purposes.

Accumulations of large, rounded granitic boulders occur in places on exposed coastlines, and in several instances these are sufficiently extensive to be depicted on the 1:20 000 scale maps. It is assumed that the boulders have been transported and thrown up to considerable heights (up to 11 m above present day sea-level) by severe storm action (Plate 46). Similarly, sand deposits containing scattered pebbles occur at heights of up to 10 m above sea-level, and these are also regarded as storm beach deposits. This survey has found no evidence in support of the pre-existence of higher sea-levels.

Beach rock has been recognized in this survey in small localised pockets up to 20 m above sea-level in the cliffs surrounding Hong Kong Island, and has been described in detail by Strange (1986). These deposits are generally not large enough to be shown on the geological maps. An exception is a deposit of sand, gravel and cobbles, cemented by a calcareous shelly matrix, east of Yung Shue Ha (3276 0668), on eastern Lamma Island.

Details

Kowloon and Stonecutters Island. The natural coastline, fringed by beach deposits, has been concealed by major reclamation projects extending from Tsing Chau (3000 2335) and Kwai Chung eastwards as far as Lei Yue Mun. Evidence of beach deposits underlying the fill has been provided by pre-development aerial photographs, for example at Mei Foo (3255 2218) in Lai Chi Kok; by borehole data, for example in the Mong Kok area (3542 2052); and from 19th Century photographs, for example on the Tsim Sha Tsui peninsula (3566 1743). At Lei Yue Mun a coarse sand beach extends from Lei Yue Mun village eastwards to Lei Yue Mun Point (4295 1632) and probably typifies the beaches that are now obscured around Kowloon. The relatively undeveloped Stonecutters Island has fringing beach sands and a well developed tombolo sand bar feature at the eastern end of the island, where (3300 2025) excavations for new buildings proved 3 m of clean, coarse, yellow beach sand.

Hong Kong Island. It is apparent from the early maps that beach deposits fringed a considerable part of the northern coast of Hong Kong Island between Sai Ying Pun (3235 1645), Central District and North Point (3785 1570). Dense building development has obscured the superficial geology in the area, but borehole

Plate 46 – Storm Beach Deposit of Boulders Rising to 11 m above Sea-level. Forming Dam across Valley near Mo Tat, Lamma Island (3330 0717)

records have indicated the existence of beach sands at or near the original coastline. Extensive beach sand accumulations are present on the popular beaches at Deep Water Bay (3740 1175), Repulse Bay (3835 1090), South Bay (3845 0960) and Chung Hom Kok (3890 0875), as well as at Stanley (4010 0920), Turtle Cove (4105 1050), Shek O (4400 1010) and Big Wave Bay(4370 1200). In most cases the sand extends inland for less than 100 m from the low water mark, and to a height of about +5 mPD. At Shek O the sand continues from Rocky Bay (4400 1037) southwards to Island Bay (4383 0990), and ranges in height from +5.2 to +6.4 mPD. This deposit, probably a storm beach, has formed a barrier across the valley draining to Rocky Bay, and has created a lacustrine alluvial area inland.

Lamma Island. Beach sand deposits are common along the more sheltered western coast extending north from Lo So Shing (3070 0730) to Yung Shue Wan. Storm beach deposits are found on the eastern side of the island, the best example being at Sham Wan (3215 0590). At this locality, the site of a neolithic settlement, the sand bar reaches 10 m in height. Archaeological excavations there (Meacham, 1978) revealed rounded fragments of pumice ranging from 5 to 50 mm in diameter in varying concentrations in the sand body. Auger holes to a depth of 7.6 m found silty and clayey patches within the dominantly coarse sand. Meacham noted that the highest elevations (+9.8 mPD) of the main bar at Sham Wan appear to have had 0.2 to 0.3 m of sand deposited in the last 300 years. A similar storm beach is found nearby at Tung O (3243 0642). Accumulations of large boulders are found along the coastline 300 m east of Tung O village (3268 0635) and 200 m east of Yung Shue Ha village (3280 0667). Farther northeast rounded boulders of granite, rhyolite and syenite, commonly up to 3 m across, have been thrown up across exposed bays east of Mo Tat (3330 0717 & 3346 0746). These boulder deposits have produced dams across the two valleys, both at heights of between +10 and +11 mPD (Plate 46).

Po Toi Island Group. Apart from small beaches at Tai Wan on Po Toi Island (4425 0296), and in the sheltered bay on southwestern Beaufort Island (Lo Chau, 4335 0477), beach deposits are not present around these islands.

Debris Flow Deposits

Debris flow deposits are accumulations of mass-transported material formed by water-mobilised gravitional processes. They are the most important component of the complex group of deposits that has been generally referred to in Hong Kong as colluvium.

Berry and Ruxton (Berry 1957; Berry & Ruxton, 1960) recognised and classified these deposits, particularly in the area around Victoria Harbour, where they noted the widespread deposits on the Mid-levels slopes and the Kowloon foothills. The Mid-levels area has been studied in considerable detail following the Po Shan landslide in 1972 (Government of Hong Kong, 1972). Huntley & Randall (1981) presented criteria for the recognition of colluvium. Following the work

of Lai (1982) the Mid-levels colluvial deposits were subdivided (GCO, 1982) into three classes based on the evidence of superposition, differences in clast-matrix ratios and the degree of decomposition of the clasts. Lai & Taylor (1983) gave examples of the colluvium classes to be seen around Kowloon and Hong Kong Island. The present survey has found that the representation of three classes of debris flow deposits is impractical at the 1:20 000 scale.

Most commonly the debris flow deposits consist of boulders and cobbles set in a gravelly clay matrix. The material is usually poorly sorted, and the clasts range from angular volcanic blocks to rounded granite boulders. They can be as large as 8 to 10 m in diameter, but average 0.3 to 0.8 m across. The largest areas of debris flow deposits are those on the northern slopes of Victoria Peak (Mid-levels), below the Lion Rock and Fei Ngo Shan, and in the Ho Chung Valley, with the thickest accumulations at the base of the steep slopes. Some offshore boreholes have recorded colluvium, but in some cases this material may actually be corestone-bearing weathered granite.

Lai & Taylor (1983) discussed in detail the probable age of the deposits, suggesting the colluvium of their Class 1 had been formed in the Early or Middle Pleistocene, Class 2 in the Late Pleistocene, and Class 3 in the Holocene.

Details

Kowloon, Junk Bay and Ho Chung. Debris flow deposits are widespread along the foothills of Beacon Hill, Lion Rock, Tate's Cairn and Fei Ngo Shan. In other areas, numerous laterally restricted debris flow deposits occupy valleys. Between Lai Chi Kok and Piper's Hill, valleys filled with debris deposits are common. A deposit at least 5 m thick is present to the west of Piper's Hill (3360 2297), consisting of rounded granite boulders up to 2 m in a sand and silt matrix. The granite blocks include both fine- and coarse-grained varieties. On the southern slopes of Piper's Hill (3382 2252), near the Caritas Hospital, the debris flow deposits have a white clay matrix immediately above the weathered rock (Whiteside, oral communication, 1986), together with elongate white flecks, 20 to 40 mm long, within the more typical brown clay matrix. Close examination of these light coloured patches has revealed root or twig fragments in their cores. This deposit contains boulders of fine-, medium- and coarse-grained granites. To the northeast of Lei Cheng Uk Estate (3473 2233), large subrounded granite boulders, up to 4 m across, are present in a debris deposit occupying a former valley draining south from Tai Wo Ping. The pre-development (1949) aerial photographs of the area around Lei Cheng Uk Tomb (3454 2212) show the debris flow as forming a fan-shaped deposit, incised by recent stream erosion.

Plate 47 – Debris Flow Deposit with Granite blocks in Silty Sand Matrix; Lung Cheung Road, Southern Flanks of Beacon Hill (3588 2267)

Debris flow deposits extend along the southern slopes of Beacon Hill and are exposed in the cut platforms immediately north of Lung Cheung Road. A typical exposure is recorded in the road cutting leading from Lung Cheung Road to Beacon Hill, near Phoenix House (3588 2267). Here, subrounded to rounded granite boulders 0.3 to 0.8 m across are present in a clast-supported matrix of sandy clay (Plate 47). Further east, on

the slopes below the Lion Rock, debris flow deposits mixed with talus or rockfall material cover a wide area; this area has been designated a mixed debris flow and talus deposit on the 1:20 000 map. Large boulders of granite are perched on the debris flow deposit, with one block at least 15 m across. Recent excavations at Chuk Yuen (3790 2308) for a new housing estate have revealed older debris flow deposits on ridge spurs and younger debris material filling valley bottoms. Debris flow deposits composed largely of volcanic rock fragments in a clay matrix are common on the slopes draining southwestwards from Tate's Cairn and Fei Ngo Shan. The valley at Diamond Hill Crematorium (3960 2293) contains thick debris deposits with large, angular blocks of tuff and feldsparphyric rhyolite common. The matrix is a sandy or gravelly brown clay. As at Chuk Yuen, two generations of deposits are found. Older material composed largely of tuff and siltstone fragments occupies ridge spurs, as seen between Jat's Incline and Diamond Hill (4007 2279), and a younger deposit containing mixed granite and volcanic material fills the valleys, for example 250 m east of the crematorium (3977 2290). Near the junction of Lung Cheung Road and Hammer Hill Road (3919 2210), borehole records indicate at least 15 m of colluvium.

Excellent exposures of debris flow deposits are seen along the old Clear Water Bay Road, 300 m east of the Choi Wan Estate (4066 2164) (Plate 48). There, at least 10 m of poorly sorted debris deposit of subangular to rounded volcanic blocks is set in a yellow to light orange-brown clay matrix; many of the clasts are highly weathered and the matrix is well consolidated. Lai & Taylor (1983) cite this locality as Class 1 colluvium, noting that some of the steep slope faces are unprotected but have been standing for 30 years without showing significant signs of erosion. Debris flow deposits form an impersistent veneer on the volcanic slopes between Tai Sheung Tok (4280 2078) and Tseung Kwan O (4387 2100). Large blocks of eutaxite and fine ash tuff up to 2 m in diameter are common. In the stream bed 300 m north of Tseung Kwan O (4377 2112), fresh rock is exposed, with 2 to 3 m of debris flow material seen in the banks. The Ho Chung Valley contains extensive debris flow deposits that grade evenly at 3 to 5° downslope from Ngau Pui Wo (4240 2330) to Yuen Ling (4330 2384). At Yuen Ling it has been incised by streams, creating the appearance of a river terrace deposit. The topography both on the alluvium and the debris flow deposits in the Ho Chung Valley has been considerably modified by agricultural terracing. The abundant boulders in the debris deposit have been utilised for the construction of the terrace walls.

Plate 48 – Debris Flow Deposit, Debris Derived from Volcanic Rocks; Old Clear Water Bay Road, East Kowloon (4066 2164)

Hong Kong Island. A mantle of debris flow material covers the north-facing slopes of Victoria Peak. This was examined in detail during the Mid-levels Study (GCO, 1982). The deposits were derived almost entirely from the volcanic rocks around the Peak, and were formed as a series of debris flows in at least three cycles of deposition and intervening erosion. The oldest deposits, 'Class 1 Colluvium', consist of stiff to very stiff silt

containing subrounded cobbles and boulders which are usually highly to completely weathered. The intermediate deposits, 'Class 2 Colluvium', have a firm to stiff sandy clay matrix with subangular to subrounded, moderately to highly weathered cobbles and boulders. The youngest material, 'Class 3 Colluvium', consists of soft to firm, uniform, pale brown clayey sandy silt with angular to subrounded, slightly to moderately weathered clasts. Figure 23 indicates the present thickness of the debris flow deposits around the Mid-levels. In most places their average thickness is about 2 m, but particularly thick deposits occur along probable former valleys, a borehole near Robinson Road penetrating some 33 m of this material. The debris flows are believed to have extended beyond their present downslope boundary above Sheung Wan and Central, and would formerly have continued to the natural shoreline or even beyond. Howat (1985) noted the presence of a lobe of terrestrial material into marine mud at a depth of about -15 mPD in excavations for Sheung Wan MTR station (3382 1644). The deposit was examined during this survey and closely resembles debris flow material seen higher in the Mid-levels, with cobbles and boulders of volcanic rocks. A wood sample collected from the base of the underlying marine mud has yielded a date of 8 600 $\pm$ 270 yr BP (Howat, 1985). M.D. Howat (oral communication, 1986) has observed similar debris flow deposits resting on marine mud in excavations beneath Johnston Road, Wan Chai (359 153).

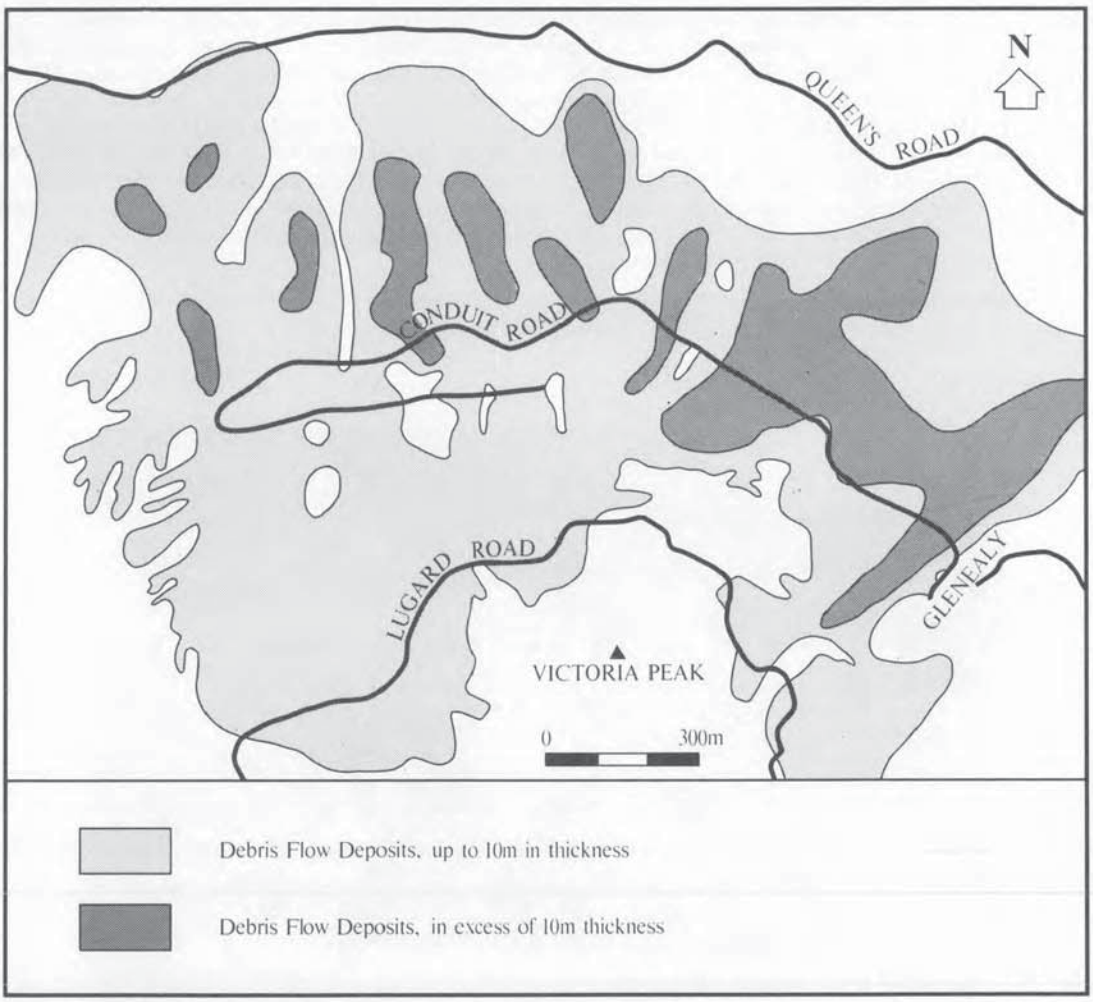


Figure 23 – The Distribution of Debris Flow Deposits in the Mid-levels of Hong Kong Island

Debris flow deposits are present on the western slopes of High West, and these are thickest along stream courses. South of Victoria Peak, in the Pok Fu Lam valley (3310 1440), there is a widespread veneer of debris deposits between 2 and 5 m thick, with only isolated exposures of bedrock visible in stream beds. Similar valley infilling is common in many stream courses through the Aberdeen Country Park, and in the valleys to the south of Mount Nicholson and Wong Nai Chung Gap. Debris flow deposits are not widespread in the Stanley, Tai Tam and Shek O areas, but occur as isolated accumulations on valley floors. Most valleys in the Chai Wan area have a 1 to 3 m infill of debris flow material, consisting of subangular to subrounded volcanic clasts set in a clay matrix. On the D'Aguilar Peninsula an unusual debris flow deposit is derived from the quartz syenite pluton centred on D'Aguilar Peak (4370 0870). This quartz-deficient plutonic rock has weathered to a fine silt but contains abundant subrounded corestones, some up to 5 m across. Debris flows consisting of this material are common on the western slopes of D'Aguilar Peak (4329 0832); subsequent erosion has removed much of the fine matrix, leaving piles of quartz syenite boulders (Plate 49).

Lamma Island. In the Yung Shue Wan area (Figure 7), debris flow deposits commonly fringe flat alluvial tracts. Subangular to rounded coarse ash tuff cobbles and boulders are common in the debris flow deposits found in the valleys radiating from the hills north of Tai Peng (3000 1040). Apart from spreads of debris flow material flanking valleys to the south and southeast of Mo Tat Wan (3300 0733), these deposits are not widespread in the southern part of the island.

Plate 49 – Mixed Talus and Debris Flow Deposit Containing Blocks of Quartz Syenite on Western Flank of D'Aguilar Peak (4328 0856)

Talus (Rockfall) Deposits

Talus is defined as a deposit of rock fragments, usually coarse and angular, derived from and lying at the base of a cliff or very steep rocky slope (Bates and Jackson, 1980). The blocks have been transported downslope by a combination of gravitational falling, rolling or sliding. In places, debris flow deposits may include a component of talus origin, as seen on the lower slopes of the Lion Rock, and delineated on the map as mixed debris flow and talus deposits.

Details

Lion Rock (Sz Tsz Shan). Talus deposits have been mapped on a steep slope (> 35°) immediately below the overhang of the 'Lion's Head' (3703 2357). The deposit consists of angular to subangular blocks of fine- and medium- grained granite between 0.1 and 0.8 m across. The accumulation is very loose, with little or no clay and silt matrix visible. The talus supports no significant vegetation. The larger blocks have travelled furthest downslope, with several boulders at least 15 m across resting on debris flow deposits (3733 2340). Site formation work for the new Chuk Yuen Estate has incorporated several boulder fences designed to protect the housing areas from falling blocks (3770 2315).

Victoria Peak and Mid-levels. Talus deposits have been delineated at three localities on the slopes between Mid-levels and Victoria Peak. About 400 m west-northwest of the Peak (3260 1537) a block field 30 to 50 m wide extends downslope for about 200 m. It contains subangular to subrounded boulders of fine ash and coarse ash tuff averaging 2 m across, with some blocks up to 8 m across. Some 250 m northwest of the Peak (3288 1544), immediately below Lugard Road, these form block streams along the stream courses. Talus forms a veneer on the slopes above Conduit Road, about 500 m northeast of the Peak (3337 1566). Angular to subrounded blocks of volcanic rock reach 6 m in diameter. The boulders are usually in contact with each other, with less than 10% sandy silt matrix present. The construction of boulder fences, and the removal of the larger exposed boulders forms part of the Landslip Preventive Measures Programme of the Geotechnical Control Office.

Fill

The coastline and topography of northern Hong Kong Island and Kowloon have changed significantly over the last century. Considerable areas of new land have been created by a series of reclamation projects; the 1:20 000 maps show the limits of reclamation at the dates indicated. The largest areas of reclamation are those around Kowloon Bay, where an average thickness of 10 m of fill has been deposited. In places, the marine muds of the Holocene Hang Hau Formation have been dredged and largely removed prior to filling, for example at Kwai Chung Container Terminal and under the runway of Kai Tak International Airport. Major reclamation projects are currently taking place at Kwai Chung, Junk Bay and Chai Wan. Most fill for reclamation has previously come from the excavation of the low-lying weathered granite hills, but recent projects have used fresh rock, for example at Junk Bay, where large borrow areas in fresh tuffs of the Ap Lei Chau Formation provide the main fill material.

During the excavation of fill material some hills lying close to the coast have been entirely removed, for example at Tai Kok Tsui (3480 2030) in western Kowloon, where low hills rising to 20 m above sea level have been reduced to a height of 5 m, level with the surrounding fill. Similarly, the Sung Wong Toi Hill near Kowloon City (3750 2080), formerly reaching 30 m in height, was levelled in the 1940s to provide fill material for the airport expansion.

Borehole records in urban areas not reclaimed from the sea show that they are commonly underlain by at least 3 m of fill; it has not been feasible, however, to identify all of these deposits on the 1:20 000 maps. Records from major construction projects involving large cut and fill areas have allowed the reasonably accurate delineation of thick fill deposits, for example around the Wang Tau Hom Estate in northeastern Kowloon and the extensive infilling of valleys around Sau Mau Ping in East Kowloon.

Sanitary landfill sites have been delineated at Kwai Chung (303 238) and at several localities in East Kowloon.

Offshore Superficial Deposits

Classification

The offshore superficial deposits of Hong Kong have received only scant attention in previous geological surveys of the Territory. Davis (1952) was concerned largely with describing the proven occurrences of marine deposits underlying the low-lying coastal valleys, and occurrences of decayed vegetation from borings within Victoria Harbour. Allen & Stephens (1971) made brief mention of marine sediments formed in the littoral zone. Other published studies have dealt in broad terms with the distribution of the offshore deposits of the Territory (e.g. Berry, 1962; Holt, 1962; Lumb, 1962, 1977) and specifically the deposits of Victoria Harbour (Berry, 1957; Berry & Ruxton, 1960). A series of studies have dealt with beach morphology and sediments around Hong Kong (So, 1972, 1981; Williams, 1971a, 1971b, 1973a, 1973b, 1973c, 1974; Williams et al, 1977) and with particular sites within the district, such as Lei Yue Mun Bay (Yim, 1984; Wang & Yim, 1985) and Causeway Bay (Willis & Shirlaw, 1984). Contemporary rates of sedimentation in Hong Kong Harbour were assessed by Harbour Area Consultants (HAC) (1983) and Chalmers (1984). Extensive geophysical surveys have been carried out for the Harbour Reclamations and Urban Growth Study (Electronic & Geophysical Services, Ltd (EGS), 1983). The development of deep water channels in Hong Kong waters, including Lei Yue Mun and the East Lamma Channel, was discussed by Arthurton (1985).

The offshore superficial deposits comprise two formations (Figure 22). The older is of Pleistocene age and consists of silt, clay, sand and gravel, largely of alluvial origin. This is the Chek Lap Kok Formation (new name) that rests with major unconformity on rock in various states of weathering. The younger formation is the Hang Hau Formation (new name) of Holocene age. It consists of marine mud with subordinate sand. The Hang Hau Formation generally rests with minor unconformity or non-sequence on the Chek Lap Kok Formation (Plate 52), but it locally overlaps the latter to rest on rock in various states of weathering. Sea-bed deposits of mud and sand that are forming in the present-day are included in this formation. The names Chek Lap Kok Formation and Hang Hau Formation are respectively equivalent to the terms Alluvium and Marine Deposits that have commonly been used in offshore engineering site investigation practice in Hong Kong.

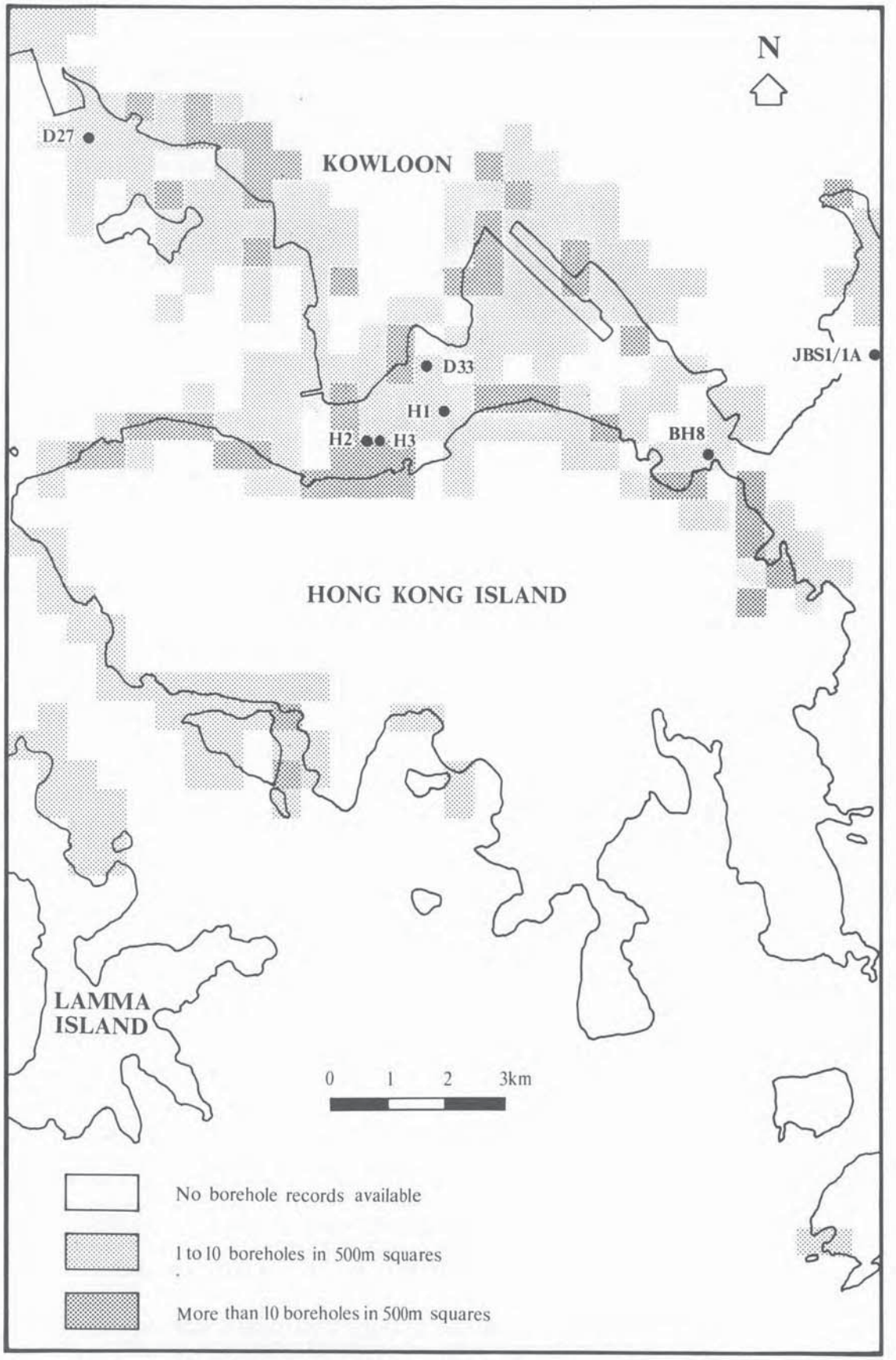


Figure 24 – Sites of Continuously Sampled Boreholes (see Appendix) and the General Distribution of Offshore Site Investigation Boreholes

Methods of Survey

The offshore deposits have been investigated by reference to data from boreholes, shallow seismic profiles and sea-bed sampling programmes. Information from some 1 600 boreholes has been collected from site investigation reports, while new stratigraphical detail has been gathered from the logging and analysis of a few continuously sampled boreholes commissioned by the Geotechnical Control Office (GCO) for this survey (Appendix). The sites of these continuously sampled boreholes and the general distribution of site investigation boreholes are shown in Figure 24.

Seismic data, obtained using Boomer equipment, combined with site investigation borehole information, formed the basis of a general appraisal of the offshore geology of this district commissioned by the GCO (EGS, 1985). In this survey the original seismic traces have been re-appraised to elucidate stratigraphical detail. In addition, the survey has benefitted from data collected by geophysical investigations commissioned by the GCO for this Geological Survey, and carried out by Port Works Division, Civil Engineering Services Department using Pinger and side-scan sonar equipment. A track plot showing the distribution of the geophysical data is given in Figure 25.

The Boomer seismic records have generally allowed unambiguous recognition of the base of the Hang Hau Formation except in parts of the central and eastern Harbour. Also, they give a clear indication of the stratification within that formation. By contrast, the boundary between the Chek Lap Kok Formation and rock or weathered rock is commonly poorly defined. The presence of biogenic gas in places within the Hang Hau Formation has a masking effect on the seismic traces, preventing resolution of all underlying reflectors. Disturbance of the sea-bed by dredging or other engineering work may also produce a masking effect.

Chek Lap Kok Formation

Distribution and Physical Characteristics

The Chek Lap Kok Formation has a widespread distribution but is masked by the Hang Hau Formation in all but a few localities. Its thickness is generally in the range 10 to 30 m. It is absent around parts of the coastal fringe, in a contemporary deep water channel at Lei Yue Mun, and over several rock knolls in the Harbour area and East Lamma Channel. The type section of the formation is the continuously sampled borehole B13/13A at Chek Lap Kok, an island off northern Lantau (Sheet 9) (Shaw, 1985; Shaw et al, 1986).

The formation is lithologically diverse, boreholes proving sequences of mainly firm to stiff clay as well as silt and dense sand and gravel and, in a few cases, boulders. Some of the clays and silts are laminated and some include grey or dark grey organic layers with wood fragments (Plate 44). The more typical colours, however, are bluish grey to light bluish grey, with sporadic yellow, brown-ochre and red mottling (Plate 44). Plots of particle size distribution analyses for samples from the formation are given in Figure 27.

Unlike the continuous sub-parallel reflectors that characterise the seismic signature of the marine muds of the Hang Hau Formation, the reflectors in the Chek Lap Kok Formation are generally impersistent to chaotic, though rather stronger than those in the marine muds (Plate 51).

Marine fossils have been recorded from the formation within the district by Yim (1984) and Howat (1985). The top of the formation commonly carries desiccation cracks filled with muddy sand of the Hang Hau Formation.

The Chek Lap Kok Formation rests unconformably on rock in various states of weathering. The surface of unconformity is generally irregular (Plate 51), and the formation may thin out against, or be confined to, channels or gullies in rock or weathered rock. Its base is probably markedly diachronous, but, in the absence of continuous seismic reflectors and of documented, stratigraphically marked horizons, such diachronism remains unproved. The formation is estimated to extend to a depth of at least -60 mPD in the East Lamma Channel. Seismic records in the central Harbour area indicate that weathered rock there lies at a maximum of about -60 mPD.

The top of the formation is an erosion surface over wide areas, particularly in the East Lamma Channel, in the central and eastern Harbour areas, and at Lei Yue Mun in the deeper parts of the contemporary channel, where the formation has been completely eroded. In the western Harbour area the top forms a gently undulating, gullied or channelled surface that falls gently southwestwards. The upper surface of the formation forms closed basins under the Hang Hau Formation off Tsim Sha Tsui and at Lei Yue Mun; these hollows are considered to be of marine origin, scoured by localised, high velocity tidal streams.

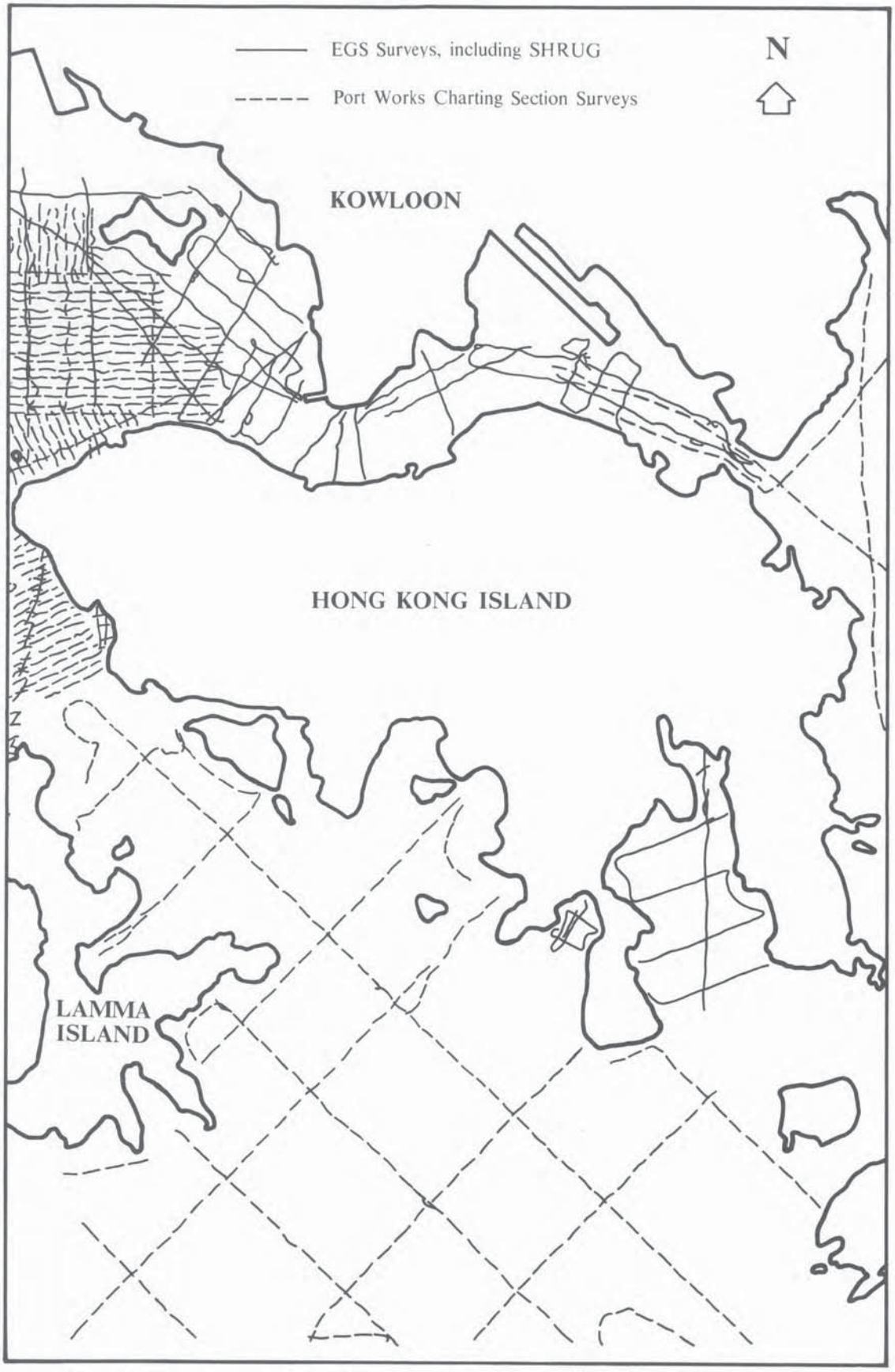


Figure 25 – Vessel Track Plot for Offshore Shallow Seismic Investigations within the District

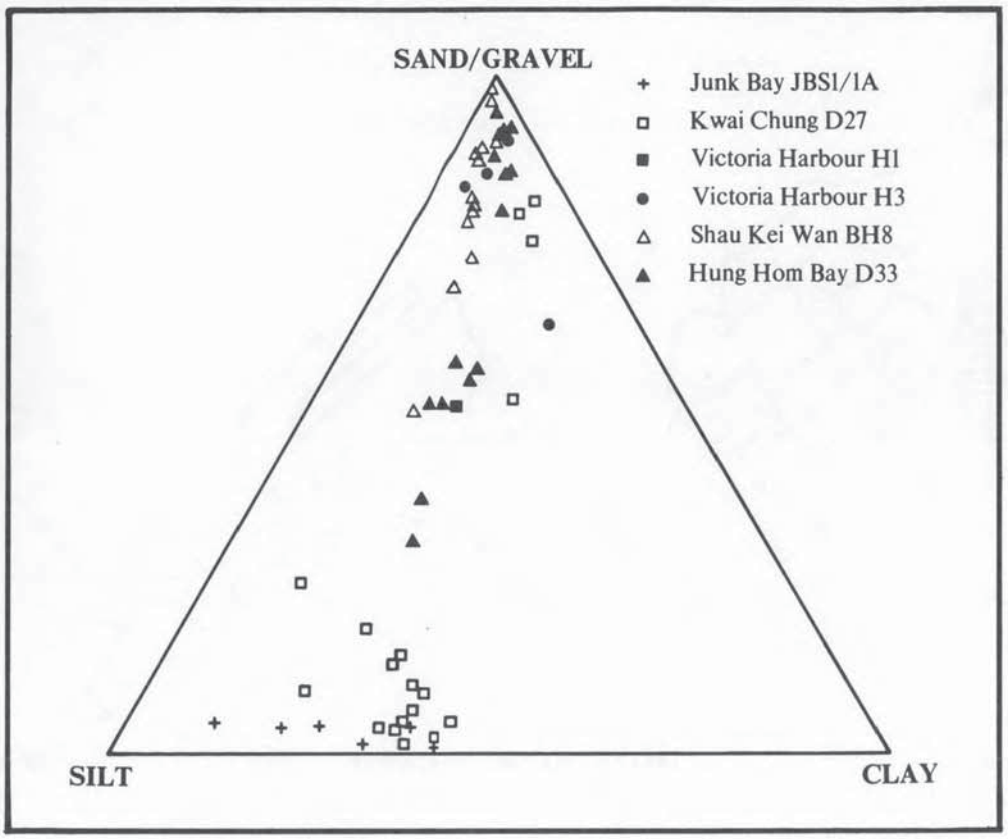


Figure 26 – Particle Size Distribution Analysis Plots for Mud Samples from the Hang Hau Formation

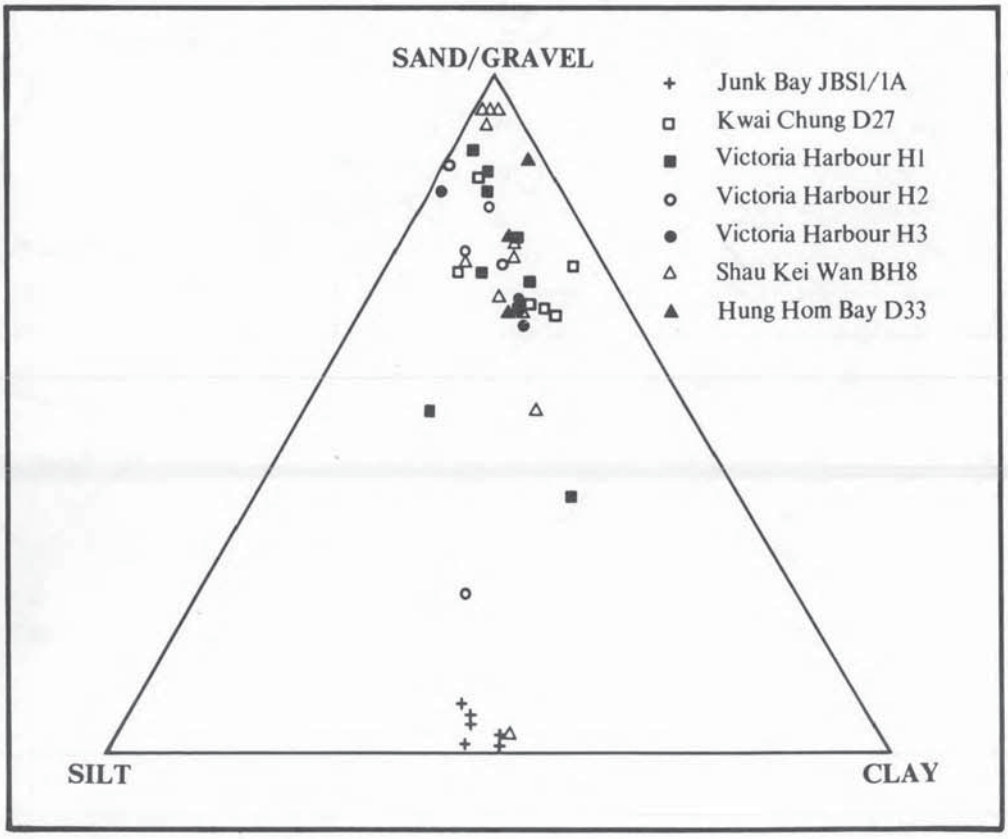


Figure 27 – Particle Size Distribution Analysis Plots for Samples from the Chek Lap Kok Formation

Age and Depositional Environment

No radiocarbon dates for material from the Chek Lap Kok Formation within the district are available. However, material has been dated from High Island (Sheet 8) and Chek Lap Kok (Sheet 9). These dates range from 16 420 ± 660 to 36 480 ± 830 yr BP at Chek Lap Kok (RMP Encon, 1982); a date of > 40 000 years BP was obtained from organic material at the base of the formation in Borehole B13/13A (CSIRO, Australia). At High Island, one sample gave a date of 36 600 yr BP, and two others were determined to be greater than 40 000 yr BP (Kendall, 1975), the limit of this analytical technique. This evidence suggests that the majority of the Chek Lap Kok Formation was deposited in the Late Pleistocene.

A marine origin for deposits within the formation has been proposed from borehole evidence at Lei Yue Mun Bay (Yim, 1984; Wang & Yim, 1985) and from sections in Western District (Howat, 1985). Of the eight samples from the Chek Lap Kok Formation in the Junk Bay Borehole JBS1/1A subjected to palynological analysis for this survey, none was indicative of a marine environment. The lowest sediments (-39.32 to -31.45 mPD) (Figure 29) accumulated in a water body that received a fluvial input, in an area of lowland evergreen subtropical forest; no evidence was found to suggest marine or littoral influences. Sediments between -29.92 and -24.16 mPD) (Figure 29) were considered to be of fluvial origin, deposited under continental conditions with a vegetation dominated by ferns.

Details

East Lamma Channel. The formation rests on an irregular surface of weathered bedrock extending to at least -60 mPD, and is unconformably overlain by the Hang Hau Formation. Under the present deep water channel its upper surface forms a broad buried channel with a floor at -40 to -42 mPD and with flanks at -30 to -35 mPD, rising to almost -20 mPD near the coast of Hong Kong Island. Logs of boreholes in Telegraph Bay record silts and sands of grey, pink-brown and yellow colours. The formation is overlapped there, some 60 to 80 m from the coast, by the Telegraph Bay Member of the Hang Hau Formation.

Western and Central Harbour. The formation in these parts of the Harbour is typically about 15 m thick and rests on an irregular surface of weathered bedrock, ranging to a depth of some -60 mPD. It is unconformably overlain or, in coastal areas and around rock knolls, overlapped by the Hang Hau Formation, except in parts of the central Harbour area between Tsim Sha Tsui and Hong Kong Island, where the Hang Hau Formation is absent. Logs of boreholes through the formation indicate a complex and highly variable sequence of stratified deposits that comprise clay, sand and fine gravel of various colours.

On seismic records the top is sharply defined in the western Harbour area but becomes difficult to distinguish from the sands of the Hang Hau Formation in the central Harbour area. Between Stonecutters Island and Tsim Sha Tsui, and also northwest of Stonecutters Island, the top surface of the formation is generally planar, falling gently southwestwards from about -15 mPD near the western Kowloon shore and around Stonecutters Island, to more than -30 mPD near Little Green Island (Figure 28). The slope is incised by a dendritic system of gullies or channels whose floors fall similarly in a southwesterly direction (Plate 51). Gullies to the northwest of Stonecutters Island are incised as much as 15 m into the formation and, locally, into rock. In common with its occurrence in the East Lamma Channel, the formation here displays moderately high amplitude, discontinuous, parallel and inclined reflectors that terminate downwards at a diffuse lower boundary on weathered bedrock.

Eastern Harbour and Lei Yue Mun. In this area the formation is typically in the range 12 to 25 m thick, but attains a thickness of some 34 m under the present main harbour channel (EGS, 1985). Seismic records show that it extends to a depth of at least -60 mPD. The formation is thin, and perhaps locally absent, under much of Kowloon Bay. It also thins out towards the sump of the contemporary deep water channel at Lei Yue Mun, which is largely rock-floored (Plate 54).

Junk Bay and the Eastern Approaches. Information on the Chek Lap Kok Formation for this area is limited to Junk Bay. In the continuously sampled Junk Bay Borehole (JBS 1/1A) the formation was about 18.5 m thick. A log of this borehole is given in the Appendix, and its sequence is illustrated in Figure 29. Other boreholes in Junk Bay confirm its widespread occurrence there, but its extension southwards into the Eastern Approaches can only be inferred.

Southeast of Lamma Island. Little is known about the base of the Chek Lap Kok Formation under the waters to the southeast of Lamma Island. The only records for this area are reconnaissance Finger traces that generally do not penetrate the formation. The top of the formation appears to be a regular surface, sloping gently southeastwards from about -20 mPD near the present coast off Ap Lei Chau to -40 mPD at the southern limit of the territorial waters. This surface is interrupted only by a shallow NW–SE trending hollow draped by Hang Hau Formation under, and to the southeast of, the East Lamma Channel.

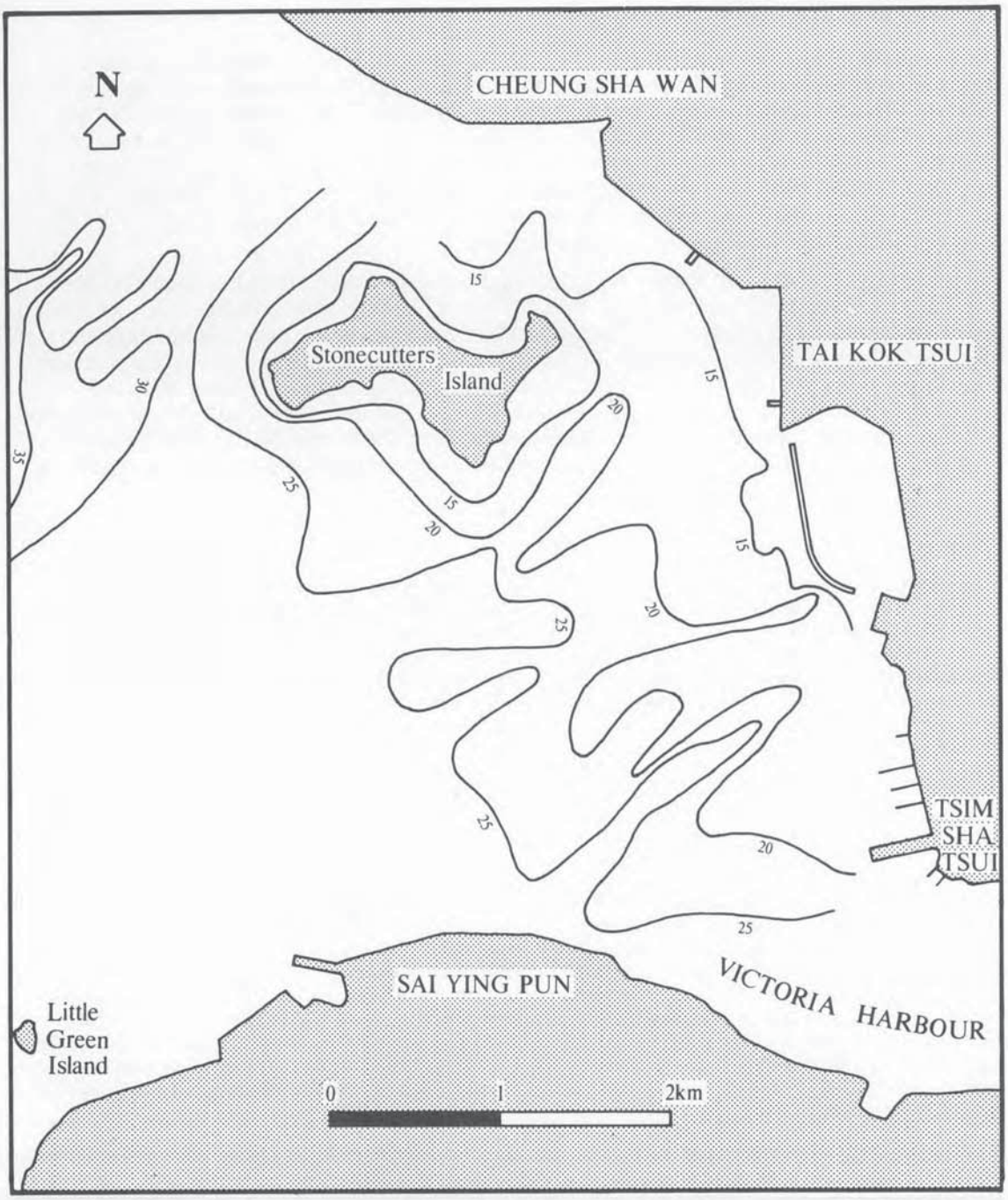


Figure 28 – Generalized Contours on the Top of the Chek Lap Kok Formation in Western Victoria Harbour (Contour Values in Metres below Principal Datum)

Hang Hau Formation

Distribution and Physical Characteristics

This formation is widespread and forms most of the sea-bed within the district, including not only the featureless tracts of the western part of Victoria Harbour and Junk Bay but also most of the deep water channels. It is absent, or represented only by a veneer of sand 1 to 2 m thick, off Tsim Sha Tsui and on much of the floor of a contemporary deep channel at Lei Yue Mun; it is also absent over several rock knolls in the Harbour area. Locally, it has been removed by dredging or disturbed by engineering works, particularly in the Harbour area.

The formation is dominated by soft to very soft, olive-grey to blue-grey, shelly mud (Plate 44) and is typically 10 to 20 m thick; its type section is a continuously sampled borehole (JBS 1/1A) in

Junk Bay, near Hang Hau Town (Sheet 12). The log of this borehole is shown in Figure 29 and given in the Appendix. The mud is generally shelly; shells may be fairly uniformly distributed, although richly shelly layers and shell-free intervals of 1 m or more are also recorded. Bivalves are the dominant shell class, and gastropods are locally abundant; sparse echinoid fragments have been noted (Plate 50).

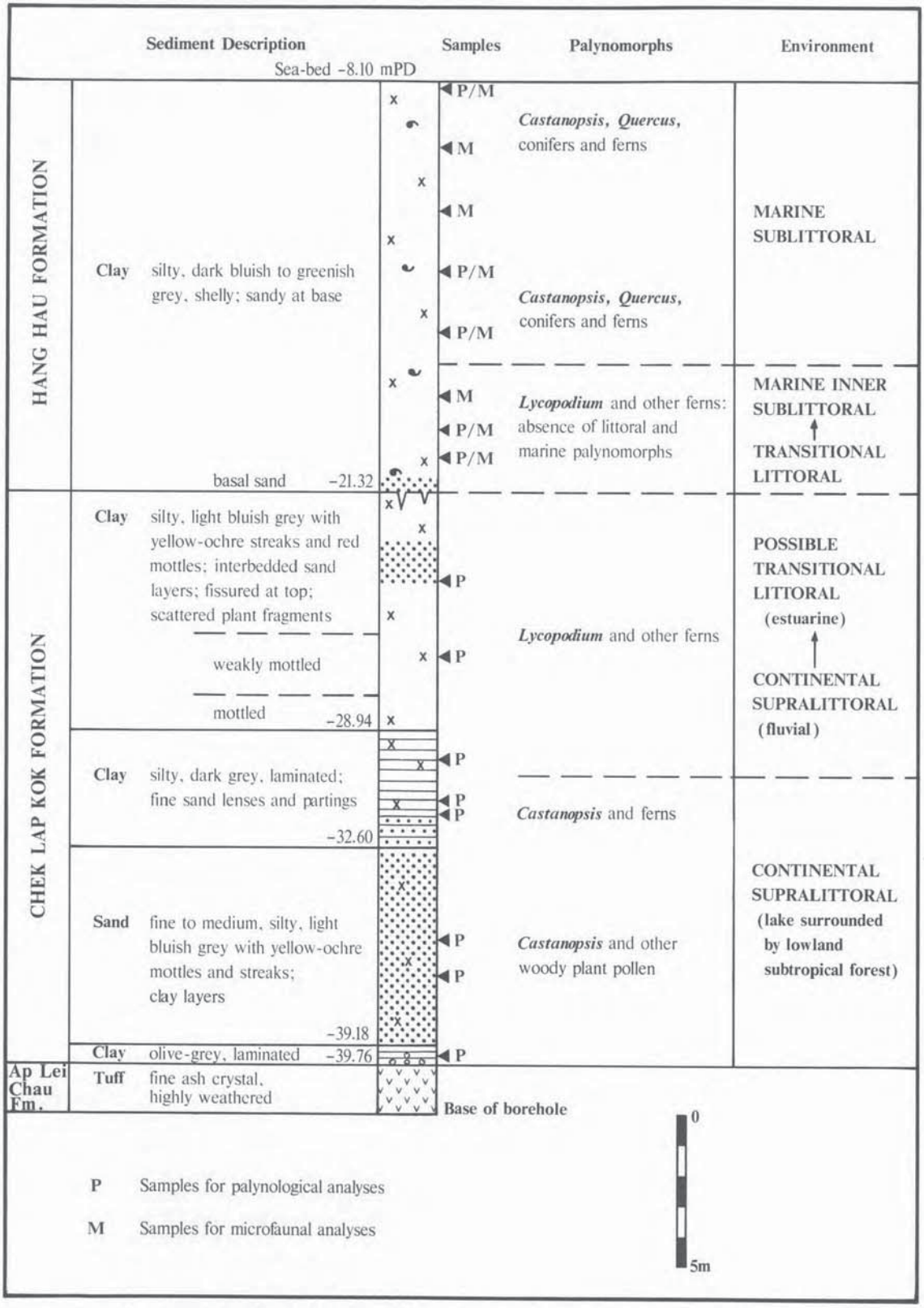


Figure 29 – Graphic Log, Description and Environmental Interpretation of Sediments from the Junk Bay Borehole, JBS 1/1A

Particle size distribution analyses of the mud plot in the silty clay range (Figure 26). No evidence of structures or discontinuities within the mud is recorded from the continuously sampled boreholes. However, well-marked and extensive, sub-parallel reflectors characterise the seismic signature (Plate 53) and, in places, notably in the East Lamma Channel, these reflectors indicate the existence of major discontinuities within the mud (Plate 52).

The Hang Hau Formation is unconformable on the Chek Lap Kok Formation (Plates 51 and 53) and locally it overlaps to rest on rock or weathered rock. Its base is diachronous, for example in the western Harbour area the formation has an eastward onlap relationship with the underlying Chek Lap Kok Formation. In the same area Hang Hau Formation mud fills and overlaps gullies or channels incised in the Chek Lap Kok Formation (Plate 51). In the East Lamma Channel the existence of two mud members within the formation, separated by a major discontinuity, is inferred from seismic records. The younger of these, the East Lamma Channel Member has the weaker seismic response and fills a complex channel eroded in the older Telegraph Bay Member (Plate 52). Continuous reflectors within both of these members show that the deposits have downlapping geometries, a further indication of the complex diachronism of the base of this formation (Plate 53).

Sand or muddy sand is present within the formation as littoral or sub-littoral deposits fringing the pre-reclamation coasts. Many of these deposits, for example around the Kowloon peninsula and along the northern coast of Hong Kong Island, are now incorporated in reclamation, while some have been dredged to supply the commercial sand market. Sand also occurs as deposits associated with past and present deep water channels. For example, in the East Lamma Channel a sand body at the base of the formation is inferred from seismic records (Plate 53), and at Lei Yue Mun sand occurs in the vicinity of the contemporary channel. A continuously sampled borehole off Shau Kei Wan (4191 1629) proved sand some 18.68 m thick between the sea-bed and the weathered rock head (Appendix), while nearby, off Chai Wan, side-scan sonar records indicate the existence of sand at the sea-bed, as well as the scars of sand dredging.

The occurrence of sand in the East Lamma Channel is inferred from seismic records as deposits up to 3 m thick on the floors of channels, both present and buried (Plate 53). In Victoria Harbour, off Tsim Sha Tsui and Wan Chai, seismic and borehole records show that the formation there is represented largely by sand. Continuously sampled boreholes off Kwai Chung and in Junk Bay included organic sand or muddy sand in the basal metre or so of the formation.

The larger sand bodies, including those off Shau Kei Wan, comprise mainly quartz sand with subordinate feldspar, as do most of the littoral and sub-littoral deposits. However, the sands lining the deep water channels on, or within, the Hang Hau Formation may be composed largely of comminuted shell debris, as recorded in three boreholes in Victoria Harbour (Appendix), off Wan Chai.

Age and Depositional Environment

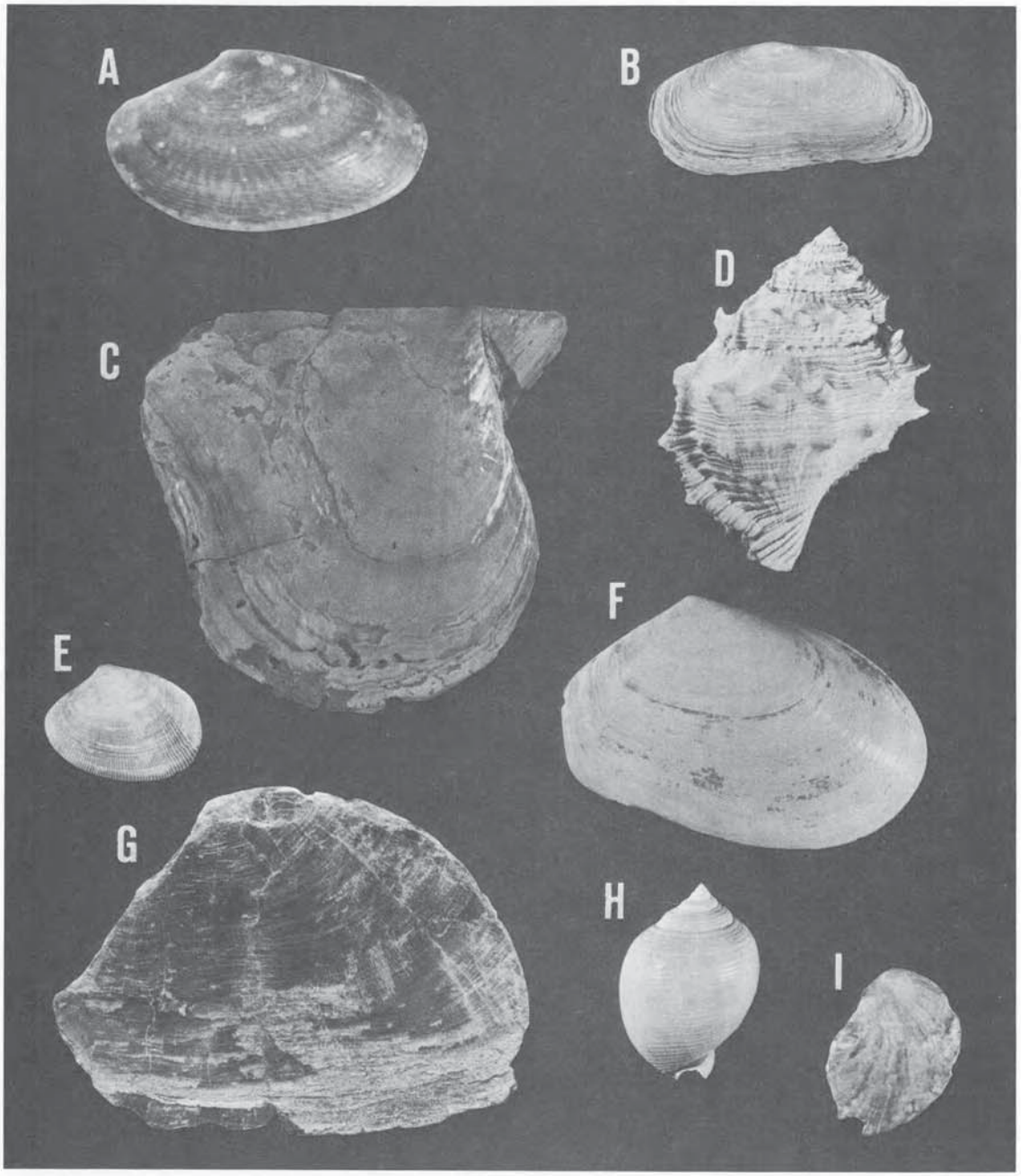
Radiocarbon dates from organic material recovered from the Hang Hau Formation within the district indicate a Holocene age. A sample of wood from a site beneath Admiralty has been dated at 6 520 $\pm$ 130 yr BP, and a sample from a site at Prince Edward at 6 580 $\pm$ 130 yr BP (Meacham, 1978). Shells from near the base of the formation in the Junk Bay Borehole (JBS 1/1A) have given a date of 8 080 $\pm$ 130 yr BP (CSIRO, Australia).

Foraminiferal analyses of eight samples from the Hang Hau Formation at Junk Bay (Borehole JBS 1/1A, Appendix) have allowed the tentative identification of four phases of marine deposition; an initial transgressive stage (-20.25 to -18.25 mPD), a period of more stable relative sea-level (-16.26 to -14.25 mPD), a period of slight shallowing -12.25 mPD) and a final phase of fairly stable shallow marine conditions (-10.25 to -8.25 mPD).

Details

East Lamma Channel. The Hang Hau Formation comprises a blanket of marine mud up to 21 m thick that rests unconformably on the Chek Lap Kok Formation. The base occurs at a depth of between -20 and -25 mPD near the coast, declining to between -30 and -35 mPD towards the middle of the channel.

Seismically, the formation can be divided into a younger and an older mud unit (Evans, 1986), respectively named the East Lamma Channel Member and the Telegraph Bay Member. These members are separated by a well-marked discontinuity, interpreted as an erosion surface. The Telegraph Bay Member occurs on the northeastern side of the channel, where it reaches a maximum thickness of 16 m, and as a buried lens to the southeast of the present channel (Sheet 11 Map Section A–B). It displays continuous, low amplitude seismic reflectors that downlap towards the centre of the present channel (Plate 52). A reduction in the degree of downlap can be seen towards the top of the member as the reflectors extend from the coast. A downward increase in the amplitude of the reflectors is also noted, a phenomenon that may be a function of increasing consolidation.



Natural Scale

A *Paphia undulata* (Born)
B *Azorinus abbreviatus* (Gould)
C *Pinctada martensii* (Dunker)
D *Bursa rana* (Linnaeus)
E *Tapes philippinarum* (Adams & Reeve)
F *Macoma galathea* Lamarck
G *Placuna placenta* (Linnaeus)
H *Semicassis pila* (Reeve)
I *Ostrea pestigris* Hanley

Plate 50 – Shells from Mud of Hang Hau Formation. Identifications by Professor B. S. Morton University of Hong Kong

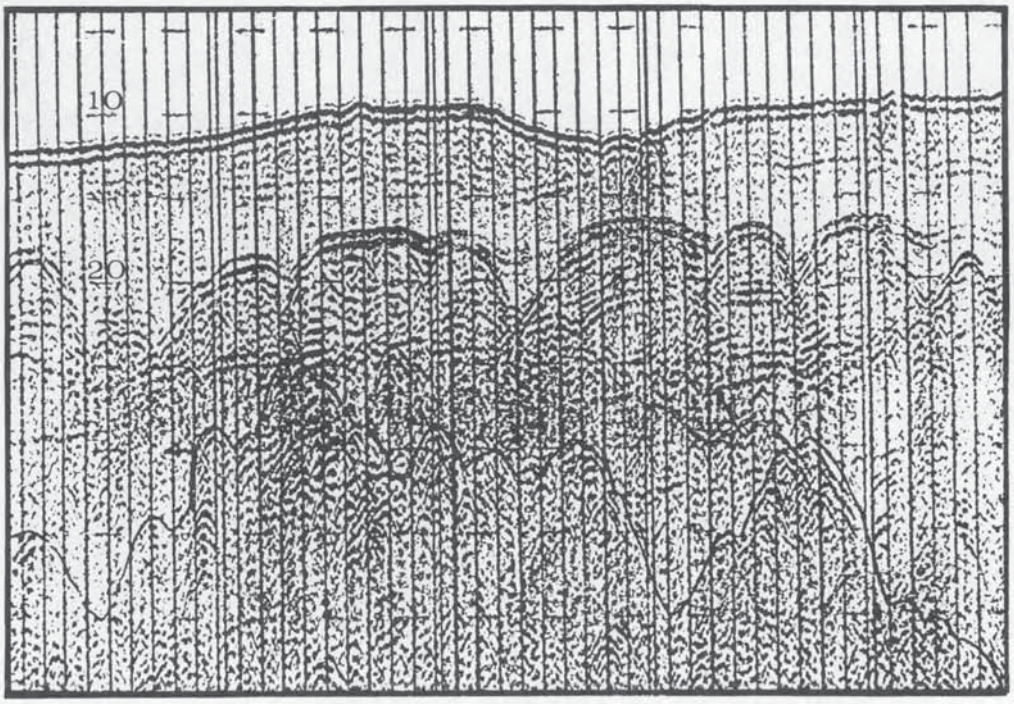


Plate 51 – Seismic Trace of Superficial Deposits and Rock in Western Victoria Harbour showing Muds of Hang Hau Formation Filling and Overlapping Gullies in Chek Lap Kok Formation, Trace by EGS Ltd for Harbour Reclamations and Urban Growth Study (Figures Indicate Approximate Depths in Metres below Principal Datum)

The overlying East Lamma Channel Member is seismically similar, but characterised by lower amplitude internal reflectors. Its main feature is its position as an inset sequence that lies on a locally steep surface truncating the underlying Telegraph Bay Member. At its base it has a seismically distinct deposit considered to be a lag deposit of sand or gravel. A seismically similar layer, 1 to 3 m thick, occupies the floor of the present channel at the top of the East Lamma Channel Member. To the southwest, reflectors within this member downlap northeastwards into the centre of the channel, while to the northeast, reflectors lap onto the steep northeast erosion surface. A rounded, levée-like feature, 100 m wide, flanks the southern margin of the present channel, rising a few metres above the adjacent channel margin and displaying strongly downlapping internal reflectors.

The seismic characteristics of the Hang Hau Formation in the East Lamma Channel indicate that the muds of the Telegraph Bay Member accumulated by downlapping out from the coast of Hong Kong Island, and that they were subsequently removed in much of the central part of the Channel by a major erosional event. Subsequently, mud accumulation resumed, depositing the overlying East Lamma Channel Member.

Western and Central Harbour. The Hang Hau Formation forms a uniform mud plain under about 10 m of water. The maximum thickness is about 18 m (EGS, 1985) but the general thickness is of the order of 10 m. The base of the formation is characterised by a layer of sand or muddy sand, and the formation is represented by littoral sand around the pre-reclamation coasts. Thickness variations are mostly attributable to variations in the underlying surface of the Chek Lap Kok Formation, which is extensively channelled or gullied across this area (Plate 51). The formation thins and becomes slightly sandier eastwards towards Tsim Sha Tsui, as it laps onto a topographic rise formed by the Chek Lap Kok Formation. Off Tsim Sha Tsui the formation is incised by a contemporary channel. On the northern flank of this channel the formation is represented by a wedge-shaped deposit of sand that is seismically transparent, exhibiting prograding reflectors that dip towards the channel. The sand attains a maximum thickness of 8.5 m. Sand also occurs on the floor of the present channel. To the east of Tsim Sha Tsui, in a narrow tract south of Hung Hom and Kowloon Bay, the Hang Hau Formation is absent or represented only by a thin veneer of mobile sand that directly overlies the Chek Lap Kok Formation.

A comparison between hydrographic surveys carried out in 1978, 1982 and 1985, (I. J. Ayson, written communication, 1986) has indicated that the level of the sea-bed has been lowered by scouring by about 0.5 m over the area of Kellett Bank to the south of Stonecutters Island. In a small area in the North Green Fairway, to the northeast of Little Green Island, the sea-bed has been lowered by up to 1 m during this interval. This represents erosion of about 2.3 million cubic metres of Hang Hau Formation muds over the period.

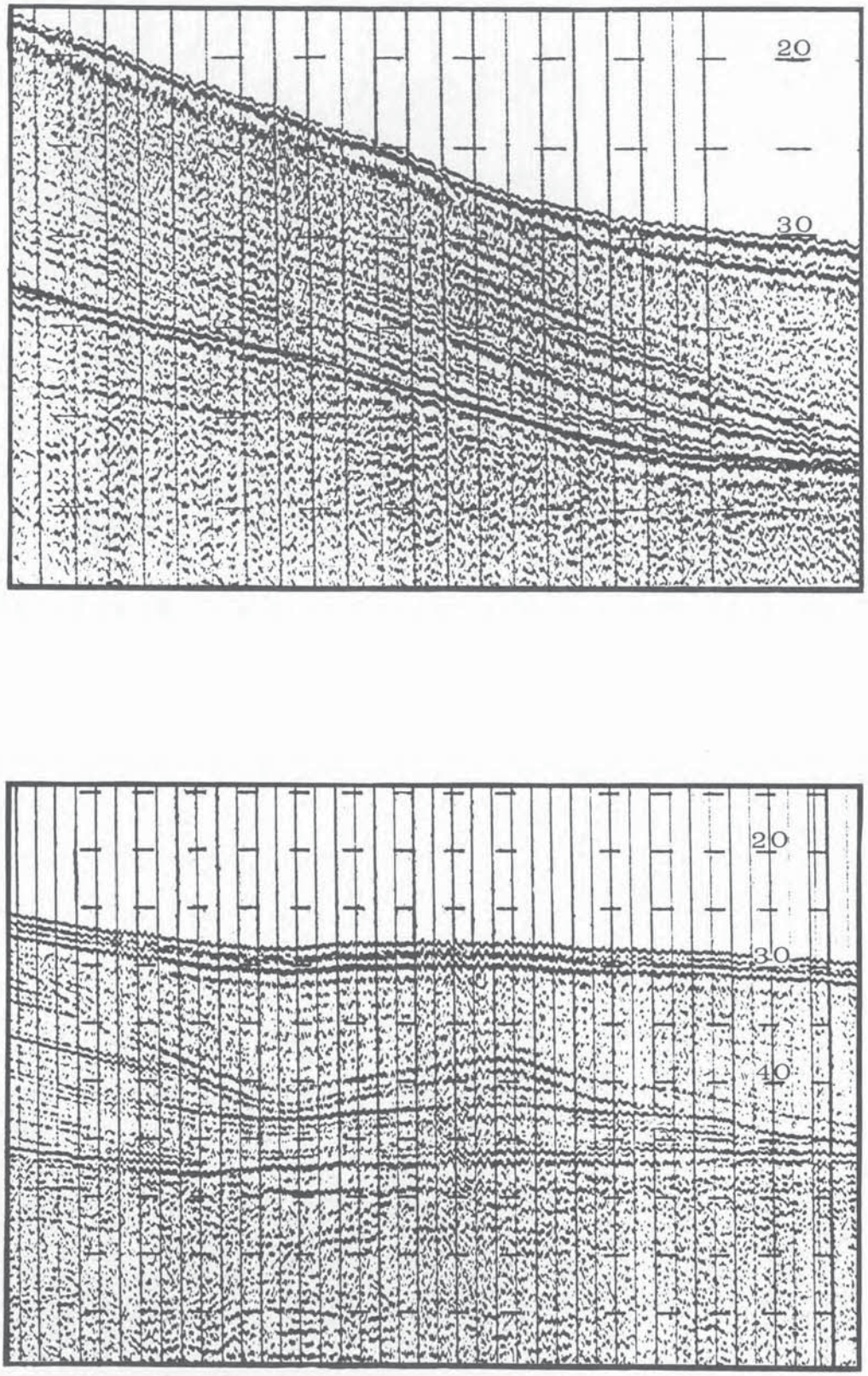


Plate 52 – Seismic Traces Showing Discontinuity within Mud of Hang Hau Formation, East Lamma Channel, Traces by EGS Ltd for Water Supplies Department, Hong Kong Government (Figures Indicate Approximate Depths in Metres below Principal Datum)

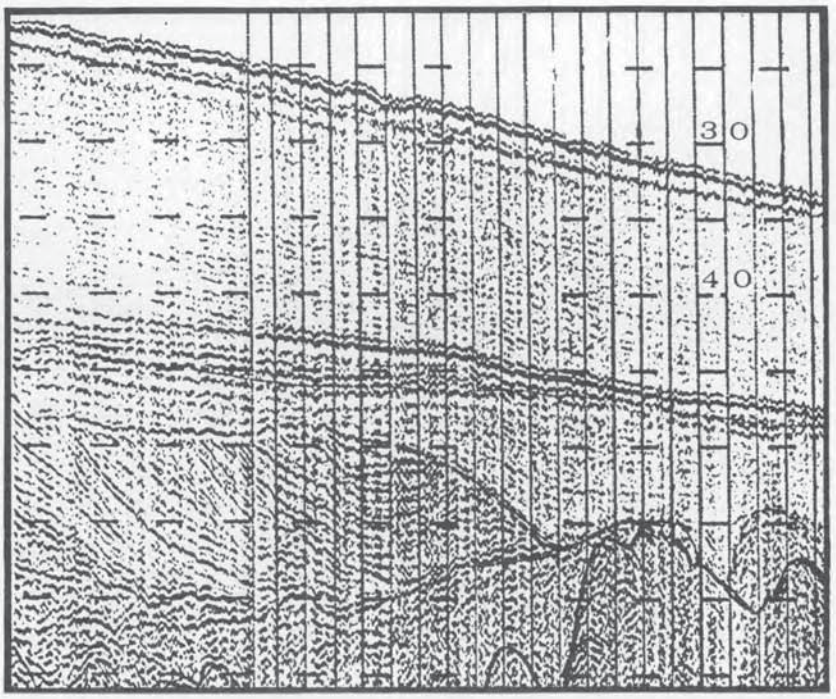


Plate 53 – Seismic Trace of Superficial Deposits in East Lamma Channel with Inferred Sand Body at Base of Hang Hau Formation; Trace by EGS Ltd, for Water Supplies Department, Hong Kong Government (Figures Indicate Approximate Depths in Metres below Principal Datum)

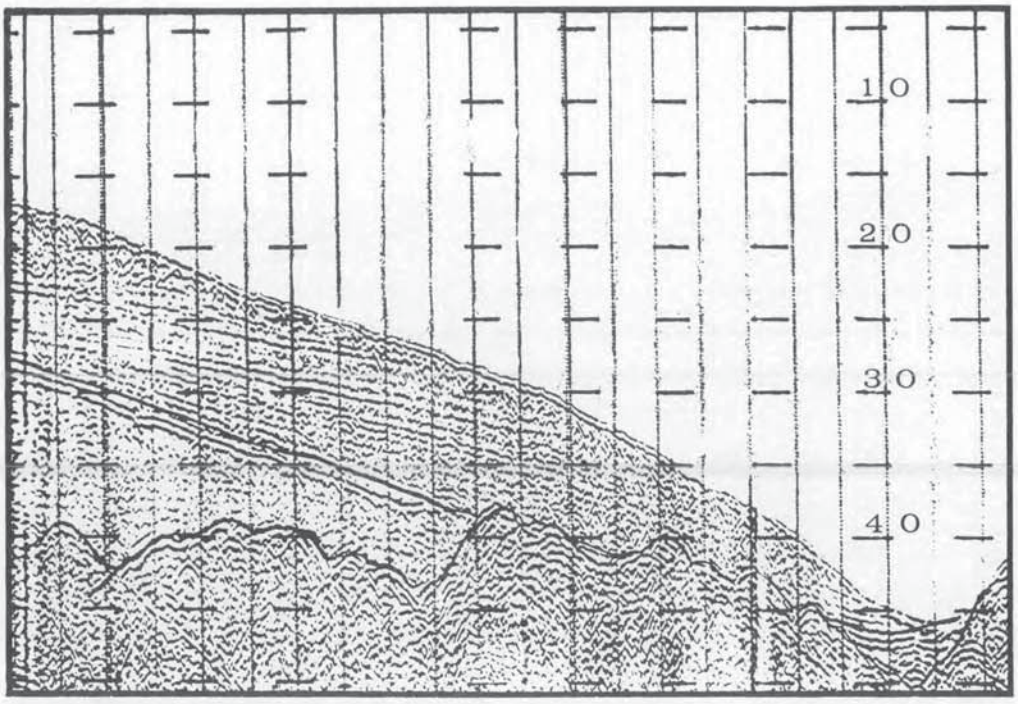


Plate 54 – Seismic Trace in Lei Yue Mun Channel Showing Patch of Sand (Hang Hau Formation) on Rock; Trace by EGS Ltd for Harbour Reclamations and Urban Growth Study (Figures Indicate Approximate Depths in Metres below Principal Datum)

Eastern Harbour and Lei Yue Mun. The Hang Hau Formation is composed mainly of sand along the main axis of the eastern Harbour floor. Marginally, in Kowloon Bay and Yau Tong Bay, silt with subordinate sand is recorded. The thickness of the formation here is generally about 2 to 4 m, with local variations up to 10 m. Off Tai Koo Shing, however, up to 18 m has been reported (EGS, 1985). The Hang Hau Formation is absent from much of the contemporary channel at Lei Yue Mun.

Junk Bay and the Eastern Approaches. The Junk Bay Borehole (JBS 1/1A) (4500 1800) is the type section of the Hang Hau Formation (Figure 29, Appendix). There the formation is represented by 13 m of mud with a basal sand layer. Southwards from Junk Bay the formation becomes generally sandier so that, off the eastern end of the Lei Yue Mun channel and to the east of Cape Collinson, it is composed mainly of sand, with sand waves developed on the sea-bed in places. In the absence of high resolution boomer traces for this area the stratigraphic relationship between the mud and these offshore sand deposits is unclear.

Southeast of Lamma Island. The Hang Hau Formation is composed mainly of mud under the open waters, but becomes more sandy towards the present coast and on the floor of the southeastern end of the East Lamma Channel. In general the formation tends to thin southeastwards from about 10 m to 8 m. It is only 3 to 4 m thick on the floor of the present East Lamma Channel. On geophysical traces it can be seen to thicken to about 17 m where it infils a hollow in the Chek Lap Kok Formation extending southeastwards from the East Lamma Channel. A minor thinning to 5 or 6 m occurs along the axis of the Sheung Sz Mun Channel.

Weathered Rocks and Sediments

An extensive regolith, or residual mantle of weathered rock, overlies fresh rock in most of the district, effectively masking much of the solid geology. The regolith consists primarily of the residue of minerals resistant to weathering, mostly quartz, combined with the weathering alteration products of ferromagnesian and feldspathic minerals. The extent to which this mantle is developed varies from place to place. It depends upon the relative resistance to weathering of the different rock types and their relative position in the landscape, as well as the extent to which the rocks have been disturbed by joints, faults and shears.

The effect of weathering upon the various rock types is broadly reflected in the relief. Volcanic rocks tend to form higher and sharper peaks with fewer surface boulders, for example Razor Hill

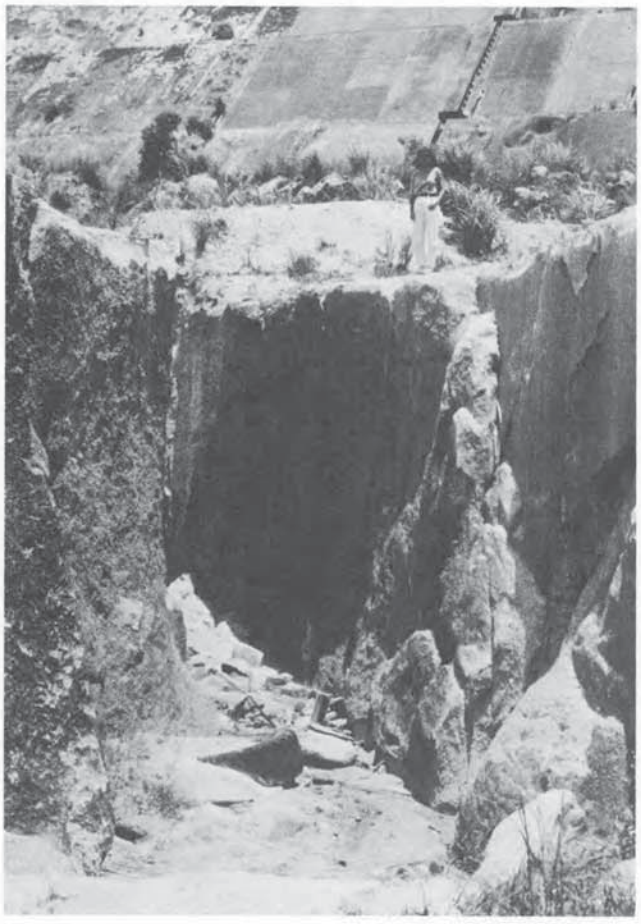
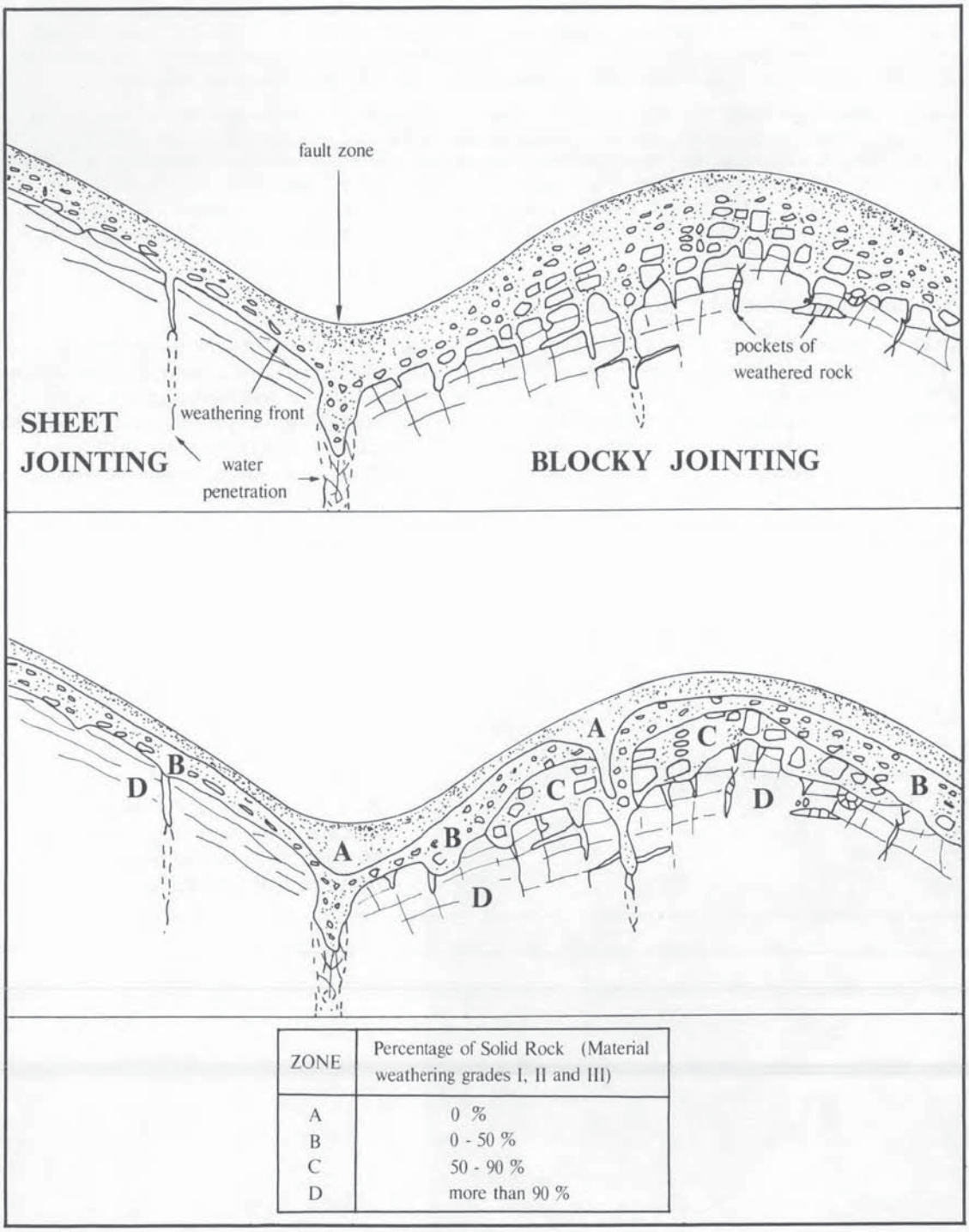


Plate 55 – Gully in Completely Weathered Medium-grained Granite Material at Ngau Chi Wan, East Kowloon (4024 2201)



ZONE	Percentage of Solid Rock (Material weathering grades I, II and III)
A	0 %
B	0 - 50 %
C	50 - 90 %
D	more than 90 %

Figure 30 – Zonal Classification of Weathering Profiles Related to Joint Patterns

and High West; granites form lower and more rounded peaks with surface boulders (exhumed corestones) more common, as seen around Mount Butler. In general the fine-grained granites are more resistant to weathering than the coarser varieties. The medium-grained granite outcrops on the Kowloon peninsula originally had a deeply weathered mantle. This provided a ready and abundant source of easily excavated fill, and facilitated the cutting of platforms. The sites of many major housing estates were formed in this way.

The Geotechnical Control Office (GCO, 1979, 1984) has adopted a six-fold scheme based on that of Moye (1955) for the classification of weathered rock material. Studies for this Geological Survey by J. Ho and A. Lai (written communication) on the material weathering grade classification of the tuffs of the Repulse Bay Volcanic Group have highlighted the different weathering characteristics of the vitric tuffs of the Ap Lei Chau Formation as compared with the crystal tuffs of the other volcanic formations mapped within the district. The colour change in the vitric tuffs from black (fresh rock) to white (moderately weathered material) is particularly striking (Plate 45).

Ruxton & Berry's (1957) scheme for the zonal classification of weathering profiles, despite the stated arbitrary nature of their zonal boundaries, has found favour with engineers in Hong Kong (GCO, 1979, 1984). However, this geological survey has indicated that incomplete profiles are more profound than Ruxton and Berry considered them to be. An illustration of Ruxton and Berry's scheme applied to complex weathering profiles is shown in Figure 30.

The distinction between sandy superficial deposits and weathered granite is often difficult to make in boreholes. Records of boulders in the supposed basal part of a superficial sequence, may, in some cases, more properly be interpreted as indicating the presence of corestones within weathered rock profiles.

Plate 56 – Pre-split Cut Slope in Medium-grained Granite Showing Incipient Corestones in Slightly Weathered Material; Hammer Hill, East Kowloon (3991 2207)

Weathering mantles on the low, rounded hills of granite in northern and eastern Kowloon are commonly deeply gullied, as seen on the flanks of Hammer Hill and Diamond Hill. A striking example of such gullying in completely weathered material may be seen at Ngau Chi Wan (4024 2201, Plate 55). The vertical walls of the gully are about 3 m high and show evidence of vertical slab failure, largely governed by disaggregation (slaking) of the weathered granite as a result of groundwater seepage, rather than by basal undercutting by attrition. Adjacent to this site, on the southern end of Hammer Hill, is a recently exposed pre-split cut slope face (3991 2207) that

Plate 57 – Cut Slope in Medium-grained Granite Showing Zone C of the Weathering Profile Overlying Zone A; Jat's Incline, East Kowloon (4021 2293)

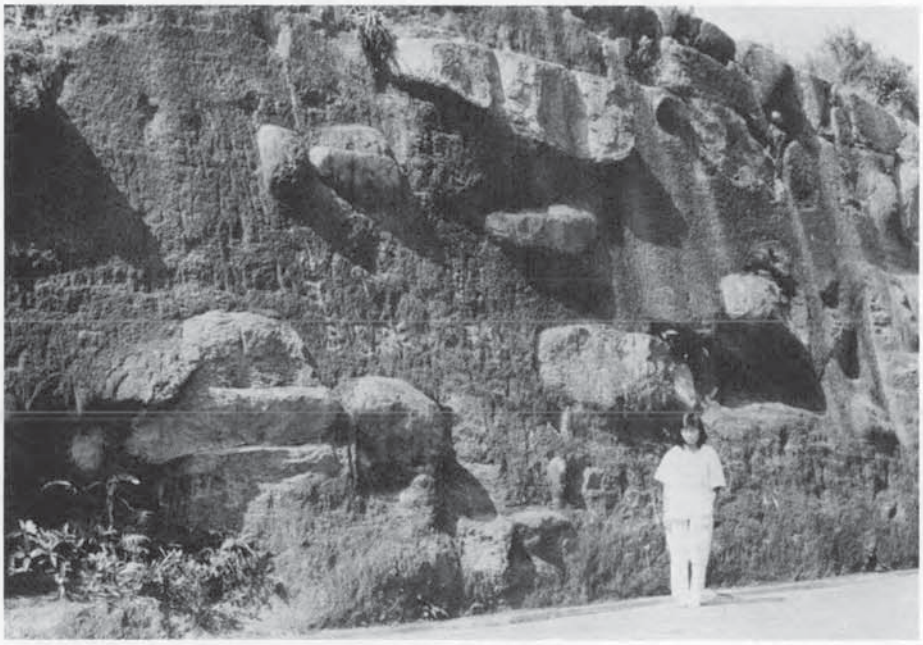


Plate 58 – Cut Slope in Fine- to Medium-grained Granite Showing Regular Distribution of Rectilinear Corestones in Zone C; Tai Tam Reservoir Road, Hong Kong Island (3852 1336)

exhibits incipient corestones (Plate 56). Dark, iron-stained rims bound corestones of Grade I material. The slightly weathered (Grade II) material around these nodes illustrates the early stages of development of a more weathered matrix. Two features of weathering micromorphology (Ollier 1975) are exemplified by large corestones forming a ridge-crest tor at Hammer Hill (3978 2220). Wide, shallow opferkessel (weathering pans) are well-developed on the upper surfaces of several of the rounded corestones. On their sloping sides can be seen large pseudokarren (grooves on insoluble rocks) of the rundkarren type (having rounded divides between the grooves). A complex, apparently inverted weathering profile may be seen on the eastern side of Jat's Incline (4021 2293). Here, a cut slope through Zone C of the weathering profile (50 to 99% rock) overlies a zone that is, in the exposed section, devoid of corestones (Plate 57). Such an occurrence may result from preferential weathering along a series of closely-spaced sub-horizontal joints.

Several interesting weathering features are displayed in sections on Hong Kong Island. Along the northern side of Tai Tam Reservoir Road a section (3851 1336) exemplifies an almost regular distribution of rectilinear core stones that would constitute Ruxton and Berry's (1957) Zone C (Plate 58). Lamellar fractures traverse the face subhorizontally, affecting matrix and corestones alike. Further east, on Tai Tam Reservoir Road (3926 1321), marked lateral variation in weathering can be seen (Plate 59). Zone B (rock less than 50%) is juxtaposed laterally against Zone C in a profile at least 8 m deep. Still further to the east (3935 1320) a weathering front is exposed in a complex profile where Zone A, free from corestones and with little granitic texture visible, rests directly on a surface of slightly weathered granite that forms an almost uninterrupted pavement. A 15 m high cut slope on the western side of Mount Nicholson Road (3656 1378) is formed in Zone A (Grade V granite material) that shows no corestones until the lowest metre of the face, where several large tabular corestones are exposed (Plate 60). This example strikingly illustrates how a ridge such as this can be completely weathered and yet maintain a positive topographic feature.

Mottling is a conspicuous feature of weathered profiles in many parts of the district. It is commonly seen in shallow sections, perhaps a metre or two deep, in weathered rock or debris flow deposits, with irregular red or yellow-brown mottles, typically 20 to 30 mm across, pervading the weathered material. This mottling is particularly apparent where it affects moderately weathered vitric tuffs of the Ap Lei Chau Formation, giving a red-mottled, white or very light grey rock, well seen for example 600 m southwest of the Peak Tram Terminus, in the Pok Fu Lam Country Park (3295 1431) on Hong Kong Island.

Plate 59 – Cut Slope in Fine- to Medium-grained Granite Showing Zone B of Weathering Profile Juxtaposed Laterally against Zone C; Tai Tam Reservoir Road, Hong Kong Island (3926 1321)

Plate 60 – Cut Slope in Completely Weathered Medium-grained Granite Material. Base Shows Tabular Corestones; Mount Nicholson Road, Hong Kong Island (3656 1378)

Geophysical studies offshore have demonstrated that a mantle of weathered bedrock is commonplace under superficial deposits. On the seismic traces it is usually feasible to broadly distinguish and separate the moderately, or less weathered, from the highly to completely weathered material surfaces (EGS, 1985). Highly to completely weathered rocks and residual soil generally form moderate amplitude reflectors, while fresh to moderately weathered rocks form relatively high amplitude reflectors (Plate 51). The strongest seismic reflection usually occurs at the top of moderately weathered (Grade III) rock material. The reflector at the top of the more weathered rock may be diffuse and discontinuous, particularly where the basal part of the superficial sequence is sandy. Contouring of these two seismic horizons (EGS, 1985) has demonstrated that an undulating topography was developed on the rock surface, analogous to the existing subaerial topography of the district, before the deposition of the superficial deposits of the Chek Lap Kok Formation. The weathered mantle (highly to completely weathered rock and residual soil) thickens to some 20 m south of Stonecutters Island and south of the runway embankment at Kai Tak International Airport. The presence of bedrock pinnacles and corestones interpreted from seismic traces suggests the existence of complex weathering profiles offshore, directly comparable to those observed onshore (Plate 61). In the continuously sampled borehole at Junk Bay (Appendix), the weathered rock is overlain within 0.2 m by organic, grey laminated mud at the base of the Chek Lap Kok Formation. These basal grey sediments show no sign of weathering. The weathering in the rock at these localities thus pre-dates the accumulation of the Chek Lap Kok Formation.

Studies of the Chek Lap Kok Formation in the continuously sampled borehole at Junk Bay have shown that parts of the offshore superficial deposits have also been affected by weathering. Similar observations were recorded by Shaw (1985) from another continuously sampled borehole at Chek Lap Kok (Sheet 9). In the Junk Bay hole the indications of weathering are yellow-brown streaks and mottles, the latter in places having red cores. The mottling affects two separate parts of the

sequence; the upper, mainly in silty clay, extending some 8 down from the top of the formation (Plate 44), and the lower, mainly in sand, extending through some 7 m in the lower part of the sequence. These two weathered zones are separated by 3.6 m of sediments, mainly of laminated, dark grey silty clay. The distribution of the mottling in this borehole shows that the Chek Lap Kok Formation was there subjected to weathering in at least two separate episodes, during and after its accumulation, but before the accumulation of the overlying marine deposits of the Hang Hau Formation.

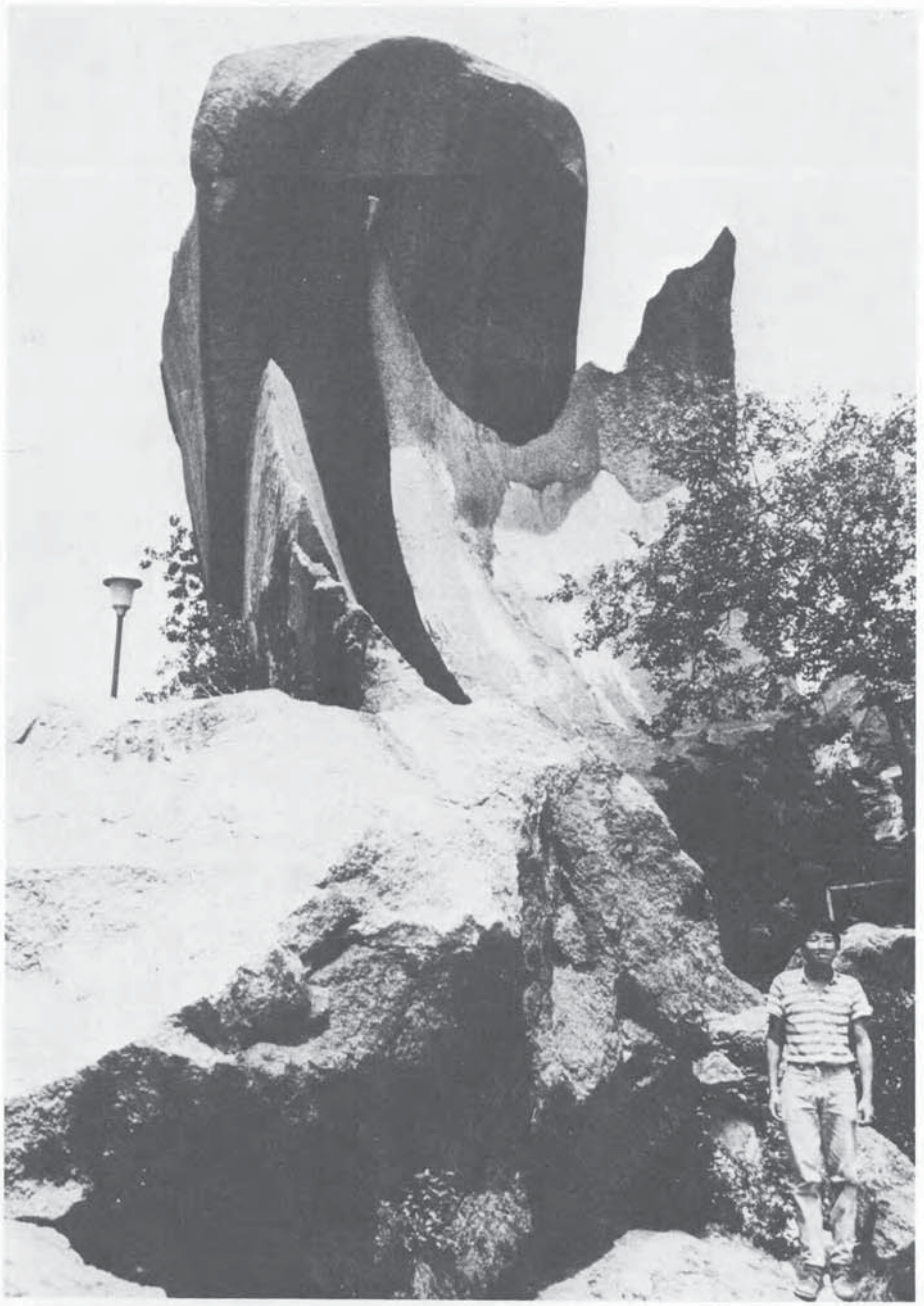


Plate 61 – Tor of Medium-grained Granite at To Kwa Wan, Kowloon (3785 1950)

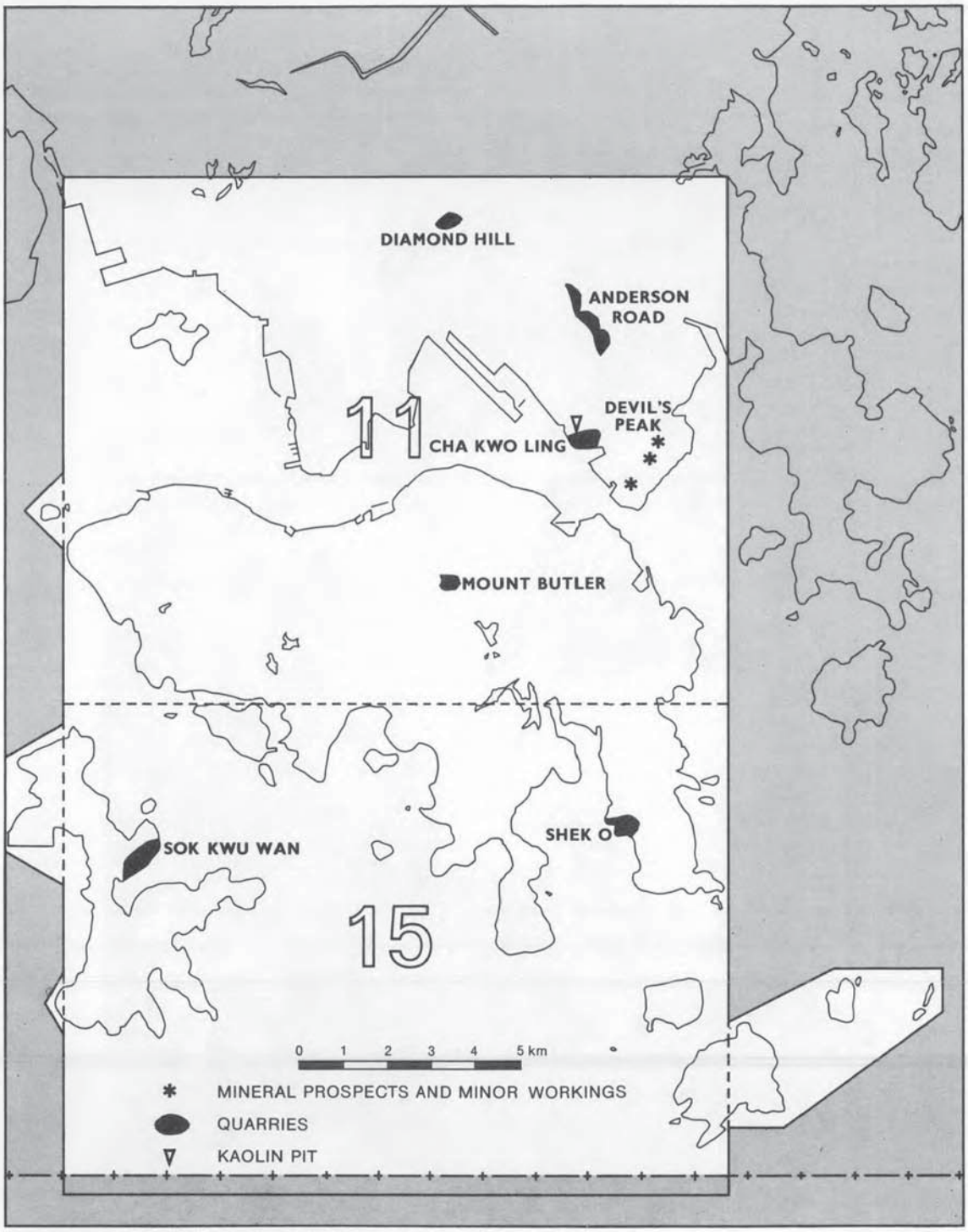


Figure 31 – Mineral Localities and Quarries within the District

Chapter 9
Economic Geology

Classification

This account of the economic geology of the district has been divided into two sections, one dealing with metalliferous and associated minerals, and the other with bulk minerals. Localities referred to are shown in Figure 31. For additional details of metalliferous and associated mineral occurrences in the district the reader is referred to the work of Peng (1978).

Metalliferous and Associated Minerals

These deposits occur as thin fissure veins and in places as isolated mineralised patches within granite bodies. The mineralisation is related to the late-stage emanations of high-temperature, mineralised fluids from the granitic plutons, and is commonest near the pluton margins.

No metalliferous mining other than trial workings has been undertaken in the district. The area between Devil's Peak (4305 1680) and Rennie's Mill (4385 1830) has been extensively prospected. Here, much of the fine-grained granite has been greisenised by late-stage hydrothermal action, and a number of WNW-trending fissure veins cut the granite. These vary from 0.1 to 1.5 m in width and are vertical. As the trial adits are horizontal or only gently inclined there are no indications of vertical extension of the ore bodies. Quartz is the dominant mineral but the veins also contain minor quantities of fluorite, chalcopyrite, molybdenite, wolframite and beryl. Ruxton (1957) noted several beryl-bearing veins, with green beryl crystals up to 0.3 m in length and 27 mm in diameter. Ruxton (1957) also noted the occurrence of beryl on the northern slopes of D'Aguilar Peak, southeastern Hong Kong Island. A minor wolframite-bearing quartz vein striking NW–SE was noted on the hillside adjoining a quarry at Anderson Road (4225 2100). On the coast of northeastern Lamma Island, at Luk Chau Wan (3058 1001), a N–S trending mineral vein cuts the coarse ash tuffs of the Yim Tin Tsai Formation. The vein is about 4 m wide and contains chalcopyrite, pyrite and haematite, with distinctive malachite staining on the weathered surfaces.

Numerous minor quartz veins are scattered throughout the district, but appear to be devoid of metalliferous mineralisation. Some of these veins have been worked on a small scale for quartz. Minor patches of mineralisation within the granite are commonly associated with pegmatite nests. At Tai Hang Road (3787 1478), molybdenite crystals up to 8 mm long are scattered throughout the medium-grained granite close to pegmatite patches. Peng (1978) noted the presence of molybdenite at Diamond Hill, North Point and Mount Butler.

Bulk Minerals

Bulk mineral production is dominated by the aggregates industry, with five major quarries operating within the district. Although these quarries provide a considerable amount of the Territory's aggregate requirement, as much as 30% of Hong Kong's total aggregate consumption is imported, mainly from China.

Until the mid-1960s almost all the quarries in the district were small workings in granite, supplying the market for aggregate, roadstone and building stone. Aggregate for concrete manufacture became important with the advent of the large-scale housing resettlement developments from 1954 onwards. About 50 small-scale 'permit' quarries provided crushed stone for aggregate use, but major mechanisation and large-scale working were introduced by the Government in the 1960s in their new quarries at Diamond Hill and Mount Butler.

Table 6 details the production output of the principal quarries within this district, together with the main rock types quarried. Diamond Hill Quarry ceased operation in late 1985, and Cha Kwo Ling Quarry closed in August 1986.

The only mining lease in existence in the district is that for the kaolin quarry at Cha Kwo Ling, East Kowloon (4170 1820). Figures provided by the quarry owners, the Hong Kong Clays and Kaolin Company, give the clay production as 8 000 tonnes for 1983, 21 000 tonnes for 1984 and 25 550 tonnes for 1985. The kaolin is derived from a 50 m wide dyke, believed to have been quartz syenite, that extends over about 300 m. It is probable the original rock has been hydrothermally

altered. There is little quartz present and the clay is of a fairly high quality, which does not deteriorate within the depth of the quarry. The surrounding fine- to medium-grained granite is not appreciably kaolinised. The main use for the clay is in the production of ornamental tiles, but a small amount is sold for local chinaware manufacture.

Table 6 – Aggregate Production from Quarries within the District

Quarry	Total Aggregate Production (Million Tonnes)					
	Main Rock Types					
	Medium-grained Granite	Fine- to Medium-grained Granite	Fine-grained Granite	1983	1984	1985
Kowloon						
Anderson Road No. 3 (427 202)			*	0.80	0.70	0.83
Cha Kwo Ling (421 180)		*		1.79	1.77	1.55
Diamond Hill (389 228)	*			0.39	0.37	0.32
Tai Sheung Tok (423 207)		*	*	1.50	1.87	1.83
Hong Kong Island						
Mount Butler (389 144)		*	*	0.32	0.32	0.28
Shek O (427 093)	*	*		1.89	1.60	2.08
Lamma Island						
Sok Kwu Wan (317 084)	*	*	*	1.88	1.82	1.95

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Appendix

Continuously Sampled Boreholes through Offshore Superficial Deposits

The following are abridged logs of boreholes sunk for various Public Works and private projects. Continuous sampling of the boreholes for detailed geological investigation was carried out at the request of the Geotechnical Control Office. The borehole locations are shown in Figure 24.

Borehole	**Hung Hom Bay D33**
Grid Ref.	3714 1787
Surface level	−12.15 mPD
Superficial deposits	16.82 m thick
Bedrock	−28.97 mPD
Date drilled	March, 1986

Geological Classification	*Lithology*	*Thickness m*	*Depth in Hole m*	*Reduced Level mPD*
Hang Hau Formation	SILT; sandy, fine, (clayey) blue grey, very shelly (shells mostly comminuted); increasingly sandy lower down	7.00	7.00	−19.15
	SAND; fine to medium becoming coarser downwards, silty, yellow brown to olive yellow, very shelly (shells mostly broken)	6.55	13.55	−25.70
Chek Lap Kok Formation	SAND; fine to medium, silty, clayey, orange yellow, mottled red and yellow ochre	3.27	16.82	−28.97
Fine-grained Granite	GRANITE; fine-grained, grey white rock, quartz and feldspar megacrysts; completely weathered	2.68	19.50	−31.65

The continuous sample from this borehole was provided by the Railway Development Office of the Engineering Development Department, Hong Kong Government.

Borehole	**Junk Bay JBS1/1A**
Grid Ref.	4500 1800
Surface level	−8.10 mPD
Superficial deposits	31.66 m thick
Bedrock	−39.76 mPD
Date drilled	October/November, 1984

Geological Classification	*Lithology*	*Thickness m*	*Depth in Hole m*	*Reduced Level mPD*
Hang Hau Formation	CLAY; silty, dark blue grey to greenish grey, shelly; sandy at base, sharp base	13.22	13.22	−21.32
Chek Lap Kok Formation	CLAY; silty, light blue grey with yellow ochre streaks and red mottles; interbedded sand layers, oxidised fissures at top, scattered black plant fragments	7.62	20.84	−28.94
	CLAY; silty, dark grey, laminated; fine sandy lenses and partings	3.66	24.50	−32.60
	SAND; fine to medium, silty, light blue grey with yellow ochre mottles and streaks; clay layers	6.58	31.08	−39.18
	CLAY; olive grey, laminated, black organic partings; gravel at base	0.8	31.66	−39.76
Ap Lei Chau Formation	TUFF; fine ash crystal, greenish grey rock, highly fractured; highly weathered	1.54	33.20	−41.30

The continuous sample from this borehole was provided by the Junk Bay Development Office of the New Territories Development Department, Hong Kong Government.

Borehole	**Kwai Chung D27**
Grid Ref.	3134 2174
Surface level	−7.78 mPD
Superficial deposits	31.45 m thick
Bedrock	−32.78 mPD
Date drilled	May, 1985

Geological Classification	*Lithology*	*Thickness m*	*Depth in Hole m*	*Reduced Level mPD*
Hang Hau Formation	SILT; clayey, dark grey, with abundant shells; bands of black plant fragments; more sandy towards base	16.45	16.45	−24.23
Chek Lap Kok Formation	SAND; fine to medium, coarsening downwards; silty or clayey, blue grey, zones of red mottling, yellow ochre bands	8.55	25.00	−32.78
Coarse-grained Granite	GRANITE; coarse-grained rock with quartz and decomposed feldspar, iron stained; completely weathered	6.45	31.45	−39.23

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Borehole	**Shau Kei Wan BH8**
Grid Ref.	4191 1629
Surface level	−26.70 mPD
Superficial deposits	18.68 m thick
Bedrock	−45.38 mPD
Date drilled	September, 1985

Geological Classification	*Lithology*	*Thickness m*	*Depth in Hole m*	*Reduced Level mPD*
Hang Hau Formation	SAND; fine to medium, silty to clayey, dark grey to yellow brown, shelly (shells mostly broken); clay and silt bands	7.45	7.45	−34.15
Chek Lap Kok Formation	SAND; fine to medium, silty to clayey, yellow ochre, olive yellow and grey white with ochre streaks and bands; clay layers	11.23	18.68	−45.38
Medium-grained Granite	GRANITE; medium-grained rock with quartz and decomposed feldspar, closely jointed; highly to completely weathered	0.82	19.50	−46.20

The continuous sample from this borehole was provided by the Planning (Liquid and Solid Wastes) Division of the Civil Engineering Office, Engineering Development Department, Hong Kong Government.

Borehole	**Victoria Harbour H1**
Grid Ref.	3750 1710
Surface level	−11.40 mPD
Superficial deposits	17.0 m thick
Bedrock	−28.4 mPD
Date drilled	August, 1985

Geological Classification	*Lithology*	*Thickness m*	*Depth in Hole m*	*Reduced Level mPD*
Hang Hau Formation	SILT; clayey and sandy, dark grey, shelly (shells mostly broken); sharp base	1.6	1.6	−13.00
Chek Lap Kok Formation	CLAY and SILT; sandy, blue grey with yellow brown mottles and streaks	5.4	7.0	−18.40
	SAND; fine to coarse, silty, olive grey to yellow; scattered black plant fragments	10.0	17.0	−28.40
Granite	GRANITE; medium-grained rock with quartz megacrysts in white clay; completely weathered	3.0	20.0	−31.40

Borehole	**Victoria Harbour H2**
Grid Ref.	3642 1657
Surface level	−11.10 mPD
Superficial deposits	19.00 m thick
Bedrock	−30.10 mPD
Date drilled	August, 1985

Geological Classification	*Lithology*	*Thickness m*	*Depth in Hole m*	*Reduced Level mPD*
Hang Hau Formation	CLAY; silty and sandy, dark olive grey, shelly (shells mostly broken)	1.75	1.75	−12.85
Chek Lap Kok Formation	SAND; fine to coarse, grey to brownish grey to white with scattered black plant fragments; occasional yellow ochre patches and streaks	17.25	19.00	−30.10
Granite	GRANITE; medium-grained with quartz megacrysts in white clay; completely weathered	1.00	20.00	−31.10

Borehole	**Victoria Harbour H3**
Grid Ref.	3642 1657
Surface level	−11.15 mPD
Superficial deposits	10.00 m thick
Bedrock	Not reached
Date drilled	August, 1985

Geological Classification	*Lithology*	*Thickness m*	*Depth in Hole m*	*Reduced Level mPD*
Hang Hau Formation	SILT; sandy and clayey with sand bands; dark olive grey, very shelly (shells mostly broken); some yellow ochre spots and streaks	3.45	3.45	−14.60
Chek Lap Kok Formation	SAND; fine to coarse, olive grey to creamy white with some yellow patches	6.55	10.00	*−21.15

*Base of the Formation was not reached.

The samples from the three Victoria Harbour boreholes were provided by the Marine Department, Hong Kong Government.

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P59120002E1
ISBN 962-02-0014-4
$78 US$13.00

Printed and Published by the Government Printer, Hong Kong 1152882—10L—2/97
Printed on paper made from woodpulp derived from renewable forests