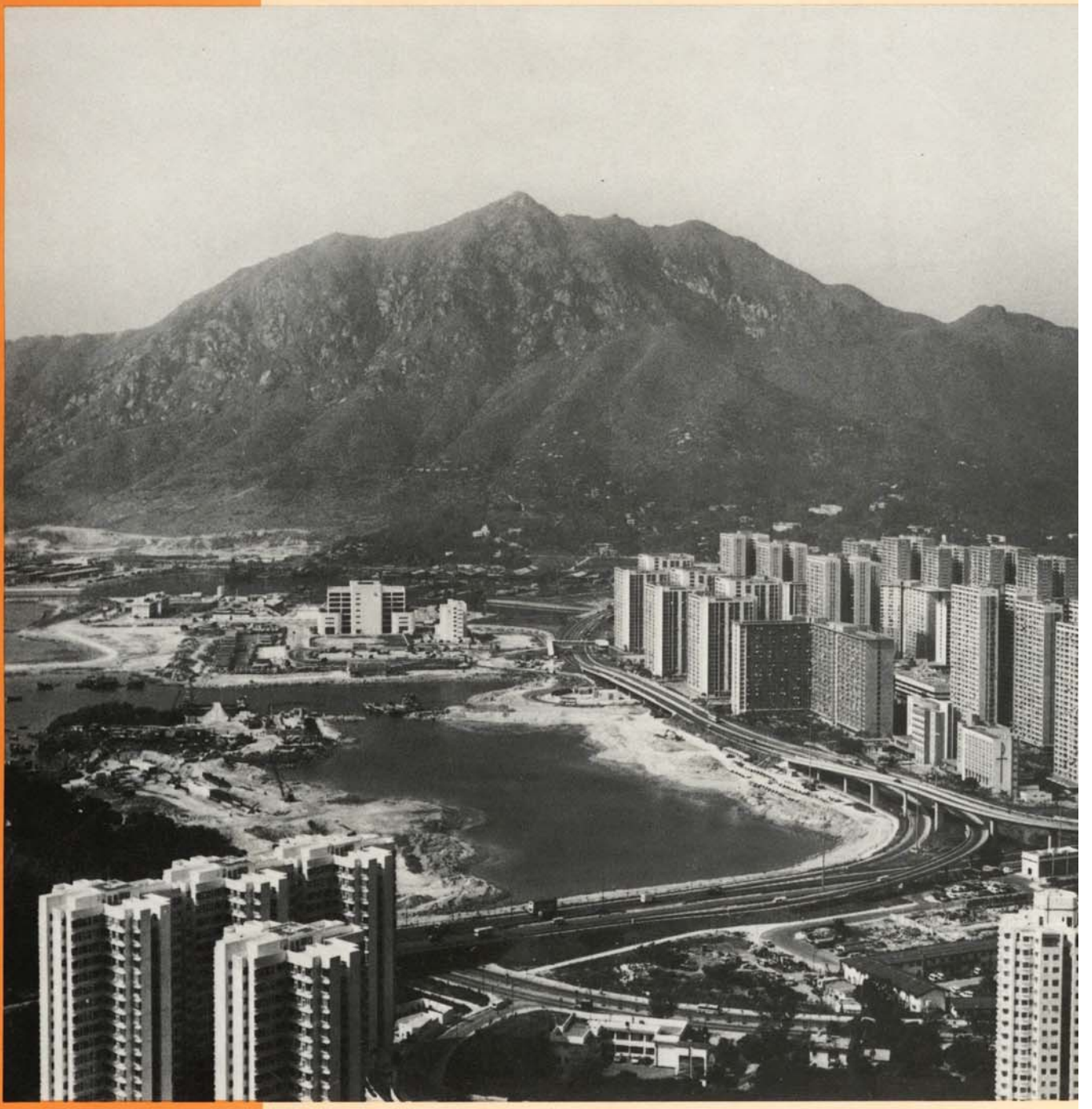
HONG KONG GEOLOGICAL SURVEY *MEMOIR No.3*

Geology of the Western New Territories



Geotechnical Control Office
Civil Engineering Services Department
HONG KONG

HONG KONG GEOLOGICAL SURVEY *MEMOIR No.3*

Geology of the Western New Territories

1:20 000 Sheets 2, 5 & 6

R.L. Langford, K.W. Lai, R.S. Arthurton & R. Shaw

Geotechnical Control Office
Civil Engineering Services Department
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Foreword

This Memoir describes the geology of the Western New Territories as depicted on Sheets 2, 5 and 6 of the 1:20 000 Geological Map Series of Hong Kong. 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 onshore and offshore geology of the Territory in considerably greater detail than has been previously attempted. It is enhancing our knowledge of the stratigraphy and structure of the Territory, 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 was led by Mr R. S. Arthurton and Dr R. Addison during the period of mapping and compilation of this report and accompanying maps; the Division is under the direction of Dr A. D. Burnett.

The Geological Survey of most of Sheet 6 was undertaken by Dr R. L. Langford, who is the principal author of this Memoir. Sheet 2, and parts of Sheets 5 and 6, were surveyed by Mr K. W. Lai, and part of Sheet 5 was surveyed by Mr R. S. Arthurton. Mr Lai is also the main author of the sections on Carboniferous, structural and onshore superficial geology. 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. Detailed interpretation of geophysical traces in some areas was done by Dr C. D. R. Evans (British Geological Survey). The Geological Survey was undertaken between 1984 and 1986, with information from ground investigation, particularly in the Yuen Long area, being added up to 1988. Mr P. J. Strange compiled the section on economic geology.

A series of reports is being published by the Geotechnical Control Office on the Geotechnical Area Studies Programme (GASP). Reports on the West New Territories, North West New Territories, North New Territories, Central New Territories and North Lantau cover the district described in this Memoir. The Study on which these reports are based was completed before the Geological Survey of Sheets 2, 5 and 6 commenced, and was based on the published 1:50 000 scale Geological Map of Allen & Stephens (1971). Mapping of the superficial deposits was undertaken independently for both the GASP and the present Geological Survey. This Memoir and the three maps sheets supersede both the solid rock geology and the mapping of superficial deposits presented in the GASP reports.

The survey of Sheet 5 benefitted from the generous co-operation of the Royal Hong Kong Auxiliary Air Force. During the construction of the Water Supplies Department Western Aqueduct, access to the works, and samples from the tunnels, were kindly provided by the resident site staff. Through the co-operation of the Project Managers for Tuen Mun and Tsuen Wan, access was gained to large numbers of boreholes from ground investigations in Tuen Mun and north Tsing Yi. The Charting Section of Port Works Division, Civil Engineering Services Department, made an important contribution to the compilation of the offshore geology. The co-operation of Scott, Wilson, Kirkpatrick & Partners Ltd, Charles Haswell & Partners (Hong Kong) Ltd, Ove Arup & Partners Ltd, Leighton MTA Consortium, Asia Stone Co. Ltd, Hong Kong Industrial Estates Corporation Ltd and Electronic and Geophysical Services Ltd is also acknowledged.

This Memoir and its accompanying map sheets will be of interest and value to earth scientists, engineers, planners, educationalists and those concerned with resource investigations. Physical resource information for the assessment of geotechnical limitations for planning purposes is available in GASP publications.

A. W. Malone
Principal Government Geotechnical Engineer
July 1989

CONTENTS

List of Appendices

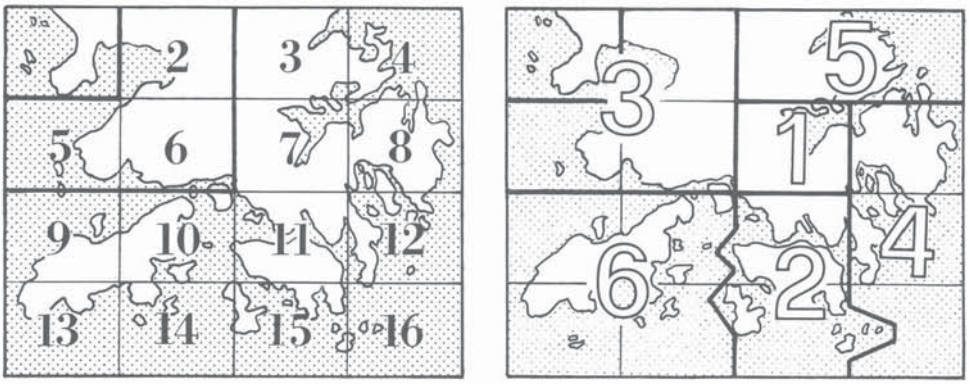
List of Tables

List of Figures

List of Plates

Map and Memoir Series Notes

- This memoir describes the geology of the western New Territory and should be read in conjunction with 1:20 000 Geological Map Sheets 2 (San Tin), 5 (Tsing Shan) and 6 (Yuen Long).
- 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 they relate is shown below.



maps *memoirs*

- Individual superficial deposits in the onshore area are not generally considered mappable if less than 2 m thick. In the offshore areas the material on the sea-bed is shown, in most cases regardless of thickness.
- Grid references are based on 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 followed by Northings, e.g. 2672 2739. 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 Port Works Division surveys, with supplementary data from Admiralty Charts, and surveys by Electronic and Geophysical Services Ltd.
- Samples in the Territory-wide rock collection archived by the Hong Kong Geological Survey are prefixed HK followed by a serial number, e.g. HK 2263.
- Boreholes are generally referred to by the contractor's number followed by the Geotechnical Information Unit accession number for the relevant ground investigation report e.g 1201D/03412. In some cases there is no report available, and a borehole may be referred to by its number alone, e.g. CLP/E1.
- The system used in this Memoir for grain size description and classification is summarized in Table 1.

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					Metamorphic Rocks	
						Acid	Acid-Intermediate	Intermediate	Basic	Other	Foliated	Other
Boulders		200	Sedimentary Breccia, Conglomerate		Pyroclastic Breccia, Agglomerate	Very Coarse Pegmatite	Quartz Syenite Quartz Monzonite	Andesite	Gabbro	Lamprophyre	Schist	Quartzite, Marble, Hornfels
Cobbles		60										
Gravel	Coarse	20			Lapilli Tuff	Coarse						
	Medium	6				Medium						
	Fine	2				Granite Granodiorite						
Sand	Coarse	0.6	Sandstone		Coarse Ash Tuff	Fine						
	Medium	0.2										
	Fine	0.06				Aplite						
Mud	Silt		Siltstone	Mudstone	Fine Ash Tuff	Very Fine Rhyolite Dacite Rhyodacite	Quartz Trachyte Quartz Latite Trachyte				Phyllite	
	Clay	0.002	Claystone								Mylonite	

Chapter 1
Introduction

Location and Physiography

This memoir describes the geology of the areas covered by Sheet 2 (San Tin), Sheet 5 (Tsing Shan) and Sheet 6 (Yuen Long). The major new town developments of Tuen Mun and Yuen Long are included, together with the development of the northern part of Tsing Yi Island. Offshore, the area includes Hau Hoi Wan (Deep Bay), Tsing Shan Wan (Castle Peak Bay), Urmston Road and the northern Ma Wan – Tsing Yi channel. The whole area is referred to in this memoir as the district (Figure 1).

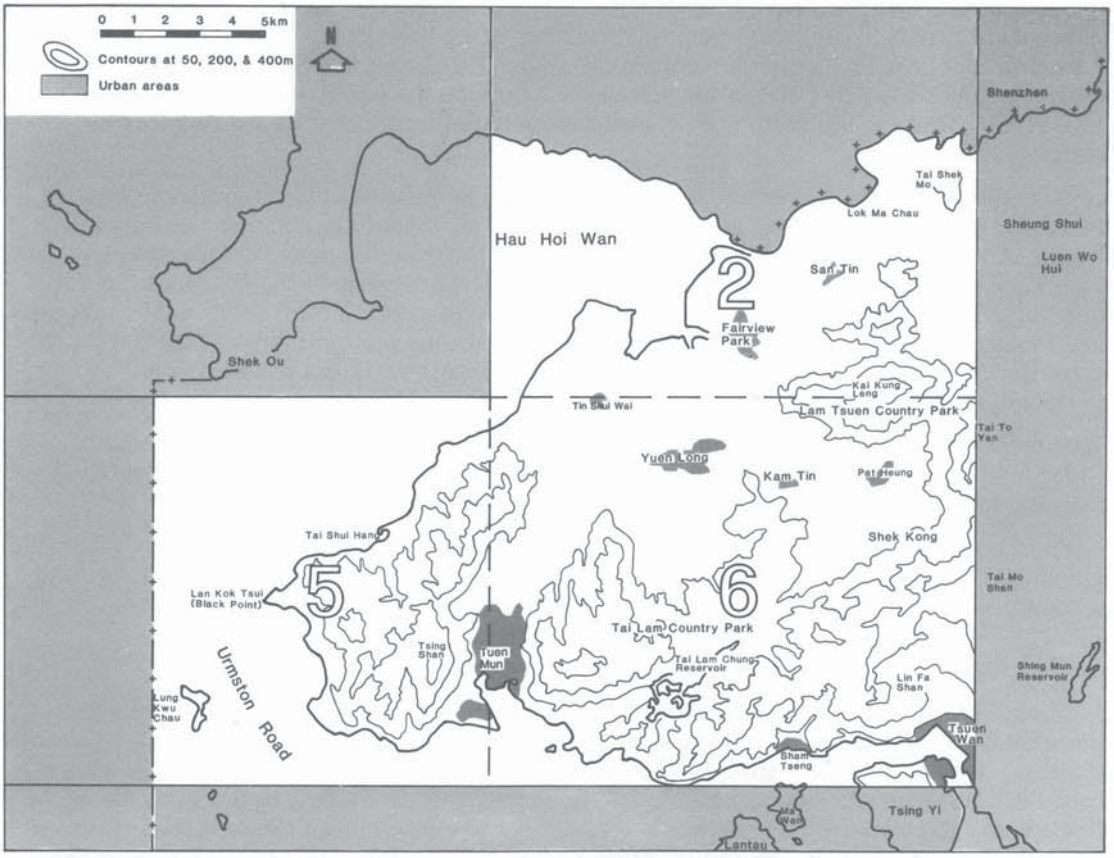


Figure 1 – Principal Topographic Features of the District

In the west of the district is a hilly area dominated by Tsing Shan (Castle Peak) (583 m). To the east of Tsing Shan (Castle Peak) is a broad valley containing Tuen Mun New Town. The southern part of this valley, extending into Tsing Shan Wan (Castle Peak Bay), has been the site of major reclamation projects over the past decade. Across the southern part of the district from Tuen Mun to Tsuen Wan is a hilly area, Tai Lam Country Park, with Tai Lam Chung Reservoir at its centre. The district becomes steeper and higher to the east, where it forms the western flanks of Tai Mo Shan (957 m).

The centre of the district is dominated by the wide, flat alluvial plains of Kam Tin and Yuen Long. North of Yuen Long there are low hills surrounded by ponds. These were established in the estuary of the Sham Chun and Shan Pui rivers, which flow into eastern Hau Hoi Wan (Deep Bay). North of the Kam Tin plain are hills stretching from Kai Keung Leng (572 m) in the south to Tai Shek Mo (182 m) near the border with Shenzhen.

Tuen Mun Road is the only major highway in the district, connecting Tsuen Wan and Tuen Mun. Elsewhere, the road network is being upgraded, and a Light Rail Transit (LRT) system is being constructed between Tuen Mun and Yuen Long. The marine channels around Ma Wan provide the main shipping access from the south into the Pearl River Estuary.

The densely populated areas are Tsuen Wan, Tuen Mun and Yuen Long, while extensive urban development is planned for Tin Shui Wai. Reclamation has taken place in all these urban areas, most importantly at Tuen Mun. The land in the west of the district (Tsing Shan) is largely used as a firing range, while the south of the district (Tai Lam) is designated Country Park and also serves as a water catchment. The plains in the centre of the district are largely agricultural and are flanked in the north by extensive fish ponds. To the northeast some of the hills are designated Country Park; close to the border with Shenzhen is a closed area.

Previous Work

The earliest geological survey of the Territory was undertaken between 1923 and 1927 by Brock, Uglow, Schofield and Williams under an agreement between the Colonial Office and the University of British Columbia. A map was published at 1:84 480 (Brock et al, 1936). There was no memoir, but their findings were recorded by Uglow (1926), Brock & Schofield (1926), Williams (1943) and Williams et al (1945). A memoir based largely on this earlier work was produced by Davis (1952). This was followed by a detailed description of the geology of the Territory by Ruxton (1960).

A systematic survey of the Territory by geologists from the Institute of Geological Sciences, United Kingdom, resulted in the publication of 1:50 000 geological maps and an accompanying memoir (Allen & Stephens, 1971). These have remained the definitive work on the geology of Hong Kong until publication of the results of the remapping began in 1986. The Geotechnical Area Study Programme (GASP) was initiated by the Geotechnical Control Office in 1979 (Brand et al, 1982). Amongst other maps, GASP produced engineering geology maps at 1:20 000 for the Territory. The geology drew extensively on Allen & Stephens (1971), but included new interpretations of superficial deposits and photolineaments.

The present remapping programme by the Geotechnical Control Office, Hong Kong, commenced in 1982, and to-date maps and memoirs for the Sha Tin district (Addison, 1986) and the Hong Kong Island and Kowloon district (Strange & Shaw, 1986) have been completed.

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

The Present Survey

Geological field mapping was undertaken between March 1984 and February 1986. Geological information for the onshore area was plotted directly onto aerial photographs at a scale of about 1:10 000. Topographic base maps at 1:5 000 scale were used latterly for local detail in developed areas. Field traverses are shown in Figure 2. Over large areas, particularly in the Tsing Shan (Castle Peak) and west Tai Lam areas, the vegetation was sparse, allowing easy access. However, in east Tai Lam the thicker vegetation restricted access to footpaths. Most coastal sections were examined, although access proved difficult on northern Tsing Yi. The large flat areas north of Tuen Mun, around Yuen Long, and between Shek Kong and Kam Tin yielded little useful field data and traverses are more widely spaced in these areas. Temporary sections were common in the three urban areas and were examined throughout the field mapping phase as the sites were developed. Numerous borehole cores were examined, particularly for ground investigations at Castle Peak Power Station, Tuen Mun, Yuen Long, Fairview Park, Tsuen Wan and northeast Tsing Yi; over 1 000 cores from these areas were seen and described.

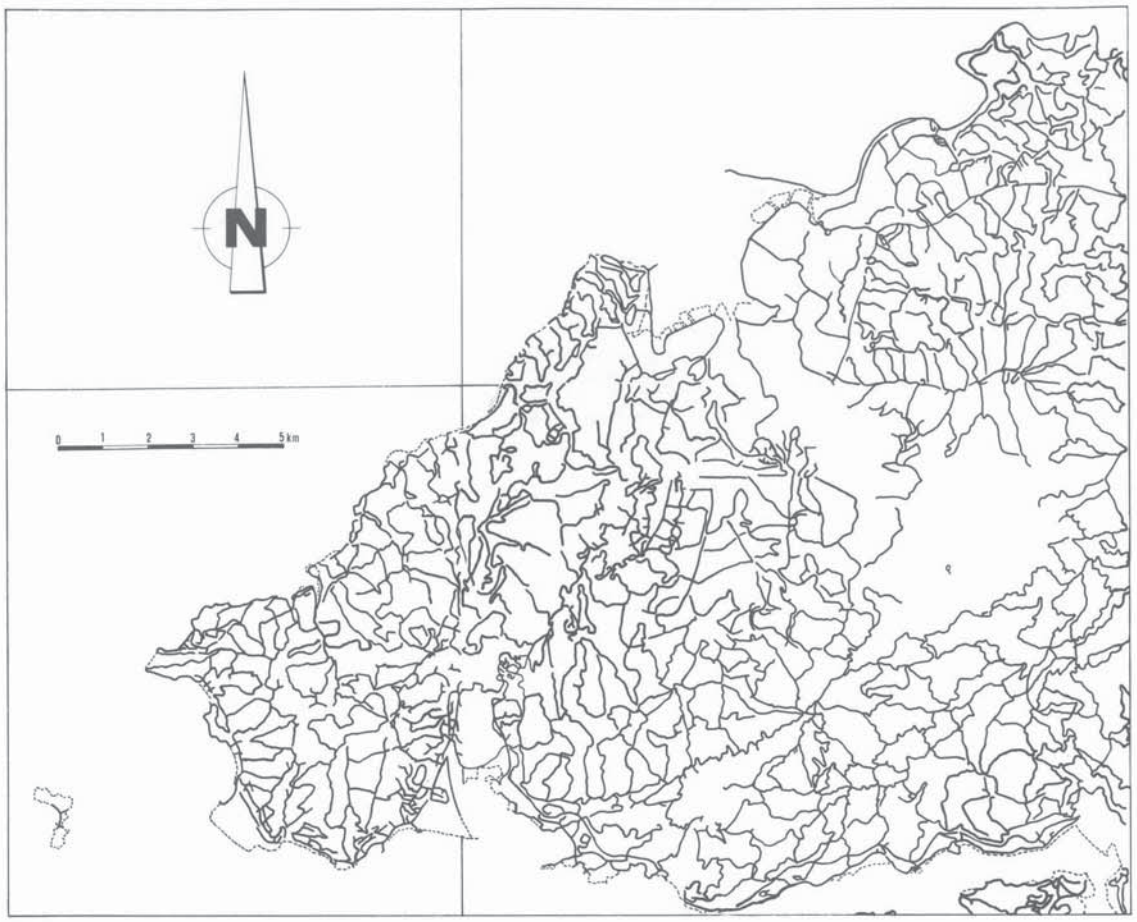


Figure 2 – Traverses Undertaken During Field Survey of the District

A desk study undertaken between 1985 and the middle of 1988 involved the examination of nearly 3 000 borehole logs, mostly from the Tuen Mun and Yuen Long areas (Figure 3). Many of the logs contained colour photographs of sufficiently high quality to allow rock types to be assigned. The logs are partly complimentary to the numerous cores which were examined. These records were of particular use in such areas, as the natural exposure was limited and the areas were covered with fill or marine deposits, or both. Other data consulted included the logs for the Western Aqueduct tunnel, accompanied by over 200 rock samples supplied by the Water Supplies Department, record drawings for various site formations and pre-development topographic maps and aerial photographs. The maps and photographs were used to determine the extent of fill, the natural coastline and the various phases of reclamation.

A photogeological interpretation of the district was completed mainly using 1963 and 1983–86 photographs. The 1949 and 1955 photographs were particularly useful for areas such as Tai Lam Chung reservoir. The extent of reclamation shown on the maps is based on data supplied by the Survey Division, Lands Department.

From a total of 3 407 rock samples collected, 1 489 were thin sectioned and 17 were sent to the Analytical Chemistry Research Group of the British Geological Survey (BGS) for geochemical analysis. A further 7 samples were sent to the Palaeontology Research Group of BGS for pollen analysis (stratigraphic dating), 3 samples were sent to the Department of Geography and Anthropology, Louisiana State University, for C14 dating and pollen analysis, 4 samples were sent to the South China Sea Institute of Oceanology, Guangzhou, for C14 dating, and 1 sample was sent to CSIRO, Australia, for C24 dating. Heavy mineral analysis was undertaken on 15 samples from the district by the British Geological Survey.

The offshore survey was completed using about 350 borehole logs, sea-bed samples, and shallow seismic records and sidescan sonar profiles undertaken by Electrical & Geophysical Services Ltd and Port Works Division, Civil Engineering Office, some specifically for this geological survey. Shallow seismic boomer profiles and ground investigation borehole information, produced as part of a search for offshore sources of reclamation fill, formed the basis of a general appraisal of the offshore geology of the Hau Hoi Wan (Deep Bay) – Urmston Road portion of the district. Further geophysical investigations, commissioned by the GCO as part of a Marine Sources of Fill Study, were carried out over the Urmston Road area. New stratigraphic details have been gathered from the logging and analysis of a continuously sampled borehole at Tsang Tsui in Hau Hoi Wan (Appendix 3).

The geological information gathered from all sources was compiled onto a series of 1:10 000 scale maps, 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, aerial photographs, manuscript maps and analytical data, are held by the Geological Survey Section, Planning Division, Geotechnical Control Office.

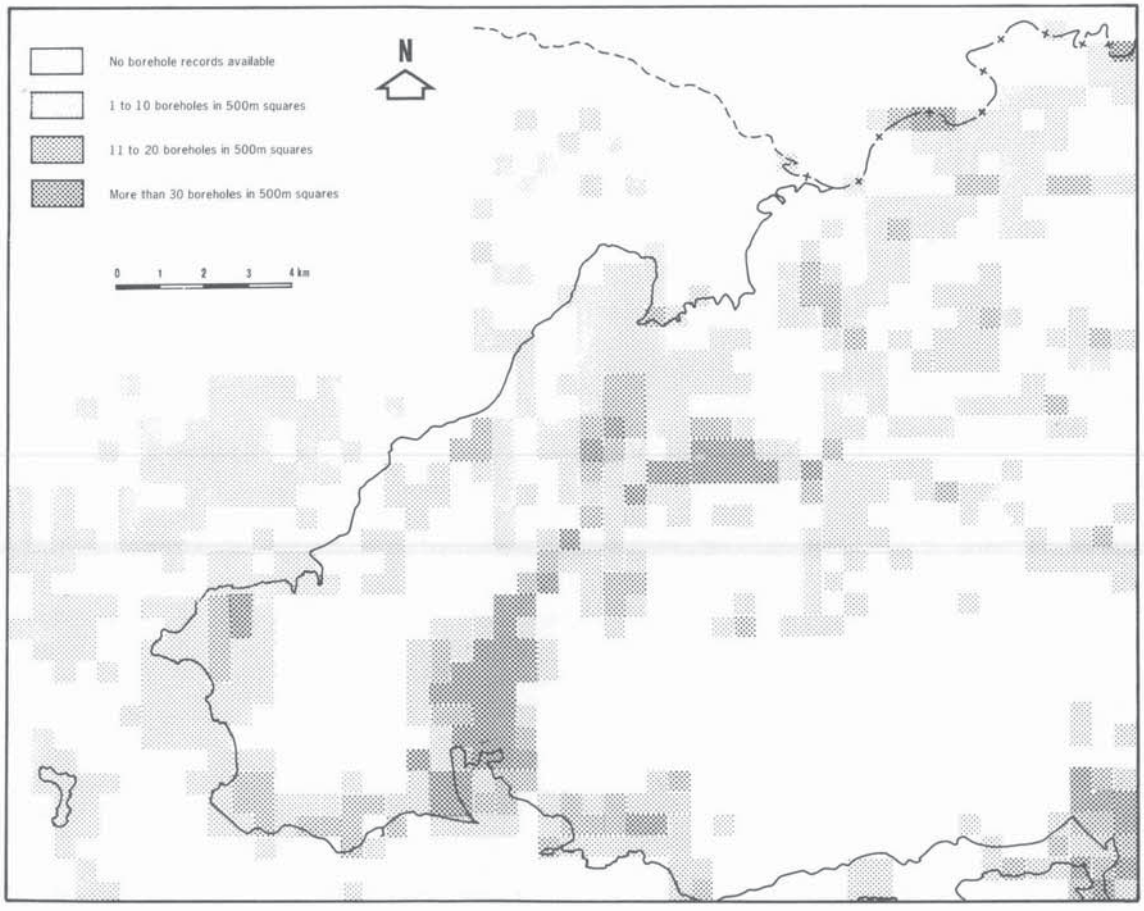


Figure 3 – General Distribution of Site Investigation Boreholes in the District

Table 2 – Solid Rocks and Superficial Deposits of the District

Superficial Deposits (Onshore)			
Age		**Genetic Classification**	**Principal Materials**
QUATERNARY	Holocene	Fill; sanitary fill	
		Alluvium	Clay, silt, sand and gravel
	Holocene and Pleistocene	Beach deposits	Sand
		Raised beach deposits	Sand
		Debris flow deposits	Silt and sand with cobbles and boulders
		Talus (rockfall deposits)	Boulders
	Pleistocene	Terraced alluvium	Clay, silt, sand and gravel
		Debris flow deposits	Silt and sand with cobbles and boulders
Superficial Deposits (Offshore)			
Age		**Named Divisions**	**Principal Materials**
QUATERNARY	Holocene	Hang Hau Formation Marine Sand	Mainly mud
	Pleistocene	Chek Lap Kok Formation	Clay, silt, sand and gravel
Solid Rocks			
Age		**Named Rock Divisions**	**Principal Rock Types**
MESOZOIC	Upper Cretaceous	Kat O Formation	Sedimentary breccia
	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
		Repulse Bay Volcanic Group — Shing Mun Formation	Lithic and crystal tuffs, tuff-breccia and tuffite
		Repulse Bay Volcanic Group — Ngau Liu Member	Ash crystal tuff
		Repulse Bay Volcanic Group — Shek Lung Kung Member	Crystal tuff and tuff-breccia
		Repulse Bay Volcanic Group — Yim Tin Tsai Formation	Coarse ash crystal tuff
		Repulse Bay Volcanic Group — Tuen Mun Formation	Meta-andesite lava
		Repulse Bay Volcanic Group — Tsing Shan Formation	Sandstone and conglomerate
PALAEOZOIC	Carboniferous	San Tin Group — Tai Shek Mo Member	Metasandstone with metaconglomerate
		San Tin Group — Mai Po Member	Metasiltstone with graphite schist
		San Tin Group — Yuen Long Formation	Marble
Major Intrusive Rocks			
MESOZOIC		Fine-grained granite	
	Upper Jurassic— Lower Cretaceous	Fine- to medium-grained granite	
		Medium-grained granite	
		Coarse-grained granite	
		Granodiorite and Dacite	
Minor Intrusive Rocks			
TERTIARY	Palaeocene	Andesite	
		Basalt and Gabbro	
		Lamprophyre	
MESOZOIC	Upper Jurassic— Lower Cretaceous	Feldsparphyric Rhyolite	
		Quartzphyric Rhyolite	
		Aplite and Fine-grained granite	
		Pegmatite	

Chapter 2
Outline of Geology

The solid geology of the district is dominated by Mesozoic volcanic and intrusive igneous rocks (Table 2, Figure 4). The district is also underlain in part by Palaeozoic sedimentary rocks, and there are extensive areas of Quaternary superficial deposits. These superficial deposits dominate the offshore area.

The Palaeozoic strata include the Carboniferous Yuen Long and Lok Ma Chau formations. The Yuen Long Formation consists of black marble, white marble and interbedded marble and phyllitic siltstone; the base of the succession is not seen. The Lok Ma Chau Formation rests on the Yuen Long Formation, and consists of metamorphosed siltstone, sandstone, carbonaceous siltstone and conglomerate. The Mesozoic volcanic rocks are of Upper Jurassic age, and are part of the Repulse Bay Volcanic Group. In the west, they comprise the Tsing Shan Formation and overlying Tuen Mun Formation. The Tsing Shan Formation consists of sandstone, conglomerate and some coarse ash tuff, while the Tuen Mun Formation consists of andesitic lava and tuff. In the east the succession comprises the Yim Tin Tsai, Shing Mun, Ap Lei Chau and Tai Mo Shan formations. The Yim Tin Tsai Formation, the oldest unit, is lithologically uniform, lapilli-bearing coarse ash tuff. The overlying Shing Mun Formation is variable, and consists of tuff, tuff-breccia and tuffite, with subordinate sandstone, siltstone and mudstone. Two members with localized distribution have been identified within the Shing Mun Formation; at the base the Shek Lung Kung Member consists of tuff-breccia, while at the top the Ngau Liu Member consists of crystal-vitric tuff. The Ap Lei Chau Formation, consisting of vitric tuff, is thin and restricted in its distribution. The uppermost unit, the Tai Mo Shan Formation, is widespread in the east and north of the district; it consists of coarse ash to lapilli crystal tuff with impersistent layers of tuffaceous sandstone and siltstone. The Cretaceous Kat O Formation is restricted in occurrence to a small area in the northwest.

The sedimentary and volcanic rocks are intruded by granodiorite and granite of Upper Jurassic to Lower Cretaceous age. Granodiorite is the oldest of these major intrusions and underlies large areas in the east and centre of the district. It forms an irregular sheet-like mass between Kam Tin and Tsuen Wan. The coarse- and medium-grained granite forms small masses, generally on the margins of the Tsing Shan (Castle Peak) and Tai Lam plutons. Both of these plutons are dominated by fine- to medium-grained and fine-grained granite, which in Tai Lam are almost invariably megacrystic. The finer granites are younger than the coarse- and medium-grained granites, which are often highly modified by the later intrusions.

Dykes of feldsparphyric and quartzphyric rhyolite, basalt and gabbro occur, mostly within the granites. Large dykes of dacite also occur, while fine-grained granite, aplite and pegmatite can form small dykes or veins; dykes of andesite and lamprophyre are rare. The acidic dykes are believed to be slightly younger than the granites, while the more basic dykes are probably Tertiary in age.

The structure of the district is dominated by northeast-trending faults, including a thrust fault between the Palaeozoic and Mesozoic rocks. North- and northwest-trending faults are commonly found in the granitic rocks. Folding is gentle and is most obvious in the Mesozoic volcanics in the east of the district. Tighter folds are known to occur in the Mesozoic strata west of Tuen Mun, and probably also occur in the concealed Palaeozoic strata around Yuen Long.

Thermal metamorphism around the granitoid intrusions has had slight effects on some tuffs and epiclastic rocks. Late stage emanations of hydrothermal fluids from the granite plutons have resulted in the greisenization of granite and the metasomatism of adjacent volcanic rocks in a few areas in the east of the district. Regional metamorphism, dominantly of post-Jurassic age, occurs in a broad belt through the district from northeast to southwest. Within this belt the effects of dynamic and hydrothermal metamorphism vary considerably, but are noted in sedimentary, volcanic and igneous rocks. The older metasediments appear to have suffered retrograde metamorphism from the main metamorphic episode, suggesting that regional metamorphism was probably reactivated at various times between the Palaeozoic and Mesozoic.

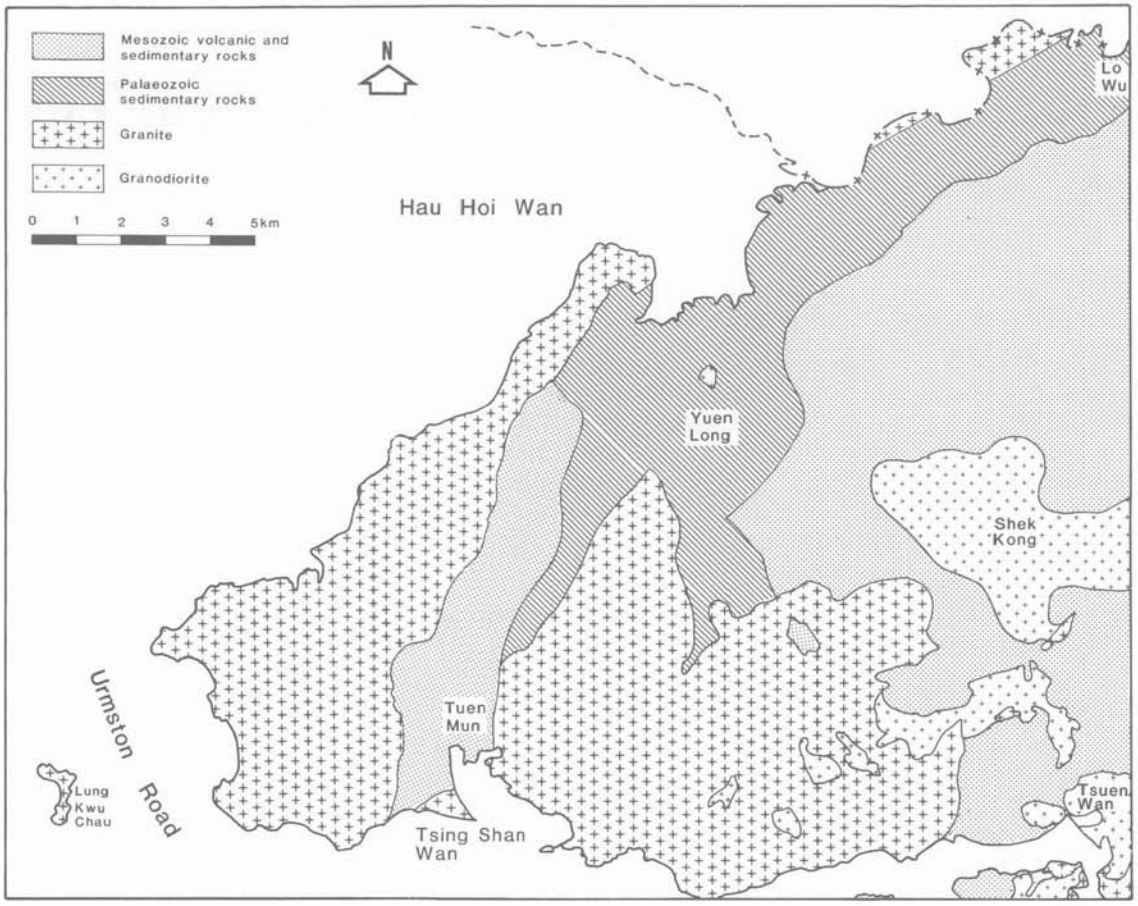


Figure 4 – Generalized Solid Geology of the District

Superficial deposits of Quaternary age form large, flat-lying areas in the centre and northwest of the district, and form the sea-bed in most of the offshore area. In the hilly areas, debris flow deposits, mostly of Pleistocene age, are common, lining valleys and grading downslope into large fans. Alluvium forms small deposits in hilly areas, but is generally restricted to areas downslope of the debris flow deposits. Pleistocene alluvium covers large areas around Kam Tin, Yuen Long and San Tin. The alluvium and debris flow deposits both occur offshore within the Pleistocene Chek Lap Kok Formation. They are generally covered by Holocene marine deposits (Hang Hau Formation). Beach deposits of sand usually form in front of alluvial deposits in coastal embayments, most notably east of Tuen Mun and on the south and west coasts of Tsing Shan (Castle Peak). Land reclamation has often disturbed or obscured the alluvial and marine deposits in the coastal fringe, especially around Tsuen Wan, northern Tsing Yi, Tuen Mun and the Tin Shui Wai – Yuen Long – Mai Po area.

A regolith, or mantle of weathered rock, occurs over most of the district. The effects of weathering on the various rock types are broadly reflected in topographic relief, with andesite, granodiorite and Palaeozoic sedimentary rocks being the most deeply weathered and eroded rocks, forming the lower ground. The granite terrain is often hilly and littered with exhumed corestones; generally the finer granites form sharper relief than coarser varieties. The acidic volcanic rocks are resistant to deep weathering and erosion, and they form rocky hills with boulder fields of large, cuboidal corestones.

Apart from one quarry extracting granite for aggregate for the construction industry, there are no active mineral workings in the district. However, in the past there has been mining for tungsten, graphite, quartz and kaolin. In addition, there are mineral occurrences of lead, zinc, tin, fluorite and beryl.

Chapter 3
Palaeozoic Sedimentary Rocks—San Tin Group

Classification and Distribution

Palaeozoic sedimentary strata occur in a northeast trending belt 1 to 5 km wide bounded by faults extending from Tuen Mun to Lo Wu in the northwestern part of the district; from there the belt extends into Shenzhen and northeast Guangdong. The strata form part of the San Tin Group and are divided into two formations; the Yuen Long Formation and the Lok Ma Chau Formation (Figure 5). Only the Lok Ma Chau Formation is exposed at the surface within the district. The two formations have different distinctive characteristics. The Lok Ma Chau Formation consists of clastic rocks and forms low hills, whereas the Yuen Long Formation consists primarily of carbonate deposits and lies concealed beneath the alluvium of the plains.

The Yuen Long Formation is dominantly calcareous, consisting of white and black marble, often interbedded, with impure marble and metasiltstone near the top. Bennett (1984b) quoted Huang (1978) and Nanjing University (1980) in stating that Hong Kong lay within the Caledonian marginal basin, and that this is characterized by the local development of carbonates.

The Lok Ma Chau Formation, which was named and defined by Williams in 1942, was first placed in the Permian System by Heim (1929). It was later grouped with the Lower Jurassic strata by Allen and Stephens (1971). Lai (1977) compared the formation with the Carboniferous strata of Shenzhen and suggested that the formation belonged to the Carboniferous System. On correlations with Shenzhen it was further suggested that the Yuen Long and Lok Ma Chau formations should be placed in the Lower Carboniferous (Ha et al 1981; Lai & Mui 1984) (Figure 6). A similar conclusion was reached by Peng (1983), Bennett (1984b) and Lee (1985). New micropalaeontological evidence has given a Tournaissian or Namurian Westphalian age for the Lok Ma Chau Formation (Appendix 1).

Yuen Long Formation

Stratigraphy

The Yuen Long Formation consists of white, light to dark grey, or black marble with some dolomitic marble, and a few small occurrences of tremolite marble; the marble can be intercalated with thin layers of phyllite. It is inferred that prior to metamorphism the succession consisted of limestone, impure in parts, intercalated with dolomitic limestone and thin siltstone horizons.

No surface outcrop of the Yuen Long Formation is known within the district. The first known record of marble was in boreholes in construction sites at Fairview Park and Yuen Long in 1977 and 1980 respectively. The formation has subsequently been proved to be widely distributed in the Yuen Long, Tin Shui Wai and San Tin areas.

The black marble, at the base of the known succession, is restricted in its extent, having mostly been found in deep boreholes penetrating the white marble in the southeast of the Palaeozoic outcrop (Figure 4). The impurity which gives the black colour is variable in amount, often defining a complex bedding structure (Plate 1). In places the bands are dark green and phyllitic. The black marble grades up into the overlying white marble (Plate 2).

The white marble is generally pure (Table 3), but can contain thin grey or black bands which define bedding. It varies from coarse- to fine-grained, and the finer varieties can also be either dolomitic, silty or sandy. In places there are beds of calcareous metasandstone or metasiltstone, and there may be bands of dark green phyllite. The white marble is largely confined to the south and east of the Palaeozoic outcrop (Figure 4). The interbedded succession grades up from the underlying white marble. The content of impurities gradually increases, passing through white calcareous metasandstones, quartzite, greenish calcareous metasiltstone, siltstone and phyllite. The siltstone and phyllite progressively become dominant, and are difficult to distinguish from the overlying Mai Po Member. The thickness of the formation is more than 300 m.

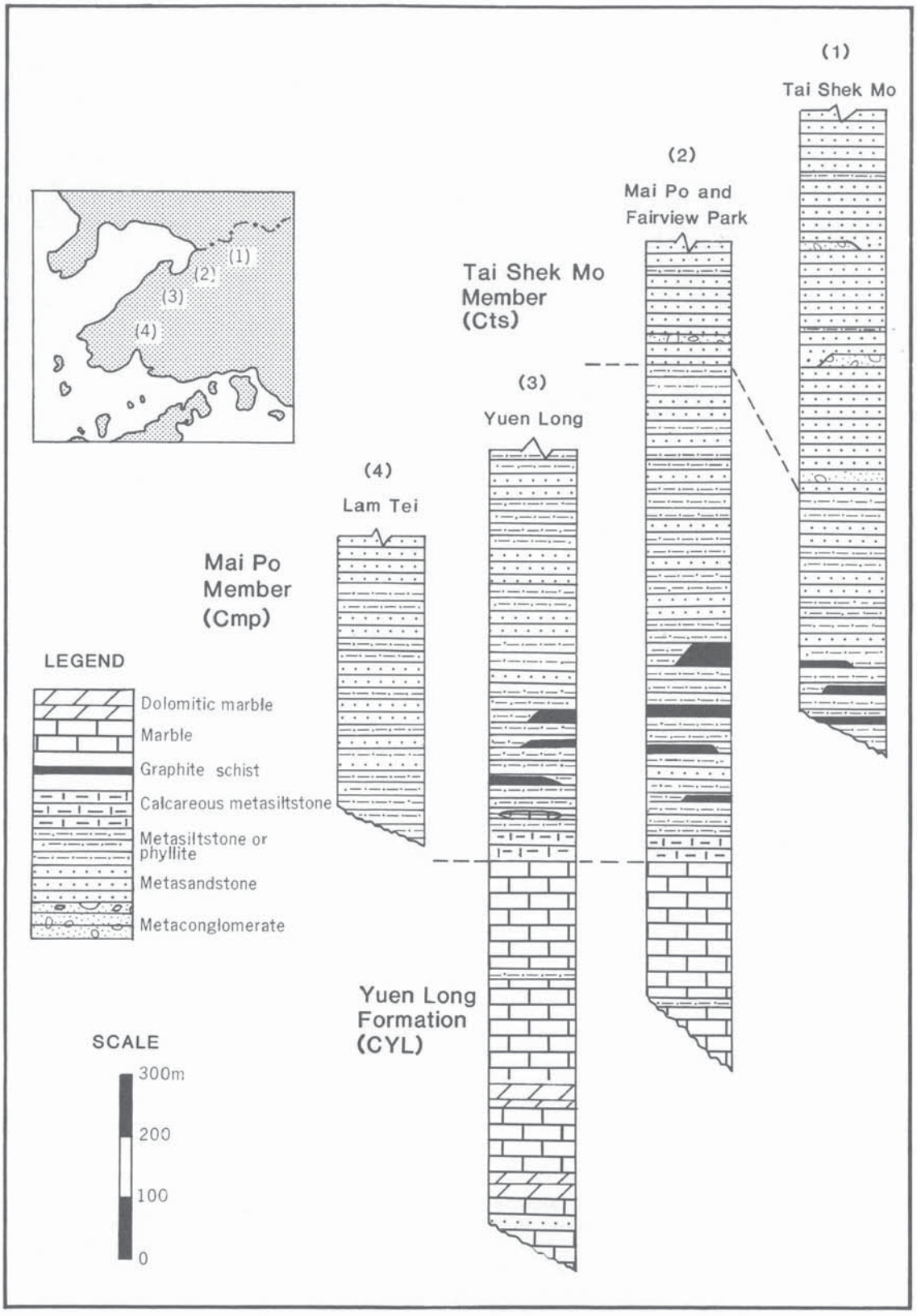


Figure 5 – Generalized Sequences of San Tin Group Rocks

Table 3 – Major Element Analyses of Carbonate Rock

Element	Dolomitic Marble	Dolomitic Marble	Marble	Marble	Marble	Marble	Marble
	Ma Tin Road (2061 3351) HK6707	Sai Ching Street (2098 3359) HK6769	Sai Ching Street (2098 3359) HK6768	Fung Ching Street (2158 3367) HK6336	Kai Tei (2166 3402) HK6702	Tin Shui Wai (1912 3684) HK6710	Fairview Park (2247 3837) HK5442
SiO_2	<0.01	0.68	1.36	0.21	0.11	<0.01	2.03
TiO_2	ND	ND	ND	ND	ND	ND	ND
Al_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe_2O_3	0.19	0.19	<0.01	0.03	<0.01	0.23	<0.01
MnO_2	0.03	0.03	<0.01	0.01	<0.01	0.01	<0.01
MgO	20.14	22.87	0.35	0.37	0.46	0.60	0.35
CaO	39.3	36.5	54.37	55.02	55.70	55.34	54.11
Na_2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co_2	39.87	40.09	40.83	40.76	40.66	41.09	39.51
LOI*	45.65	45.53	42.75	43.50	43.76	43.51	42.45
Moisture	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total	105.31	105.80	98.83	99.14	100.03	99.69	98.94

* CO_2 was measured as it evolved by a manometric method. For all the marble samples under test, the rate of evolution was too slow. LOI results gave a better measure, in this case.

The marble strata are readily susceptible to weathering and erosion, with the formation of karst; the karst surface to the marble is blanketed by superficial deposits. Cavities formed by solution and erosion are common; deposits of yellowish brown clayey silt with gravel of marble, quartz, weathered siltstone, basalt and sandstone can be found inside some cavities.

Although no fossils have been found in the marble of Hong Kong, a comparison has been made with similar rocks in Shenzhen (Lai & Mui, 1985). Here, the calcareous succession belongs to the Lower Carboniferous, based on macrofossils. The Yuen Long Formation may, therefore, be the lithostratigraphic equivalent of the Shidengzi Formation in Shenzhen and Guangzhou.

Details

Southeast Yuen Long. The largest subcrop of the formation has been revealed by more than 700 boreholes in the area from Ying Lung Wai (220 340) to south of Lung Tin Tsuen (202 324). Fresh marble is buried 18 to 43 m below the surface, with a highly irregular rockhead or karst surface consisting of pinnacles and slots. The Yuen Long Formation forms an anticline, with metasiltstones and graphite schist of the Mai Po Member on both limbs. The southeast limb is cut by a northeast-trending fault, so the Mai Po Member on that side forms only a narrow strip. The rock type is mainly white and pale grey marble; dolomitic marble and thin layers of metasiltstone and metasandstone occur near the top, while the lower part is dominated by black, banded marble. At a site on Sai Ching Street (210 335) a 1.4 m thick siltstone is intercalated with the marble, and at a site on Ma Tin Road (206 335) a siltstone lens 0.3 to 0.7 m thick and a thin layer of fine-grained sandstone 1.8 m thick were found in the marble sequence. An unmetamorphosed gabbro dyke about 0 m wide cuts the marble on this site.

Solution cavities are preferentially developed along discontinuities within the marble. The greatest development of cavities in the marble has been reported in a site between Ying Lung Wai and Castle Peak Road (217 340). According to the borehole logs, the commonest cavities are from 0.1 to 2 m in height, fewer range from 5 to 15 m, but the largest cavity is 24.6 m in height; most cavities have been encountered above −70 mPD.

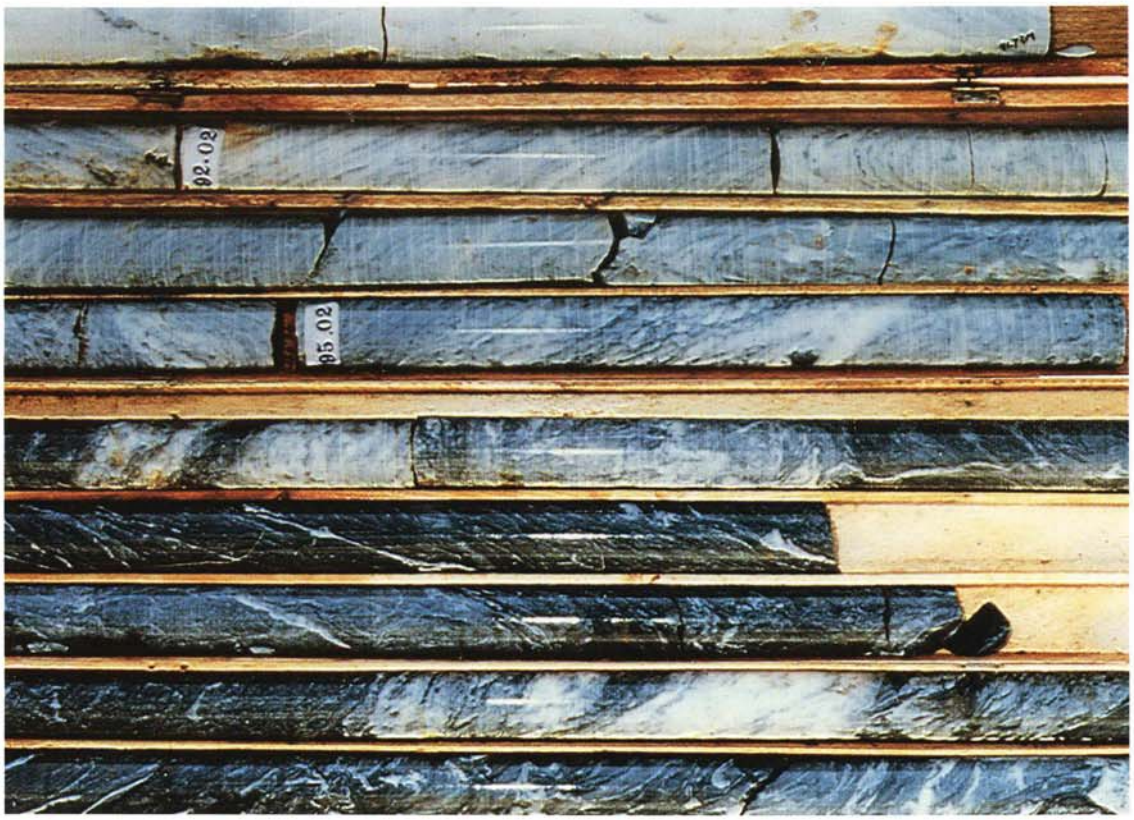


Plate 1 – Gradation from Black Marble to White Marble in Borehole AH98, LRT Interchange, Yuen Long (2171 3401) (Photograph Courtesy of KCRC-SHK JV Development)

Plate 2 – Marble in Yuen Long Formation (HK6768) from Yuen Long (2098 3359); Natural Scale

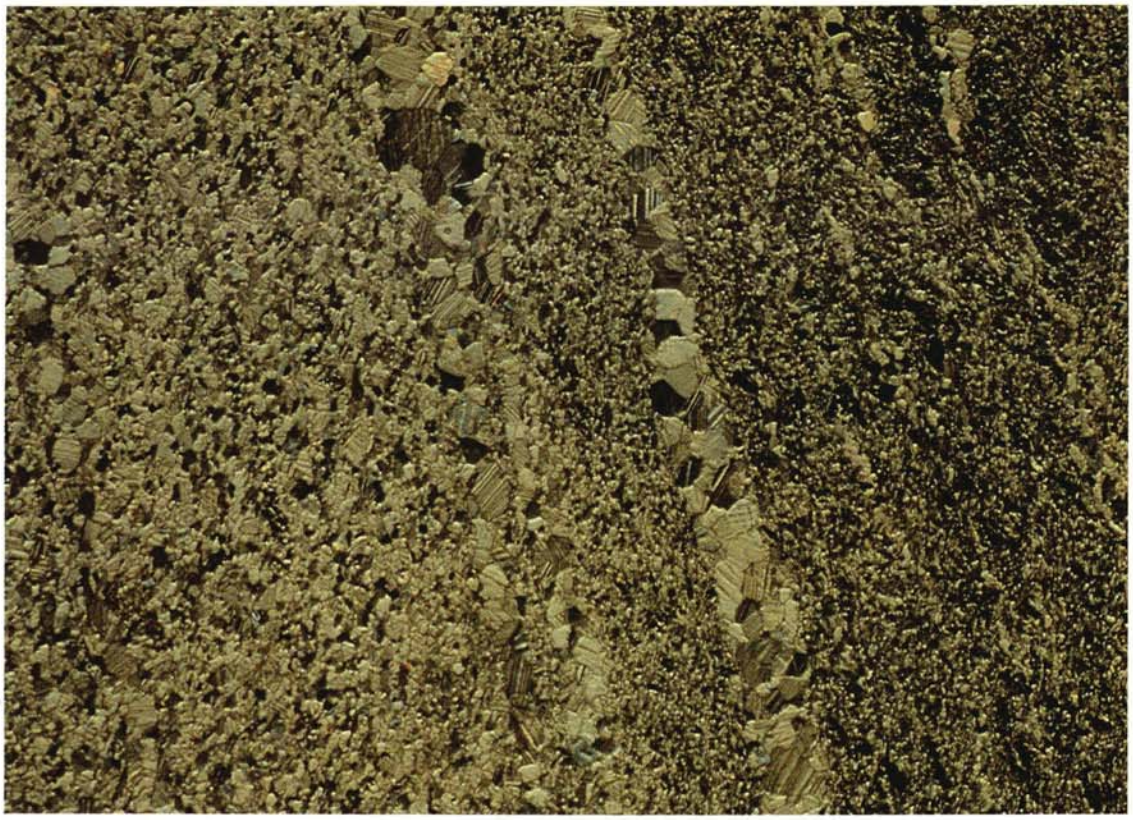


Plate 3 – Thin Section of Marble in Yuen Long Formation (HK3025) from Yuen Long (2056 3573); XPL × 10

Plate 4 – Graphite Schist in Mai Po Member (HK6748) from near Mai Po (2466 3916); Natural Scale

Plate 5 – Thin Section of Andesite in Tuen Mun Formation (HK4931) from Tuen Mun (1350 2624); XPL × 10

Plate 6 – Ash Crystal Tuff in Yim Tin Tsai Formation (HK3988) from Tsuen Wan (2709 2593); Natural Scale

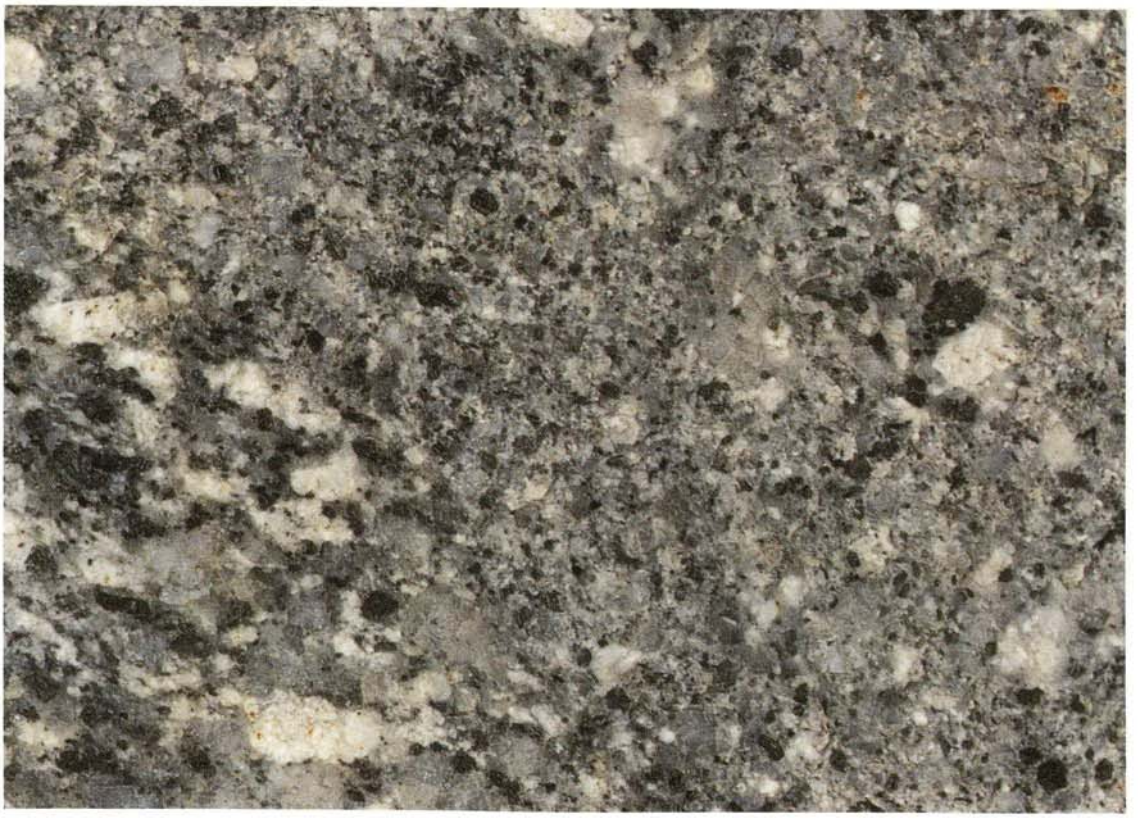


Plate 7 – Thin Section of Diffuse-edged Lapilli in Yim Tin Tsai Formation (HK2263) from Tsing Yi (2678 2427); XPL × 10

Plate 8 – Tuff-breccia in Shing Mun Formation (HK5862) near Tsuen Wan (2904 2742); Natural Scale

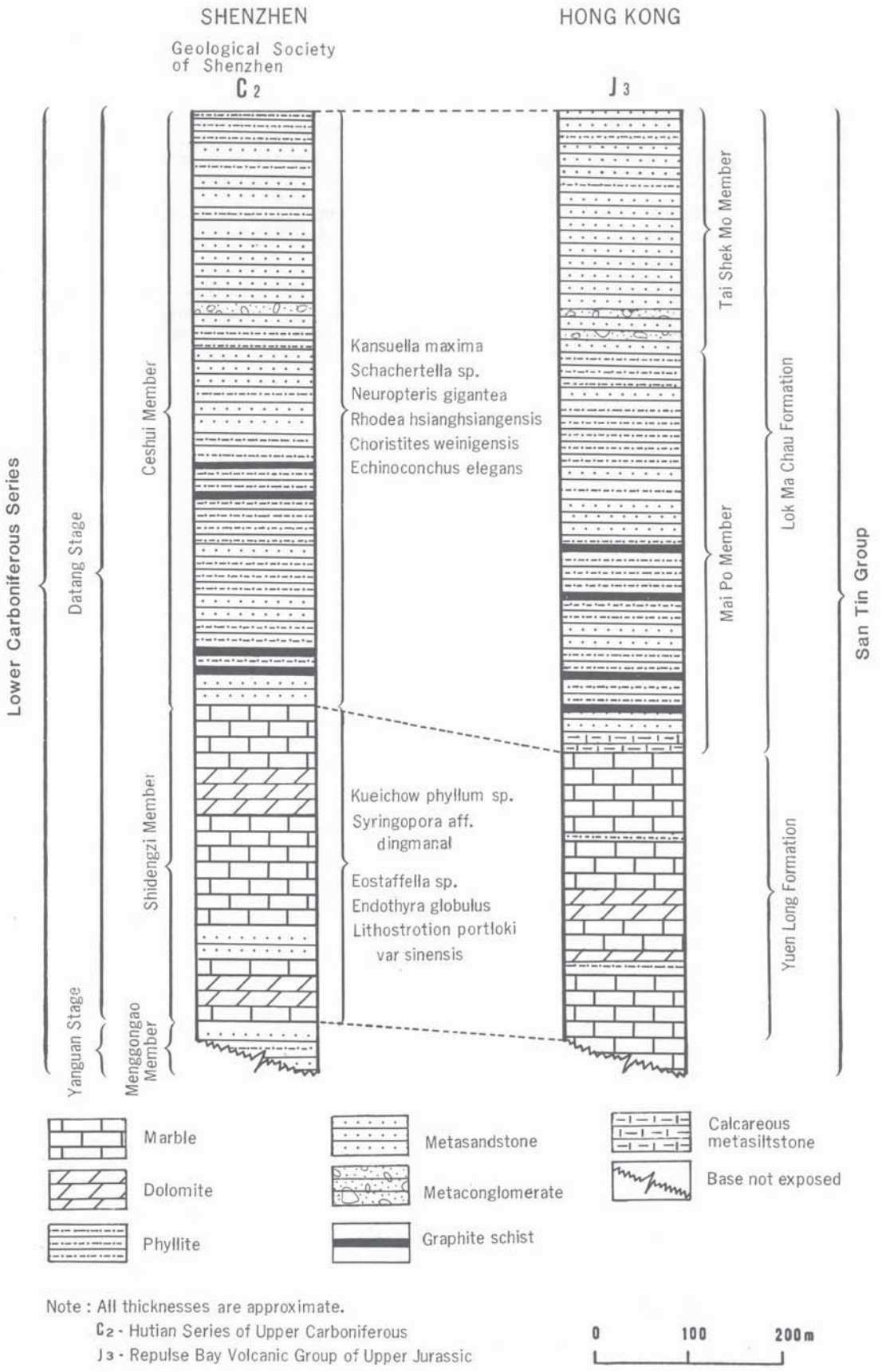


Figure 6 – Lithostratigraphic Comparison of the San Tin Group with the Carboniferous Strata of Shenzhen

Most of the cavities so far encountered in southeast Yuen Long are less than 1 m in height, a few reach 2 to 3 m or occasionally 8 to 10 m. Generally the cavities contain deposits of brown laminated clayey silt with weathered rock fragments. In small areas of Yuen Long, deep boreholes into the marble have proved free of cavities.

Fairview Park to Lok Ma Chau. Two subcrops occur in Fairview Park, one along the northwest boundary (224 384 to 224 383), the second within the estate (225 382 to 226 380). The marble occurs 20 to 58 m below the surface, and consists of white to dark grey, fine- to medium-grained marble, with some dolomitic marble. In one borehole (B182, 2246 3753) the marble has been thrust over the graphite schist of the Mai Po Member.

Boreholes northwest of Lok Ma Chau (259 417) proved the Yuen Long Formation 25 m below the surface beneath 11 m of superficial deposits and 14 m of metasiltstone of the Mai Po Member. The marble is greenish grey and rich in manganese.

North and West Yuen Long. The Yuen Long Formation was found in boreholes in Yuen Long Industrial Estate (356 205) (Langford, 1988). Within the Estate the white marble, interbedded marble and metasiltstone were found in boreholes. The white marble is confined to the southeast, while the interbedded succession was found at depth in the southwest. Metagranite and metagranodiorite cut the marble close to the line of a westnorthwest-trending fault which passes through the centre of the Estate.

The Yuen Long Formation occurs 30 to 55 m below ground surface beneath the metamorphosed sandstone and siltstone of the Mai Po Member at the Long Ping Estate (205 343). In a number of places in Yuen Long town centre, boreholes have penetrated the Mai Po Member to intersect the marble. Such occurrences have been found west of Tai Kiu (205 341) and on Castle Peak Road (208 338); the Yuen Long Formation underlies the Mai Po Member some 23 to 68 m below the surface.

The Yuen Long Formation was found in boreholes west of Shui Pin Wai (197 338) and to the west of Lam Hau (196 330) along the Shan Ha Road. The formation is mainly composed of pale grey to white, fine- to medium-grained marble and is concealed by a layer of superficial deposits of between 18 and 40 m thickness. Metasandstone of the Mai Po Member occurs on the both sides of the marble, forming low rounded hills. From this disposition of the formations a thrust faulted structure is inferred. A basalt dyke trending 050° intrudes the marble west of Lam Hau (1965 3313).

Tin Shui Wai. The formation occurs north of Tin Shui Wai (191 367) and northeast of the Ha Tsuen San Wai (185 348), where it is covered by a 23 to 28 m thick sequence of marine and alluvial deposits. The marble forms an intermittent subcrop along an inferred anticline axis. Some thin layers of metasiltstone are intercalated in the formation in this area and the marble is also intruded by a rhyolite dyke. To the west of Sheung Cheung Wai (186 341) and to the east of Ha Tsuen (178 341) the Yuen Long Formation underlies metamorphosed siltstone and sandstone of the Mai Po Member 28 to 47 m below the surface.

Petrography

The white marble typically ranges in grain size from 0.1 to 0.5 mm (HK 6330, 2159 3399), and the recrystallized calcite forms polygonal crystals. In some samples there are traces of minerals such as tremolite, epidote-zoisite, wollastonite, quartz and opaques (Lai, 1984). In particular, the presence of poikiloblastic (partially resorbed) wollastonite in HK 3026, (2054 3569) is taken as indicating retrograde metamorphism by Chan (1987). In thin section (HK 3025, HK 3026, HK 6332 & HK 6335) recrystallized calcite is dominant, with some dolomite and sericite; the accessory minerals are tremolite, wollastonite, quartz, epidote, sphene, serpentine and pyrite (Plate 3). Chemical analysis confirms that the marble is mainly calcium carbonate, with the dolomitic marble being rich in magnesium carbonate. The compositions of the marble varieties are given in Table 3.

Sedimentary Environment

The original limestone, silty limestone, dolomitic limestone, sandstone and siltstone which formed the Yuen Long Formation have all been strongly metamorphosed. All original sedimentary structures appear to have been modified or destroyed, and it is therefore difficult to determine the original sedimentary environment. At times the marginal basin in which these rocks formed would have been subject to influxes of silty or sandy material, giving the impure carbonates (Plate 1). Towards the end of the cycle of deposition, silt dominated the sediment inflow, preventing the deposition of carbonate.

Lok Ma Chau Formation

Stratigraphy

The Lok Ma Chau Formation is widespread between Lo Wu and Tuen Mun, and can be divided on lithology into two members, the Mai Po Member and the Tai Shek Mo Member (Figure 5). The older Mai Po Member mainly consists of metamorphosed siltstone, fine-grained sandstone and carbonaceous siltstone. The younger Tai Shek Mo Member is composed of metamorphosed sandstone and conglomerate. The metamorphism is low-grade greenschist facies, with dynamic metamorphism producing phyllite, graphite schist and schistose conglomerate in narrow zones.

There is possible stratigraphic equivalence between the Lok Ma Chau Formation and the Lower Carboniferous Ceshui Formation which outcrops in Shenzhen.

Palaeontology

Until recently the only evidence for the age of the Lok Ma Chau Formation came from macrofossils in supposedly equivalent strata in Guangdong. Recent microfaunal evidence suggests either a Tournaissian or Namurian-Westphalian age. These Carboniferous ages are based on analyses by the Guangdong Institute of Geological Sciences and the British Geological Survey (Appendix 1). Most of the samples analyzed come from graphitic intercalations within the Mai Po Member, but two samples (HK 3005, 2231 3181 and HK 6721, 2243 3176) come from within or close to the presumed basal breccia between the Mai Po Member and Shing Mun Formation.

Sedimentary Environment

The sedimentary units in the Lok Ma Chau Formation are indicative of a neritic swamp in a prograding deltaic succession. Low in the succession are silts, fine sands and carbonaceous horizons, probably deposited in a deltaic floodplain. Although repeated occurrences of the various lithologies were noted, no cyclic pattern of deposition can be established. As the delta built up the sediment-type gradually changed to medium sand, coarse sand and pebbles. From a distal alluvial floodplain environment there is a progradation to a proximal alluvial sequence.

Mai Po Member

Stratigraphy

The Mai Po Member lies in a series of folds trending northeast from Tuen Mun to Lo Wu. The type locality of the member is at Mai Po Hill (246 393), but it is also well exposed to the northeast of Ho Sheung Heung (291 416). The dominant lithology is light to dark grey metasandstone and metasiltstone, with some silver grey phyllite and thin layers of graphite schist. The graphite schist is dark grey to black when fresh, and has a well developed schistose structure (Plate 4). The widespread occurrence of thin layers or lenses of graphite schist is characteristic of the member. Such layers are moderately thick on Mai Po Hill and at Tam Kon Chau (233 394). To the south of Mai Po Hill, from Shing Uk Tsuen (200 360) to Ping Shan (193 340), the strata are mainly metasiltstone with sandstone, and the graphite schist layers are thin or absent. To the northwest of the Ma Tso Lung Fault the member occurs on a number of isolated low hills. The most southerly occurrence of the member is on Mouse Island, in southern Tuen Mun. The thickness of the member exceeds 400 m. Ground investigation boreholes have shown that the Mai Po Member is conformable and transitional with the underlying marble.

Details

Lo Wu to Lok Ma Chau. The Mai Po Member occurs on the northwest side of the northeast-trending Lo Wu – Tuen Mun Fault (Burnett & Lai, 1985) in an outcrop some 3.5 km long, where it is thrust over metatuff of the Repulse Bay Volcanic Group. The main rock type of the member in this area is light grey to dark grey phyllite and metasiltstone, with metasandstone and thin layers of graphite schist.

The member is exposed northwest of Ho Sheung Heung (291 416), where the succession can be divided into three parts. The lower part consists mainly of grey to dark grey phyllite and sericite schist, with two layers, 1 to 2 m thick, of fine-grained metasandstone, and four thin layers of graphite schist. In the middle part of the succession there are phyllite and metasiltstone, with a 15 m thick greyish white, fine-grained quartzitic metasandstone, while in the upper part the main rock type is metasiltstone, with some sericite schist and several layers of thick bedded fine-grained metasandstone.

Two to four thin layers or lenses of graphite schist occur intermittently southwest of Lo Wu Camp (293 418) towards Fung Kong Shan (284 417), each varying in thickness from 0.1 to 0.5 m. North of Fung Kong (287 415) there are two layers of graphite schist, 1.2 and 1.5 m thick.

The unit attains a total thickness of 300 m to the southeast of Tit Hang. The lower part of the member here is predominantly phyllite, with five layers of metasandstone 1 to 12 m thick; these rocks form a northeast-trending low hill (276 412). The middle part of the succession comprises phyllite with three layers of graphite schist which are 2 m, 5 m and 8 m thick respectively. The thickest graphite schist outcrops southeast of Tit Hang (276 414). To the south a 1.8 m thick graphite schist forms a minor syncline south of Pak Shek Au (275 410) and extends east of Chau Tau (271 408), where the upper part of the member is phyllite, with three layers of fine-grained metasandstone.

The Mai Po Member is exposed on isolated low hills stretching from Sheung Ma Lei Yue near Lo Wu, west of Liu Pok (284 431), and from northeast of Ping Hang (273 425) to Ha Wan Tsuen (258 414). The outcrops are repeated by a northeast-trending reverse fault.

At Sheung Ma Lai Yue and west of Liu Pok the dominant rocks are greenish grey phyllite and metasiltstone with metasandstone. Northeast of Ping Hang the phyllite is the only rock type present. At Ha Wan Tsuen a greenish grey phyllite with good schistosity is exposed on the south side of the Shenzhen River near Lok Ma

Chau Road. In a borehole (D246/03335, 2591 4169) the metasiltstone of the Mai Po Member was found overlying the marble of Yuen Long Formation at −21.69 mPD.

Mai Po to Fairview Park. The Mai Po Member exposed on Mai Po Hill comprises silver grey to greenish grey phyllite with metasandstone and four layers of graphite schist, all with an excellent schistosity. The member overlies schistose metatuff of the Tai Mo Shan Formation, with a reverse fault at the contact. A stratigraphic section was examined east of Mai Po Lo Wai (244 393) towards Mai Po San Tsuen (247 392), the details of which are shown in Figure 5.

The lithology of the member changes towards the northwest, with arenaceous rocks becoming dominant. Graphite schist forms in four layers extending east of Mai Po San Tsuen (244 392), and can be seen in a new road cutting on the southeast side of Mai Po Hill. However, the geological structure is complicated and the strata may be repeated by thrusting.

At Fairview Park the member was encountered in the boreholes in the northwestern part of the estate (204 380). The main rock type is dark grey phyllite, with some fine-grained metasandstone. Two layers of graphite schist 0.5 m and 7 m thick were found in a borehole (2246 3753), respectively at 19 and 42 m beneath the surface.

An isolated exposure of the Mai Po Member, surrounded by superficial deposits, can be seen at Tam Kon Chau (233 394). The strata comprise greenish grey phyllite with greyish white metasandstone, white thick-bedded quartzite and graphite schist. Between 1966 and 1974, six boreholes and two shafts were sunk to investigate the graphite at Tam Kon Chau. At least four layers of graphite schist were found, varying in thickness from 1 to 12 m. The deepest borehole (220 m) failed to penetrate the base of the Mai Po Member.

Yuen Long. Exposures of the Mai Po Member occur from Ng Uk Tsuen to Ping Shan, north and west of Yuen Long, and at Tung Tau Tsuen, northeast of Yuen Long. Small exposures have also be found on the granite and volcanic foothills to the south, around Tai Tong.

At Chu Wong Ling the strata are greyish white, thickly bedded fine-grained metasandstone, with metasiltstone and thin layers of graphite schist; the graphite schist is exposed at the top of Chu Wong Ling (208 353). At Tung Tau Tsuen, fine-grained metasandstone with metasiltstone is displaced by a northwest-trending fault (218 345).

There are no exposures in Yuen Long, but ground investigation reports indicate that the Mai Po Member outcrops beneath the alluvium in the town area. In the eastern part of the town the strata consist of metasiltstone with some metasandstone and graphite schist, and are characterized by being rich in carbonaceous material; up to four layers of graphite schist, varying in thickness from 1 to 22 m, have been found in boreholes. In the western part of the town the strata are less carbonaceous and more arenaceous, with one or two layers of metasandstone or quartzite which vary in thickness from 10 to 40 m. There are several layers of calcareous metasiltstone varying from from 1 to 2 m in thickness near the base of the member.

At Long Ping Estate (206 344), including Kit Yeung Tsuen, the strata are similar to those in the western part of Yuen Long, in this case with two to five layers of metasandstone or quartzite. The thickness of each sandstone layer ranges from 4 to 22 m.

To the southwest, at Ng Uk Tsuen (203 363), the rock is mainly yellowish brown, thick-bedded fine-grained metasandstone with phyllite. The member is intruded by granitic rocks to the southwest of Ng Uk Tsuen (202 362). Fine-grained metasandstone forms the top of low hills northeast of Fung Ka Wai (197 355). Dark grey to greenish grey metasiltstone and phyllite underly Ping Shan (192 340), Wang Chau (197 354) and Shui Ngau Leng (200 335).

To the south of Yuen Long, around Tai Tong, there are several isolated exposures of siltstone and fine sandstone. These are believed to form part of the larger outcrop of Palaeozoic strata, but may be isolated from other outcrops of the Mai Po Member. Near a small reservoir (200 292) are exposures of grey quartzite, metasandstone and metasiltstone, either massive or foliated. To the north the outcrop can be clearly defined as a roof capping to the underlying fine-grained granite.

Near Sung Shan San Tsuen (223 317) an inlier of carbonaceous metasiltstone is faulted against tuffs of the Shing Mun Formation to the southwest, while to the northeast the metasiltstone appears to lie unconformably beneath a breccia which contains abundant clasts of the carbonaceous metasiltstone, and grades upwards into the overlying tuffs. Carbonaceous metasiltstone and siltstone is also exposed southeast of Tai Tong (211 305).

Tin Shui Wai to Tuen Mun. The Mai Po Member is covered by between 6 and 20 m of superficial deposits. The main rock type is metasiltstone or phyllite, with subordinate metasandstone and quartzite. There are four to six intercalations of sandstone with thicknesses varying from 1 to 10 m. Between Tin Shui Wai and Ha Tsuen San Wai, boreholes indicate that the metasiltstone of the Mai Po Member is conformable with the underlying Yuen Long Formation, and an anticlinal structure can be defined. West of Ha Tsuen San Wai, thin lenses of calcareous siltstone were found in the lower part of the Mai Po Member in seven boreholes (178 341). Rhyolite dykes intrude the member, but are only found in boreholes (178 341).

The member outcrops in the Tuen Mun valley from Ha Tsuen (173 342) to Tseng Tau Sheung Tsuen (158 294), and again at Mouse Island, south of Tuen Mun (155 271). For the most part it is concealed beneath alluvium, with exposures only along the northeast-trending faulted margin of the granite. The strata

Plate 9 – Phyllite in Mai Po Member at Wong Fung Lek, Tuen Mun (1630 2967)

comprise greenish grey phyllite and dark grey metasandstone with a strong metamorphic fabric, well seen at Lo Fu Han (170 305) and Tuen Mun Treatment Works (163 297) (Plate 9). The southernmost outcrop, at Mouse Island, is isolated from the main outcrop, and is intruded by the adjacent granite. The metasandstone here forms a low hill, with phyllite and graphite schist exposed at the northeast end of the island. Colour banded siltstone has been found in boreholes south of the island (1918D/07183, 1546 2717).

Petrography

Metasiltstone from Ping Shan has a clastic component mainly of quartz, with a few heavy minerals such as tourmaline. The cementing material has recrystallized to form sericite, with dispersed microgranular haematite; the grain size is in the silt size range. Modal analyses of thin sections shows 54 to 65% quartz, 35 to 45% sericite and 1 to 3% opaque minerals (haematite and pyrite). The quartz grains are often strained and flattened, with undulatory extinction. Preferred orientation of the sericite defines the schistosity. In thin sections of some rocks, for example HK 3034 (1987 3530) to HK 3037 (1998 3510), there are two foliations.

The graphite schist in thin section contains sericite (50 to 70%), quartz (20 to 30%), graphite (mostly 5 to 10%, some up to 25%), feldspar (5%), haematite (3 to 5%), and minor amounts of pyrite and tourmaline. All crystals are very small, the grain size of quartz being about 0.02 mm; graphite and sericite occur as platy aggregates disseminated within the matrix. The micaceous minerals are strongly oriented in a schistose fabric with minutely porphyroblastic texture. Chemically, the graphite schist contains 1.5 to 6.2 % carbon.

Three samples from the Mai Po Member have been subjected to heavy mineral analysis (Morton, 1988). Of these, one did not yield useful data, and the remaining two were heavily weathered. The source was probably a mixed volcanic and sedimentary terrain, possibly with some andesitic rocks.

Tai Shek Mo Member

Stratigraphy

The Tai Shek Mo Member outcrops mainly in the north of the district between Lo Wu and Lok Ma Chau. A typical stratigraphic section is exposed on Tai Shek Mo (Crest Hill). The dominant lithology is greyish white to yellowish white, medium- to fine-grained metasandstone, with some quartzite, metaconglomerate and phyllite. Near the base of the succession, up to three metaconglomerate beds have been noted, with a second group of up to three beds occurring in the middle part of the member.

The Tai Shek Mo Member is conformable with the underlying Mai Po Member, and the contact can be seen northeast of Ho Sheung Heung (291 418) and northeast of Tit Hang (275 416); the contact between the two members is transitional. To the southwest the member occurs in isolated outcrops at Shek Shan (223 400) and Mong Tseng Wai (186 377), where the northwest boundary is a northeast-trending fault. The thickness of the member is more than 300 m.

Details

Tai Shek Mo to Lok Ma Chau. The strata occur in a section northeast of Ho Sheung Heung (291 418) and west of Fuk Tak Kung (295 430); the succession is summarized in Figure 5. Metaconglomerate and conglomeratic metasandstone are well exposed on the ridges around Tai Shek Mo (291 424, 292 427, 287 426), at Ma Tso Lung Police Station (282 428). The metasandstone with conglomeratic sandstone also occurs on hills southeast of Lo Wu (300 431).

The coarser-grained clastic rocks are well developed between Tit Hang (275 416) and Ping Hang (271 422). Generally there are one to two beds of metaconglomerate intercalated in the metasandstone, but in some areas five beds of metaconglomerate occur, for example from the northeast of Pak Shek Au (276 410) to the east of Lok Ma Chau (266 416). A metaconglomerate bed approximately 2 to 3 m thick extends for 1 km from southeast of Tai Law Hau (269 417) to the southwest of Ma Tso Lung (276 423); metaconglomerate is also exposed northeast of Pun Uk Tsuen (266 412).

San Tin to Tin Shui Wai. The Tai Shek Mo Member is covered by superficial deposits in this area and only isolated outcrops occur, for example at Shek Shan (223 400) where white, quartzitic sandstone forms a small rocky hill at the river mouth of Shenzhen River. Fine-grained metasandstone with phyllite is the main rock type at Mong Tseng Wai (186 377), while conglomeratic metasandstone occurs to the northeast of Mong Tseng Wai (186 379).

Petrography

The conglomeratic metasandstone in thin section (HK3473, 2920 4271) consists of sub-rounded clastic material, but with flattened quartz grains and elongated quartzite fragments; the rock displays a good foliation. The content of quartz is 60 to 80%, with a grain size mostly from 0.1 to 0.2 mm. The large quartz grains and clasts range from 0.5 to 30 mm, and commonly show undulatory extinction. The matrix is sericite (15 to 25%) and microgranular quartz.

In thin section, the fine-grained sandstone (HK3890, 2843 4297) is essentially quartz, with a distinct bedding structure. The relict clastic materials are quartz grains (60 to 80%) and haematite (5% or less), with minor feldspar and pyrite. The grain size varies from 0.02 to 0.05 mm, with some grains from 0.1 to 0.5 mm. The quartz grain orientation is subparallel, with undulatory extinction. Cementing materials are recrystallized as sericite, forming 15 to 25% of the section and displaying a preferred orientation.

Three samples from the Tai Shek Mo Member have been subjected to heavy mineral analysis (Morton, 1988). Of these, one did not yield useful data, but one was fresh enough to reveal of suite of heavy minerals (HK 6741, 2904 4239). Supply from an andesitic terrain is indicated by the presence of apatite, clinopyroxene, epidote and calcic amphibole, with biotite as a notable extra component.

Chapter 4
Mesozoic Volcanic and Sedimentary Rocks

Classification and Distribution

The earliest work on the detailed stratigraphy of the Mesozoic volcanic and sedimentary rocks of Hong Kong (Uglow, 1926; Brock & Schofield, 1926; Williams et al, 1945; Ruxton, 1960; Allen & Stephens, 1971) is described by Addison (1986) and Strange & Shaw (1986). The first detailed lithostratigraphy of the volcanic rocks is presented by Addison (1986) for the Sha Tin District (Sheet 7). He established the Upper Jurassic Repulse Bay Volcanic Group, and recognised four formations which can be traced westwards into the district (Table 2). In addition, two new formations have been established for the Tuen Mun area, the Tsing Shan Formation and the Tuen Mun Formation, and these formations may be laterally equivalent to the Shing Mun Formation. Allen & Stephens (1971) considered the Repulse Bay volcanics to be equivalent to the Gaojiping Group of Guangdong, which is placed in the Upper Jurassic by Huang (1960) and Nan (1979).

The Repulse Bay Volcanic Group within the district is dominated by tuffs, but there are also outcrops of lavas and sedimentary rocks. As well as the named formations, the present survey has delineated lithological units within the formations such as epiclastic rocks (conglomerate, sandstone, siltstone), tuff-breccia and distinctive crystal tuffs; generalized sequences within the district are given in Figure 7.

Two distinctive formations, the mainly sedimentary Tsing Shan Formation and the Tuen Mun Formation consisting largely of andesite lavas, represent the Repulse Bay Volcanic Group in the Tuen Mun area. While the Tsing Shan Formation is believed to be the older of these two units, the evidence is unclear and the order of superposition should be regarded as speculative. The correlation of these formations with the components of the Group further east is also uncertain, although the weight of lithological evidence suggests lateral equivalents with the Shing Mun Formation.

The Kat O Formation was the name given to red breccias by Ruxton (1960); the type section is on the north point of Kat O Chau. The name has been retained but its age is now considered to be Cretaceous.

The nomenclature and classification of the pyroclastic rocks are based on the recommendations of the IUGS subcommission on the systematics of igneous rocks (Schmid, 1981), and on the work of Fisher & Schmincke (1984), and is summarized in Figures 8 and 9.

Tsing Shan Formation

Stratigraphy

Rocks of the Tsing Shan Formation outcrop as a series of smooth, rounded hills that form a buttress to the granite of Tsing Shan (Castle Peak) on the western side of the Tuen Mun valley. Their contact with the granite is an intrusive shear zone, inclined steeply to the west in most recorded sections. Their eastern boundary is unexposed but appears to be faulted along at least part of its length. Site investigation boreholes southwest of Tuen Mun have permitted the delineation of this boundary under a cover of mass wasting deposits, and have shown that the contact with andesites of the Tuen Mun Formation is also steeply inclined to the west.

The formation comprises a sequence of sandstone, metasiltstone and phyllite, with subordinate tuff, tuffite and conglomerate. Fresh sandstone, siltstone and phyllite are exposed in the steep stream courses that drain across the outcrop from Tsing Shan. The sandstone is mostly fine-grained and quartzitic, and is grey to light greenish grey in colour; it may be weakly foliated. The sandstone is interbedded with foliated siltstone and phyllite of similar colours, although on the interfluves the latter are weathered to light purplish and reddish greys. Cross-bedding and cross-lamination has been recorded in the sandstone.

The eastern part of the outcrop is lithologically varied. Sandstone and foliated siltstone are interbedded with tuff, tuffite and conglomerate, and some layers of sandstone and siltstone carry a scatter of quartz lapilli. The tuff and tuffite include abundant quartz, feldspar and lithic lapilli.

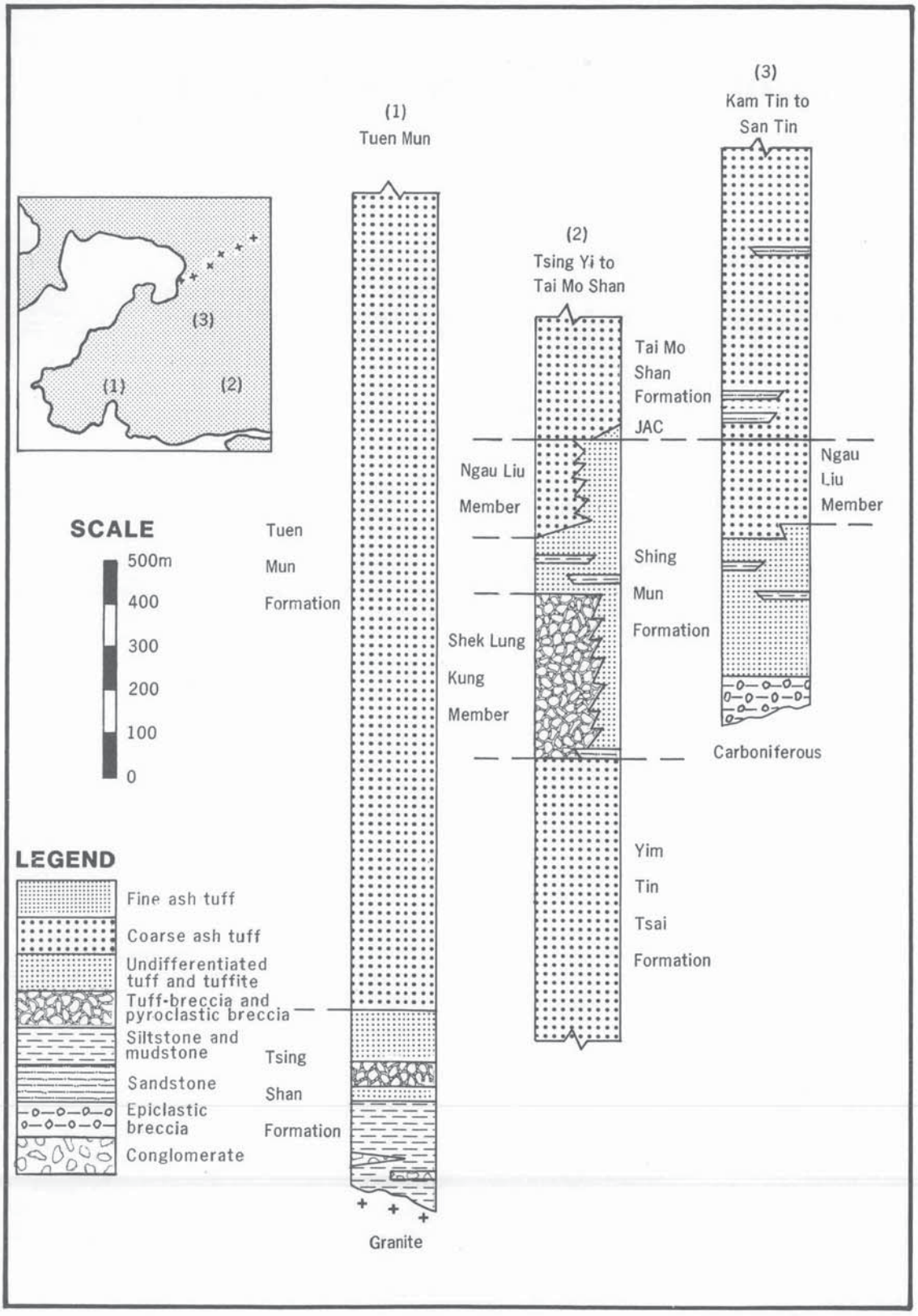


Figure 7 – Generalized Sequences of Repulse Bay Volcanic Group Rocks

The conglomerate comprises gravel, cobbles and boulders up to at least 0.5 m across, with a cemented matrix of sand. Clasts range from sub-angular to sub-rounded, and include sandstone, vein quartz and andesite. Individual beds of conglomerate have been recorded up to 2 m thick; some of these are sharp-based and fine upwards stratigraphically through pebbly coarse sand to fine sand. The conglomerate is typically carious, due to the selective solution of cobbles or gravel clasts.

The stratigraphic sequence through the formation is obscure because of uncertainties over structure. On the basis of sedimentary structures the conglomerate, tuff and tuffite occupy the lower part of the sequence while the upper part is largely composed of sandstone and phyllite. The total thickness of the succession probably does not exceed 250 m.

The relationship between the Tsing Shan and the Tuen Mun formations is uncertain. No andesite has been noted as an intercalation in the sedimentary sequence; borehole data indicates that this contact may be faulted, at least in southwestern Tuen Mun. However, outcrops of lapilli-bearing ash crystal tuff similar to the tuff of the eastern part of the Tsing Shan outcrop have been mapped within the main outcrop of the Tuen Mun Formation. Also, altered andesite was recorded at one locality at the extreme western margin of the Tsing Shan outcrop (1355 2817). Whether this andesite should be regarded as a minor intercalation within the sedimentary sequence or as the basal representative of the Tuen Mun Formation is uncertain, but the latter solution has been adopted.

Details

Tsing Shan (Castle Peak). Quartzitic sandstone, siltstone and phyllite, mostly steeply inclined, are well exposed in the steep stream courses draining the eastern flanks of Tsing Shan. A section in the southern part of the outcrop, near San Shek Wan Tsuen, is representative (1353 2670). Massive to thick-bedded fine-grained quartzitic sandstone showing traces of sedimentary lamination and cross-lamination alternates with beds and partings of grey or pale grey phyllitic siltstone. A more northerly section (1384 2760) includes coarse- to fine-grained sandstone and foliated sandy siltstone, with fining-upward sedimentary units that indicate that the strata are overturned. A bed of light greyish green, slightly foliated tuffaceous siltstone is exposed upstream (1376 2761).

Sandstone and siltstone associated with tuffite and conglomerate were proved under mass wasting deposits in boreholes near San Shek Wan San Tsuen. Borehole 1960D (1375 2726) passed from conglomerate into grey tuff, tuffaceous fine-grained sandstone and siltstone, with layers of coarse-grained quartz sandstone and tuffite as well as scattered coarse sand grains; cross-bedding was noted. Another hole (1962D, 1379 2750) encountered greenish grey metasiltstone, with lithic clasts in some layers.

The conglomerate proved in these boreholes was mainly massive but included some beds of sandstone and tuffite. The lithological features recorded in boreholes 1965D (1383 2724) and 1971D (1385 2730) are representative. Clasts up to about 50 mm across were noted; these were sub-angular to sub-rounded and comprised sandstone, vein quartz and lava. The rock is greenish grey with irregular light brown and white tones in the matrix. Where weathered, the rock was generally ochre-brown, though some clasts were very light grey, white or yellow. Joint surfaces and cavities within the weathered rock fabric formed by the selective corrosion of clasts commonly carried a dark brown or black coating.

The carious weathering of the conglomerate is conspicuous, for example, on the hillside west of the Shan King Estate (1369 2886). In a section of almost vertical strata, conglomerate forms beds up to 2 m thick. The clasts range up to 0.3 m across and comprise coarse- to fine-grained sandstone, vein quartz and dark greenish grey porphyritic lava; the matrix is limonitic and veined with quartz. A fining-upward sequence from conglomerate through pebbly coarse-grained sandstone to fine-grained sandstone was noted, indicating that the strata there are younger towards the east.

Grey to greenish grey, lithic-bearing quartz-rich ash and lapilli tuff, and tuffite are associated with conglomerate along the northeastern margin of the outcrop. A hillside exposure near Tsing Shan Monastery (1392 2802) shows a layer of tuff including rounded boulders of sandstone and abundant dark grey clasts of lava. Similar rocks are well exposed in a stream section southwest of Leung Tin Estate (1363 2920). Tuffites recorded in the boreholes near San Shek Wan San Tsuen (137 273) were light greenish grey and included lapilli and coarse ash debris, mainly of quartz, with angular to sub-rounded lithic clasts up to 40 mm across (1962D, 1379 2725; 1969D, 1383 2724). These tuffites are interbedded variously with sandstone, siltstone and conglomerate.

Sedimentary Environment

For the most part, the formation is characterized by well-graded sediments derived from a siliceous basement. The sediments possibly formed in an intermontane basin, with periodic influxes of coarser material resulting in impersistent conglomerate horizons. Well preserved sedimentary structures indicate a fluvial origin, and the limited lateral extent of the formation points to a narrow basin or channel of deposition. Towards the top of the formation an influx of volcanic material marks a change in the environment from erosional with local deposition to an accretionary volcanic succession.

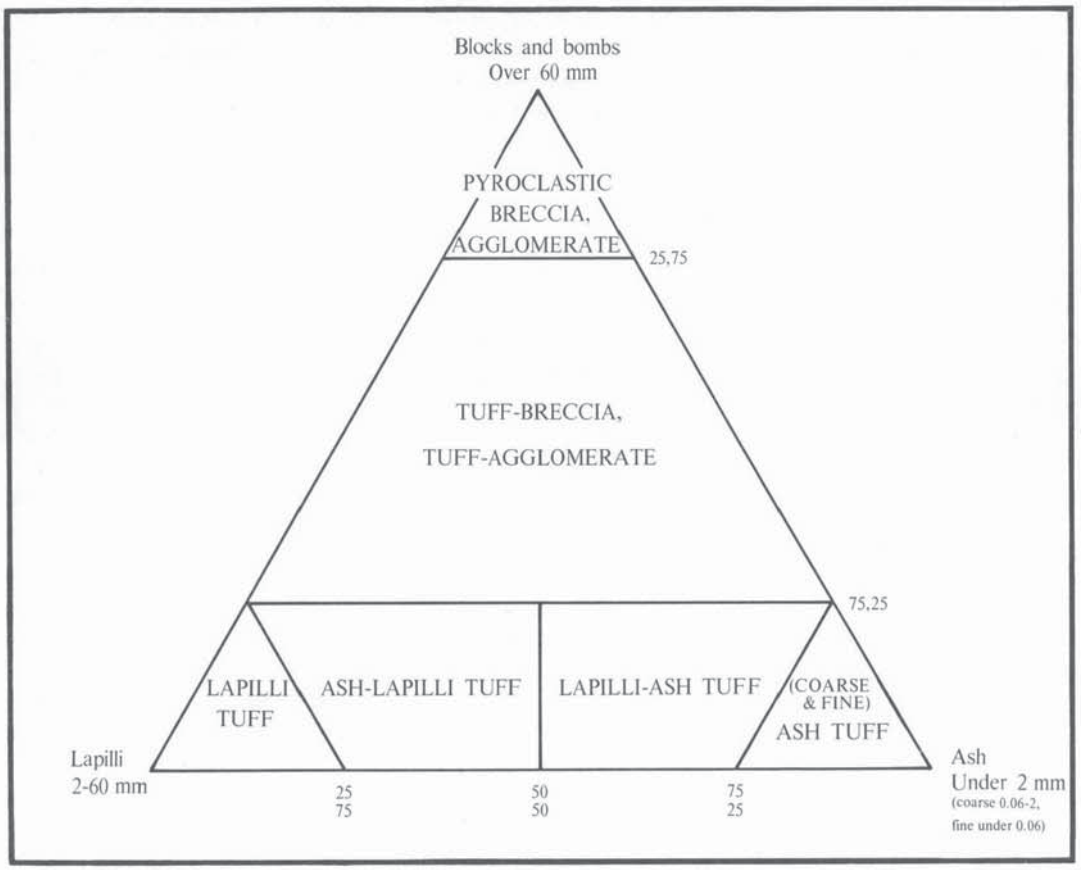


Figure 8 – Classification of Pyroclastic Rocks Based on Composition (after Schmid, 1981)

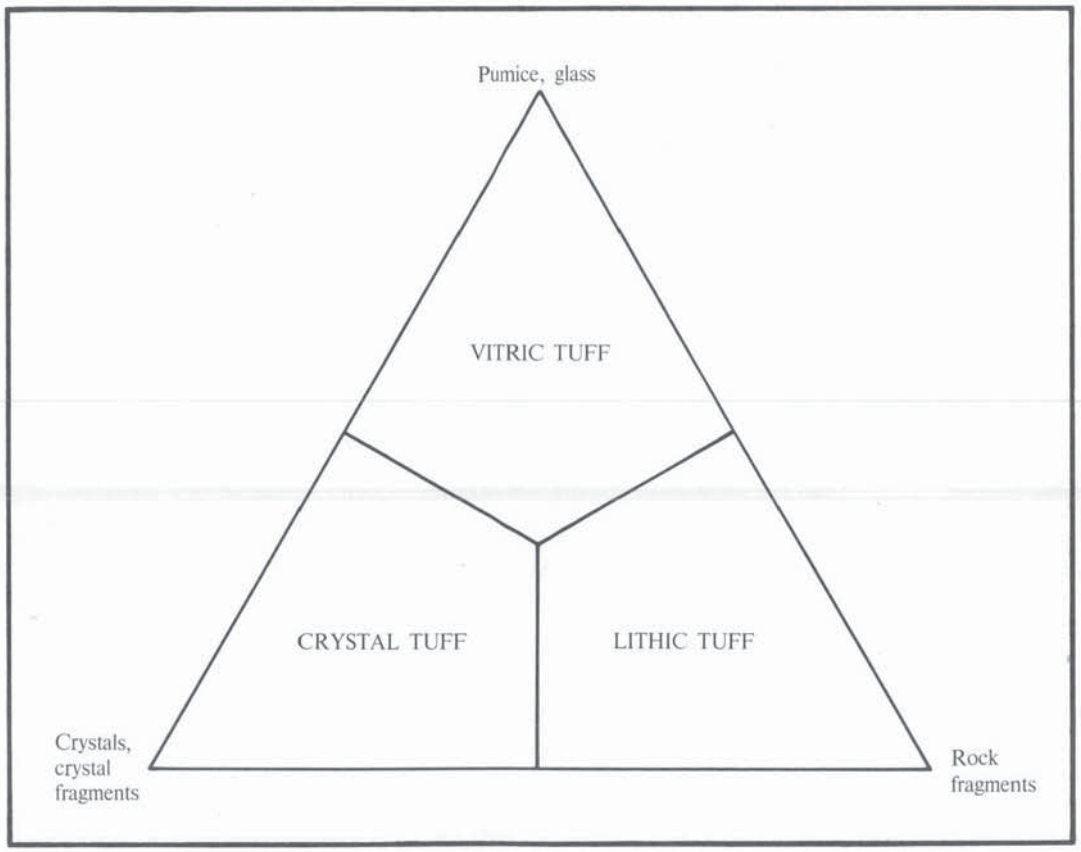


Figure 9 – Classification of Pyroclastic Rocks Based on Grain Size (adapted from Schmid, 1981, Fischer & Schmincke, 1984)

Tuen Mun Formation

Stratigraphy

Volcanic rocks of the Tuen Mun Formation underlie much of the broad valley between Tsing Shan Wan (Castle Peak Bay) and Ha Tsuen to the north. In some parts of their outcrop they form low hills; elsewhere they are deeply weathered and concealed by superficial deposits. The best exposures of fresh rock are in rock cuts for site formations in northwestern Tuen Mun, and these are taken as the type area.

The outcrop of the Tuen Mun Formation is bounded to the east by metasediments of the Lok Ma Chau Formation. The nature of the boundary is unclear, but the existence of conglomerate within the volcanic sequence in a borehole near Mouse Island (1918D/07183, 1546 2717) suggests the possibility of an unconformable relationship. The western limit to the outcrop is formed by the mainly sedimentary Tsing Shan Formation, the contact being steeply inclined and faulted along at least part of its length. In the absence of any structural markers the thickness of the succession cannot be accurately gauged, but it may exceed 2 000 m.

Much of the formation consists of andesite lavas that are dark grey or greenish grey. The lavas are generally massive and may include sub-angular to sub-rounded clasts of similar lava or, more rarely, quartzite. Secondary epidote and pyrite are common. Apparently interbedded with the lavas are pyroclastic layers, mostly lapilli-bearing ash crystal tuffs. The tuffs are light grey to grey, and include lapilli of quartz and lithic clasts in ash dominated by quartz and feldspar; the lithic clasts include tuff, siltstone and fine-grained quartzitic sandstone.

Over much of its outcrop the Tuen Mun Formation has been dynamically metamorphosed, forming light grey and light green phyllite and schist. Associated with these foliated metamorphic rocks are zones in which the rocks have been mineralogically reconstituted so as to largely or completely mask their original nature. It has not proved feasible to subdivide these altered rocks, and they are represented throughout as metamorphosed andesite or, locally, as metamorphosed tuff and tuffite.

Foliation is conspicuous in the vicinity of the granite, striking parallel to the contact. Strong, schistose foliation with an approximate northerly trend affects the formation near Shan King Estate, where it is associated with greisen and quartz veins. Some of the low hills in southwestern Tuen Mun are formed of altered, though not conspicuously foliated, volcanic rocks that are commonly strongly epidotized; thin sections indicate that these rocks are andesite lavas.

Details

Northwestern Tuen Mun. The site formation for the Leung Tin Estate involved the excavation of mainly weathered andesites that were well exposed in temporary trenches at the time of survey. Zones of foliation were noted, as were thin veins of quartz and greisen. Sub-angular to rounded clasts of coarser textured andesite, with feldspar and mafic phenocrysts, were noted, these lithic clasts being up to 70 mm across.

Andesite is well exposed in a stream to the southwest of this site (1380 2944—1349 2926), and includes clasts of a similar rock type up to 0.25 m. There are also clasts up to 80 mm that appear to consist of epidotized quartzitic sandstone. Foliation was noted in parts of this section, as were veins of epidote and quartz. At the top of the section the andesites are in faulted contact with conglomerate of the Tsing Shan Formation.

Further east, towards Tai Hing Estate, metamorphosed andesites form an irregular ridge feature, largely free from superficial deposits. The alteration is extreme on the hillside beside the Shan King Estate (1447 2889). The rock there is schistose and shows tectonic discontinuities with associated contortion, crenulation and quartz veins. In roadside rock-cuts at Shek Pai Tau the formation comprises andesites altered to various degrees; the rock is dark greyish green, slightly foliated and aphanitic (1493 2882). These dark volcanic rocks are cut at intervals by steeply inclined shear zones trending eastnortheast. The rock in the shear zones is sericite schist with a conspicuous light greyish green colour.

An outcrop of tuffs within the formation has been identified some 300 m west of Tai Hing Estate. Like the surrounding andesites, the tuffs are metamorphosed; the rock consists of quartz lapilli up to 8 mm across in a fine-grained sericitized matrix (1464 2918).

Western Tuen Mun. Andesites were recorded in several temporary sections, notably in excavations for a factory building (1478 2828), and in a site formation (1422 2792) and a roadside trench (1453 2795) near Tsing Shan Tsuen. In excavations for road construction (1450 2823) near Yeung Siu Hang the andesites are foliated.

Meta-andesites are exposed in former sea-cliffs and rock-cuts at Tuen Mun Kau Hui. They are dark grey or, where epidotized, green. Temporary sections recorded during road construction nearby showed outcrops of very light greyish green to purplish grey sericite schist (HK 0989, 1473 2804) as well as light grey lithic lapilli-bearing metatuff; the metatuff (1471 2805) is foliated, with lithic clasts streaked out in the plane of foliation.

Southwestern Tuen Mun. Andesite is widespread between the foothills of Tsing Shan and Lung Mun Road, although it is generally deeply weathered and largely concealed by superficial deposits. A major borrow area northeast of San Shek Wan Tsuen (New Town Development Area 19) has been excavated into these weathered andesites, and temporary sections examined during this survey showed khaki silt with white flecks after feldspar phenocrysts and, in places, dark brown blotches after mafic phenocrysts. The fresh rock is exposed in a few places as a result of excavation (e.g. 1402 2685), and consists of dark grey or greyish green andesite containing sporadic clasts of andesite and, rarely, quartzitic sandstone (1380 2685). Epidote staining is common, as is the presence of secondary pyrite. Calcite has been observed as joint coatings. Foliation was noted in some boreholes, notably in those near the contact with the Tsing Shan Formation.

An outcrop of massive, lapilli-bearing ash crystal tuff within the formation was exposed near the southern limit of the Area 19 borrow area (1383 2693). The tuff is light grey and includes lithic and quartz lapilli up to 20 mm across, the lithics comprising siltstone and quartzitic sandstone.

Metamorphosed volcanic rocks included in the Tuen Mun Formation have a wide outcrop both east of Lung Mun Road and to the west of this road in the Hung Lau – Pak Kok area. They are poorly exposed in the low hills to the north of Hung Lau. The rock (1399 2662) is light brown with a crude foliation. Further southwest, at Hung Lau, there are hillside exposures of strongly foliated, very light brown rock.

Strongly foliated, metamorphosed volcanic rocks resembling siltstones are exposed in a stream bed near Pak Kok (1391 2630). Similar rocks, in contact with granite, can be seen at low tide on the shore at the western end of Wu Tip Wan (Butterfly Beach) (131 255), and consist of contorted, highly foliated, partly phyllitic sericite rock, with secondary quartz and iron ore.

Metamorphosed volcanic rocks assigned to the Tuen Mun Formation have been encountered in many boreholes at Pak Kok and in the reclamation area to the east. At the Pak Kok Sewage Pumping Station (1385 2613) is a greenish grey, highly foliated, sericitized rock with pods of andesite aligned in the plane of foliation.

A steeply inclined sheet of volcanic rocks up to 25 m wide outcrops within the Tsing Shan granite and is well exposed in a valley (1096 2664—1095 2619) between Tap Shek Kok and Mong Hau Shek (Pillar Point). The rocks, classified arbitrarily as Tuen Mun Formation, are grey and greenish grey, with pink patches in places. They are partly silicified and foliated in the upstream part of the section, and locally strongly foliated and contorted. Further downstream (1093 2624) there are conspicuous lithic clasts of pink and light green altered andesite and dark grey, fine-grained sandstone; clasts up to 150 mm across were noted.

Eastern Tuen Mun. Volcanic rocks are nowhere exposed in the area south of the Pumping Station at Wong Fung Lek (158 295). However, numerous ground investigation boreholes have penetrated andesitic volcanic and volcaniclastic rocks. Most of the fresh rock is at considerable depth below a thick weathered profile. This weathered andesite is over 130 m thick in fault zones, and is typically 20 m thick (Hunt et al, 1982). The rock is pale grey to greenish grey, often strongly epidotized and sometimes possessing a marked, steeply dipping foliation. Some boreholes clearly show magmatic characters, with small phenocrysts of altered feldspar. However, much of the rock is uniformly fine-grained, strongly fractured and veined. In Boreholes 1912D/7183 (1563 2728) the poorly foliated metavolcanic lies above silvery grey phyllite of the Mai Po Member. A polymictic conglomerate, believed to be a basal unit above the Carboniferous (Langford et al, 1987), was seen in Borehole 1918D/7183 (1546 2717). The clasts of siltstone, quartzite and andesite are found in an andesite matrix which is probably pyroclastic.

Northern Tuen Mun. Around and to the north of Wong Fung Lek (158 295) are exposures of foliated andesitic volcanic rocks (Langford et al, 1987). The foliated rock is exposed on the southern end of the hill (1593 2952) dipping southeast at 63°. The rock is grey, with the foliation well-displayed in secondary biotite. To the northwest, numerous ground investigation boreholes have found a marble clast-bearing andesite. This rock is typically foliated, and the marble clasts are streaked out in the plane of the schistosity. In other boreholes the marble forms angular clasts up to 0.1 m across set in a fine-grained matrix. This block-bearing tuff is probably a vent, as its extent is limited to this small area of northern Tuen Mun.

Petrography

In thin section (HK 4917, 4920, 4931), magmatic fabrics may be seen, with abundant phenocrysts of plagioclase feldspar typically 1 to 2 mm across set in an aphanitic matrix. Many samples show, in addition, altered phenocrysts after a mafic mineral up to 3 mm across. Traces of ragged, primary feldspar can occasionally be seen, with secondary amphibole, biotite and chlorite. Sample HK 4931 (1350 2624) (Plate 5) shows a magmatic fabric, with crowded phenocrysts of feldspar up to 3 mm as well as scattered altered mafic phenocrysts, probably originally of pyroxene. The andesitic nature of the rock is shown by chemical analyses of two samples (Table 4).

Volcanic Environment

Much of the original nature of the rocks is obscured by metamorphism, but it is clear that the formation is dominated by andesitic lavas and pyroclastic rocks. A vent from which some of these rocks may have emanated can be inferred in north Tuen Mun, where marble and other clasts can be found in an andesitic matrix. Breccias or conglomerates which are probably locally derived have been found. These sedimentary rocks may indicate a relatively quiescent start to the volcanic episode.

Table 4 – Major Element Analyses of Meta-tuff Samples from the Repulse Bay Volcanic Group

Element	Tuen Mun Formation		Tai Mo Shan Formation	
	Tuen Mun (1427 2888) HK856	Tuen Mun (1517 2910) HK3788	Kai Keung Leng (2469 3664) HK3587	Lok Ma Chau (2737 4026) HK3588
SiO_2	54.39	53.46	67.91	68.86
TiO_2	1.01	1.48	0.49	0.46
Al_2O	17.19	18.45	13.35	13.61
Fe_2O_3	3.63	6.08	0.37	0.99
FeO	4.87	3.31	3.04	2.28
MnO	0.15	0.11	0.06	0.07
MgO	3.87	1.30	1.30	1.18
CaO	7.26	4.54	2.90	3.60
Na_2O	2.36	4.57	3.15	2.24
K_2O	2.05	4.94	3.75	3.78
H_2O+	2.23	1.44	1.33	1.36
H_2O-	0.11	0.00	0.07	0.06
P_2O_5	0.21	0.79	0.10	0.09
Total	99.33	100.47	98.02	98.58

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 locality is on Yim Tin Tsai in Tolo Harbour, where about 200 m of strata are estimated to lie above a basal sedimentary breccia. In this district the formation has an extensive outcrop up to 300 m thick to the north and west of Tsuen Wan, and on both Tsing Yi and Ma Wan. The formation also occurs beneath superficial deposits at Tsuen Wan, and in the channel north of Tsing Yi and Ma Wan. It has also been found in the Western Aqueduct tunnel between Yau Kom Tau and Tsing Tam Village.

The lithology is a uniform grey to black lapilli-ash crystal tuff, characterized by the presence of elongate or sub-rounded lapilli of coarsely porphyritic lava (Plate 6). Crystals in the matrix are feldspar and quartz, with primary magmatic hornblende and biotite usually present in minor amounts.

On Ma Wan, several thin tuffite bands have been seen. Elsewhere, the only epiclastic features are found where the Yim Tin Tsai Formation tuffs grade into the overlying tuffites of the Shing Mun Formation.

Details

Ting Kau to Yau Kom Tau. The Yim Tin Tsai Formation outcrops on the lower, southern slopes of Shek Lung Kung, where it is in contact with fine-grained granite to the west, and is faulted against sandstone and granodiorite to the east. When weathered, as at Ting Kau headland (2604 2545), the rock is pale creamish grey, and its crystallinity gives it a granite-like appearance. When fresh, as at Sunny Villa, Castle Peak Road (2709 2593), the rock is grey, with prominent, elongated lapilli up to 150 mm long. North of here (2717 2595) the structure of the lapilli is accentuated in the weathered surface of boulders in debris flow deposits. White feldspar crystals in the matrix are up to 7 mm, with quartz up to 3 mm; there is a characteristic speckling of mafic minerals up to 3 mm across, and rare dark lithic lapilli up to 90 mm.

Tsing Yi. The outcrop of the formation on northern Tsing Yi occurs on either side of a granodiorite intrusion. In the west is dark greenish grey to black, porphyritic lava lapilli-bearing ash crystal tuff. In weathered exposures the rock is pale cream with prominent mafics, quartz and feldspar, but indistinct lapilli. On eastern Tsing Yi, 0.5 km north of Fung Shue Wo, dark greenish grey to grey, porphyritic lava lapilli-bearing ash crystal tuff was exposed in the extensive cuts for housing development (284 246). The lapilli are indistinct, and there is much jointing and veining, obscuring the texture of the rock.

Ma Wan. The tuffs of Ma Wan are similar to, or slightly coarser than, those of Tsing Yi. On northwestern Ma Wan (2392 2405) are thin beds of ash tuff, up to 30 mm thick, in a zone less than 5 m wide. Within the beds there are rapid alternations from fine ash to coarse ash; these strata dip roughly north at 56°.

Tsuen Wan. The formation outcrops to the north and west of Tsuen Wan and lies beneath the part of the town reclaimed from the bay. It is well exposed on the slope of Pun Shan Tsuen, above Tuen Mun Road (2855 2620), and behind Allway Gardens (2860 2650); eastwards to the river at Tso Kung Tam (2910 2680) the intrusive contact with the granodiorite is well seen, or can be accurately inferred from boreholes. The rock in this area is grey to dark greenish grey, and resembles the melanocratic and crystalline granodiorite. However, porphyritic lava lapilli and blocks up to 150 mm are present; at Pun Shan Tsuen there are also dark aphanitic lapilli up to 20 mm across. The rock is composed of feldspar and hornblende up to 3 mm, and quartz up to 4 mm set in a fine ash matrix.

Western Aqueduct. The Yim Tin Tsai Formation occurs in the water tunnel along a 2 km section north of the portal at Yau Kom Tau (278 259), again close to the contact with fine-grained granite (2.3 km from the portal) and along a 0.5 km stretch of the tunnel north of the granodiorite, about 1.5 km south of the portal at Tsing Tam (274 313). These exposures indicate a gentle northerly dip, with some disturbance next to the steep-sided igneous intrusions. The rock is almost invariably very dark greenish grey or black, lapilli-bearing ash crystal tuff. The lapilli can be up to 40 mm across in hand specimen, containing feldspar crystals up to 10 mm. Dark lithic lapilli up to 15 mm also occur, in an epidotized matrix dominated both by quartz and feldspar crystals up to 3 mm and by fine ash; mafic minerals are common up to 2 mm.

Petrography

In a typical thin section from the tuffs on Ma Wan (HK 2351, 2386 2401), angular quartz crystals make up 15% of the rock and are up to 4 mm across. The feldspars, equal amounts of both plagioclase and alkali, are up to 4 mm and make up 24% of the rock. Biotite is present either as single flakes up to 1.5 mm or as aggregates of small crystals. The alkali feldspar is often epidotized, while the plagioclase is sericitized. The matrix, 45% of the rock, is finely crystalline, and is the product of recrystallization of an originally glassy and microcrystalline matrix. Hornblende was probably present before alteration, but now only rare, euhedral pseudomorphs composed of epidote and chlorite can be seen.

At Pun Shan Tsuen another typical sample (HK 5052, 2855 2619) has a dominant, finely crystalline matrix of quartz and feldspar (c. 46%), with large quartz pyroclasts as a marked feature (c. 21%). The alkali feldspar, sometimes slightly chloritized, makes up c. 13%, while plagioclase, twinned, zoned and sericitized, forms c. 12% of the rock. There are some euhedral, twinned hornblende crystals (c. 3%) and some biotites (c. 2%).

Diffuse-edged lapilli are often well displayed in thin section (HK 2263; 2678 2427), with a texture like snowflakes (felsic platelets) seen in crossed-polarizers (Plate 7).

Modal analyses were undertaken on seven samples from the formation (Figure 10). Similar modal analyses were obtained by Addison (1986). Relative to the range of rocks found in the Repulse Bay Volcanic Group they are deficient in quartz and rich in plagioclase, with one sample in particular having these characteristics (HK 3987, 2740 2587).

Volcanic Environment

The Yim Tin Tsai Formation is welded and must have been deposited from incandescent ash flows of considerable size. The source of the flow would have been a vent, but there is no evidence that this occurs within the district. The rock unit is notable for its thickness and its extent, stretching north and east into the Sha Tin district (Addison, 1986), as well as south (Strange & Shaw, 1986) and probably to the southwest into Lantau (Strange, oral communication, 1987). The base is not seen, but the top is gradational into the overlying Shing Mun Formation. Epiclastic horizons are absent except near this transitional zone, indicating the dominance of pyroclastic flow in the creation of the rock unit. Flow is indicated by elongation of the lapilli, but no directions can be given. The high temperature of the flows probably resulted in the partial resorption of the lapilli, giving them diffuse edges.

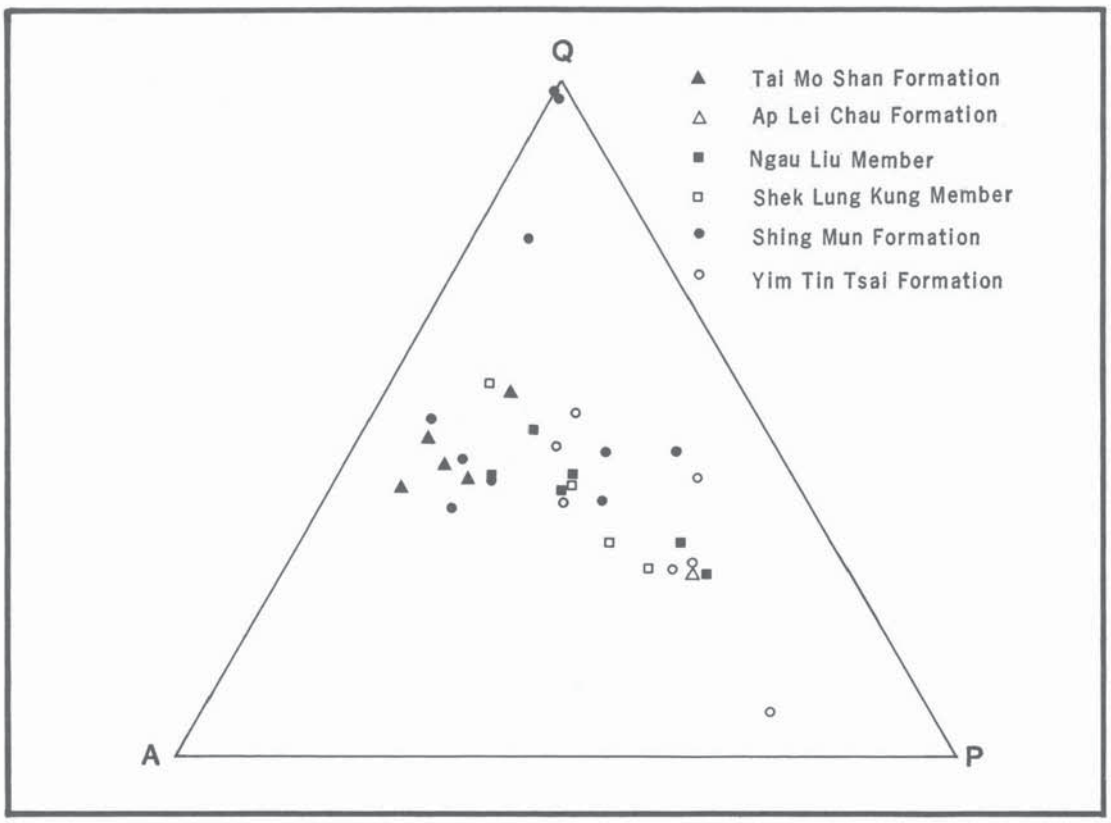


Figure 10 – QAP Diagram Showing Relative Proportions of Minerals in Rocks from the Repulse Bay Volcanic Group

Shing Mun Formation

Stratigraphy

The Shing Mun Formation is characterized by the variety of lithologies within it, although it is dominantly composed of pyroclastic rocks. In this district, two mappable units have been established as members, namely the Shek Lung Kung Member and the Ngau Liu Member. These members are dominantly tuff respectively, and they are described separately. The remainder of the formation includes units of tuff, tuffite and epiclastic horizons which are not differentiated on the map. The undifferentiated formation is up to 300 m thick.

The type locality northeast of Tsuen Wan (Sheet 7) was defined by Addison (1986), and is contiguous with the outcrop north of Tsuen Wan in this district. Similar rocks can be found around Kap Lung, east of Ho Pui Reservoir, north of Tin Fu Tsai and in the hills north and south of Kam Tin. The formation outcrops on the southern and eastern flanks of Tai To Yan, and was found in the Western Aqueduct tunnel between Yau Kom Tau and Tsing Tam Village, and between Tai Lam Reservoir and Ko Po San Tsuen. A small outcrop of the formation lies on the northern shore of Tsing Yi. The outliers of tuff east of the Tai Tong borrow area are included in this formation, although definition of the lithologies is very difficult.

Details

Tai Mo Shan to Tso Kung Tam. There are exposures of tuff, tuffite and sedimentary rocks on the southern and southwestern flanks of Tai Mo Shan. These lie above typical tuffs of the Yim Tin Tsai Formation, and below a thin, probably impersistent outcrop of Ap Lei Chau Formation. The dominant pyroclastic rocks in the area are block- and lapilli-bearing ash crystal tuffs, although there are also tuff-breccias (Plate 8). These lithologies are best seen on the catchwater north of Route Twisk (290 277), and were also seen in site formation works north of Tso Kung Tam (290 274). The rock is grey or, more usually, greenish grey, with lapilli and blocks up to 400 mm of crystal tuff, mudstone, limestone and sandstone. The matrix contains quartz crystals up to 4 mm, feldspar up to 2 mm and lithic clasts up to at least 5 mm.

Pale greenish grey, lithic lapilli-bearing ash crystal tuffs are found around Chuen Lung (290 283) and east towards the Country Park Management Centre (2961 2797). The pyroclasts are dominantly quartz up to 3 mm, feldspar up to 2 mm and lithics ranging from 40 mm down to fine ash, but commonly around 5 mm. The rocks are slightly tuffaceous, and have the characteristic highly varied appearance of the Shing Mun Formation.

Epiclastic and tuffaceous horizons are common, such as in the area east of the Country Park Management Centre (296 280), where a tuffaceous siltstone up to 50 m thick outcrops. Along the catchwater above Route Twisk (2944 2738), finely laminated pale brown siltstone dips roughly westnorthwest at 15 to 25°. On the catchwater west of Route Twisk (2882 2749), tuffaceous siltstone contains lithic lapilli up to 15 mm that sometimes display reaction haloes. North of Chuen Lung (2898 2878) is a grey medium-grained sandstone with indistinct bedding dipping south at 55°. A short way to the north of this exposure is tuffaceous siltstone (2895 2882) with fine irregular bedding dipping roughly northeast at 15°.

Kap Lung. From Route Twisk northwest towards Kap Lung (288 311) the Shing Mun Formation outcrops below the Tai Mo Shan Formation. Dynamic metamorphism of the tuff, tuffite and sedimentary rocks resulted in recrystallization of the matrix to quartz and sericite, so differentiation of mappable rock units is not possible. The pyroclastic rocks are typically grey, lithic lapilli-bearing ash crystal tuff containing quartz and feldspar crystals up to 3 mm across; small lithic lapilli with reaction haloes are common.

On the footpath west of the Shek Kong Lookout (2920 3045) is finely laminated tuffite dipping northnorthwest at 21°. Along strike to the northeast (2970 3075) a pale greenish grey tuffite is exposed on Route Twisk, and this appears to dip southeast at 70°. A dip of 69° roughly southeast was recorded a short distance to the northeast (2978 3091) in a 1 m wide tuffaceous siltstone band within ash crystal tuffs.

Ho Pui Reservoir. Lapilli-bearing coarse ash crystal tuffs outcrop to the east of the reservoir, below crystal tuffs of the Ngau Liu Member. These are generally pale grey, with blocks up to 250 mm and dark lithic lapilli up to 20 mm; the lapilli may have reaction haloes. In parts of the outcrop (2634 3006) there are abundant large clasts and the rock is a tuff-breccia. Contact metamorphism of these tuffs can be seen in the stream north of Ho Pui Reservoir (2555 3011).

North of Tin Fu Tsai, sandstone and tuff form an isolated outcrop bounded by Ngau Liu Member, fine-grained granite and porphyritic fine-grained granodiorite. There are exposures of deeply weathered reddish brown tuff, and the presence of epiclastic rocks is taken as evidence that this outcrop is stratigraphically part of the Shing Mun Formation. The sandstone is only seen as debris on the slopes west of the Fire Lookout (247 287).

South of Kam Tin. The outcrop is characterized by an abundance of epiclastic horizons relative to the main Shing Mun Formation outcrop to the east. This increase in sedimentary intercalations to the west is believed to be a transition to the thick sedimentary pile of the Tsing Shan Formation. Pale grey fine ash crystal tuff (2371 3131) contains quartz pyroclasts up to 3 mm and dark elongated lithics defining a sub-horizontal fabric. Nearby, lithic lapilli-bearing ash crystal tuff (2375 3125) contains scarce pebble-like lapilli up to 15 mm across in a fine ash matrix that contains quartz crystals up to 2 mm.

In an eroded hollow (2363 3085), finely bedded siltstones can be seen overlying pinkish weathered tuffs dipping northnorthwest at 29°. A thermally metamorphosed siltstone with sericitized chiastolite (2345 3102) is exposed to the northwest of this contact dipping eastnortheast at 12 to 22°. These changes of dip result in a complex outcrop pattern, and are caused by the irregular intrusive surface of the nearby granite.

Tai To Yan. On the southern flanks of Tai To Yan the dynamic metamorphism of the tuffs and underlying granodiorite is often severe, resulting in a quartz-sericite metatuff. Original texture is rarely seen, although it is possible to distinguish some sandstone and some lithic lapilli-bearing ash crystal tuff. A possible tuffite can be seen on the path from Kadoorie Farm to Tai To Yan (2922 3321), containing scattered pyroclasts generally less than 1 mm. On the eastern flanks (2871 3339) is a pale brown weathered, medium-grained sandstone which is probably conglomeratic in part; the conglomerate clasts have been dissolved away, leaving well rounded, slightly elongated holes. The clasts probably define bedding that dips roughly northwest at 56°.

Western Aqueduct. North of the portal at Yau Kom Tau (278 259) the succession passes upwards from Yim Tin Tsai Formation into undifferentiated Shing Mun Formation. The dips are very low, but tectonic disturbance at the granite contact produces a repetition of the Yim Tin Tsai Formation. However, from about 1.9 to 2.3 km from the portal the Shing Mun Formation occurs as dominantly fine ash tuff, with quartz up to 3 mm and feldspar up to 2 mm (2721 2773).

North of the granite and granodiorite intrusions, towards the portal at Tsing Tam (274 313), lithic lapilli-bearing, lithic and crystal tuffs are interbedded with tuffaceous siltstone and sandstone. There were parts of the tunnel where sharp-edged, pink porphyritic lapilli could be seen (HK 4671, 2662 2992), such as those typical of the Shek Lung Kung Member. However, for the most part the clasts in the tuffs are dark lithic lapilli up to 25 mm with reaction haloes or, more rarely, quartzite lapilli. The matrix contains quartz crystals up to 4 mm, and feldspar generally less than 3 mm.

South of the portal near Kam Tin (235 329), Shing Mun Formation was exposed in the tunnel between tuffs of the Ngau Liu Member to the north and granite to the south. Shing Mun Formation also forms the roof to a granodiorite intrusion about 1.4 km south of the portal. The formation includes tuffaceous siltstone, sedimentary breccia, tuffite, lithic lapilli-bearing ash crystal tuff, black mudstone with pyrite and pale grey fine-grained sandstone. About 1.6 km south of the portal a dark grey quartzitic siltstone with pyrite dips roughly south at 15° (2367 3148), while a short way to the north the contact between quartzite and overlying ash crystal tuff dips gently in a generally northerly direction; fragments of quartzite are incorporated in the tuff near the contact. The tuff between 1.8 and 2 km south of the portal is dark grey, with quartz up to 3 mm and feldspar up to 4 mm, pale lithic lapilli up to 40 mm and small dark lapilli with pronounced pale reaction haloes.

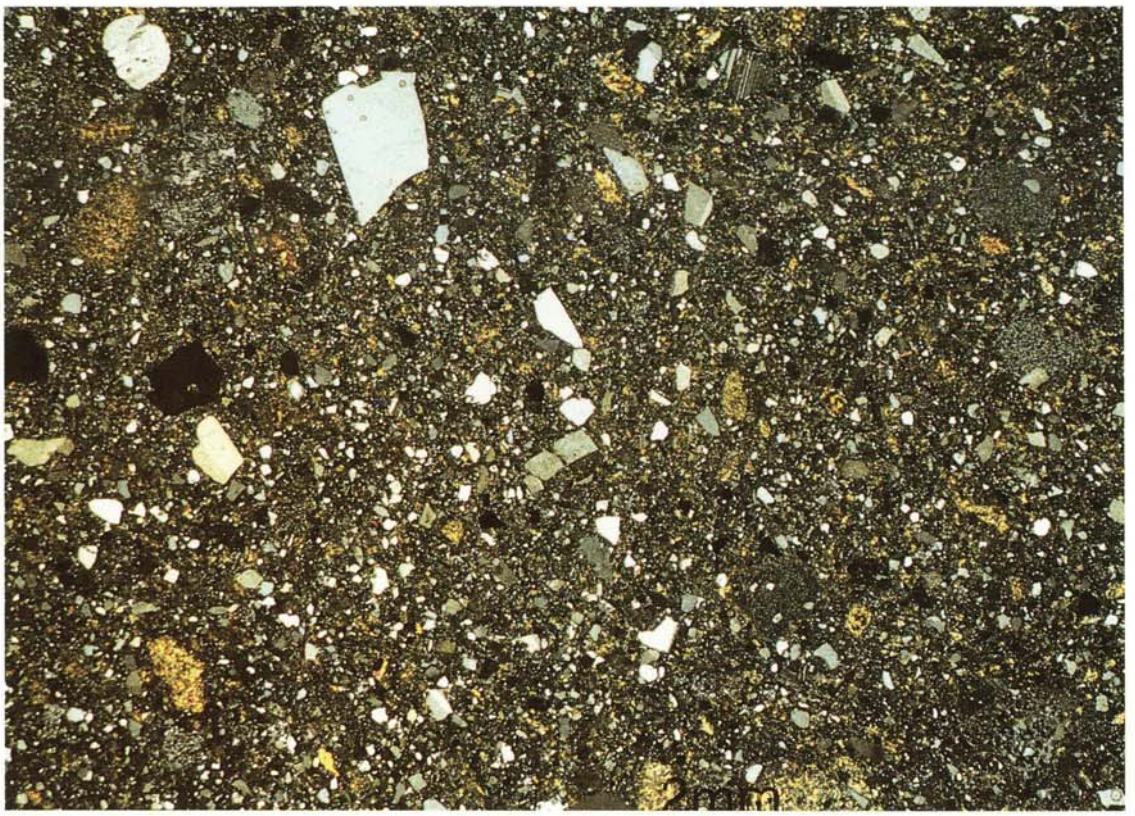


Plate 10 – Thin Section of Tuffite in Shing Mun Formation (HK3246) near Tsuen Wan (2882 2749); XPL × 10

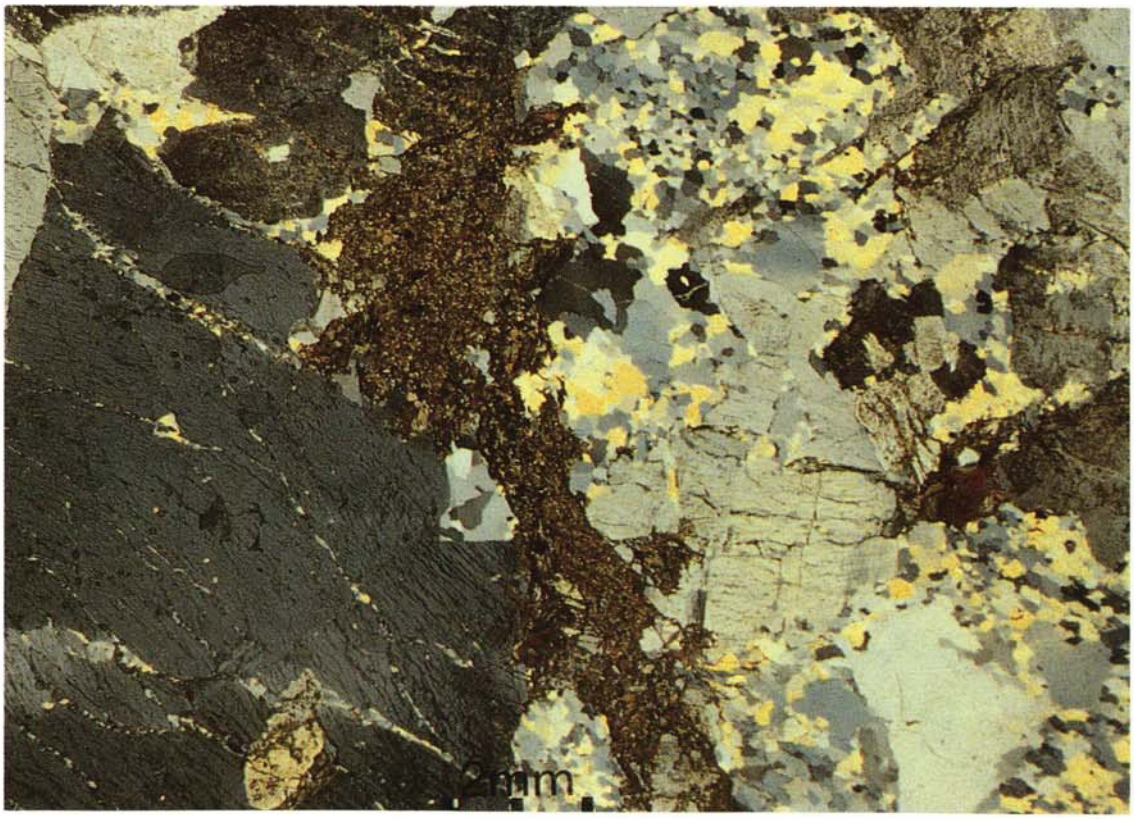
Plate 11 – Thin Section of Lapilli-Ash Crystal Tuff in Shek Lung Kung Member (HK5045) from Shek Lung Kung (2077 2681); XPL × 10

Plate 12 – Leucocratic Granodiorite (HK3381) from Shek Kong (2946 3245); Natural Scale

Plate 13 – Mesocratic Granodiorite (HK5031) from Tsing Yi (2783 2429); Natural Scale

Plate 14 – Coarse-grained Granite (HK2416) from Tuen Mun (161 276); Natural Scale

Plate 15 – Thin Section of Coarse-grained Granite with Microcrystic Texture (HK2416) from Tuen Mun (161 276); XPL plus $\frac{1}{4}\lambda$ plate × 10



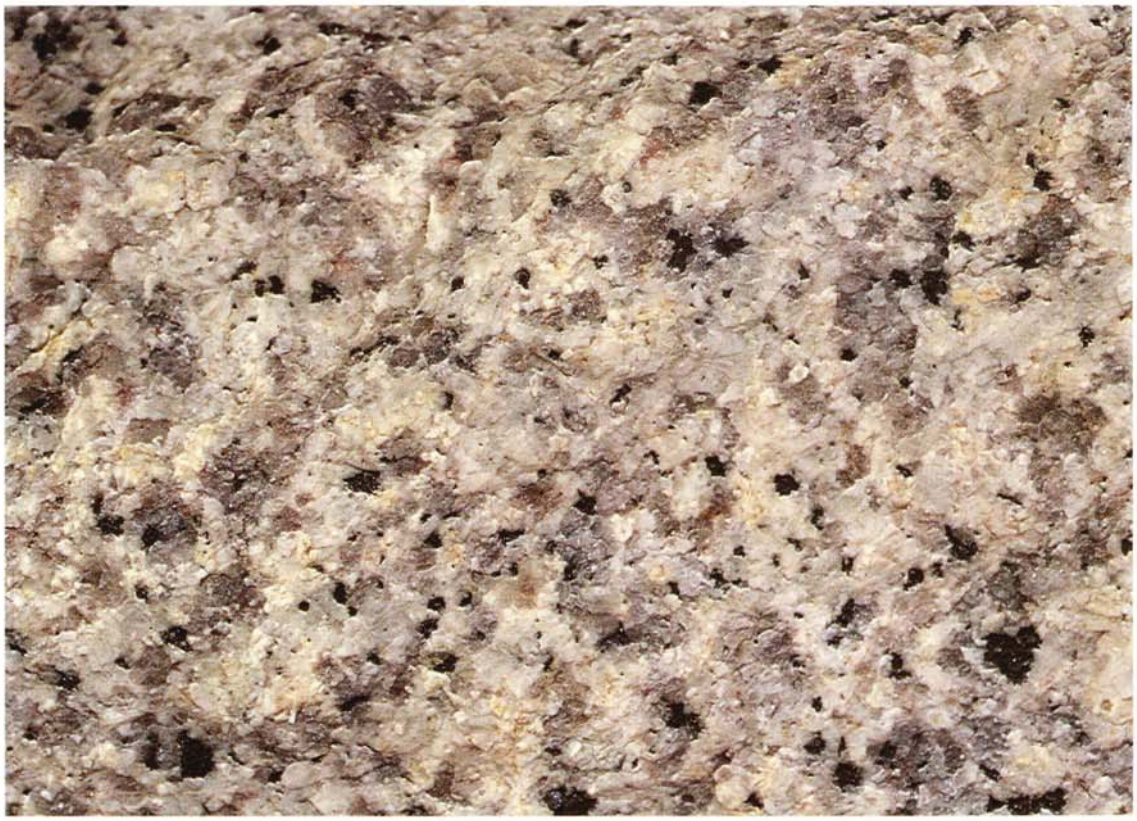
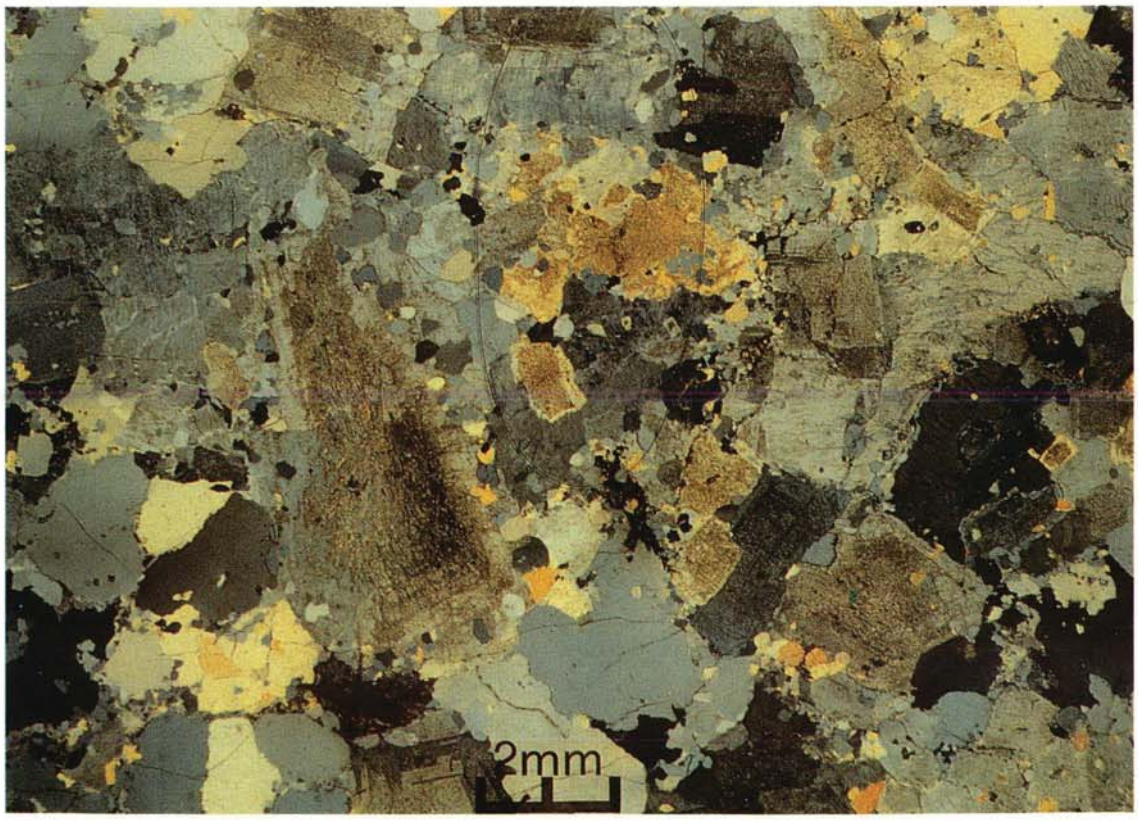


Plate 16 – Medium-grained Granite (HK3112) from Tai Tong (2151 2983); Natural Scale

Plate 17 – Thin Section of Medium-grained Granite with Microcrystic Texture (HK2725) from Tai Tong (2162 3019); XPL plus $\frac{1}{4}\lambda$ plate × 10



Tsing Yi to Yau Kom Tau. From the northern flanks of Tsing Yi to Western Aqueduct portal H at Yau Kom Tau the outcrop of the Shing Mun Formation is dominated by sandstone. A related outcrop of sandstone lies northwest of Pun Shan Tsuen (281 263). This sandstone lies within the Shing Mun Formation, close to the underlying Yim Tin Tsai Formation and at the base of the Ngau Liu Member. Boreholes and large-scale site formation have proved the sandstones and associated tuffites on north Tsing Yi at Fung Shue Wo (274 241). These dominantly epiclastic rocks form a near-continuous band from Fung Shue Wo to the hill slopes at Yau Kom Tau. The rock is either grey or, more usually, it is epidotized and pale green or greenish white. At both Fung Shue Wo and Yau Kom Tau there are sandstones that are more tuffaceous in appearance.

Numerous boreholes south of Ngau Kok Wan (270 245) have proved a transition from the Yim Tin Tsai Formation into distinctively finer tuffaceous rocks of the Shing Mun Formation. However, no exposures were seen, although the contact between the formations, dipping at about 40° to the north, forms a slight erosional feature.

Tai Lam. North of the Tai Lam Country Park Management Centre (229 285) are several outliers of undifferentiated tuff. These may be part of the Shing Mun Formation, although poor exposure and thermal metamorphism by the granite makes assignation uncertain. At one locality on the largest outlier (2291 2997) is grey coarse ash crystal tuff. To the north (2259 3080) is an outcrop containing siltstone, sandstone and crystal tuff. This assemblage is similar to that seen 1 km to the east, which is part of the Shing Mun Formation.

Petrography

Typical tuff from north of Tsuen Wan in thin section (HK 3205, 2884 2783) contains c. 60% fine ash matrix, composed of crystal fragments and alteration products, probably derived from lithic fragments. The pyroclasts are mostly coarse ash, with c. 11% quartz, c. 3% alkali feldspar, c. 10% plagioclase and c. 6% lithic fragments. In addition the rock contains epidote formed by the alteration of lithic clasts and plagioclase.

In thin section a typical tuffite (Plate 10) (HK 3246, 2882 2749) is composed of c. 55% crystals and lithic fragments less than sand-size; the larger crystal fragments are quartz (c. 23%), alkali feldspar (c. 5%) and plagioclase (c. 2%). There are also lithic fragments (c. 5%) and secondary epidote (c. 9%). North of Chuen Lung (2898 2878) is a grey, medium-grained sandstone which, in thin section (HK 3973), contains c. 64% quartz and c. 28% fine quartz-sericite matrix. The tuffaceous origin is shown by alkali feldspar, including microcline (c. 2%), and plagioclase (c. 1%). There are also small quartzitic lithic clasts (c. 5%). Tuffaceous sandstone from Tsing Yi (HK 5034, 2790 2411) contains c. 63% quartz, c. 35% epidote and minor amounts of feldspar and lithics.

A modal analysis of tuffs, tuffites and sedimentary rocks from the Shing Mun Formation (Figure 10) shows that with increasing epiclastic content the quartz content increases. The tuffs fall within the main range for the Repulse Bay Volcanic Group, containing roughly equal proportions of quartz, alkali feldspar and plagioclase.

Palaeontology

Microfossils are rare or absent in most of the samples which have been analyzed, but have been found in the Shing Mun Formation east of Tai Tong (235 310). Here, sandstone and carbonaceous siltstone horizons produced in one instance a moderately diverse Namurian or Westphalian flora (HK 5134, 2355 3118), and in another some poorly preserved bisaccate pollen of Mesozoic age (HK 5311, 2345 3102). The outcrops are probably close to the supposed basal breccia and unconformity between Carboniferous and Jurassic, hence the presence of a derived Carboniferous fauna in one sample. A Mesozoic age for sedimentary intercalations in the Shing Mun Formation is considered likely.

Volcanic and Sedimentary Environment

As the Shing Mun Formation is characterized by thin siltstone and sandstone beds it is assumed that the environment was relatively stable. The sediments and the lahars or mudflows probably accumulated in intermontane basins close to volcanic centres. Some lithic clasts in the tuffs and tuffites have reaction haloes, indicating a high temperature water content on deposition. The tuffaceous nature of most of the sediments indicates local erosion of the volcanic sequence.

Shek Lung Kung Member

Stratigraphy

The Shek Lung Kung Member is roughly equivalent to the agglomerate mapped by Allen & Stephens (1971). It is predominantly a tuff-breccia, with lapilli of an originally vitric nature, and often possesses a flow fabric. The member outcrops only in a restricted area west of Tsuen Wan, around the summit of Shek Lung Kung (2706 2691), where it is about 200 m thick. It lies immediately above Yim Tin Tsai Formation outcrops south of Shek Lung Kung, although the contact is not exposed. To the east, above the catchwater, it lies above tuffs, tuffites and sandstones that form the base of the undifferentiated Shing Mun Formation.

Plate 18 – Pyroclastic Breccia in Shek Lung Kung Member on Shek Lung Kung (2708 2701); Scale Bar 150 mm

Details

Shek Lung Kung to Lin Fa Shan. The type area for the member is on Shek Lung Kung and on smaller hills to the west. The rock is dominantly either tuff-breccia or lithic lapilli-bearing lapilli-ash crystal tuff. It is pale grey, and most of the lithic lapilli are of porphyritic rock with a pale pink glassy matrix. The glassy lapilli have sharp edges and are up to 70 mm long. They are elongated or flattened and define a linear or planar fabric. The pyroclasts are mostly coarse ash crystals of quartz up to 5 mm and feldspar up to 7 mm. There are also lithic lapilli and blocks of tuff or epiclastic material up to 150 mm. Westsouthwest of Shek Lung Kung (2677 2681) the welding fabric dips southsoutheast at 30°, while nearby (2675 2664) it dips roughly northnorthwest at 18°.

North of Shek Lung Kung (2708 2701) is an exposure of pyroclastic breccia with poor sub-horizontal layering (Plate 18). This rock contains blocks of crystal tuff up to 1.5 m across, although most clasts are 0.1 to 0.5 m. East of Ha Fa Shan (282 267) is a pale grey tuff-breccia with some blocks up to 250 mm. There is a sub-horizontal elongation in the blocks and lapilli. Some of the lapilli are glassy and porphyritic, as seen at the type area.

Eastsoutheast of Sheung Fa Shan (279 275) the member comprises pale grey lapilli-bearing ash crystal tuffs characterized by the presence of pale porphyritic lapilli and blocks up to 100 mm. In the matrix are quartz crystals up to 4 mm and feldspar up to 3 mm.

On a summit north of the abandoned school (2672 2739) the clasts in the lithic lapilli and block-bearing tuff display a rough layering which is either sub-horizontal or dipping gently south (Plate 19). The rock is grey, and contains quartz crystals up to 3 mm and dark lithic fragments around 6 mm across.

Petrography

In a thin section of a sample from Shek Lung Kung (HK 5045, 2077 2681) the porphyritic lapilli are readily apparent (Plate 11). The porphyritic lapilli are composed of 59% matrix with a devitrified, snowflake-like texture. The phenocrysts are glomeroporphyritic plagioclase (c. 18%), alkali feldspar (c. 9%), hornblende (c. 10%), quartz (c. 2%) and possible altered biotite (c. 2%). The tuff matrix in which the lapilli are set is composed of c. 48% microcrystalline material, quartz (c. 13%), alkali feldspar (c. 11%) and plagioclase (c. 21%), with minor amounts of hornblende and possible altered biotite.

A modal analysis of four specimens from the Shek Lung Kung Member shows a broad spread across the centre of the range for the Repulse Bay Volcanic Group. Overall, the tuffs have a QAP composition between that of the underlying Yim Tin Tsai Formation and the overlying undifferentiated Shing Mun Formation.

Volcanic Environment

The Shek Lung Kung Member is a localized, welded pyroclastic flow. The impersistent nature probably indicates a restricted, possibly valley-controlled flow or caldera collapse, and the flow direction can be inferred from the linear fabric as roughly northwest-southeast (Fisher & Schmincke, 1984).

Ngau Liu Member

Stratigraphy

The Ngau Liu Member is roughly equivalent to the coarse tuff as mapped by Allen and Stephens (1971) in the area west of Tai Mo Shan towards Tin Fu Tsai. It is composed of crystal-vitric tuff, tuff in which the crystal and vitric components are roughly equal. The rock is characteristically pale grey, with prominent mafic minerals, and has a granite-like appearance. It outcrops between Ngau Liu, Tin Fu Tsai and Tsing Tam Village, and in the vicinity of Kam Tin. It was also exposed in the Western Aqueduct both south and north of Kam Tin. The distinctive rock type of the member has also been seen on Tai To Yan, but the member remains undifferentiated in that area. The member is up to 250 m thick near the type locality at Ngau Liu.

Details

Ngau Liu to Tin Fu Tsai. The type locality is east of the Forestry Post on Route Twisk, near Ngau Liu (283 295). A complex fault zone obscures stratigraphic relationships with the overlying Ap Lei Chau and Tai Mo Shan formations. To the north and west of the outcrop are tuffs and sedimentary rocks of the lower part of the Shing Mun Formation, while granodiorite outcrops to the south. The rock is pale grey, almost white, and superficially resembles fine-grained granite. It is a lapilli-ash to coarse ash crystal tuff, dominated by crystals of quartz and white feldspar less than 4 mm across and mafic minerals less than 3 mm, set in a very fine-grained matrix.

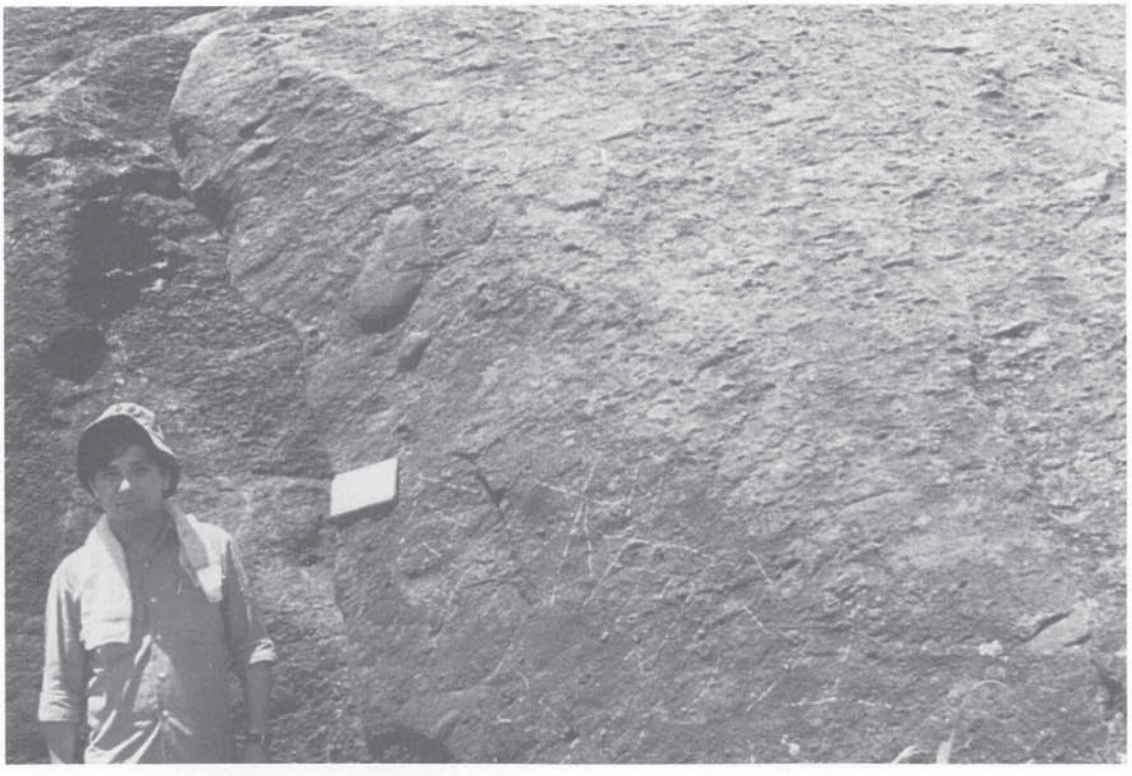


Plate 19 – Flow Fabric in Lapilli-ash Crystal Tuff in Shek Lung Kung Member on Lin Fa Shan (2672 2739)

To the west of the type locality, around a Fire Lookout (273 293), the rock is pale crystal tuff with prominent mafics less than 1 mm, and it contains small, dark rounded lithic lapilli up to 50 mm across. In the hills about 1 km east of Tin Fu Tsai, at another Fire Lookout (2502 2864), is a pale grey lapilli-bearing ash crystal tuff with small mafic crystals and pale, porphyritic lapilli less than 15 mm.

South of Kam Tin. In the hills to the south of Kam Tin an outcrop of crystal tuff is overlain by lapilli-ash crystal tuff of the Tai Mo Shan Formation. To the south are fine ash tuff, siltstone and sandstone of the underlying undifferentiated part of the Shing Mun Formation. Dynamic metamorphism has affected the tuffs of the Ngau Liu Member, but when unaltered the rock is pale grey with the characteristic granite-like appearance.

Kap Lung. Crystal tuff of the Ngau Liu Member outcrops about 1 km south of Kap Lung (288 307). Most of the outcrop is, however, dynamically metamorphosed, and the coarse ash crystal tuff is altered to a dark quartz relict-bearing fine-grained metatuff. This metamorphism obscures the relationship with the rest of the Shing Mun Formation below and with the granodiorite and fine-grained granite surrounding the outcrop. The unmetamorphosed rock (2836 3089) has quartz and feldspar crystals up to 3 mm, abundant small mafic crystals and the characteristic crystalline appearance.

Western Aqueduct. Crystal tuffs of this member have been exposed in the water tunnel in two places. About 1 km south of the portal at Ko Po Shan Tsuen is pale grey lapilli-ash crystal tuffs with a crystalline appearance. The tuff bears the characteristic small mafic crystals seen elsewhere in the member, and has quartz and feldspar crystals up to 4 mm across. In thin section they are known to have small microcline crystals, hornblende or biotite, and a finely crystalline matrix. About 250 m north of the portal at Fung Kat Heung were exposures of crystal metatuff finely speckled with mafic crystals.

Tai To Yan. On the southern flanks of the hill (298 332) is an isolated exposure of markedly crystalline, grey lapilli-ash crystal tuff speckled with mafic minerals. The area is one of intense dynamic metamorphism, although original rock textures are preserved in isolated patches. The lithology is ascribed to the Ngau Liu Member, but cannot be distinguished on the map from the rest of the Shing Mun Formation.

Tsing Tam Reservoir. Exposures of a pale grey granite-like tuff outcrop to the north of the typical undifferentiated Shing Mun Formation. The pale, lapilli-ash crystal tuff (2630 3079) has a scattering of mafics up to 2 mm, and quartz and feldspar crystals up to 5 mm; the matrix is very fine-grained.

Yuen Shan. North of Kong A Leng are exposures of lithic lapilli-bearing coarse ash crystal tuff (2505 3422) with the appearance of typical Ngau Liu Member. The rock is grey, with lithics up to 8 mm, quartz up to 3 mm and partially replaced feldspars with secondary biotite rims. Further north (2587 3474) is a pale grey ash crystal tuff with quartz up to 4 mm and feldspar up to 6 mm. The dominant matrix and presence of microcline in thin section are typical features of the member.

Petrography

In thin section, the Ngau Liu Member is characterized by a microcrystalline matrix which makes up 45 to 55% of the rock. Within this matrix, microcline pyroclasts are a characteristic feature, and biotite or hornblende may also be found.

In a typical sample from Ngau Liu (HK 3965, 2831 2949), the rock is composed of c. 50% microcrystalline matrix. Quartz is the dominant pyroclast type (c. 15%), while plagioclase (c. 11%) and alkali feldspar (c. 10%) are the other major crystal components; microcline makes up c. 20% of the alkali feldspar content. The mafic mineral is biotite, mostly secondary regrowth, but including primary crystals up to 2 mm long.

In a thin section of a sample from near Tin Fu Tsai (HK 5861, 2740 2940) the quartz pyroclasts (c. 13%) show some signs of resorption as well as pyroclastic features. The alkali feldspar (c. 10%) has slight incipient alteration, while the plagioclase (c. 28%) is sericitized and epidotized. The only mafic mineral is hornblende (c. 4%), while c. 5% of this section is composed of lithic clasts. The matrix is finely crystalline and makes up c. 45% of the rock.

Alteration in the tuffs in the Western Aqueduct shows itself as calcite and epidote in thin section (HK 4590, 2434 3563). It is possible to distinguish microcline even though it is partially altered. Similarly, near Kam Tin (HK 5315, 2505 3422), the effects of the metamorphism are readily apparent, with secondary biotite, calcite, sericite and recrystallization of quartz. However, the texture is dominated by the finely crystalline matrix, and there is possible microcline altered to biotite and calcite.

The modal analysis of six samples from the Ngau Liu Member (Figure 10) shows that they are compositionally broadly equivalent to the rest of the group. However, some samples tend towards the anomalous Yim Tin Tsai Formation composition.

Volcanic Environment

The Ngau Liu Member was deposited as a pyroclastic flow which, although widespread, is small by comparison with some of the formations. The tuff is welded and structureless.

Ap Lei Chau Formation

Stratigraphy

The Ap Lei Chau Formation was described from the type locality on Ap Lei Chau by Strange & Shaw (1986). The typical welded tuff with prominent eutaxite bands is not seen in this district. Rather, the outcrops are a continuation of those seen on Tai Mo Shan by Addison (1986), who mapped the formation between the underlying Shing Mun Formation and the overlying Tai Mo Shan Formation. In this district the formation is less than 15 m thick.

In this district the formation outcrops in the area between Ngau Liu and Tai Mo Shan. Here, the limited exposures are of light grey vitric tuff, sometimes with possible fiamme. There are usually scattered, small quartz crystals present, but the overriding character, consistent with typical Ap Lei Chau Formation, is of a vitric rock. The outcrop is discontinuous, and relationships with other rock units are unclear. Although the Ngau Liu Member and the Ap Lei Chau Formation are in apparent contact, superposition cannot be demonstrated.

Details

Chuen Lung to Ngau Liu. The characteristic rocks of the Ap Lei Chau Formation in this area are grey, crystal-bearing fine ash tuffs. The crystals are dominantly quartz, mostly less than 5 mm across, although there are also biotite plates up to 2 mm and feldspars up to 3 mm. There may also be lithic lapilli up to 10 mm. At some localities there is a planar fabric in the rock, probably the result of welding, and in an exposure on Route Twisk (2890 2925) this is evident from a biotite alignment which dips roughly northwest at 21°. Near the Country Park Management Centre (2882 2972) the tuff has a fiamme-like structure, but it is very poorly developed.

Petrography

In thin section, the rocks vary from crystal-poor to crystal-rich tuff, but with a characteristically glassy, recrystallized matrix. Sample HK 3964 (2882 2972) has been metamorphosed, and the matrix is very fine-grained quartz and sericite. However, good quartz crystal splinters can been seen, as well as possible feldspar and biotite crystals. The matrix makes up over 90% of the rock, with quartz pyroclasts only c. 4%. A lapilli-ash crystal tuff with vitric matrix is exposed 0.7 km westnorthwest of Chuen Lung (HK 3978, 2850 2869). It has only c. 38% matrix, with c. 14% quartz, c. 11% clear alkali feldspar, c. 29% sericitized plagioclase and c. 8% biotite. A modal analysis of this specimen shows it to be compositionally similar to the Yim Tin Tsai Formation. However, this is not necessarily representative, particularly as the matrix content is much lower than more typical Ap Lei Chau Formation rocks (Strange & Shaw, 1986).

Volcanic Environment

The Ap Lei Chau Formation originated as an incandescent ash flow. The unit is very thin and impersistent in the district, and may be the distal portion of a much larger flow extending from the east and south. A similar, poor development was found in Sha Tin district (Addison, 1986).

Tai Mo Shan Formation

Stratigraphy

The Tai Mo Shan Formation is best exposed on Tai Mo Shan, where Addison (1986) describes the type locality. It is dominantly a lapilli-ash or coarse ash crystal tuff, and the outcrop is contiguous with that in the district. The rock varies from pale grey to dark grey, and is characterized by a matrix containing euhedral white feldspar crystals and quartz crystals. Small lithic lapilli of dark aphanitic volcanic rock or sandstone are usually present.

The formation outcrops on the western flanks of Tai Mo Shan, across most of Tai To Yan, over the whole of Kai Keung Leng and all the hills north to Hadden Hill, and on Ho Hok Shan and hills to the south. The formation was also intersected in the Western Aqueduct between Tai Lam Reservoir and Hadden Hill. The total thickness of the formation is in excess of 500 m. Nearly all of these outcrops are metamorphosed to some degree, with the loss of much of the original texture. Only west of Tai Mo Shan is the rock seen in its typical state.

Within the tuffs are rare bands of slightly tuffaceous sandstone. The bands are narrow and impersistent, but provide the only structural data in an otherwise featureless expanse of crystal tuffs. These sandstones, up to 30 m thick, are found north and northeast of Ngau Tam Mei, on the southern flanks of Kai Keung Leng and south of Kam Tin.

Details

Tai Mo Shan to Ngau Liu. To the west of Tai Mo Shan, above Route Twisk, are exposures of pale grey, lithic lapilli-bearing, ash and lapilli-ash crystal tuff. The lithics are generally rounded to sub-rounded, up to

15 mm across, dark grey and very fine-grained. The pyroclasts are dominantly quartz and feldspar that range in size from 6 mm to down to fine ash. The rock is characterized by the uniform scattering of subhedral, white feldspar crystals (Plate 20) and the small, dark, pebble-like lapilli.

South and southeast of Ngau Liu are outliers of the formation, probably resting on Ap Lei Chau Formation. At one locality (2854 2896) the grey ash crystal tuff is bomb-bearing. The bombs are up to 150 mm across and are very fine-grained in thin section (HK 3976); they may be lava or densely welded tuff. The tuff of this area is typically homogeneous, containing quartz and feldspar crystals up to about 3 mm, and, apart from the bombs, contains very rare, small lithic clasts.

Tai To Yan. On the southern and western flanks of Tai To Yan is lithic lapilli-bearing lapilli-ash crystal tuff of the Tai Mo Shan Formation. The rocks are dynamically metamorphosed to some degree, and the metamorphism is severe in a northeast-trending belt from Pat Heung across the summit of Tai To Yan. The slightly metamorphosed tuff is pale grey to grey, with prominent feldspar crystals up to 8 mm, quartz up to 6 mm and rare lithics, mostly grey aphanitic lapilli up to 30 mm. The slight metamorphism obscures fine detail in the matrix, and in the strongly metamorphosed zones only relict quartz megacrysts remain of the original tuff texture.

Ho Hok Shan. The northern part of this area is dominated by schistose metatuff, but south of the summit of Ho Hok Shan the metamorphosed zones are restricted. The rocks are lithic lapilli-bearing coarse ash crystal tuff, with at least one narrow sandstone unit. The tuff is pale grey, weathering pale orange brown, with quartz and feldspar crystals generally up to 4 mm, and lithic clasts up to 25 mm. Some lapilli are porphyritic and pale, while others are aphanitic and dark.

Pale brownish grey tuffaceous sandstone about 30 m thick is exposed on a ridge about 2 km southeast of Ho Hok Shan (2454 3214), dipping 20° eastsoutheast. Tuffaceous siltstone debris indicates the presence of another sedimentary unit stratigraphically below the sand stone, but the outcrop form has not been determined. These two sedimentary units may correlate with those seen on the southern flanks of Kai Keung Leng.

Kai Keung Leng. The tuffs of Kai Keung Leng are mostly affected by dynamic metamorphism, either in broad zones or narrow northeast-trending belts. Where original tuff textures are not obscured the rock is dark grey lapilli-ash crystal tuff, often bomb- and lithic lapilli-bearing. Sandstone units outcrop on the southern slopes of the hill. On the western end of the ridge (2464 3600) the tuff contains bombs of vesicular lava and possible pumice up to 250 mm across. At two localities east of Kai Keung Leng (572 m) the large clasts define a flow fabric that dips gently to the south (2720 3612) or southwest (2727 3593).

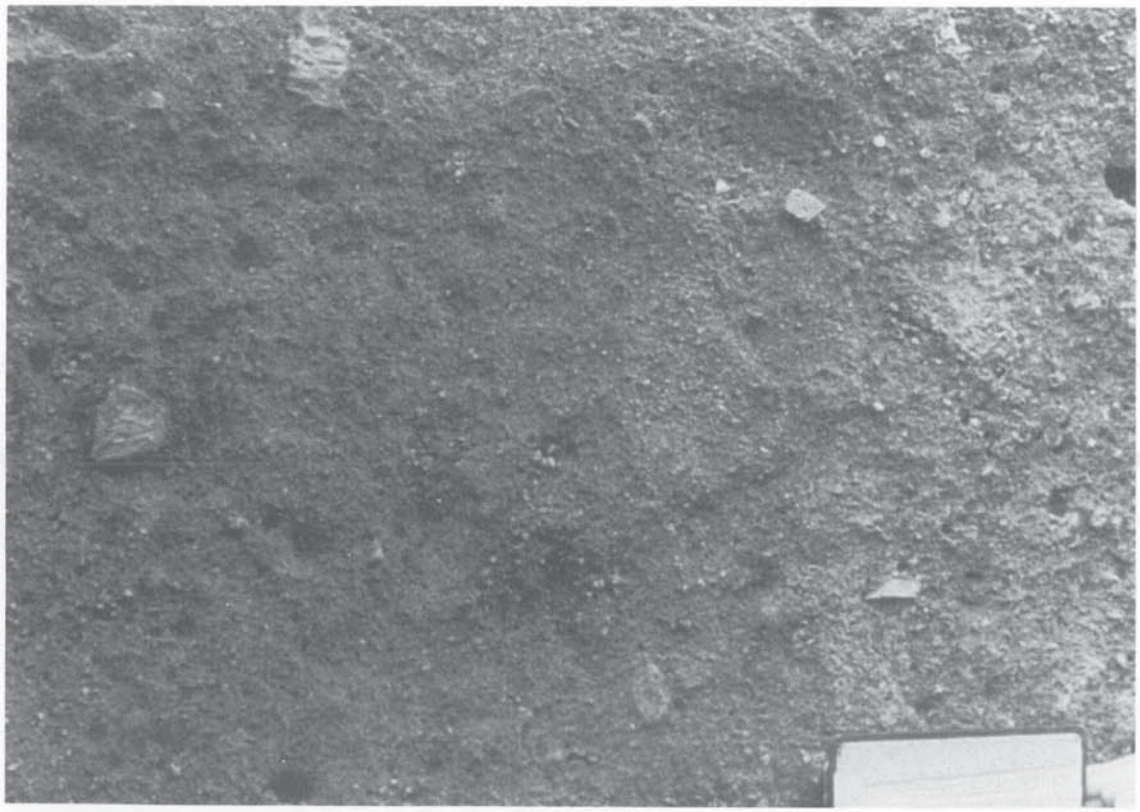


Plate 20 – Lithic Lapilli-bearing Coarse Ash Tuff in Tai Mo Shan Formation on Tai To Yan (2958 3440); Scale Bar 150 mm

Two tuffaceous sandstone units can be traced along the hillside south of the summit (260 352). Each unit is less than 20 m thick and impersistent along strike; they probably dip steeply to the north, and may correlate with two metasandstones on the western end of the hill (246 354). A series of exposures of fine-grained sandstone can be seen near the base of the southeast flanks of the hill, for example behind the Fire Services Department Training School (2810 3528). At one locality (2709 3481) the sandstone dips roughly north at 57°.

Western Aqueduct. Grey, lithic block- and lapilli-bearing, lapilli-ash crystal tuff was exposed in the water tunnel for about 1 km south from the portal at Ko Po Shan Tsuen (235 329). The rock contains scattered dark lithic clasts up to 200 mm, conspicuous feldspar crystals up to 6 mm and quartz pyroclasts up to 4 mm across, but dynamic metamorphism obscures the original detail of the finer matrix.

About 0.4 km northeast of the portal at Fung Kat Heung are grey metatuffs and quartzite (2419 3593). For the most part the effects of dynamic metamorphism obscure the original texture. Close to the portal (2457 3576) is a grey lapilli-ash crystal tuff with quartz crystals, feldspar crystals and possible lithics up to 4 mm. Further along the tunnel (2476 3586) there was a narrow exposure of quartzite with scattered quartz crystals less than 1 mm.

Petrography

Typical tuff found west of Tai Mo Shan contains in thin section c. 24% quartz, c. 22% alkali feldspar and c. 5% plagioclase (HK 3223, 2982 3003). There are well-defined lithics (c. 11%), either aphanitic igneous rock or fine-grained sandstone, and the rock also contains c. 37% fine ash matrix.

In a slightly metamorphosed tuff from the Western Aqueduct south of Kam Tin (HK 872, 2370 3217), the matrix is dominant (c. 51%), and is composed of finely divided quartz, secondary biotite and calcite. This matrix may obscure the lithic clasts (c. 2%), but the crystal pyroclasts generally show little alteration. Quartz forms c. 25% of the rock, with alkali feldspar c. 14% and plagioclase c. 7%. There may have been some biotite, but only secondary mineral assemblages remain as pseudomorphs.

Modally, the Tai Mo Shan Formation of this district is quite distinct (Figure 10). The five samples analyzed are markedly deficient in plagioclase relative to the broad spread for the group as a whole. Furthermore, they appear to be compositionally uniform, and have their closest equivalents is some tuffs of the Shing Mun Formation. This contrasts with the findings of Addison (1986) in the Tai Mo Shan and Pak Kong areas.

Geochemistry

In this district, two samples of Tai Mo Shan Formation tuff have been chemically analyzed (Table 4). Both are metamorphosed to some degree, but are essentially the same composition as tuffs from Sha Tin district (Addison, 1986).

Volcanic and Sedimentary Environment

The Tai Mo Shan Formation is dominated by tuffs formed from incandescent ash flows (Addison, 1986). As the formation is extensively developed throughout the east and north of the district, and both east (Addison, 1986) and southeast (Strange & Shaw, 1986) into adjacent districts, the flows would have been very large. The formation is lithologically uniform, and probably originated from a large fissure or fissures. That the formation is composed of more than one flow, at least in part, is shown by the sedimentary intercalations. These sandstones are tuffaceous and are probably derived from erosion of the unlithified tuffs of the formation.

Kat O Formation

Stratigraphy

The Cretaceous Kat O Formation is characterized by breccia, conglomerate, sandstone and siltstone with a red or reddish brown colour. These rocks are exposed in a narrow faulted outcrop about 800 m long that forms a small headland at Lau Fau Shan (166 370) on the south coast of Hau Hoi Wan (Deep Bay). It may also be exposed at Shan Pui near Yuen Long, where the sedimentary breccia may be sufficiently lithologically distinctive to identify the formation.

Details

Lau Fau Shan. The succession at Lau Fau Shan comprises about 100 m of dark reddish brown, thickly bedded, poorly to semi-sorted breccia with some conglomerate, thin beds of coarse-grained gritty sandstone and well-sorted siltstone; some of the strata show graded bedding. The fragments are mainly angular to subangular ranging from 5 to 65 mm in diameter, and occasionally up to 300 mm; most are composed of tuff, quartzite, sandstone and siltstone set in a muddy sand matrix. Coarse-grained arkosic sandstone occurs near the margin of the fault basin (167 371) and appears to be derived from the adjacent granite area.

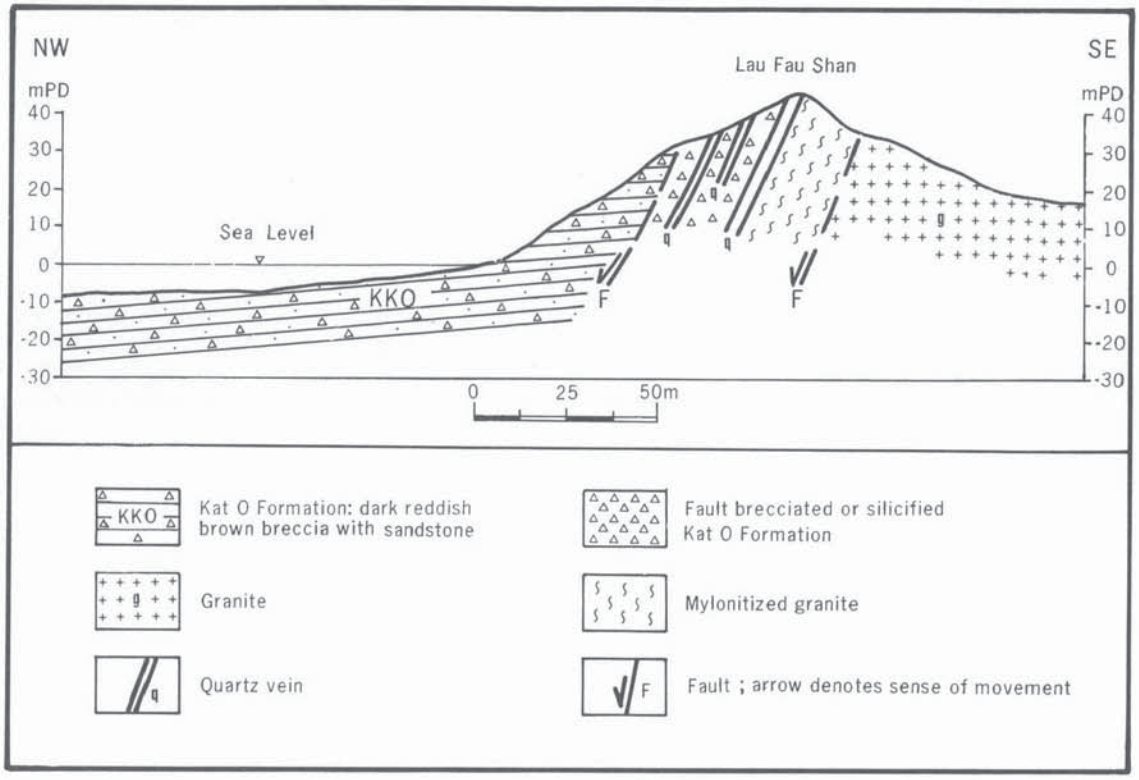


Figure 11 – Geological Section of the Kat O Formation at Lau Fau Shan (116 370)

The contact between the formation and granite is the Lau Fau Shan fault forming a fault scarp facing the sea on the northwest (Figure 11). The strata dip at 20° to the southwest. Near the fault zone the strata are intensely silicified; fractures in the strata are filled by reticulate quartz veins.

Shan Pui. An outcrop of Carboniferous siltstones at Shan Pui yielded one sample of graphitic siltstone that gave a clear Cretaceous age when analyzed for palynomorphs. The sample came from exposures at the base of the slope on the western side of a small hill about 0.7 km east of Shan Pui (2253 3491) that comprise fine-grained sandstone with two beds of carbonaceous siltstone or graphite schist. The rock is black and foliated or finely bedded, and the beds within the sandstone dip 30° to the southsoutheast. One of the beds also yielded a moderately diverse Carboniferous flora (Appendix 1).

Palaeontology

By comparison with similar lithostratigraphic units in Shenzhen and Guangdong the age of the rocks is inferred to be Upper Cretaceous (Lai, 1986). The distinctive outcrop at Lau Fau Shan has revealed no palaeontological evidence as to its age. However, the structurally complex exposures east of Shan Pui have given clear Carboniferous and Cretaceous ages. It is believed that the dinoflagellates of Upper Cretaceous age found here are from a thrust slice of the Kat O Formation within the Lo Wu – Tuen Mun Fault Zone.

Sedimentary Environment

The strata are the products of piedmont alluvial fan deposition in a terrestrial environment. They are found adjacent to fault planes, and are probably related to the scarp features associated with these structures. Such deposits are usually very localized in distribution, and correlation between outcrops is difficult.

Chapter 5
Major Intrusions

Classification

The major intrusions found within the district are composed of granodiorite or granite; the nomenclature based on composition (Figure 12) is that of Streckeisen (1967, 1974), and is the same as that used by Allen and Stephens (1971). The division of the intrusive rocks based on grain size is modified from Allen and Stephens, and based on Strange (1985). In addition, the work of Cobbing et al (1986) on granite textures has been taken into account.

The engineering system (Table 5) using 0.06, 2, 6 and 20 mm for grain size divisions is adopted (BSI, 1981). In this respect the work here differs from Allen & Stephens (1971), who used the common geological practice of 0.05, 1 and 5 mm for grain size ranges. Where megacrystic texture is a distinctive mappable feature of the granite it is shown by an overprint on the published map sheets.

Full silicate analyses have been carried out on thirteen samples from major intrusions in the district. The results are given as Tables 6 & 7 and selected data from each sample are plotted on an ACF diagram (Figure 13). A QAP diagram of modal analyses of mineral contents for a selection of samples from the major intrusions are given as Figure 14.

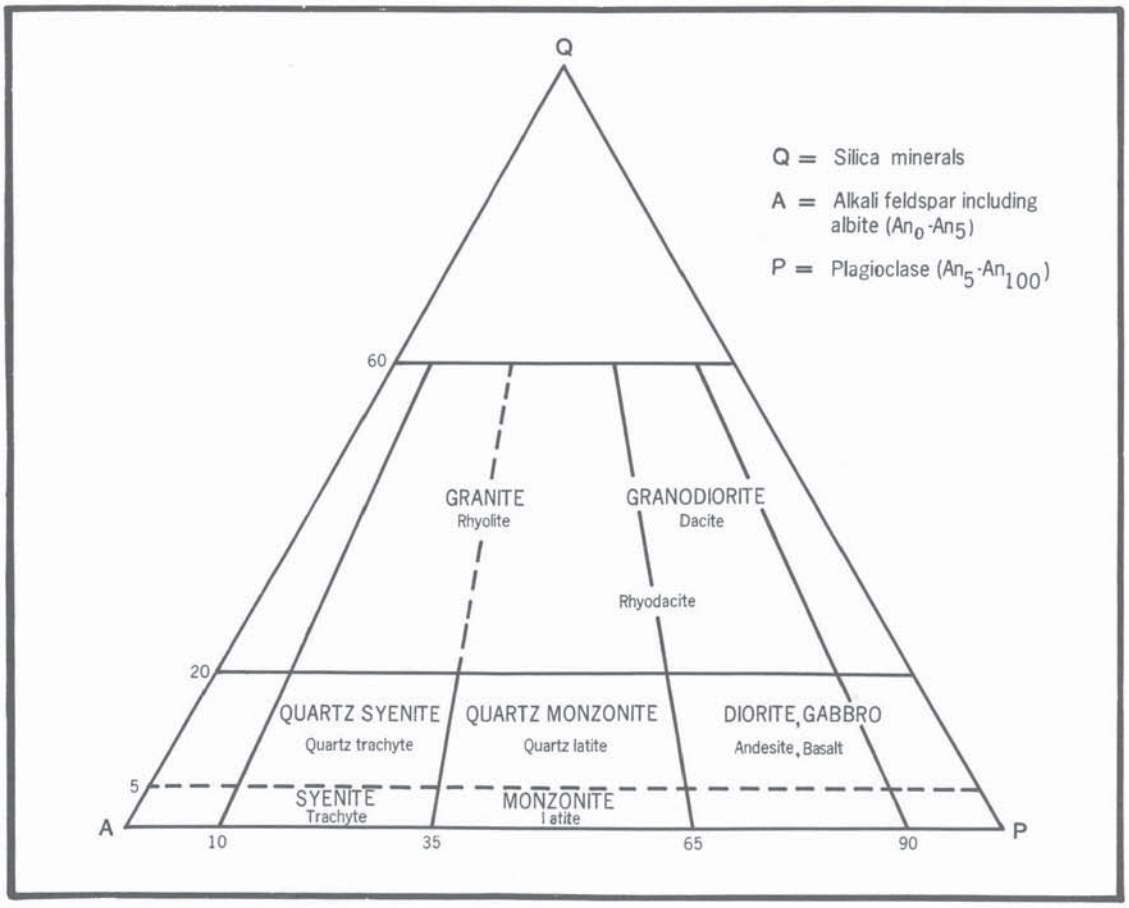


Figure 12 – General Classification and Nomenclature of Major and Minor Intrusive Rocks (after Streckeisen, 1974)

Table 5 – 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 and Dacite

Distribution and Lithology

Granodiorite and dacite outcrop within the district in Tsuen Wan, on Tsing Yi, between Kam Tin and Shek Kong, and in eastern Tai Lam Country Park. The rock is also found in the Western Aqueduct between Yau Kom Tau and Ko Po San Tsuen, and in boreholes to the north and east of Yuen Long. Exposures are generally poor, but the landform, soil colour and change in vegetation often form useful field indicators of their presence.

The granodiorite is, for the most part, fine-grained and porphyritic. Varieties include equigranular medium-grained and porphyritic very fine-grained (dacite). The granodiorite and dacite are mesocratic in most areas, but can be leucocratic. The rocks are composed of white feldspar and quartz in roughly equal proportions, with abundant dark biotite forming clots throughout the matrix (Plates 12 & 13). The rock is generally characterized by a uniformity of texture, with dark xenoliths a rare feature.

The granodiorite forms either steep-sided intrusions, with many irregularities in the upper surfaces, or outliers on the granite. When weathered the rock forms a reddish brown saprolite, usually many metres thick. The landforms tend to be smoother as a result of this thick soil, which supports a richer vegetation, rather than, for example, the granite landforms. Around Shek Kong the granodiorite is metamorphosed, and this results in a change of mineralogy and texture.

Details

Tsuen Wan to Tsing Yi. Granodiorite underlies Tsuen Wan and is found in hillslopes to the north. In north Tsuen Wan, and to the west through Pun Shan Tsuen to Yau Kom Tau, outcrops of dacite grade imperceptibly into fine-grained granodiorite. The granodiorite and dacite are both markedly porphyritic, with feldspar up to 20 mm, quartz up to 8 mm and black clots of biotite around 8 mm, giving the rock its characteristic black and white speckled appearance. From Pun Shan Tsuen to Yau Kom Tau the rock is epidotized and takes on a more uniform dark greenish grey colour. Along Route Twisk the dacite is almost leucocratic, with discrete clots of biotite; it is intruded by feldsparphyric rhyolite.

Tsing Yi. Granodiorite outcrops in northeast Tsing Yi, and is probably contiguous beneath offshore superficial deposits with outcrops around Tsuen Wan. The rock is typically dark grey or composed of contrasting black biotite and pale felsic minerals, giving a speckled texture. West of Fung Shue Wo (281 241) it is markedly porphyritic, varying from fine-grained to dacitic. Near Wok Tai Wan on northwestern Tsing Yi is an outcrop of porphyritic dacite. The rock is dark greenish grey to grey, with feldspar phenocrysts up to 20 mm across and quartz up to 10 mm. There are rare recrystallized xenoliths up to 100 mm across set in an aphanitic groundmass.

On Nga Ying Chau, a small island east of Tsing Yi which is now joined to the main island by reclamation, there are two varieties of granodiorite which differ from the typical variety seen to the west. One is a dark grey, finely porphyritic granodiorite, dominated by a fine-grained groundmass of about 0.25 mm (2901 2447), and the other (2912 2458) is a speckled black and white variety with phenocrysts of feldspar commonly up to 10 mm, and a groundmass of around 1 mm.

Tsing Tam Reservoir to Shek Kong Village. This outcrop consists of porphyritic fine-grained granodiorite, speckled black and white when unaltered, but often sheared and metamorphosed. The unaltered granodiorite was well exposed in the road widening near Kadoorie Farm and in the borrow area between Lam Kam Road and Route Twisk (295 324). It can also be seen along the catchwater west of Shek Kong Village (282 318), but these exposures are generally deeply weathered. In the borrow area the rock is leucocratic (Plate 12), becoming melanocratic with increasing metamorphism (2946 3245). Euhedral feldspar crystals are up to 15 mm across, quartz up to 10 mm and biotite clots up to 5 mm, set in a fine-grained matrix. Epidotization associated with the metamorphism, particularly in the feldspar phenocrysts, gives the rock a greenish colour.

Kam Tin to Shek Kong Camp. Coarsely porphyritic dark grey granodiorite has been found in many boreholes around Kam Tin, Shek Kong Camp and eastsoutheast of Shek Kong. Granodiorite therefore probably underlies most of the Kam Tin – Shek Kong alluvial plain.

In the small village of Yuen Kong, on a low hill rising above the alluvial plain, exposures of saprolite occur east of the school (2604 3179). Although no recognizable fresh rock has been recorded, the outcrop is believed to be granodiorite.

Kong A Leng hill is covered with corestones and debris of weathered porphyritic fine-grained granodiorite. The rock displays typical black and white mottling, with feldspar up to 12 mm, quartz up to 10 mm and a fine-grained groundmass.

North of Pat Heung, on the footslopes of Kai Keung Leng, is an outcrop of metagranodiorite. Exposures of the rock (2720 3450) are pale grey, with quartz and relict feldspar phenocrysts up to 4 mm. The characteristic texture of a porphyritic fine-grained granodiorite is preserved in the relict crystals, with secondary growth of quartz and sericite dominant in the groundmass.

Chuen Lung to Tin Fu Tsai. One of the largest outcrops of granodiorite and dacite in the area stretches from Route Twisk west of Chuen Lung to Tin Fu Tsai, taking in Lin Fa Shan. This outcrop displays the greatest variety of granodiorite textures, ranging from porphyritic dacite through porphyritic fine-grained granodiorite to equigranular fine- to medium-grained granodiorite.

The area of dacite close to Route Twisk is porphyritic, with feldspar up to 20 mm across and quartz up to 8 mm. Biotite crystal aggregates are generally small, up to 4 mm.

Two areas of non-porphyritic fine- to medium-grained granodiorite were noted at Pak Shek Kiu (289 277) and Lin Fa Shan (268 280). The granodiorite is typically speckled black and white, and where porphyritic contains feldspar up to 20 mm across and quartz up to 10 mm.

Table 6 – Major Element Analyses of Andesite, Granodiorite, Coarse-grained Granite and Medium-grained Granite

Element	Andesite	Granodiorite	Coarse-grained Granite		Medium-grained Granite	
	Tsing Lung Tau (2241 2474) HK 6047	Shek Kong (2946 3245) HK 3381	Tuen Mun (1610 2760) HK 2416	Tuen Mun (1649 2670) HK 2383	Ha Pak Nai (1251 3170) HK 3959	Tai Lam (2010 2431) HK 4327
SiO_2	61.29	68.67	71.50	75.60	75.76	76.03
TiO_2	0.82	0.58	0.26	0.09	0.12	0.07
Al_2O_3	17.37	14.36	13.75	12.68	12.83	12.67
Fe_2O_3	1.75	1.38	0.67	0.56	0.45	0.26
FeO	4.16	2.82	1.65	1.10	1.12	0.91
MnO	0.08	0.07	0.04	0.04	0.04	0.04
MgO	3.10	1.16	0.32	0.16	0.13	0.06
CaO	1.33	3.21	1.79	1.05	0.89	0.88
Na_2O	3.10	3.11	2.87	3.39	3.14	2.93
K_2O	4.00	3.97	5.61	5.00	5.06	5.22
H_2O+	3.26	1.10	0.35	0.17	0.69	0.43
H_2O-	0.15	0.10	0.13	0.35	0.03	0.05
P_2O_5	0.46	0.13	0.05	0.02	0.01	0.01
Total	100.87	100.66	98.99	100.23	100.27	99.83

Table 7 – Major Element Analyses of Fine- and Fine- to Medium grained Granite

Element	Fine- to Medium-grained Granite						Fine-grained Granite	
	Tsang Kok (1424 3328) HK 1345	Tsz Tin Tsuen (1490 3152) HK 1553	Pak Nai (1282 3350) HK 2072	Ngau Hom Shek (1553 3527) HK 2561	Mong Hau Shek (1202 2557) HK 3503	Tsing Lung Tau (2204 2484) HK 4075	Lam Tei (1753 3026) HK 3178	Siu Lam (1945 2515) HK 3504
SiO_2	76.33	76.91	75.62	74.35	75.48	78.09	76.41	77.44
TiO_2	0.07	0.08	0.09	0.13	0.09	0.06	0.04	0.03
Al_2O_3	12.67	11.81	12.70	13.25	13.44	12.22	12.76	12.06
Fe_2O_3	0.46	0.25	0.57	0.89	0.29	0.27	0.38	0.39
FeO	0.79	0.56	0.86	0.81	0.79	0.76	0.60	0.68
MnO	0.05	0.03	0.05	0.03	0.04	0.04	0.05	0.02
MgO	0.09	0.07	0.18	0.15	0.13	0.04	0.09	0.04
CaO	0.82	0.82	1.22	0.59	1.14	0.66	0.86	0.53
Na_2O	3.41	2.75	3.35	2.94	3.63	3.10	3.68	3.71
K_2O	4.79	5.34	4.89	5.44	4.85	4.59	4.65	4.52
H_2O+	0.62	0.50	0.59	0.78	0.43	0.54	0.51	0.48
H_2O-	0.08	0.04	0.08	0.04	0.07	0.06	0.06	0.08
P_2O_5	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00
Total	100.18	99.16	100.21	99.41	100.38	100.43	100.10	99.98

Tsing Fai Tong to Tai Lam Chung Reservoir. There are four outliers of granodiorite in this area that can be recognized by their reddish brown clay-rich soils, contrasting sharply with the pale granite soils. Rare exposures of fine-grained granodiorite occur in road cuttings near Tsing Fai Tong (240 274). To the west the composite outlier of granodiorite and tuff can be seen best in a road cutting (2310 2676) where equigranular fine-grained granite, altered tuffs and fine-grained granodiorite are exposed. Elsewhere in the outlier, the fresh granodiorite has the characteristic speckled black and white texture and is typically fine- to medium-grained, with feldspar up to 4 mm.

Around Yuen Tun and Tai Lam Chung Reservoir, the granodiorite outcrop is inferred from the presence of red saprolitic soil, with boulders of porphyritic and non-porphyritic fine-grained granodiorite. A sheared contact with mylonite and schistose granite separates the granite and granodiorite on the large island (2034 2646) in Tai Lam Chung Reservoir.

Western Aqueduct. Granodiorite was found in two places during construction of the water tunnel. North of Lin Fa Shan the exposures in the tunnel are part of the Chuen Lung to Tin Fu Tsai outcrop. About 2 km west of Yuen Kong the tunnel exposures have no direct surface expression, and are believed to be part of the outcrop beneath the Kam Tin – Shek Kong alluvial plain.

From 2.0 to 2.8 km south of the portal near Tsing Tam were exposures of fine-grained granodiorite. The rock is usually non-porphyritic with feldspar less than 4 mm, but rarely contains phenocrysts of white feldspar up to 20 mm across.

About 1 km along the tunnel from the portal at Ko Po San Tsuen, exposures of porphyritic fine-grained granodiorite or dacite are speckled black and white, sometimes greenish, with feldspar phenocrysts up to 20 mm and quartz up to 10 mm. The groundmass in generally very fine-grained, in thin section being less than 0.06 mm.

Yuen Long. Metagranodiorite has been found in many boreholes to the north and east of Yuen Long. Beneath Yuen Long Industrial Estate (205 358) it occurs with fine-grained metagranite and a marble-bearing sequence adjacent to an eastnortheast-trnding fault. Near Yuen Long Old Town (216 341) it overlies white marble, with a steep, westerly dipping contact zone. It may also outcrop on the low hills at Shan Pui (219 345), where the rock has been tentatively ascribed to the Tai Mo Shan Formation. The rock in all these localities is usually foliated, often strongly so; the foliation obscures the original rock texture. When fresh it is pale grey with mafic blotches or streaks, and may possess recognizable feldspar relicts.

Petrography

Typical porphyritic fine-grained granodiorite from Fung Shue Wo (HK5035, 2820 2421) has feldspar up to 15 mm across and quartz up to 5 mm, with a groundmass of around 0.1 to 0.2 mm. Biotite aggregates up to 10 mm across give the characteristic speckled texture, and the rock is crossed by fine, green epidote veins. In thin section it is composed of c. 52% phenocrysts of quartz, plagioclase, alkali feldspar and biotite, and c. 48% matrix, which includes accessory epidote and hornblende. Overall there is c. 27% quartz, c. 20% alkali feldspar and c. 37% plagioclase. However, most of the phenocrysts are plagioclase, with most of the quartz and alkali feldspar in the groundmass. The plagioclase is commonly sericitized and may be weakly zoned. The biotite is commonly chloritized, and may be single crystals or felted aggregates.

In typical dacite (HK3209, 2974 2655), the groundmass is generally in the range 0.03 to 0.1 mm. This fine- to very fine-grained groundmass makes up c. 42% of the rock, and contains c. 13% quartz, c. 4% alkali feldspar and c. 34% plagioclase phenocrysts. The plagioclase is usually sericitized and may be slightly epidotized. The alkali feldspar is clear, and either slightly perthitic or displaying albite-alkali feldspar exsolution. Biotite forms small clots, usually chloritized, and makes up c. 2% of the rock. There is preferential development of plagioclase phenocrysts and much of the alkali feldspar is in the groundmass.

In another variety of dacite (HK3256, 2876 2797) there is abundant perthitic alkali feldspar (c. 21%), plagioclase (c. 15%) and quartz (c. 10%) set in a groundmass making up c. 53% of the rock. There are minor amounts of biotite and epidote pseudomorphs after hornblende. Rocks of similar appearance on Lamma Island have been termed feldsparphyric rhyodacite (Strange & Shaw, 1986).

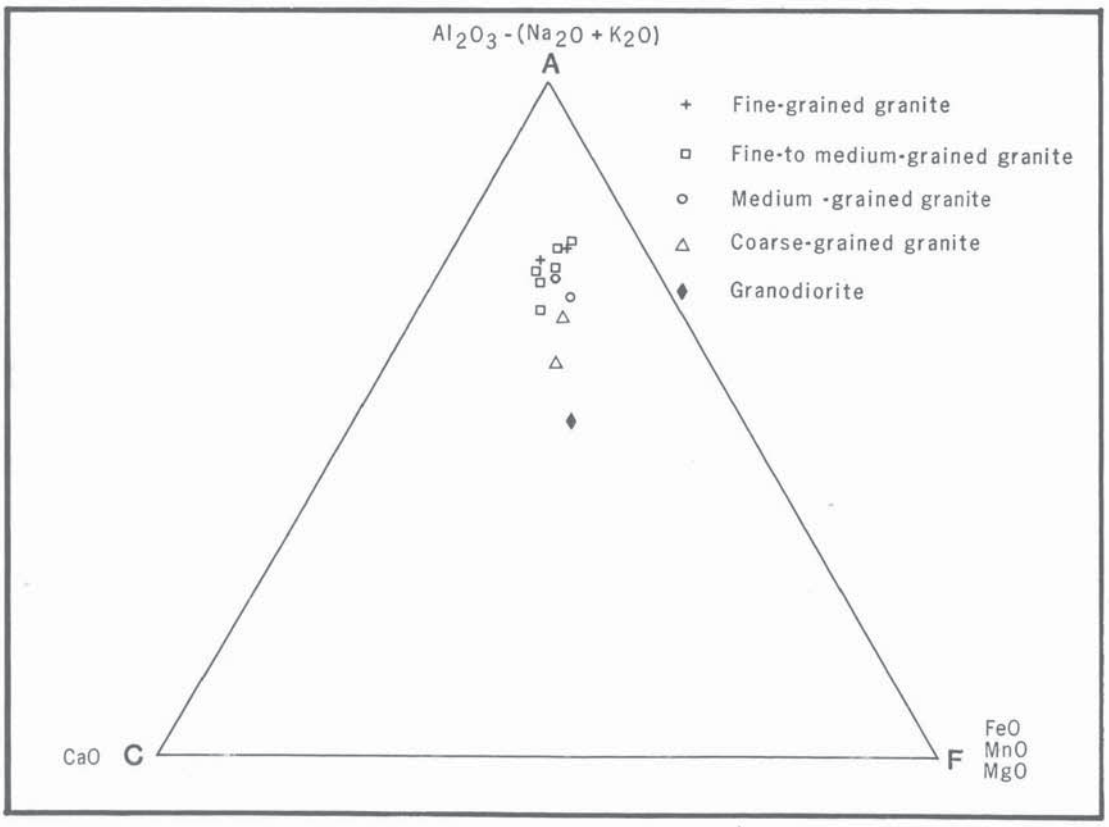


Figure 13 – ACF Diagram Showing Relative Proportions of Alumina Minus Alkalis, Lime and Combined Ferrous Manganese Oxide and Magnesia in Samples of the Major Intrusive Rocks

In thin section the non-porphyritic fine- to medium-grained granodiorite from Pak Shek Kiu (HK3966, 2805 2896) is equigranular and contains c. 31% quartz, c. 7% alkali feldspar and c. 43% plagioclase. There is also biotite (c. 16%) and hornblende (c. 3%). The plagioclase is strongly zoned, with alkali feldspar overgrowth at the edges and strong sericitization in the centres. The alkali feldspar is clear and perthitic, with some microcline. Overall the crystals range in size from 1 to 4 mm.

Geochemistry

One sample of granodiorite from the district has been chemically analyzed (Table 6). Although distinctly different from the granite intrusions, the rock is chemically similar to those noted by Addison (1986). The ACF plot (Figure 13) confirms the difference with the granites, with a relatively low silica and high lime (CaO) in the granodiorite.

The modal composition of six granodiorite specimens from the district is given in Figure 14. The granodiorite is clearly distinct from the granites, but three samples fall within the granite field (Streckeisen, 1974). However, these three samples are all porphyritic, while the remaining three are relatively equigranular. Although there may be some chemical difference between these varieties, it is more likely to be a bias introduced by the relative depletion of the matrix in plagioclase.

Age Relations

The granodiorite is presumed to be the oldest of the granitoid intrusions, and is known to be cut by fine-grained granite and most types of dyke (Addison, 1986). In the district it is clearly cut by fine-grained granite in the Western Aqueduct, and it forms a roof capping to fine-grained granite from Tsing Fai Tong to Tai Lam Reservoir.

Dykes of feldsparphyric rhyolite, quartzphyric rhyolite and fine-grained granite cut the granodiorite on Tsing Yi. Hydrothermal alteration and epidotization affect the granodiorite throughout its outcrop. Metagranodiorite has been found in boreholes around Yuen Long, and may outcrop at Shan Pui; the granodiorite has been metamorphosed and foliated in the regional metamorphic belt.

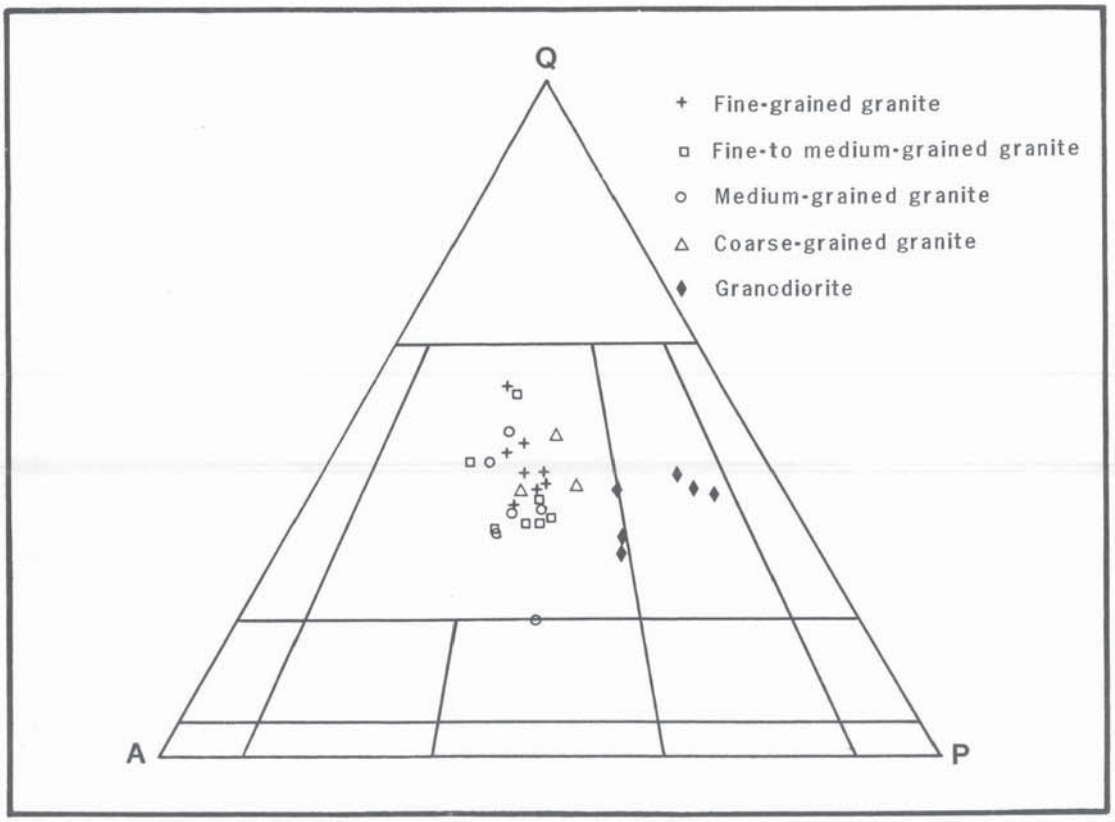


Figure 14 – QAP Diagram (after Streckeisen, 1974) Showing Relative Proportions of Minerals in Rocks from the Major Intrusions

Coarse-grained granite

Distribution and Lithology

The coarse-grained granite outcrops on the hillslopes southeast of Tuen Mun, and beneath the adjacent areas of superficial deposits and reclamation. Part of this area coincides with that mapped by Allen & Stephens (1971) as Sung Kong Granite. There is also a small outcrop of coarse-grained granite on the peninsula east of Lung Chue To (Pearl Island).

The outcrop includes small areas of undifferentiated medium- and medium- to coarse-grained granite. Although the granite displays great textural variation, and both grades into and is intruded by fine-grained granite, equigranular coarse-grained granite is dominant. All the coarser rocks contain characteristic large alkali feldspar and irregular biotite clots. Equigranular coarse-grained granite is exposed between Wong Ka Wai, Chi Lok Fa Yuen and Sam Shing Hui in Tuen Mun, and east of Lung Chue To (Pearl Island). Alkali feldspar crystals are commonly up to 20 mm, sometimes much larger, sericitized plagioclase crystals are up to 10 mm and irregular clots of biotite are usually over 6 mm (Plate 14).

In places throughout the outcrop the granite shows a distinctive texture in which subordinate patches of fine-grained granite separate the coarser crystals (Plate 15). This texture has been described as inequigranular (Plate 19 *in* Addison, 1986) but here is termed microcrystic. As described by Strange (1985) and Addison (1986) this texture grades into the related megacrystic texture, in which the finer grained matrix dominates the larger crystals. Similar textural variations have been described in granites of the southeast Asian Tin Belt by Cobbing et al (1986).

Details

Tuen Mun. Equigranular coarse-grained granite was seen in exposures and boreholes east of Chi Lok Fa Yuen (1610 2760), in part with a small microcrystic content. The granite has alkali feldspar crystals up to 50 mm, pools of interstitial quartz around 5 mm and irregular clots of black biotite up to 10 mm. Zoned sericitized plagioclase crystals are up to 10 mm across and have a characteristic greenish colour; the alkali feldspar is usually white, but can be pinkish. Thin basalt dykes and quartz veins also occur in this area.

On the pre-reclamation coastline at Sam Shing Hui (1588 2698) there are exposures of coarse-grained granite with alkali feldspar up to 10 mm, pools of interstitial quartz up to 8 mm, and sericitized plagioclase up to 6 mm. Although most of the irregular clots of biotite are small, some are up to 6 mm across. Although essentially similar to the equigranular coarse-grained granite further north, there is a significant microcrystic content.

Microcrystic coarse-grained granite with dykes or veins of fine-grained granite was intersected by a number of boreholes north and east of Sam Shing Hui (160 272). The granite contains alkali feldspar up to 25 mm quartz up to 7 mm and white plagioclase up to 8 mm; black biotite clots are less than 7 mm across. The groundmass is clearly microcrystic, with a grain size visible in hand specimen much less than 0.5 mm. In exposures on the cutting for the Tuen Mun Road (1602 2711), coarse-grained granite with irregular bands of dark, biotite-rich fine-grained granite is cut by aplite dykes up to 150 mm wide and basalt dykes up to 2.5 m (1634 2680). Along the whole of this cutting the coarse-grained granite is characterized by concentrations of biotite, often in bands about 50 mm thick (1625 2689).

Between Castle Peak Beach and Ka Fei Wan (Cafeteria Beach) (161 264) the coarse-grained granite is cut by numerous, irregular fine-grained granite dykes. On the southeast end of Castle Peak Beach (1606 2656) these dykes are generally flat lying (Figure 15, Plate 31). Southeast of Kadoorie Beach a quartzphyric rhyolite dyke (1622 2632) and a thin belt of mylonite (1626 2633) cut the coarse-grained granite.

East of Wong Ka Wai (162 284) the coarse-grained granite grades northwards into medium-grained granite, and on the catchwater (1627 2819) it is cut by thick fine-grained granite dykes. The rock is microcrystic in parts, and the contacts with the fine-grained dykes are sharp in some exposures and gradational in others.

East of Lung Chue To (Pearl Island). On the peninsula (170 251) there is an isolated outcrop of equigranular coarse-grained granite bounded to the east by a texturally similar medium-grained granite. In this rock the alkali feldspar crystals are up to 25 mm, quartz pools up to 10 mm and biotite clots up to 7 mm.

Petrography

The coarse-grained granite is usually equigranular, or has a noticeable microcrystic content. The equigranular granite from Borehole 1201D/03412 in eastern Tuen Mun (HK4770, 1625 2757) is dominated by large crystals of alkali feldspar (c. 27%) with subordinate microcline (c. 4%), sericitized plagioclase (c. 26%) and pools of quartz (c. 36%). The accessory biotite is largely chloritized (c. 5%) and forms aggregates of small crystals.

Apparently equigranular granite from Sam Shing Hui (HK2308, 1588 2698) can be seen in thin section to contain pools of quartz made up of large primary relicts (c. 9%) and smaller crystals 0.2 to 1 mm across (c. 30%). The relicts show more internal straining than the recrystallized material. There is c. 33% plagioclase of oligoclase composition, some only slightly sericitized, and c. 25% alkali feldspar, including minor amounts of microcline. Secondary chlorite after biotite is the only accessory (c. 3%).

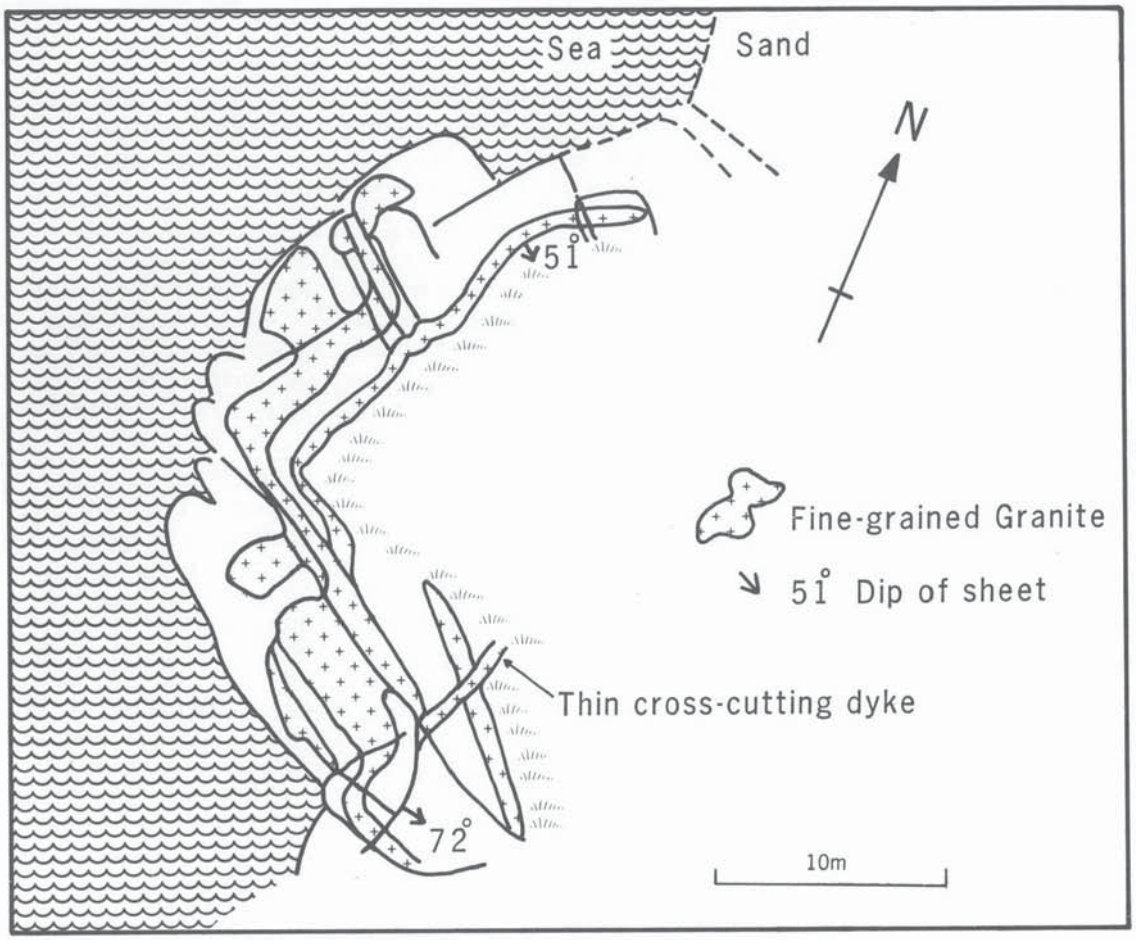


Figure 15 – Plan of Fine-grained Granite Dykes Intruding Coarse-grained Granite at Castle Peak Beach (1606 2656)

The extreme development of microcrystic texture can be seen in Borehole 171D/00724 (HK4347, 2602 2719) at the northern end of the Tuen Mun Road cutting at Sam Shing Hui. In thin section the fine-grained microcrysts surround the individual relict megacrysts; the megacrysts make up c. 51% of the rock. Overall, the modal mineral content is c. 48% quartz, c. 23% alkali feldspar, including microcline, and c. 27% plagioclase. Most of the plagioclase occurs as megacrysts, while most of the alkali feldspar occurs as microcrysts. There is a small amount of secondary chlorite and epidote after biotite.

Modal analyses of three coarse-grained granite samples (Figure 14) show that the rock is slightly enriched in plagioclase relative to the finer granites. The composition falls towards the granodiorite side of granite composition (Figure 12), with an average proportion of quartz, alkali feldspar and plagioclase of 43:28:30.

Geochemistry

Full silicate analyses have been undertaken on two samples of coarse-grained granite from Tuen Mun (Table 6). One of the samples is markedly depleted in silica relative to the other granites, and has a higher lime (CaO) content; it falls between the granite and granodiorite samples in chemical composition. The ACF plot (Figure 13) confirms the difference between the two coarse-grained granite samples.

Age Relations

The coarse-grained granite appears to be closely related to adjacent outcrops of medium-grained granite, with the two rocks as grain size variations in the same pluton. Textural modification on the edge of the pluton and within the rock mass indicates that the adjacent fine-grained and fine- to medium-grained granites are younger. The granite is also cut by fine-grained granite, aplite and basalt dykes. There are no signs of metamorphism, shown in finer granites as a foliation, and the

Plate 21 – Fine- to Medium-grained Granite (HK4075) from Tsing Lung Tau (2240 2484); Natural Scale

Plate 22 – Thin Section of Fine- to Medium-grained Granite (HK4075) from Tsing Lung Tau (2240 2484); XPL plus $\frac{1}{4}\lambda$ plate × 10

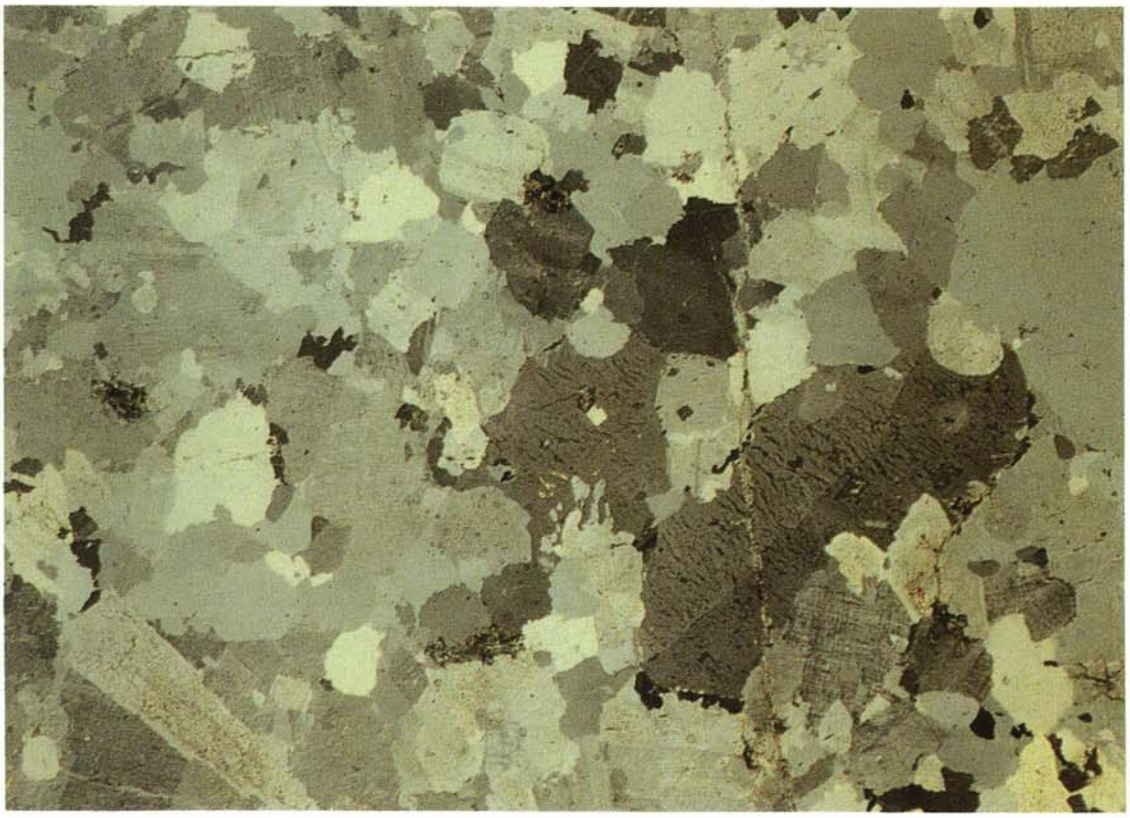


Plate 23 – Fine-grained Granite (HK3178) from Lam Tei (1753 3026); Natural Scale

Plate 24 – Thin Section of Fine-grained Granite (HK3178) from Lam Tei (1753 3026); XPL plus $\frac{1}{4}\lambda$ plate × 10

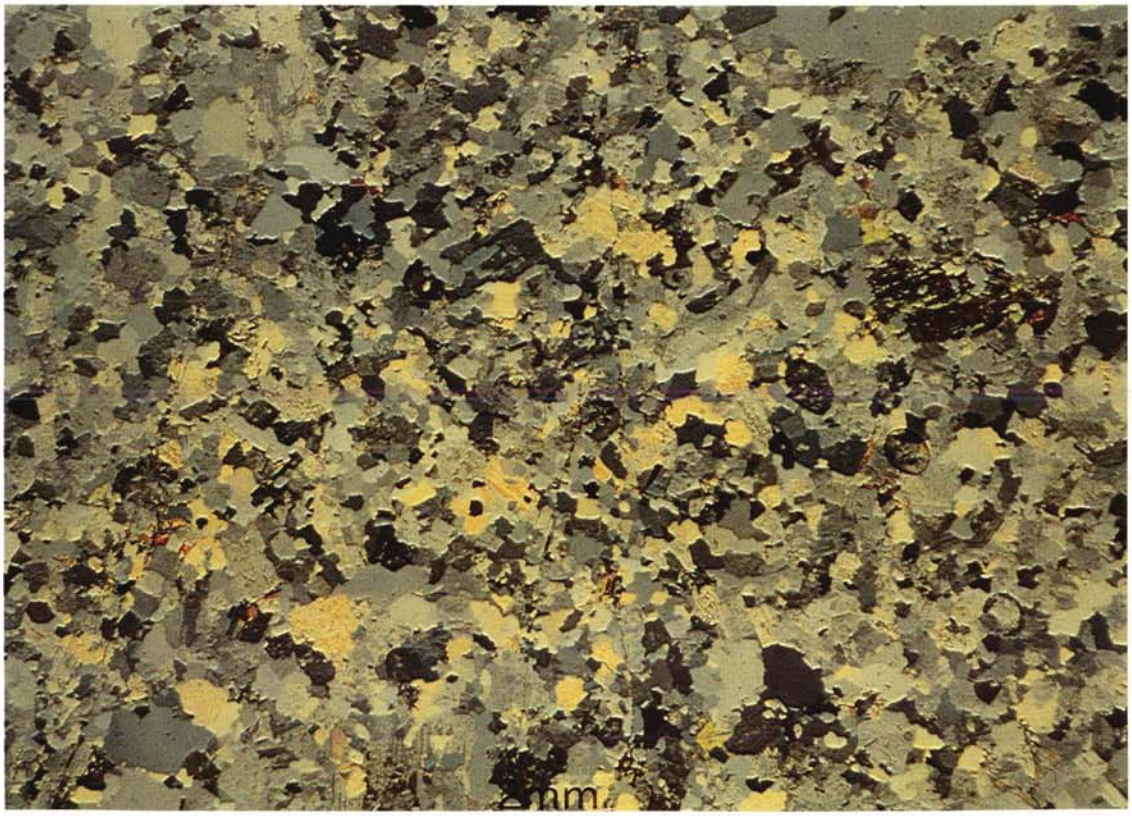


Plate 25 – Granophyric Fine-grained Granite (HK5032) from Tsing Yi (2775 2432); Natural Scale

Plate 26 – Thin Section of Granophyric Fine-grained Granite (HK5032) from Tsing Yi (2775 2432); XPL plus $\frac{1}{4}\lambda$ plate

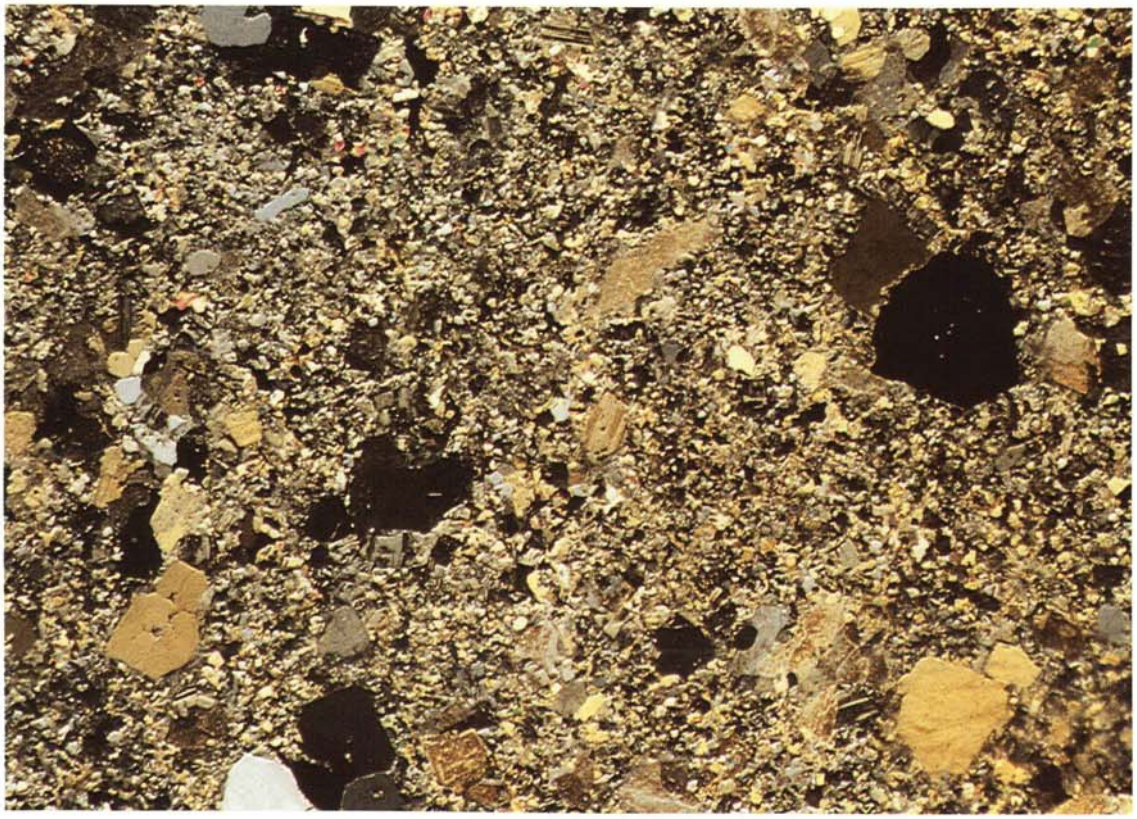
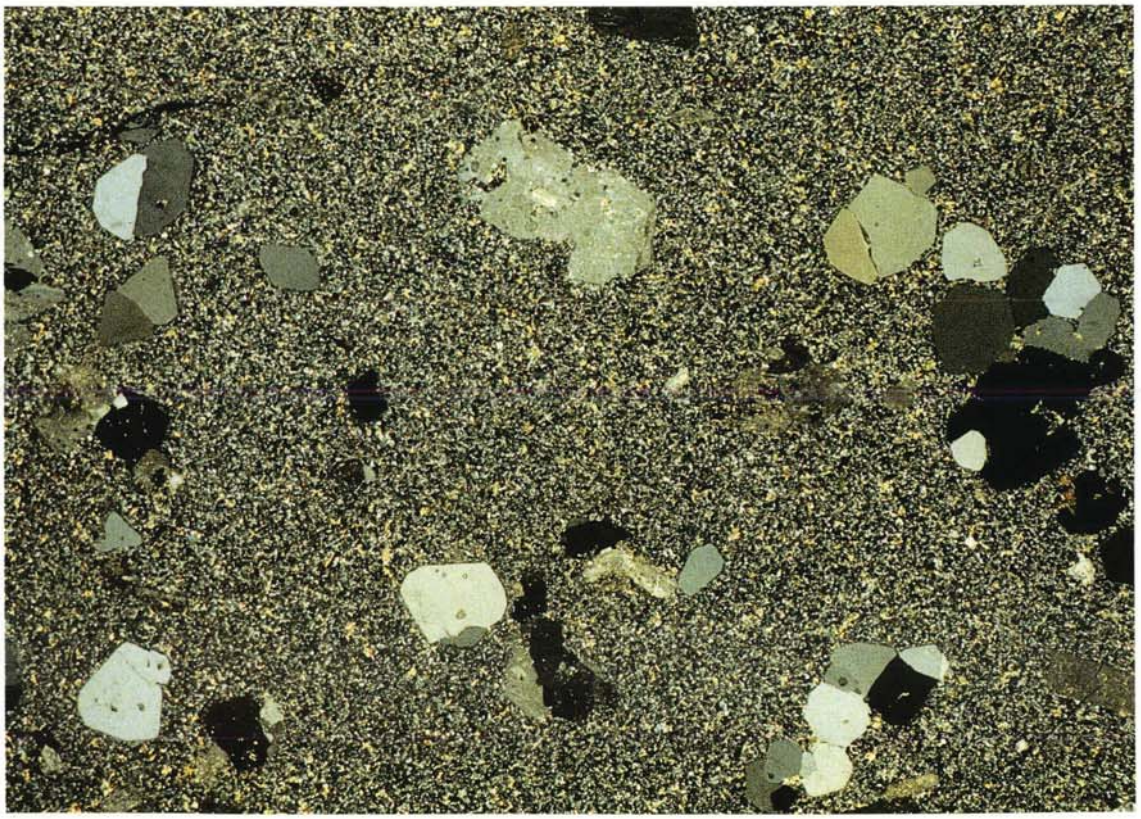


Plate 27 – Thin Section of Feldsparphyric Rhyolite (HK2267) from Tsing Yi (2640 2411); XPL × 10

Plate 28 – Thin Section of Quartzphyric Rhyolite (HK2283) from Tsing Yi (2832 2477); XPL × 10



rock has an intrusive contact with adjacent metavolcanics and metasedimentary rocks. It is likely that the granite was intruded in a non-active phase in the development of the regional metamorphic belt, and crystallized before dynamic metamorphism increased again. In Sha Tin district the coarse-grained granite was sheared while still hot (Addison, 1986), and may therefore be younger.

Medium-grained granite

Distribution and Lithology

The major outcrops of medium-grained granite are in a broad north-south trending belt to the west of Tsing Shan (Castle Peak), east of Tuen Mun between Tai Lam Chung and Ting Kau, around Tai Tong and in northeast Tai Lam Country Park. The rock can also be found in the Western Aqueduct and near Tsuen Wan. Allen & Stephens (1971) mapped the medium-grained granite as Sung Kong, Sung Kong Medium or Cheung Chau Granite. Their outcrop boundaries do not correspond closely with those now assigned to this rock type. The medium-grained granite of the district can be divided into two types; equigranular and microcrystic.

The major outcrops of equigranular medium-grained granite (Plate 16) are between Tai Lam Chung and Ting Kau, and between Tai Tong and Ma On Kong. The rock is uniform in appearance and white in colour, with alkali feldspar typically less than 10 mm, plagioclase between 2 and 6 mm and accessory biotite as clots or single crystals between 2 and 4 mm. The rock usually forms a clear mappable unit distinct from the fine- and fine- to medium-grained granite.

The microcrystic medium-grained granite is closely associated with the outcrop of microcrystic coarse-grained granite at Tuen Mun, but it also occurs as patches within the fine- and fine- to medium-grained granite outcrop. Microcrystic medium-grained granite (Plate 17), in which there is an infiltration of fine-grained material or granulation of existing crystals, is usually less easy to distinguish in the field than the equigranular rock; the outcrops grade into the surrounding coarser or finer rocks. The medium-grained texture is a relict which has survived the wholesale modification seen elsewhere. As such these rocks are similar to those seen on Lamma Island (Strange & Shaw, 1986).

Details

Tsing Shan. Medium-grained granite forms the western part of the Tsing Shan area. It is commonly megacrystic, with feldspar up to 30 mm. Xenoliths of basic lava, sometimes containing feldspar megacrysts, are present in parts of the outcrop. The contact with the adjacent fine- to medium-grained granite is gradational. The medium-grained granite generally possesses an equigranular texture, while progressive modification results in the adjacent megacrystic fine- to medium-grained variety. A distinct megacrystic variety of medium-grained granite was proved in boreholes at Castle Peak Power Station (100 260). It is characterized by prominent biotite clots up to 8 mm and alkali feldspar phenocrysts up to 35 mm set in a groundmass of 2 to 6 mm. This variety also contains xenoliths of basaltic lava.

The medium-grained granite is almost invariably microcrystic in thin section, and is often foliated. Typical granite from Lung Kwu Tan (0945 2853) contains feldspar up to 15 mm, but overall has an apparently equigranular texture of 5 mm or less. The biotite forms as felted aggregates up to 7 mm and well developed single crystals up to 3 mm.

Tuen Mun to Siu Lam San Tsuen. There are four outcrops of medium-grained granite in this area, of which three are intimately related to the coarse-grained granite, for example in the development of secondary textures and in the form of the biotite. The most northerly outcrop is an extension to the coarse-grained granite outcrop east of Wong Ka Wai. The rock contains megacrysts of alkali feldspar up to 20 mm across, and biotite clots up to 10 mm, but it has a dominant grain size of 1 to 6 mm; the biotite also occurs as single crystals up to 2 mm.

The outcrop southeast of Tuen Mun, around Perowne Barracks, is very variable, with microcrystic coarse- and medium-grained granite as well as equigranular medium-grained granite. To the north and east the rock grades progressively into megacrystic fine- and fine- to medium-grained granite. To the west the microcrystic content may be significant, but the dominant megacrysts become generally coarser and the rock grades into coarse-grained granite. The outcrop contains quartzphyric rhyolite and basalt dykes.

To the east of Lung Chue To (Pearl Island) is a small outcrop of equigranular medium-grained granite bounded to the west by equigranular coarse-grained granite and to the east by fine- to medium-grained granite. On the southern side of the peninsula (1776 2495) the rock is cut by irregular fine-grained granite dykes and pegmatite. The granite contains alkali feldspar less than 10 mm across, plagioclase between 2 and 6 mm, quartz between 2 and 8 mm, and biotite crystals between 2 and 4 mm.

Around the Desalting Plant, near Siu Lam San Tsuen, the granite is mostly medium-grained and equigranular. The granite (1822 2515) has quartz which is slightly microcrystic in parts. The form of the biotite clots is reminiscent of that found in the coarse-grained granite and surrounding medium-grained

granite at Tuen Mun. On Tuen Mun Road, adjacent to fine-grained granite, the contact can be seen to be gradational (1841 2536), with a microcrystic coarse-grained granite against sparsely megacrystic fine-grained granite.

Tai Lam Chung to Ting Kau. In this area there are four outcrops of medium-grained granite; south of Tai Lam Chung, at Tsing Lung Tau, at Sham Tseng, and between Sham Tseng and Ting Kau. The medium-grained granite of these outcrops is mostly equigranular, although there are rare megacrystic and microcrystic varieties. Typically, the alkali feldspar is up to 15 mm across, although it can be up to 25 mm, with sericitized plagioclase in the range 2 to 8 mm. Quartz crystals range from 2 to 6 mm in size, with biotite clots in the same range.

South of Tai Lam Chung the granite has a gradational contact with fine- to medium-grained granite to the north, but has a sharp boundary with fine-grained granite to the east, particularly well seen both on the ridge north of Tuen Mun Road (212 242) and on Castle Peak Road (219 243). The Tai Lam Chung outcrop contains numerous fine-grained granite dykes with sharp margins. Along Tuen Mun Road south of Tai Lam Chung the granite is microfractured, preferentially in the quartz, and this is parallel to extensive southerly dipping sheeting joints. On Castle Peak Road (2102 2408) the granite is noticeably quartz-deficient (c. 20%).

At Tsing Lung Tau the equigranular medium-grained granite grades into an inequigranular, microcrystic variety both within and around the outcrop. There are thin fine-grained granite dykes to be seen in exposures on Castle Peak Road (2306 2469). Offshore to the southeast several boreholes have proved medium-grained granite lying between Yim Tin Tsai Formation tuffs to the south and fine- to medium-grained granite to the north.

At Sham Tseng the rock texture is slightly inequigranular, and there is poorly developed microfracturing in the quartz seen in exposures on Castle Peak Road (2403 2521). This microfracturing is parallel to sheet-like joints dipping gently east. At the road junction on Tuen Mun Road (2435 2559) an equigranular medium-grained granite grades into megacrystic fine-grained granite over a few metres. The outcrops west of Sham Tseng grade progressively into the surrounding fine- to medium-grained granite, while to the east the outcrop is sharply divided from the fine-grained granite, for example on a ridge north of Tuen Mun Road (254 257).

Between Sham Tseng and Ting Kau an outcrop of medium-grained granite is bounded to the north by fine-grained granite. On a ridge above Tuen Mun Road (2540 2575) the contact between the granites can be inferred from the weathered profile, with coarse sand to the southwest and fine sand to the northeast. This contact can also be seen on Tuen Mun Road (2545 2544), where the rock grades from megacrystic fine-grained granite to microcrystic medium-grained granite over a distance of 50 m. Megacrysts, relicts of the medium-grained texture, are abundant, with alkali feldspar up to 12 mm, quartz up to 10 mm, plagioclase up to 4 mm and biotite clots up to 3 mm; the average megacryst size is less than 6 mm. Within the outcrop are thin dykes of fine-grained granite and aplite. Boreholes offshore northern Ma Wan indicate that the Tsing Lung Tau and Ting Kau outcrops are contiguous, and only obscured by thin superficial deposits.

Tai Tong to Ma On Kong. In this area, north of Tai Lam Chung Reservoir, a large, irregular outcrop of medium-grained granite is surrounded by, and includes, outcrops of fine-grained granite. The contact with the enclosed outcrop of fine-grained granite is well defined, and where exposed (2165 2893) is gradational, with microcrystic and megacrystic varieties present. In a borrow area 1 km southeast of Tai Tong (216 299) the granite is white and equigranular, with alkali feldspar up to 10 mm, greenish plagioclase between 2 and 5 mm, pools of quartz between 2 and 8 mm, and biotite clots from 2 to 5 mm across (Plate 16). Very few fine-grained granite dykes occur in the medium-grained granite outcrop.

North of the reservoir the granite is not uniformly equigranular, but contains megacrystic fine-grained and microcrystic coarse-grained varieties. A contact between sparsely megacrystic fine-grained granite below and medium-grained granite above dips gently northwest to the west of the Country Park Management Centre (2270 2858). The contact is gradational, and there are also patches of medium-grained granite within the fine. North of here, along a footpath, the infiltration of finer material into the medium-grained granite can be seen over a 30 m wide section (2267 2891).

Along the catchwater west of Ma On Kong the medium-grained granite is equigranular. The rock is white, with alkali feldspar generally less than 6 mm, although sometimes up to 12 mm; greenish plagioclase varies from 2 to 4 mm, with quartz pools less than 10 mm and biotite clots less than 7 mm. There are also single crystals of biotite between 1 and 4 mm. The contact with the megacrystic fine-grained granite to the north is well defined, and on the ridge (2341 3068) a microcrystic medium-grained granite is exposed at the contact.

Northwest Tai Lam Country Park. A sizeable outcrop of medium-grained granite occurs around the northern end of the catchwater 1 km west of Yeung Ka Tsuen. Small, isolated bodies outcrop about 1.5 km south of Yeung Ka Tsuen, near a small reservoir (198 288), and just north of the Country Park (166 320). The rocks are white, with alkali feldspar rarely up to 25 mm, greenish plagioclase up to 4 mm and biotite clots between 1 and 4 mm; the groundmass is microcrystic.

Microcrystic medium-grained granite, texturally close to the megacrystic fine- and fine- to medium-grained rocks, occurs in isolated outcrops in the northwest of Tai Lam Country Park. Exposures at a tunnel entrance south of a small reservoir (1994 2873) contains alkali and plagioclase feldspar crystals mostly between 2 and 6 mm, but the quartz is microcrystalline and interstitial. Elsewhere the microcrystic texture becomes more noticeable as the rock grades into the surrounding megacrystic fine- to medium-grained granite.

Western Aqueduct. Medium-grained granite is exposed along two long sections of the water tunnel between the portal at Ko Po Shan Tsuen and the shaft at the northeastern end of the reservoir. These exposures correlate with the part of the Tai Tong – Ma On Kong outcrop. The granite is white, and contains pink pegmatite nests, for example 2377 m (2341 3079) and 2888 m (2322 3031) from the portal at Ko Po Shan Tsuen. The granite is either equigranular or shows signs of microcrystic infiltration. The equigranular medium-grained granite contains alkali feldspar up to 15 mm across, greenish plagioclase mostly 2 to 4 mm, quartz pools less than 10 mm and biotite clots less than 4 mm.

Tsuen Wan. There is a small outcrop of medium-grained granite south of Tsuen Wan, and this outcrop is contiguous with a larger outcrop to the east and south (Addison, 1986; Strange & Shaw, 1986).

Petrography

Most samples of medium-grained granite are equigranular, but some show slight development of microcrystic textures. This is particularly so in proximity to outcrops of megacrystic fine- and fine-to medium-grained granite. The equigranular medium-grained granite from Castle Peak Road south of Tai Lam Chung (HK5028, 2125 2410) contains alkali feldspar, dominantly microcline, up to 10 mm (c. 34%). The plagioclase, around 2 mm, is zoned and slightly sericitized (c. 19%), while strained quartz with serrated margins makes up c. 40% of the rock. Biotite and secondary chlorite occur as small crystal aggregates up to 5 mm across (c. 7%). Equigranular medium-grained granite from west of Ting Kau (HK4087, 2538 2533) contains plagioclase of oligoclase composition (c. 30%), perthitic alkali feldspar with some microcline (c. 32%) and quartz (c. 35%). The plagioclase has zoned extinction and is sericitized. There is accessory biotite (c. 3%), sometimes unaltered pleochroic green to pale brown, but also altered to chlorite and epidote. The medium-grained granite from the outcrops about 1.5 km southeast of Tai Tong is essentially equigranular, but in thin section shows signs of developing a microcrystic texture. Sample HK2725 (2162 3019) (Plate 17) shows quartz granulation on the edges of large sericitized plagioclase crystals, and the development of a granophyric texture.

Modal analyses of six medium-grained granite samples (Figure 14) fall within the main range for all granites from the district, with a mean QAP (quartz-alkali feldspar-plagioclase feldspar) ratio of 37:36:27.

Geochemistry

Full silicate analyses have been undertaken on two samples of medium-grained granite (Table 6). As with most other granites from the district, they are enriched in silica (SiO_2) and potash (K_2O), and poorer in soda (Na_2O) relative to normal granites (Cox et al, 1979).

The ACF plot (Figure 13) shows that the medium-grained granite falls between the coarse- and fine-grained, but cannot be differentiated from most of the fine- to medium-grained granite samples. These characters were also noted in granites from adjacent districts (Addison, 1986; Strange and Shaw, 1986).

Age Relations

Three groups of medium-grained granite have been differentiated; west Tsing Shan (Castle Peak), Tuen Mun and the Tai Lam area. In the west of Tsing Shan the granite is adjacent to fine- to medium-grained granite, and textural modification of the medium-grained granite appears to indicate that it is older. The rock is cut by feldsparphyric rhyolite, quartzphyric rhyolite, aplite and basalt dykes. In addition, it contains shear zones with associated quartz veins that appear to be related to the regional dynamic metamorphism.

At Tuen Mun the medium-grained granite is the same age as the coarse-grained granite. Textural modification, often severe, separates it from adjacent finer grained outcrops. This outcrop is also cut by feldsparphyric rhyolite fine-grained granite, aplite and basalt dykes. It is not evidently affected by the regional dynamic metamorphism.

Fringing the Tai Lam pluton are a number of other outcrops of medium-grained granite. These are often texturally modified in contact with finer rocks, but are also texturally distinct from the Tuen Mun granites; they appear to have more in common with medium-grained granite from Tsing Shan (Castle Peak). The Tai Lam medium-grained granite outcrops are cut by fine-grained granite and basalt dykes, and are not affected by dynamic metamorphism. It can be inferred that the medium-grained granite was intruded in two phases, with the oldest being at Tuen Mun, and that they all pre-date the finer varieties of granite.

Fine- to Medium-grained Granite

Distribution and Lithology

This granite occurs in belts of varying width between the fine-grained granite and the coarser varieties. There is an extensive outcrop on Tsing Shan (Castle Peak), between fine-grained granite to the east and medium-grained granite to the west. In Tai Lam Country Park there is a large, irregular outcrop within the fine-grained granite, lying between the outcrops of coarse- and medium-grained granite at Tuen Mun, Siu Lam and northwest Tai Lam. There are also small outcrops associated with the medium-grained granite between Tai Lam Chung and Sham Tseng.

Allen & Stephens (1971) assigned this granite to various named units; the Tsing Shan outcrops, including the fine- and medium-grained granite, are shown by them as Cheung Chau Granite, while most of the Tai Lam outcrops are classed as Sung Kong Granite. However, the boundaries as recognized in the present survey differ markedly from those delineated by Allen & Stephens.

The fine- to medium-grained granite is always inequigranular, and very variable in texture. The average grain size of the groundmass is usually in the range 1 to 3 mm, although both larger and smaller crystals are common. The rock does not form a clear mappable unit in many areas, although the contacts with the uniform variety of fine-grained granite are well defined. The gradation from equigranular medium- and coarse-grained granite through microcrystic varieties into megacrystic fine- to medium-grained granite is commonly seen.

One feature of both the fine- and the fine- to medium-grained granite which is exclusive to the Tsing Shan and Tai Lam outcrops is the presence of mylonite or schist bands. These are generally very thin, only a few centimetres wide, and often occur close to the contacts between the two granites. The trends are dealt with in the chapter on structure.

Details

Tsing Shan. The fine- to medium-grained granite of Tsing Shan is typically megacrystic. In the south, near Mong Hau Shek (121 256), the granite contains pegmatite nests and associated layers enriched in biotite; the granite here is also foliated. There are quartz and feldspar megacrysts up to 5 mm, but they are indistinct. The groundmass varies from 1 to 3 mm, with a microcrystic infiltration visible only in thin section. Typical fine- to medium-grained granite from south of Lung Kwu Tan (113 263) is microcrystic and slightly foliated.

West Tai Lam Country Park. The fine- to medium-grained granite of this area forms a single, complex outcrop which is aligned with the surrounding fine-grained granite on a northeast trend. The outcrop is divided by sheets of fine-grained granite mostly between 100 and 500 m wide. Most of the outcrop is deeply weathered, but fresh rock has been exposed along catchwaters, in excavations and in boreholes. The contact between the rock types is usually obscure, but in a number of places can be accurately located. For example, east of Chi Lok Fa Yuen (165 278), above the catchwater, an abrupt change can be observed between megacrystic fine-grained granite to the north and megacrystic fine- to medium-grained granite to the south; this contact zone also includes pegmatite veins and nests. Similarly, northwest of So Kwun Wat (1789 2735) the contact zone with adjacent fine-grained granite includes fine-grained granite dykes and pegmatite, and forms a dyke-like body 50 to 150 m wide.

Near Wong Ka Wai, eastern Tuen Mun, an isolated outcrop is cut both by basalt dykes and a thick quartz vein trending parallel to the contact with the volcanics to the west. Exposures in the stream at Wong Ka Wai (1580 2843) show greenish white granite with megacrysts of feldspar up to 25 mm and quartz up to 10 mm set in an inequigranular groundmass ranging from 1 to 5 mm.

To the west of Lam Tei Reservoir (186 202) the fine- to medium-grained granite lies between an area of equigranular medium-grained granite and the surrounding megacrystic fine-grained granite. This outcrop is traversed by quartzphyric rhyolite and basalt dykes, and very thin schist bands. The contact between the fine- to medium-grained and fine-grained granite is not seen, but is probably gradational, for example in the excavations southeast of Tan Kwai Tsuen (185 317).

On the catchwater north of a small reservoir (1970 2912) there is a sharp contact between fine-grained granite to the south and inequigranular fine- to medium-grained granite to the north. Fine-grained granite dykes are not common, but a small one, about 50 mm wide, can be seen in the centre of the outcrop (1848 2803), and another can be seen on the catchwater above So Kwun Wat (1815 2667).

Along the catchwater north of So Kwun Wat (181 266) the granite is white to grey in colour, with feldspar megacrysts up to 25 mm long, biotite clots up to 7 mm, and quartz megacrysts up to 7 mm. The groundmass mostly falls in the range 1 to 4 mm. In boreholes south of So Kwun Wat the granite varies from pink to white in colour. Alkali feldspar is up to 15 mm, while greenish plagioclase is between 2 and 7 mm. Quartz megacrysts are often clearly defined, and are up to 10 mm across. Biotite clots are generally less than 7 mm, and the groundmass varies from 2 to 4 mm in some parts, to less than 0.5 to 1 mm in others.

On Lung Chue To (Pearl Island) (170 251) the outcrop of fine- to medium-grained granite is weathered brownish white and contains megacrysts of feldspar up to 20 mm, quartz up to 8 mm and biotite clots up to 6 mm. The groundmass varies from 1 to more than 3 mm.

Tai Lam Chung to Sham Tseng. There are two outcrops of fine- to medium-grained granite in this area, both closely associated with the equigranular medium-grained granite to the south. Around Tai Lam Chung no exposed contacts were noted between the megacrystic fine- to medium-grained granite and the surrounding megacrystic fine-grained granite. However, east of the prison a progressive change can be seen, with the groundmass increasing in proportion and becoming both finer and more equigranular. Near Tai Lam Chung Tsuen (2035 2541), fine- to medium-grained granite is very variable in texture and is believed to lie at the margin of the intrusion. Further north, within the outcrop, (204 256) the coarsely megacrystic fine- to medium-grained granite has a relatively uniform texture. The feldspar megacrysts are up to 30 mm, and the groundmass varies from less than 1 to more than 3 mm. There are also thin pegmatite and biotite-rich veins.

To the east a continuous outcrop can be seen between Tsing Lung Tau and Sham Tseng. This has also been traced offshore Sham Tseng using borehole information. The granite is pale pink to white in colour and contains megacrysts of alkali feldspar mostly less than 10 mm, with plagioclase less than 6 mm and aggregates of small biotite crystals less than 7 mm, as well as single biotite crystals up to 4 mm. There is a markedly inequigranular groundmass varying from 0.5 to 3 mm. The rock contrasts with the medium-grained granite to the south and with the fine-grained granite to the north, but no sharp contacts have been observed.

At Sham Tseng the outcrop of fine- to medium-grained granite is cut by dykes of basalt and fine-grained granite (2373 2501). To the west of Tsing Lung Tau (220 244) a group of basalt dykes cut the contact between the fine-grained and fine- to medium-grained granite.

Petrography

The fine- to medium-grained granite is characterized by a markedly inequigranular groundmass and the presence of megacrysts of quartz, feldspar and biotite. Across the outcrops the rock forms a continuum from megacrystic fine-grained to megacrystic medium-grained. Typical megacrystic fine- to medium-grained granite from Tsing Lung Tau (HK 4075, 2240 2484) (Plates 21 & 22) contains megacrysts up to 25 mm, although most crystals are 1 to 4 mm. The modal composition is c. 34% quartz, c. 31% plagioclase and c. 33% alkali feldspar, which includes c. 12% microcline. There is accessory biotite and chlorite (c. 1%) as clots, and there are rare flakes of muscovite.

About 1.5 km southwest of Yeung Ka Tsuen the fine- to medium-grained granite from the contact zone with the adjacent fine-grained granite (HK 2622, 1667 2923) shows microcrystic modification of the groundmass. The quartz megacrysts, and some of the feldspar megacrysts, are noticeably granulated on the margins. The thin section is composed of c. 48% groundmass, which is dominantly quartz. Overall, the modal analysis is c. 53% quartz, c. 27% alkali feldspar and c. 19% plagioclase; accessory biotite is less than 1%.

Modal analyses of six samples of fine- to medium-grained granite are given in Figure 14. Most fall within the main range for all the granites of the district, but included are samples which are relatively enriched in quartz and alkali feldspar. The mean ratio of quartz, alkali feldspar and plagioclase for all six samples is 39:34:27.

Geochemistry

Full silicate analyses have been undertaken on six samples of fine- to medium-grained granite from the district (Table 7). All samples are enriched in silica (SiO_2) and potash (K_2O), and poorer in soda (Na_2O) relative to normal granites (Cox et al, 1979). The ACF plot (Figure 13) shows a wide range for the fine- to medium-grained granite, with equivalent compositions in the fine-grained granite and medium-grained granite.

Age Relations

The fine- to medium-grained granite often appears to be the result of textural modification of coarser granites, and is probably the result of a later intrusion mixing with or modifying earlier rocks. The extreme modification is found in the fine-grained granite, but the age of the fine-grained and fine- to medium-grained granites is probably the same over most of the district. The fine- to medium-grained granite is cut by feldsparphyric rhyolite, quartzphyric rhyolite, aplite, fine-grained granite, basalt and andesite dykes. In both the Tsing Shan and Tai Lam plutons the fine- to medium-grained granite contains zones of schistosity, mostly trending northeast; the contacts between this rock and the fine-grained granite appears to be controlled by this shear trend in parts of the Tai Lam pluton.

Fine-grained Granite

Distribution and Lithology

Fine-grained granite forms the bulk of granite outcrop in the district. On Tsing Shan (Castle Peak) the granite outcrops on the eastern slopes, with fine- to medium-grained granite to the west. To the east are sedimentary and volcanic rocks of the Tsing Shan and Tuen Mun formations. Fine-grained granite outcrops throughout Tai Lam Country Park and surrounding areas. The

contacts with the fine- to medium-grained granite are complex, but dominated by a northeast-southwest trend. The medium- and coarse-grained granite is largely peripheral to the fine-grained outcrop. Fine-grained granite also outcrops on Tsing Yi and in southern Tsuen Wan.

Allen & Stephen (1971) assigned the fine-grained granite type in Tai Lam to the Needle Hill Granite. To the west, on Tsing Shan, they assigned the whole area to the Cheung Chau Granite type.

The fine-grained granite is typically pale pink or white (Plate 23) with a strong contrast between megacrysts and groundmass. However, gradations into the fine- to medium-grained granite can be found, particularly in western Tai Lam. Megacrysts of subhedral feldspar are commonly up to 10 mm, while anhedral quartz is commonly up to 7 mm. Biotite occurs as small aggregates or single crystals, usually less than 3 mm across. The groundmass crystals are less than 0.5 mm, but are not usually very uniform in size.

Contacts with adjacent non-granitic rocks are usually sharp, with no signs of chilling, but hydrothermal activity is sometimes evident as greisenization. Fine-grained granite dykes are known to cut the fine-grained granite, and can be mapped because the texture of the dykes is more uniform, with fewer or no megacrysts. On Tsing Yi and east of Sam Shing Hui, granophyric fine-grained granite has been noted, forming narrow bodies and extending into dykes.

Details

Tsing Shan. Fine-grained granite forms the main massif of Tsing Shan, being noticeably more resistant to erosion than adjacent coarser-grained varieties. The rock is generally megacrystic, and on the watershed west of Leung Tin Estate shows a progressive westward increase in megacryst content. A xenolith of basic igneous rock up to 150 mm across was seen about 1 km south of Tsing Shan (132 267). This rock, possibly lava, is fine-grained and greyish green, with small feldspar phenocrysts. The contact between the granite and country rock to the east appears to have a faulted intrusive nature, with a shear zone typically up to 5 m wide. The fine-grained granite is often metamorphosed to granite schist or mylonite, for example northwest of Po Tong Ha (148 313). The contact dips 47° to the west near Tsing Shan (1348 2690), and to the northwest at 62° near Leung Tin Estate. About 1 km north of Tsing Shan (1341 2853) the contact between fine-grained granite and sandstone is irregular, with leaves of foliated granite within the sandstone; the contact dips west at about 50°. A small intrusion of fine-grained granite, separate from the main mass, outcrops within the Tsing Shan Formation west of Shan King Estate (1358 2878). The granite is slightly foliated, with irregular dykes of aplite and small quartz veins.

Typical fine-grained granite from Tsing Shan (127 282) is megacrystic, with quartz up to 8 mm and feldspar up to 12 mm. Megacrysts are almost invariably abundant, dominating the rock texture, while the matrix is almost very fine-grained. In thin section the groundmass is generally less than 0.1 mm, with pronounced granulation of the edges of the megacrysts. Biotite forms small, felted aggregates up to 3 mm, and rarely as single crystals.

Tuen Mun to Tan Kwai Tsuen. This outcrop is bounded to the west by a fault separating it from Carboniferous sedimentary rock, and to the east by fine- to medium-grained granite. Well defined contacts with other granite varieties are found in a few places, but sharp contacts have been observed. About 1.5 km east of Wong Ka Wai (170 282) the fine-grained granite outcrop extends in a dyke-like form, trending northeast and gradually reducing to less than 100 m in width. The rock is megacrystic fine-grained granite, and there is a gradual increase in both megacryst content and groundmass grain size towards adjacent fine- to medium-grained granite outcrops. This same contact with the fine- to medium-grained granite can be seen in a stream to the northeast (1715 2880). About 500 m to the north (1693 2863) the change from megacrystic fine-grained granite is marked by an increase in the grain size of the soil.

In the few places where the fine-grained granite is in direct contact with medium- or coarse-grained granite the boundaries are usually sharp and distinct. About 1 km east of Tan Kwai Tsuen (1869 3191) the contact with a small outcrop of equigranular medium-grained granite is well-defined, striking roughly southeast with a vertical dip. The adjacent fine-grained granite is typically uniform and sparsely megacrystic. About 0.5 km east of Wong Ka Wai (161 283) there is a marked transition from the megacrystic fine-grained granite to the west into a complex of coarser granite types cut by fine-grained granite dykes.

The intrusive contact of the fine-grained granite with Carboniferous sediments to the west is also faulted. About 500 m northeast of Tuen Mun San Hui, two boreholes intersect highly fractured granite beneath superficial deposits (900D/03410, 15784 29078; 1384D/03546, 15740 29075), and 30 m to the west a borehole intersected phyllitic siltstone. At Wong Fung Lek (1635 2966) a contact between deeply weathered granite and foliated quartzite trends northeast.

A dyke of fine-grained granite trending northeast occurs to the east of Sam Shing Hui (163 268). The rock grades into the adjacent coarse-grained granite.

The fine-grained granite is cut by quartzphyric rhyolite and basalt dykes, particularly in a broad belt to the east of Lam Tei (184 310). Fault breccia or zones of strong shattering are found in most north-trending valleys, and thin bands of mylonite can also be found within the outcrop. Fine-grained granite dykes are very rare, but can be seen in the megacrystic host rock.

Central and Eastern Tai Lam Country Park. One of the largest continuous outcrops of fine-grained granite occupies the centre of Tai Lam Country Park, from So Kwun Wat in the southwest to Ting Kau in the southeast, and extending to the northeast and northwest of Tai Lam Chung Reservoir.

The fine-grained granite is best exposed along the road running parallel to the southeast side of Tai Lam Chung Reservoir (212 261). The rock is pink, weathering brown, and is dominated by a fine-grained groundmass of around 0.5 mm. Megacrysts are common, ranging up to 25 mm for the feldspar and 8 mm for the quartz. Biotite occurs as clusters of small crystals up to 3 mm across. The rock is cut by quartz veins, basalt dykes and rhyolite dykes. At one locality (2185 2740) the granite is hydrothermally altered to a dyke-like body about 4 m wide trending southeast.

To the northeast and southeast of the Tai Lam Chung outcrop the granite is in contact with volcanic rocks. North of Ho Pui Reservoir (2555 3011), in the river valley, fine-grained granite lies below thermally metamorphosed tuffs of the Shing Mun Formation. There is an isolated knoll of equigranular fine-grained granite about 20 m across within the tuff, probably indicating the shallow, irregular nature of the contact. This same intrusive contact is also clearly defined on a track west of the reservoir (2533 2937), where fine-grained granite lies below crystal tuffs of the Ngau Liu Member. This contact can be seen again to the west, about 0.7 km north of Tin Fu Tsai (247 289), where it is sub-horizontal or dipping gently east.

At Ting Kau, in the southeast of the outcrop, the contact between megacrystic fine-grained granite and tuffs of the Yim Tin Tsai Formation is faulted. Altered and silicified granite can be seen in a valley, with a fault zone dipping steeply east (2625 2591). On the catchwater the granite is strongly jointed (2624 2598), and the adjacent valley marks erosion along the weaker rocks in the fault.

A sheared contact of megacrystic fine-grained granite and granodiorite can be seen on an island in Tai Lam Chung Reservoir (209 265). The shearing is associated with quartz veins and greisen, and follows the dominant northeast structural trend of the faults in the area. Similar shears seen near the main dam (2075 2607) contain basalt dykes and thin mylonite bands.

To the east of the main outcrop are three small inliers of equigranular or megacrystic fine-grained granite. About 1 km east of Tin Fu Tsai (255 281) are a few exposures of equigranular or sparsely megacrystic fine-grained granite, largely within granodiorite. Further east (2758 2826), between outcrops of granodiorite and tuffs, is a larger outcrop of megacrystic fine-grained granite. This outcrop is contiguous with exposures in the Western Aqueduct tunnel some 400 m below, and is the expression of a small, steep-sided intrusion. About 1 km south of Kap Lung is an outcrop of partially metamorphosed, equigranular fine-grained granite.

Tai Tong to Ma On Kong. To the southeast of Tai Tong are several isolated outcrops of fine-grained granite within the outcrop of medium-grained granite. A contact between the megacrystic fine-grained granite and overlying thermally metamorphosed tuffs and sedimentary rocks can be defined on a small knoll in the northeast of the outcrop (238 309). About 250 m to the south of this intrusive contact an outlier of tuff straddles the fine-grained and medium-grained granite boundary.

At the largest outcrop of megacrystic fine-grained granite in the area the granite is greisenized at its contact with the overlying tuffs (2293 2973). The outcrop is surrounded by medium-grained granite and the contact is well seen on a track to the south (2265 2890). The presence of a microcrystic groundmass to the medium-grained granite becomes progressively more noticeable over a distance of 30 m, until fine-grained granite with many megacrysts is dominant. Along a northnorthwest-trending valley (223 296) the fine-grained granite contains fault breccia, greisen veins and pegmatite. A schistosity is also developed along this trend in belts up to 200 mm wide. To the north (211 304) the contact with Carboniferous sedimentary rocks is believed to be intrusive, dipping gently northwards.

Western Aqueduct. Megacrystic fine-grained granite was intersected by the tunnel in exposures which can be directly related to outcrop. West of Ma On Kong the granite was found both adjacent to the tuffs of the Shing Mun Formation and within the medium-grained granite. The contact with the tuff (2353 3110) is sharp and intrusive, and dips 18° to the north with a small normal fault displacing it about 0.5 m. Below Lin Fa Shan, megacrystic fine-grained granite is intruded between granodiorite to the north and Shing Mun Formation tuffs to the south.

Tsing Yi and Tsuen Wan. Fine-grained granite outcrops in parts of north and northeast Tsing Yi, and in adjacent areas south of Tsuen Wan. The granite is different from that seen elsewhere in the district, but has close affinities to dykes of quartzphyric rhyolite found in the area. Strange & Shaw (1986) noted a similar granite in northwest Kowloon. The granite forms dyke-like bodies, common on Tsing Yi, and grades into quartzphyric rhyolite. The granite is usually granophyric, and contains abundant small megacrysts, mostly of quartz (Plates 25 & 26). South of Cheung Shue Tau (2775 2432) there is a contact between granophyric fine-grained granite to the north and granodiorite to the south. A basalt dyke lies on the contact, and a small fault cuts these rocks, displacing the contact by about 5 m. Northeast of Fung Shue Wo (283 247) the granite intrudes tuffs of the Yim Tin Tsai Formation. The contact is highly fractured but has an irregular trend which probably indicates an intrusive rather than a faulted nature. At Fung Shue Wo (2847 2431) the boundary between megacrystic fine-grained granite and granodiorite was exposed during road construction. Excavations at the Oil Depot south of Tsuen Wan (297 247) revealed highly fractured or jointed fine-grained granite next to porphyritic fine-grained granodiorite. Offshore boreholes between Tsing Yi and Yau Kom Tau revealed granophyric fine-grained granite, strongly fractured and cut by basalt dykes.

Petrography

Typical megacrystic fine-grained granite (HK 4064, 2575 2611) from the east of the Tai Lam Country Park outcrop, near Ting Kau, is pink in colour, with megacrysts of quartz and feldspar less than 5 mm. Small, greenish biotite clots are less than 2 mm, and in thin section the groundmass is 0.2 to 0.5 mm. Modal analysis indicates a quartz content of c. 36%, alkali feldspar, including microcline, of c. 34% and plagioclase of c. 26%. Accessory biotite, including minor amounts of associated muscovite and chlorite, makes up c. 4% of the rock.

Sparsely megacrystic fine-grained granite (Plate 24) can be found in the quarry at Lam Tei (Sample HK3178, 1753 3026) (Table 7). In thin section it contains very few megacrysts, and the groundmass grain size varies from 0.2 to 0.5 mm. The modal composition is c. 44% quartz, c. 28% alkali feldspar and c. 22% plagioclase. The alkali feldspar includes microcline in part, and the plagioclase is zoned, slightly sericitized oligoclase. Muscovite (c. 3%) occurs as single flakes up to 0.4 mm, sometimes as an overgrowth on the plagioclase. Biotite (c. 1%) occurs in small aggregates which include muscovite and other accessory minerals.

Coarsely megacrystic fine-grained granite adjacent to microcrystic medium-grained granite is evident southsoutheast of Tai Tong. In thin section (HK 3159, 2135 2964) the granite has abundant megacrysts (c. 40%) set in a groundmass ranging in size from 0.2 to 0.8 mm. The megacrysts are subhedral, with granulation of the crystal boundaries in the recrystallized groundmass. Overall, the modal composition is typical of the fine-grained granites (Figure 14), with c. 41% quartz, c. 28% alkali feldspar and c. 27% plagioclase. The accessory is biotite (c. 3%), occurring as small flakes up to 2 mm across.

Modal analyses of eight samples of fine-grained granite are given in Figure 14. There is little distinction between these samples and others from the district, although a slight increase in plagioclase and alkali feldspar can be seen. One sample with well-defined megacrysts (HK 707, 2702 2842) showed no appreciable difference in the composition of the groundmass relative to the megacrysts; this would not normally be expected if the megacrysts were a crystal fractionation on cooling.

Geochemistry

Two samples of fine-grained granite from the district have been chemically analyzed (Table 7). Both are particularly rich is soda (Na_2O) relative to other granites, but not as high as some granites from adjacent districts (Addison, 1986; Strange & Shaw, 1986). This is probably because the fine-grained granite in the district has absorbed material from the coarser, soda-poor varieties. The ACF plot (Figure 13) shows the two samples to be at the upper end of the trend, but not as clearly differentiated as those in Hong Kong Island and Kowloon (Strange & Shaw, 1986).

Age Relations

The fine-grained granite is similar in age to the fine- to medium-grained granite in most of the district. Textural relicts from the coarser varieties which have been assimilated in the fine-grained granite are usually present, particularly in the Tai Lam pluton. In the Tai Lam and Tsing Shan plutons the rock is cut by feldsparphyric rhyolite, quartzphyric rhyolite, fine-grained granite, aplite, dacite and basalt dykes. In addition, the rock is often sheared on a northeasterly trend, particularly in Tsing Shan, and has been affected by the regional dynamic metamorphism in the district. On Tsing Yi the fine-grained granite is not cut by quartzphyric or feldsparphyric rhyolite, but often grades into these dykes. It is, however, cut by basalt dykes.

Chapter 6
Minor Intrusions

Classification and Distribution

The minor intrusions of the district occur as dykes varying in width from a few centimetres to 200 metres. Most of the dykes can only be traced for a few tens of metres, but some are over a kilometre in length. The dykes are of eight different types; feldsparphyric rhyolite, quartzphyric rhyolite, aplite or fine-grained granite, dacite, basalt and gabbro, andesite, lamprophyre and pegmatite. With the exception of the basalt, gabbro and lamprophyre, the minor intrusions are related to the Mesozoic granite emplacement. Most of the basic intrusions are considered to be of Tertiary age (Allen & Stephens, 1971).

Hatch et al (1972) recommended the use of the names rhyolite, dacite and basalt as a non-genetic system for both minor intrusions and volcanics. Streckeisen (1980) made recommendations on the classification of volcanic rocks which use these names, and these divisions are used in this survey (Figure 12). It is therefore possible to give a rock the correct name even if field relationships and mode of occurrence are unclear, as the system depends mainly on the identification of mineral content in hand specimen or thin section, with confirmation by chemical analysis rarely being necessary. On their map, Allen & Stephens recorded a feldspar porphyry dyke swarm (La), loosely referred to as the Lantau Porphyry. This swarm passes through Ma Wan and northern Tsing Yi. The rhyolite and dacite dykes correspond to the granite and granodiorite porphyry dykes of Allen & Stephens (1971), and their dolerites are mapped as basalt or gabbro.

Feldsparphyric Rhyolite

Distribution and Lithology

The feldsparphyric rhyolite dykes contains abundant, large megacrysts of feldspar, often up to 20 mm long, but they also contain smaller megacrysts of quartz and biotite. These are set in an aphanitic, pale grey groundmass. This is the dominant lithology of the minor intrusions in the district, but is confined largely to the Ma Wan – Tsing Yi – Tsuen Wan area, where it forms wide dykes and small igneous masses. Feldsparphyric rhyolite is also found as thin dykes near Kap Lung, at Mong Hau Shek (Pillar Point) and on Kai Keung Leng.

Details

Ma Wan, Tsing Yi and Tsuen Wan. On Ma Wan, feldsparphyric rhyolite is closely related to intrusions of quartzphyric rhyolite and fine-grained granite. Offshore Ma Wan a borehole (15/05845, 2450 2429) intersected feldsparphyric rhyolite. In a northeast-trending dyke near Wok Tai Wan (2640 2411) the feldspar megacrysts are aligned parallel to the dyke margin (Plate 29). Close by (2644 2407) there is a complex relationship between feldsparphyric rhyolite, quartzphyric rhyolite and a 4 m wide granite body, in which the quartzphyric rhyolite is the latest of these three intrusions. There is also a younger, thin basalt dyke, about 0.5 m wide. South of Yau Kom Tau, two eastnortheast-trending feldsparphyric rhyolite dykes grade into granophyric fine-grained granite to the south, and along the coast at Yau Kom Tau the feldsparphyric dykes have sharp contacts with easterly-trending quartzphyric rhyolite.

A large body of feldsparphyric rhyolite about 0.5 km west of Pun Shan Tsuen (280 260) contains feldspar megacrysts up to 20 mm, and quartz and biotite megacrysts up to 6 mm. On Castle Peak Road (2811 2550) the rhyolite has a dyke-like form and varies from aphanitic to feldsparphyric, with feldspar up to 10 mm across. This dyke lies along the faulted contact between epidotized tuffaceous sandstone to the east and Yim Tin Tsai Formation tuffs to the west. Further north the body is up to 200 m across.

North of Tsuen Wan, along Route Twisk, are two irregular outcrops of feldsparphyric rhyolite. At Pak Tin Pa (2983 2648) the feldsparphyric rhyolite intrudes fine-grained granite and dacite. It can be distinguished from the porphyritic dacite by its minimal biotite content.

Tai Lam Country Park. At Ting Kau (2616 2568) a feldsparphyric rhyolite dyke lies on the faulted contact between fine-grained granite to the west and tuffs of the Yim Tin Tsai Formation. Feldsparphyric rhyolite intrudes tuffs about 0.5 km northwest of Chuen Lung (289 287). The dyke is poorly exposed, but forms a linear feature on aerial photographs. Feldsparphyric rhyolite dykes are found along Route Twisk about 1 km east of Kap Lung. One dyke cuts tuffaceous sandstone of the Shing Mun Formation, and is displaced a few metres by a north-south fault (2963 3061). It is exposed again about 200 m to the northnortheast. A second dyke, exposed along Route Twisk further northeast (2999 3110), is about 5 m wide, with a pale, noticeably megacrystic centre and dark aphanitic edge.

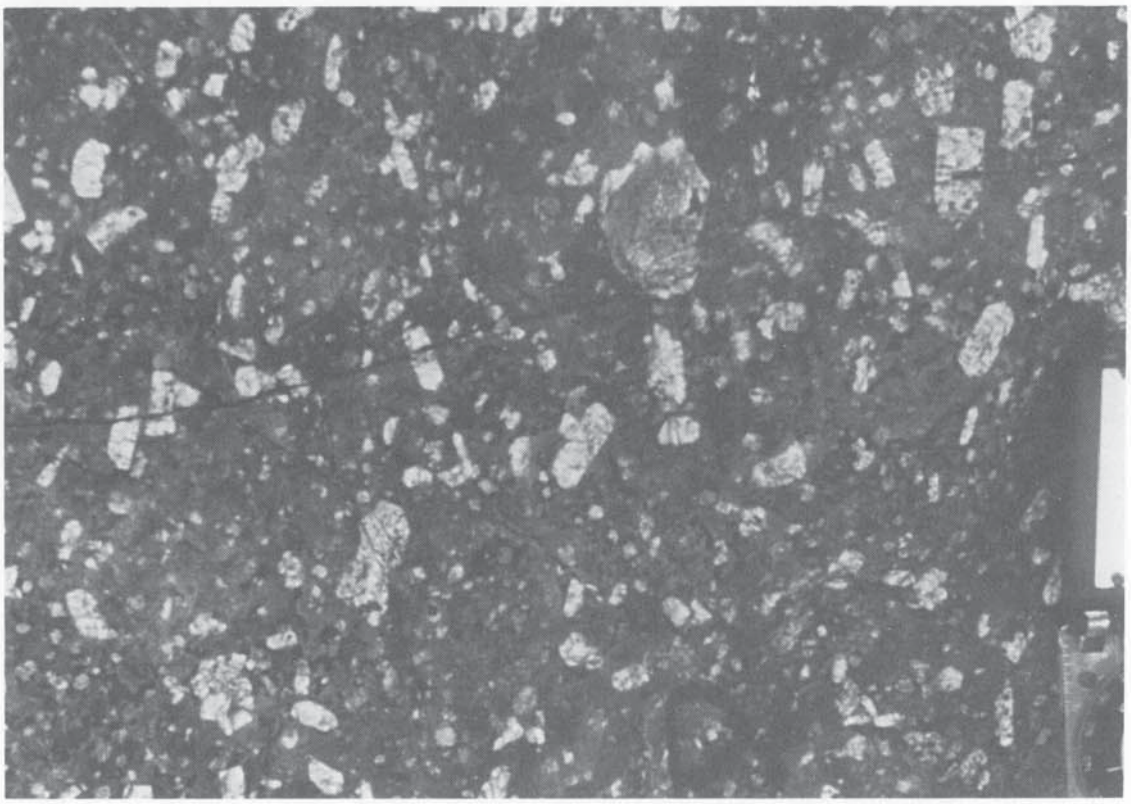


Plate 29 – Feldsparphyric Rhyolite Dyke at Wok Tai Wan, Tsing Yi (2640 2411)

Tsing Shan (Castle Peak). A dyke of feldsparphyric rhyolite trends approximately north-south through medium-grained granite at the Castle Peak Power Station site at Tap Shek Kok. This dyke was formerly exposed in rock cuts forming the back wall of the site (1005 2663), where it is recorded as being up to 10 m thick; it was also found in excavations for chimney foundations (1000 2607).

Kai Keung Leng. About 1 km north of Tsat Sing Kong is a prominent feature corresponding to exposures of feldsparphyric rhyolite dyke. The dyke is about 20 m wide and trends roughly east-west. At the eastern end of the feature (2689 3515) the dyke is affected by metamorphism, and some parts are schistose.

Petrography

Feldsparphyric rhyolite from Wok Tai Wan, northwest Tsing Yi, (HK2267, 2640 2411) consists of c. 63% microcrystalline groundmass and c. 35% megacrysts of plagioclase, quartz and alkali feldspar (Plate 27). The groundmass has a crystal size dominantly in the range 0.02 to 0.04 mm. The dominant megacrysts are euhedral oligoclase (c. 14%) which is sericitized and epidotized. Quartz (c. 11%) occurs as subhedral crystals or crystal aggregates, and the alkali feldspar (c. 9%) occurs as large euhedral crystals. The mafic minerals (c. 2%) comprise biotite plus secondary epidote, chlorite and opaques.

The rhyolite from the large bodies on Route Twisk (HK3207, 2961 2695) contains c. 56% microcrystalline groundmass. The megacrysts are dominantly sericitized plagioclase (c. 22%), with quartz (c. 14%) and alkali feldspar (c. 6%); all the megacrysts are euhedral or subhedral. Biotite occurs mostly as small single crystals and makes up only 2% of the rock.

Age Relations

Feldsparphyric rhyolite dykes have been found cutting granite and granodiorite intrusions, and tuffs of the Repulse Bay Volcanic Group. In west Tsing Yi the dykes are associated with both basalt and quartzphyric rhyolite dykes. The basalt dykes clearly cross-cut the feldsparphyric rhyolite dykes, while the quartzphyric rhyolite dykes, although on the same trend, have chilled margins against them. The feldsparphyric rhyolite is hydrothermally altered in the regional metamorphic belt on the flanks of Kai Keung Leng.

The petrography, field characteristics and outcrop form of the feldsparphyric rhyolite around Tsing Yi and Ma Wan suggest that they are part of a high-level granitic intrusion. They appear to be part of the early phase in the development of this intrusion, grading into fine-grained granite in parts.

Quartzphyric Rhyolite

Distribution and Lithology

The quartzphyric rhyolite is characterized by scattered small quartz megacrysts but may also contain small feldspar megacrysts. Unlike the feldsparphyric rhyolite, the quartzphyric variety is found throughout the granite outcrops. In particular, there are two eastnortheast-trending swarms of dykes, one north of Mong Hau Shek (Pillar Point) and the other east of Lam Tei. A number of thin dykes occur southeast of Tuen Mun, and a large number of thicker dykes are found on northern Ma Wan and Tsing Yi.

Quartzphyric rhyolite is generally pale grey, and often intensely fractured. The groundmass is aphanitic, and contains few, scattered megacrysts of quartz up to 3 mm across. Where margins to the dykes are seen these are finely flow banded, essentially non-megacrystic and often a darker colour than the main body of rock.

Details

Tsing Shan (Castle Peak). A swarm of eastnortheast-trending quartzphyric rhyolite dykes crosses the southern part of the Tsing Shan range, intruding granites and rocks of the Tsing Shan and Tuen Mun formations. In its fresh state the rhyolite is very pale grey, though in most exposures it appears pale yellowish green, saccharoidal and locally chalky. It contains quartz phenocrysts, generally subhedral to euhedral, in the range 1 to 2 mm (1155 2591); exceptionally, quartz grains up to 10 mm have been recorded (1206 2600). The rock is generally foliated, in places to the extent that quartz phenocrysts may be obliterated or recrystallized; the dykes are, with a few exceptions, associated with parallel or subparallel quartz veins (1248 2523), and the adjoining host rock is commonly strongly sheared. The thickest dyke of the swarm, about 10 m across, was noted in excavations around a landfill site north of Mong Hau Shek (Pillar Point) (1259 2634).

Lam Tei. A swarm of quartzphyric rhyolite dykes with an eastnortheast trend intrudes the granite east of Lam Tei. The largest dyke is 1.2 km long and is exposed in the northern part of the quarry, where it varies from 3 to 6 m wide. Further east (1787 3076) the dyke is 20 m wide and has quartz megacrysts up to 2 mm, with minor amounts of biotite and feldspar. The margins of this dyke are aphanitic, non-megacrystic and flow banded (Plate 30). When traced further east to the ridge (185 310) this dyke divides into two thin dykes of 3 m and 2 m.

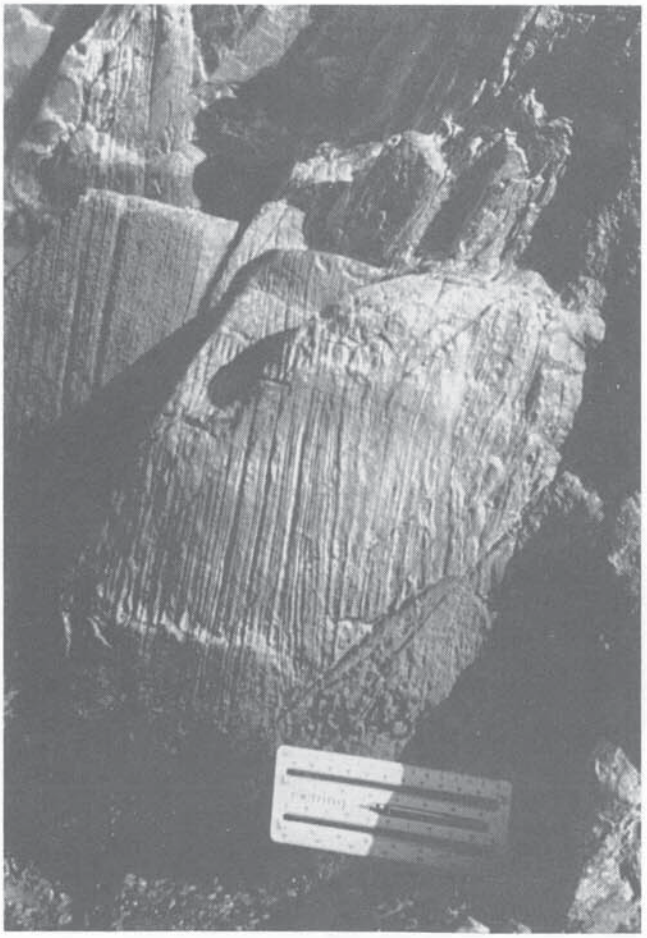


Plate 30 – Flow-banded Quartzphyric Rhyolite Dyke at Lam Tei (1287 3076)

To the north (183 318), in a temporary excavation, a quartzphyric rhyolite dyke varies in width from 6 to 17 m and is accompanied by further thin dykes of around 0.1 m width. To the northeast (188 320) a quartzphyric rhyolite up to 10 m wide is exposed along a new road; the dyke gradually thins to 2 m or less to the west.

Southeast Tuen Mun. Quartzphyric rhyolite dykes are exposed along the coast southeast of Tuen Mun, in Perowne Camp and at Siu Sau. The largest of these dykes, at Siu Sau (1770 2551), is about 10 m wide and trends eastnortheast; the centre of the dyke is grey, with quartz megacrysts up to 1 mm and a fine scattering of biotite, while the margins are slightly flow banded and much paler. Close by to the south is a similar dyke 1 m wide.

East of Ka Fei Wan (Cafeteria Beach) a 17 m wide quartzphyric rhyolite dyke has sheared margins and trends roughly northeast. A quartzphyric rhyolite dyke lying on the same trend outcrops to the northeast in Perowne Camp (1732 2635). The centre of the dyke is pale greenish grey, while a narrow zone seen on one margin is a darker bluish grey.

Tsing Yi. Many of the quartzphyric rhyolite dykes that trend east-west across northern Tsing Yi were proven in ground investigation boreholes. The best exposures are along the western coast, for example south of Wok Tai Wan (2646 2406), where an 18 m wide quartzphyric rhyolite dyke with flow banding on the margins cuts a large feldsparphyric rhyolite body. Both rhyolites have subsequently been cut by thin basalt dykes. Quartzphyric rhyolite dykes form part of a complex intrusive suite to the north of Fung Shue Wo (2832 2477). The dykes cut Yim Tin Tsai Formation tuffs and are closely associated with fine-grained granite. Quartzphyric rhyolite forms a dyke up to 2 m wide at Fung Shue Wo (2810 2410) and has characteristic flow banding parallel to the margin.

Petrography

Most of the quartzphyric rhyolite dykes have a groundmass with distinct crystals of quartz, alkali feldspar, plagioclase and muscovite ranging in size from 0.02 to 0.1 mm. Where the dyke is small, or in the flow banded margins, the groundmass is microcrystalline around 0.005 mm.

Typical quartzphyric rhyolite (Plate 28) from an eastnortheast-trending dyke in northeast Tsing Yi (HK2283, 2832 2477) comprises c. 80% groundmass, including c. 8% muscovite ranging in size from 0.02 to 0.05 mm. The megacrysts of quartz (c. 7%) are euhedral to subhedral, often bipyramidal. The alkali feldspar, which has a micrographic texture in parts, makes up c. 7% of this thin section, while the plagioclase, of oligoclase composition, is c. 5%. Both feldspars are often euhedral and occur in clusters, and all megacrysts are less than 1 mm across. Flow banded quartzphyric rhyolite from the quarry east of Lam Tei (HK3179, 1753 3026) is representative of the finer, virtually non-megacrystic variety. Modally the rock contains c. 95% groundmass, with c. 1% quartz, c. 2% alkali feldspar and c. 0.5% plagioclase. The mafic mineral is biotite, both in the small clots and in the microcrystalline groundmass.

Age Relations

Quartzphyric rhyolite dykes cut all the major intrusions and volcanics of the Repulse Bay Volcanic Group. They have also been noted in boreholes cutting metamorphosed Palaeozoic rocks. The dykes form in swarms across parts of Tsing Shan and Tai Lam plutons, following an eastnortheast trend. This same trend is evident in the Tsing Yi – Ma Wan area, where the dykes cut earlier feldsparphyric rhyolite dykes. On Tsing Yi, quartzphyric rhyolite is closely associated with granophyric fine-grained granite.

The dykes probably formed as the late stage in a high-level intrusion, with chilled, sheared margins indicating rapid cooling. Basalt dykes cut the quartzphyric rhyolite, and clearly post-date them.

Fine-grained Granite and Aplite

Distribution and Lithology

Small impersistent dykes of fine-grained granite and aplite are found throughout the granite outcrop. In addition, a number of extensive aplite dykes can be found from northeast of Lan Kok Tsui (Black Point) to Tai Shui Hang (118 312). The dykes are usually found within the outcrops of medium-grained and coarse-grained granite, for example at Tuen Mun and Tai Lam Kok (Brothers Point), but can also be found in the finer granites. They occur commonly where medium-grained granite grades into finer granites. The only occurrences of fine-grained granite dykes outside the main granite outcrop are on Ma Wan and Tsing Yi, where they form part of a dyke complex which includes quartzphyric and feldsparphyric rhyolite.

Fine-grained granite and aplite dykes are both light-coloured, with a grain size of around 0.2 to 0.5 mm. Aplite is of granitic composition, although it has very little apparent biotite and a markedly equigranular texture, termed saccharoidal (Bates & Jackson, 1980), unlike the generally less uniform fine-grained granite dykes, which may also be megacrystic.

Details

Tai Lam Country Park. Fine-grained granite dykes are exposed along the catchwater east of Wong Ka Wai (162 282). The dykes trend roughly northnortheast and are found close to the contact of coarse-grained granite with fine-grained granite. At Sam Shing Hui, aplite and fine-grained granite dykes cut coarse-grained granite. The dykes range in width from 0.1 to 0.14 m and trend roughly east-west. A number of fine-grained granite dykes outcrop along the coast between Castle Peak Beach and Kadoorie Beach. At the southern end of Castle Peak Beach (1606 2656) a group of flat-lying fine-grained granite dykes intrude coarse-grained granite. These flat-lying dykes are in turn cut by thin steeply dipping fine-grained granite dykes (Figure 15, Plate 31). A number of fine-grained granite dykes outcrop within the medium-grained granite close to the boundary with the surrounding megacrystic fine-grained granite west of Tsing Lung Tau (220 244). These dykes trend eastnortheast to northeast, across the main granite boundary. Aplite dykes cut the granodiorite about 1.2 km west of Tsing Fai Tong (2319 2700), where three dykes up to 0.25 m wide can be seen. These dykes trend northeast, east and southsoutheast.

Tsing Shan (Castle Peak). Minor dykes or veins of aplite are a feature of the medium-grained granite outcrop of the western part of the Tsing Shan range, typically weathering to a whitish powdery rock. Recorded thicknesses range from 30 mm to about 1 m, and some are foliated and associated with quartz veins. North of Tsing Shan (1295 2930), aplite forms a lenticular body some 13 m wide in fine-grained granite.

Petrography

In thin section the fine-grained granite dykes are less uniform than the aplites. The granite may have small megacrysts of quartz and feldspar, and has a groundmass which varies from 0.1 to 1 mm. By contrast, the aplite dykes are very uniform in grain size, for example at Sam Shing Hui (Sample HK3107, 1602 2711) (Plate 32). The groundmass in this rock is mostly around 0.25 mm, ranging from 0.05 to 0.35 mm, and consists of quartz (c. 37%), alkali feldspar (c. 39%) and sericitized plagioclase (c. 11%). The alkali feldspar is microcline or sometimes orthoclase. There are also flakes of biotite (c. 13%) and accessory epidote.

Plate 31 – Fine-grained Granite Dyke Intruding Coarse-grained Granite at Castle Peak Beach (1606 2656)

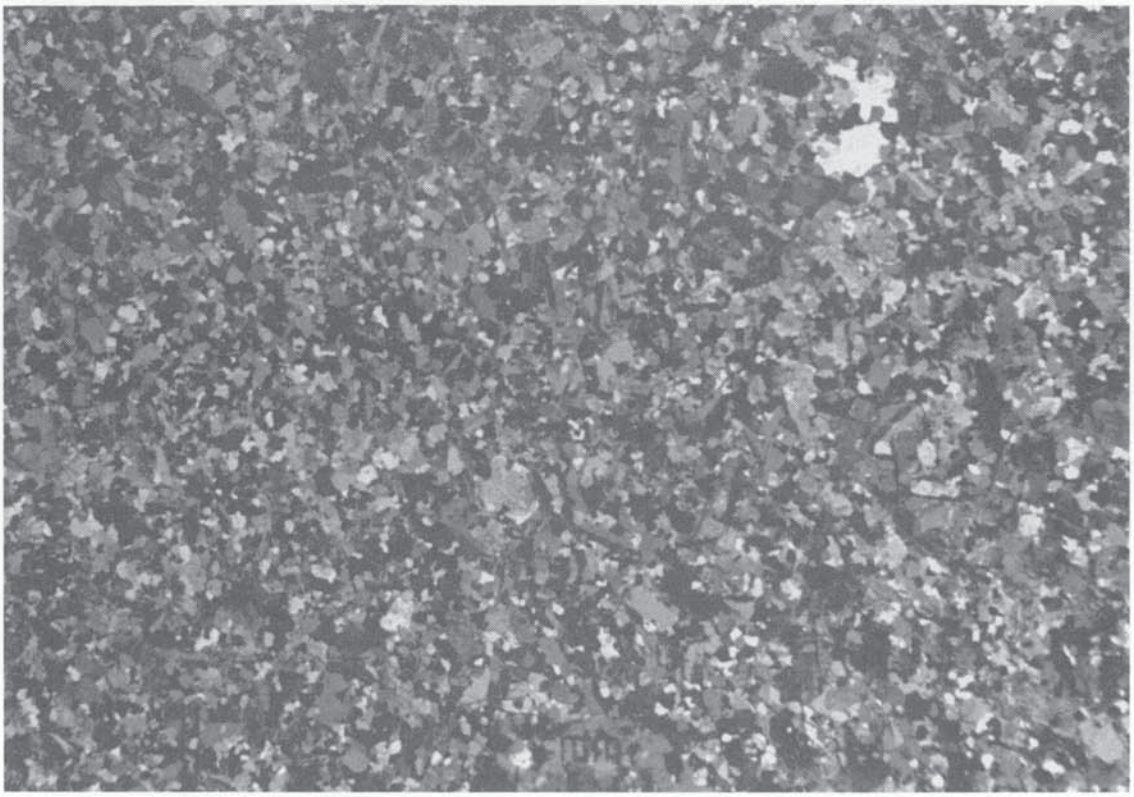


Plate 32 – Thin Section of Aplite (HK3107) from Sam Shing Hui, Tuen Mun (1602 2711); XPL × 10

Age Relations

Fine-grained granite dykes are almost exclusively found within the granite intrusions; in the southeast of the district they form part of an intrusive complex of major and minor bodies, including feldsparphyric and quartzphyric rhyolite dykes. Aplite dykes are only found within the major granite and granodiorite intrusions. Fine-grained granite dykes are cut by basalt dykes, but no instances of basalt cross-cutting aplite dykes have been recorded. The fine-grained granite dykes appear to be of two generations in exposures near Tuen Mun.

Petrography, field characteristics and outcrop form point a very close link between the granite major intrusions and these dykes. They rarely intrude the granodiorite, and only when in close proximity to major granite intrusions. They are probably coeval with the granite, forming at the end of intrusion emplacement and cooling.

Basalt, Gabbro, Andesite and Lamprophyre

Distribution and Lithology

Basaltic dykes are widespread throughout the district, mostly within the granitic rocks, but all are thin and most are impersistent. They are found in swarms trending northeast at Tap Shek Kok, associated with the northeast-trending fault belt running through Tai Lam Chung Reservoir, and with the northeast-trending quartzphyric rhyolite dyke swarms east of Lam Tei and at Mong Hau Shek (Pillar Point). Lamprophyre has only been found at Lan Kok Tsui, at Yau Kom Tau and on Shek Lung Kung. Andesite was seen as a dyke at Tsing Lung Tau.

Basaltic dykes are black to dark green, and vary from aphanitic basalt to porphyritic fine-grained gabbro (Table 5). The rock is often foliated parallel to the margins of the intrusion, especially when the dykes are thin. The dykes weather to a reddish brown or pale brown colour.

Details

Tsing Shan (Castle Peak). Basic dykes are common features of the southern part of the Tsing Shan range. In most exposures they are weathered and their precise rock type is difficult to determine; in such cases they have been represented arbitrarily as basalt on the published map.

A swarm of foliated basalt dykes individually trending east to northeast, and associated with quartz veins, cuts the medium-grained granite and the fine- to medium-grained granite northeast of Tai Lang Shui (115 290). Basalt dykes cutting granite were reported during the site investigation and construction of the Castle Peak Power Station at Tap Shek Kok. The dykes were exposed trending mainly east-west, and extend to the granite hills to the east. They are mostly less than 3 m wide, although a dyke up to about 15 m wide with an irregular trend was observed (1038 2631). Further east, near Mong Hau Shek (Pillar Point), dykes of basalt were noted intruding fine- to medium-grained granite. Northerly trends are common in this area, with thicknesses ranging up to 3 m; foliation is not recorded, although the basalt exposed in a stream north of Mong Hau Shek (1239 2666) is brecciated and sheared along a fault zone.

A 1.6 m wide basic dyke with an easterly trend intersects the contact of the granite pluton of Tsing Shan and foliated metavolcanics of the Tuen Mun Formation at the western end of Wu Tip Wan (Butterfly Beach) (1315 2564). The host rocks are veined with quartz. The dyke carries no quartz veins and displays no sign of displacement across the pluton-metavolcanic contact, presumably postdating both events.

A group of foliated lamprophyre dykes associated with vein quartz forms the spine of the headland of Lan Kok Tsui (Black Point), cutting medium-grained granite. Individual dykes range up to about 5 m wide and trend between northnortheast and eastnortheast.

Tuen Mun. A group of northeast-trending basalt dykes is exposed east of Sam Shing Hui both on Tuen Mun Road and on the catchwater above. These dykes lie parallel to a dyke-like outcrop of fine-grained granite. They vary in width from 0.4 to 3 m and may have foliated margins. The contact with the surrounding coarse-grained granite is irregular. Further north, at Wong Ka Wai (158 283), an irregular 0.1 to 1 m wide basalt dyke can be traced for 200 m. The dyke is fresh, black and aphanitic in Borehole 1445D (1587 2822). About 0.8 km south of Tan Kwai Tsuen (1793 3149) is a basalt dyke up to 1 m wide and very irregular, with branches extending into the granite. This dyke has thin quartz veins within it and parallel to the margins.

Siu Lam to Tai Lam. Basalt dykes are well exposed in a road cutting on Tuen Mun Road at Siu Lam (195 251). Five dykes were noted, ranging in thickness from 0.2 to 3 m, all trending roughly north-south. All the dykes have irregular foliated margins, with small splays penetrating the surrounding granite (Plate 33). To the northeast, along the southern shores of Tai Lam Chung Reservoir, a number of basalt dykes lie parallel to or slightly oblique to northeasterly-trending faults. The widest dyke is about 5 m and contains a lens or xenolith of the granite country rock (2022 2619).

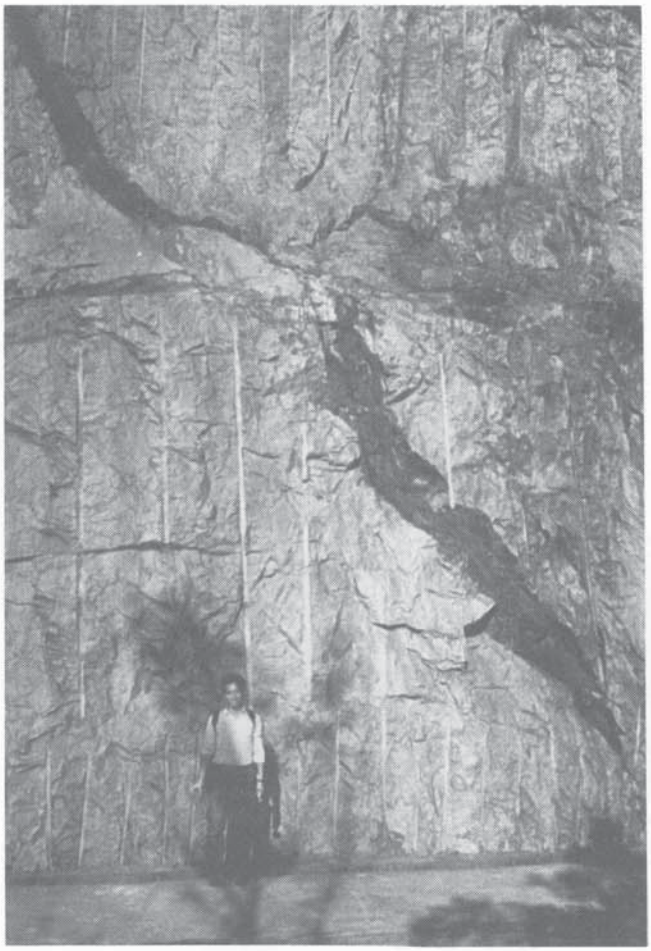


Plate 33 – Basalt Dyke with Foliated Margin Intruding Fine-grained Granite at Siu Lam (1950 2509)

Three dykes of fine-grained olivine gabbro outcrop in the rock slope behind the Desalting Plant (182 250); they are between 1 and 1.8 m thick, dip steeply east and strike southsoutheast. The rock at the centre of the dykes is olive green, with black phenocrysts up to 3 mm, while in a narrow band at the margins it is darker, finer and slightly foliated.

Tsing Lung Tau to Ting Kau. A northeasterly-trending group of deeply weathered basalt dykes was temporarily exposed in site formation work at Tsing Lung Tau (222 247). Two of the dykes are 1 to 2 m wide, while the largest is 5 m wide and extends for at least 150 m. The dykes have foliated margins with some quartz veining. A northeasterly-trending basalt dyke up to 1.5 m wide is exposed north of Ting Kau in a narrow gorge above the catchwater (2589 2627). This dyke is dark greenish grey, strongly jointed and sinistrally sheared, indicating a fault or shatter belt. A northerly-trending basalt dyke can be traced for 200 m along a valley at Tiu Yue Wan (Angler's Beach) (237 250). The dyke is at least 0.5 m wide inland and divides into dykes 2 m and 1 m wide on the coast (2371 2499).

A northerly-trending andesite dyke was temporarily exposed at Tsing Lung Tau (2241 2474). The dyke is 2 to 2.5 m wide and pale greenish grey, with lath-like mafics up to 3 mm and feldspar up to 4 mm. It was identified as an andesite on its petrography and geochemistry (HK6047, Table 6).

There were exposures of lamprophyre in the construction site for the Western Aqueduct at Yau Kom Tau (2738 2581). The dyke trends north, and is black with an aphanitic groundmass and abundant mafic phenocrysts around 1 to 2 mm; there is no visible feldspar. Further north (269 265) there is localized boulder debris of lamprophyre within a debris flow deposit consisting of tuff. The rock is greenish grey with mafic phenocrysts up to 5 mm set in an aphanitic groundmass. The dyke from which the debris is derived probably trends east-west.

Tsing Yi. South of Cheung Shue Tau (2775 2432), in a deeply weathered temporary exposure, an irregular basalt dyke up to 2 m wide has been intruded along the contact between fine-grained granite to the north and porphyritic fine-grained granodiorite to the south. The dyke is displaced sinistrally about 5 m by two small north-trending faults.

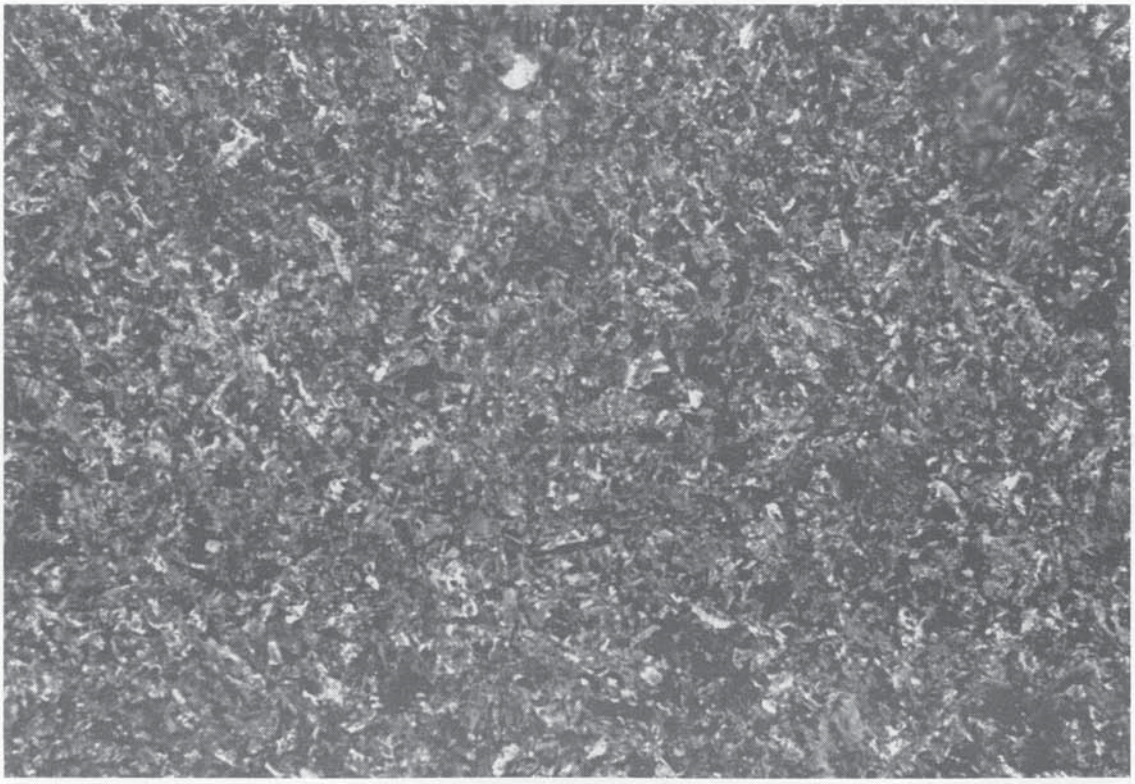


Plate 34 – Thin Section of Fine-grained Gabbro (HK5024) from the Desalting Plant (1819 2501); XPL × 10

Plate 35 – Foliated Metavolcanic in Tuen Mun Formation (HK2105) from Tuen Mun (1447 2889); Natural Scale

Plate 36 – Thin Section of Metatuff in Tai Mo Shan Formation (HK3375) from Tai To Yan (2970 3400); XPL × 10

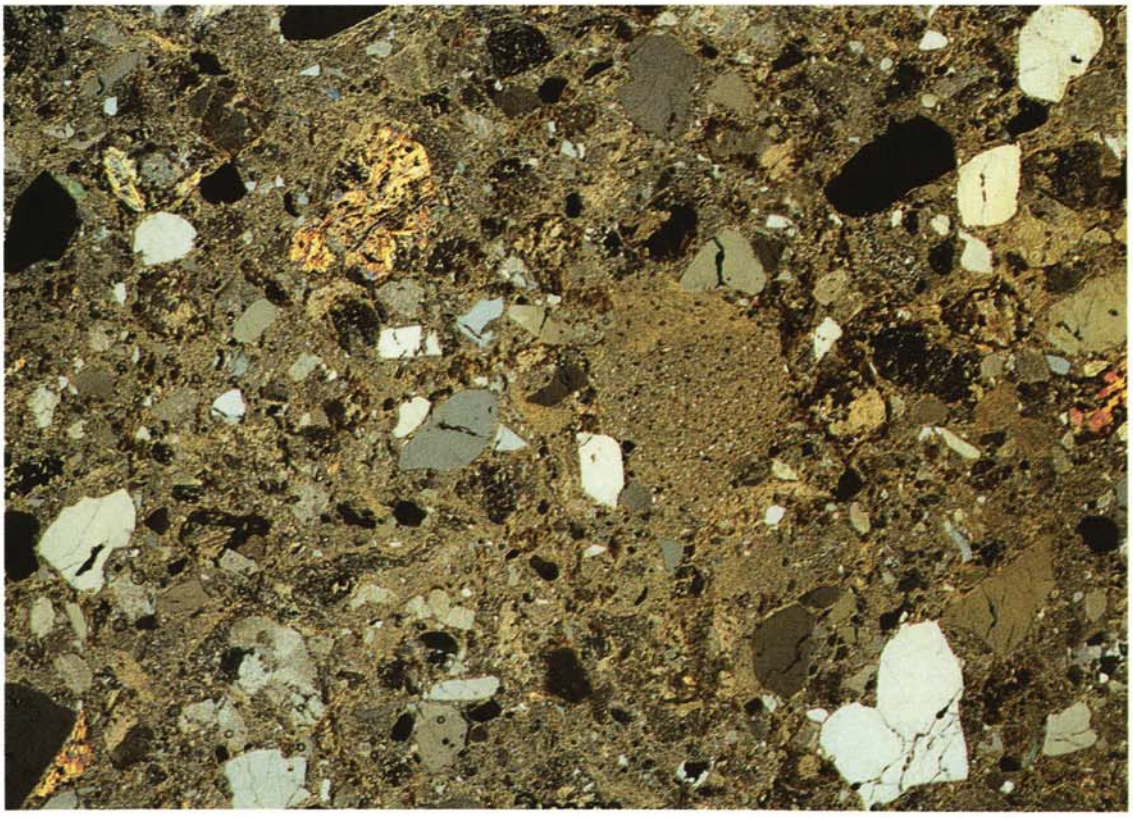


Plate 37 – Peaty Clay in Pleistocene Alluvium at Shan Ha Tsuen, Yuen Long (1918 3208)

Plate 38 – Grey Holocene Marine Mud overlying Mottled Pleistocene Alluvium at Chau Tau (2648 4045)

Plate 39 – Alluvium in Valley at Lung Kwu Sheung Tan surrounded by Deeply Weathered Granite Hills covered with Corestones. Acuminate Blade in Foreground (0965 2851)

Plate 40 – Upland Tors of Corestones Feeding Boulder Sheets and Streams near Tuen Mun (172 273)

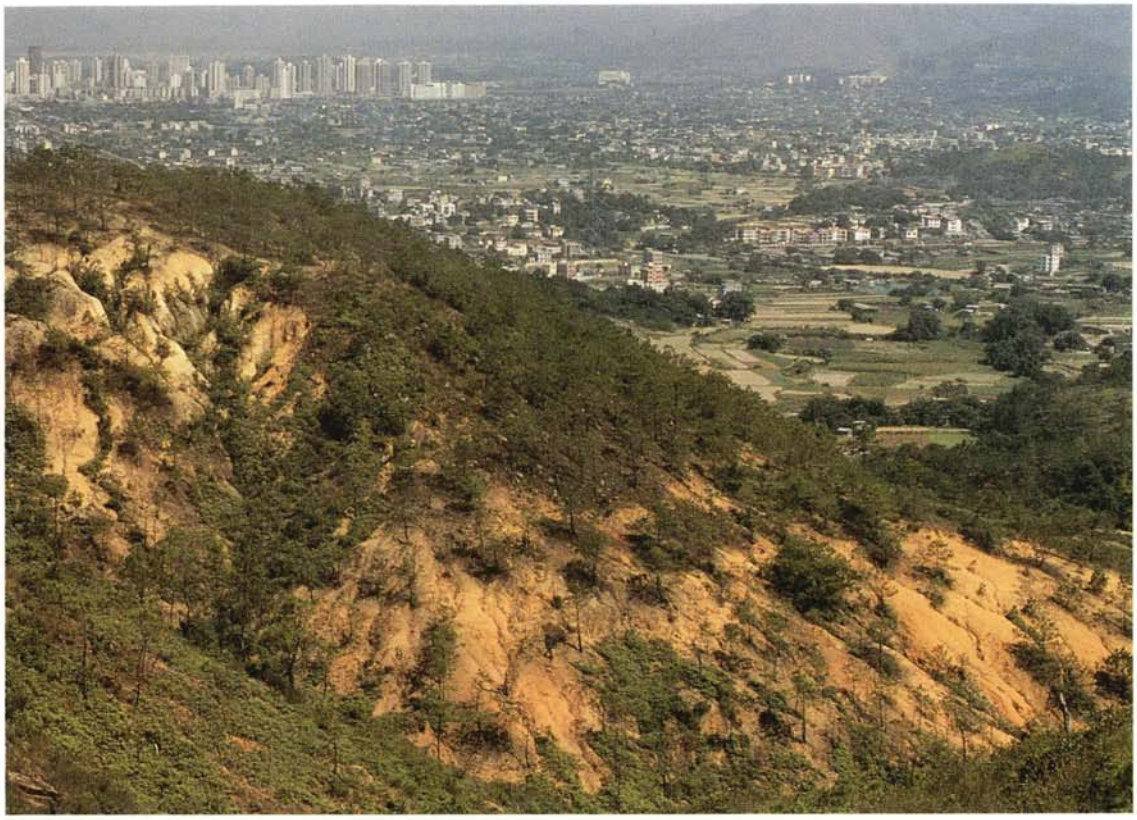
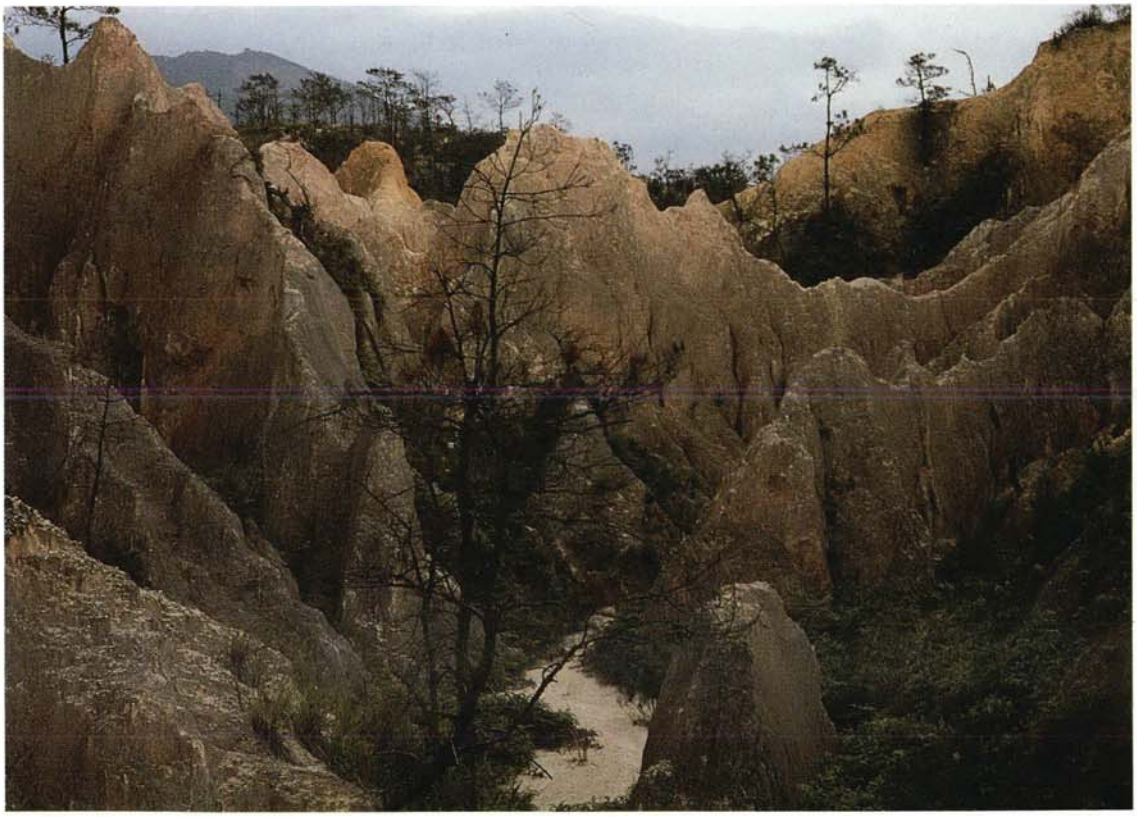


Plate 41 – Badlands Erosion in Granite South of Yuen Long (195 295)

Plate 42 – Deep Gully Development in Granite near Tai Lam Chung Reservoir (226 293)



Petrography

In thin section the basaltic dykes vary from microcrystalline, with a groundmass grain size of around 0.03 mm, to fine-grained, with crystals ranging from 0.1 to 0.4 mm (gabbro). Porphyritic basalt from Nga Ying Chau (HK2295, 2913 2458) has a groundmass of 0.05 to 0.1 mm dominantly composed of plagioclase feldspar and pyroxene, with a scattering of opaque minerals between 0.01 and 0.03 mm. Euhedral phenocrysts of feldspar and pyroxene are up to 1 mm across. Fine-grained gabbro from the Desalting Plant (HK5024, 1819 2501) is non-porphyritic and contains abundant crystals of plagioclase of oligoclase composition (Plate 34). There are laths of hornblende up to 1 mm long, and much chlorite. This rock has an ophitic texture, with crystals of augite embedded in the plagioclase.

In thin section the andesite (HK6047, 2241 2474) contains euhedral sericitized plagioclase of andesine composition up to 4 mm across, with altered hornblende laths and biotite crystals (Plate 43).

Geochemistry

Only one sample from a minor intrusion in the district has been chemically analyzed. This is andesite from Tsing Lung Tau (HK6047, 2241 2474). On a plot of silica (SiO_2) against alkalis (Na_2O+K_2O) the analysis falls in the andesite field (Cox et al, 1979).

Age Relations

Basaltic dykes from elsewhere in Hong Kong were dated by Chandy & Snelling (1971) using potassium-argon age determination methods. This gave dates ranging from 76 $\pm$ 2 to 57 $\pm$ 2 Ma. The basaltic dykes of the district are believed to be of similar age.

Basalt and gabbro dykes cut across the granite intrusions, and can rarely be found cutting the volcanic rocks. Although the basalt dykes often have foliated margins, the dykes are not sheared; they probably post-date the fault lines they often follow. It is probable that these basic dykes belong to a Tertiary extensional phase in the opening of the South China Sea basin (Chandy & Snelling, 1971; Holloway, 1982).

Andesite has only been found cutting granite in the district, and lamprophyre has been found in both the granite of Tsing Shan (Castle Peak) and volcanics near Tsuen Wan. Although both are probably related to the basic intrusions in age, there is no positive evidence.

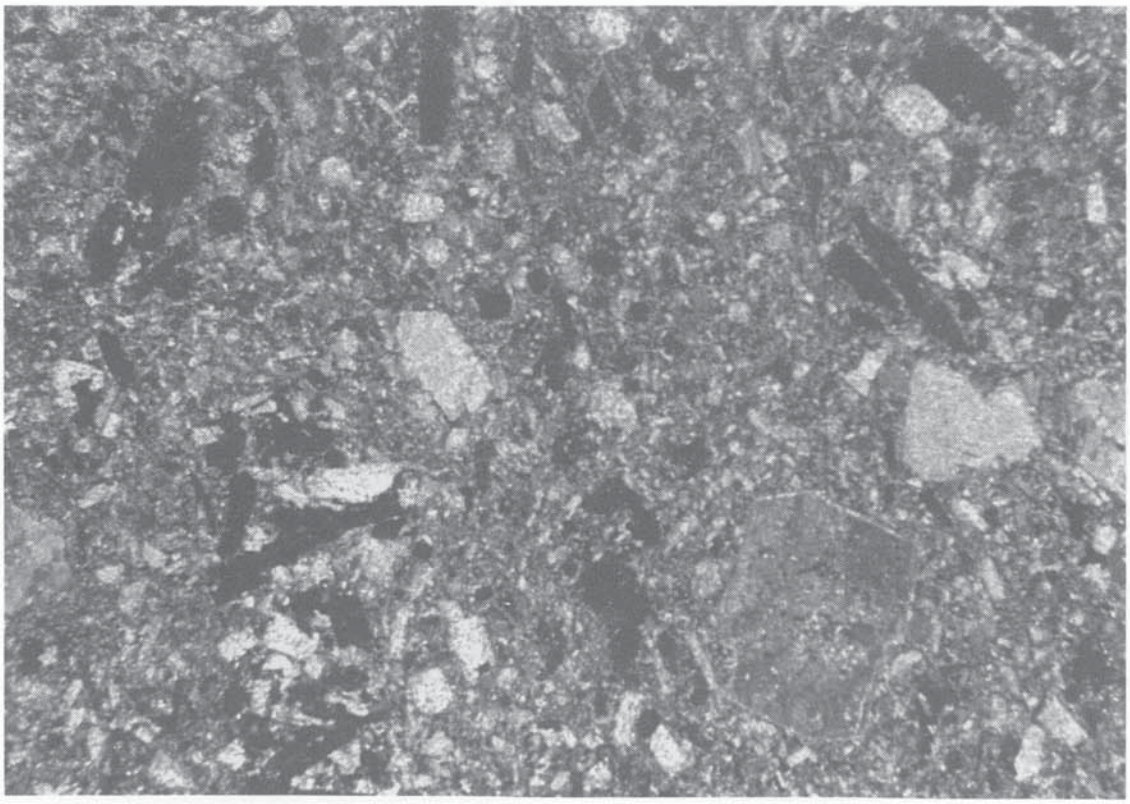


Plate 43 – Thin Section of Andesite (HK6047) from Tsing Lung Tau (2241 2474); XPL × 10

Pegmatite

Distribution and Lithology

Pegmatite is very coarse-grained rock, usually of granitic composition, with crystals over 20 mm across (Table 5). The pegmatites of the district are all granitic, and occur as thin veins and lenticular patches. They are composed of pink or white alkali feldspar and quartz, with large aggregates of biotite, sometimes chloritized. Pegmatite is rare in the district, and the outcrops are generally too small to be separately shown.

Details

Tsing Shan (Castle Peak). A pegmatite lens some 2.5 m thick and 2.0 m across was recorded in fine- to medium-grained granite in a site formation rock cut (1211 2559) north of Mong Hau Shek (Pillar Point). The pegmatite was grey to pale pink with crystals of feldspar up to 150 mm long in a matrix of quartz. A 200 mm thick aureole of fine-grained granite around the pegmatite was flow banded, brecciated and conspicuously enriched in biotite.

Tai Lam Country Park. A sheared pegmatite vein about 1 m wide outcrops within the medium-grained granite in a stream about 1.5 km eastsoutheast of Tai Tong (2186 3028). A near vertical pegmatite about 0.25 m wide was exposed within the medium-grained granite in the Western Aqueduct (2341 3080).

Age Relations

Pegmatite is only found in the granite major intrusions, generally in intimate association with the surrounding granite. It is coeval with the formation of the granite, resulting from hydrothermal emanations late in the cooling of the plutons.

Chapter 7
Structure

The geological structure of the district is dominated by the northeast-trending Lo Wu – Tuen Mun fault and fold belt which contains a series of parallel or subparallel faults, folds and shear zones. The Lo Wu – Tuen Mun Fault Zone is a part of the Wuhua – Shenzhen Fault Zone (Burnett & Lai, 1985) which trends northeast to Shenzhen and Wuhua in Guangdong, and beyond into Fujian. Crustal movement in the district has been intense and frequent. The principle structural elements within the district are shown in Figure 16.

Folds

Folding in the district is obscured by the intense faulting, magmatism and metamorphism, and in the low-lying areas of the district by superficial deposits. However, two ages of structures can be recognized; Palaeozoic and Mesozoic.

Palaeozoic folds. These folds mainly occur within the Lo Wu – Tuen Mun Fault Zone. Generally, the anticlines are thrust faulted along their axial zones, which trend northeast to northnortheast. Northwest limbs are broad and gentle whereas southeast limbs are narrow and steep, and may be cut out by faulting. The folds are thus asymmetrical, open to close, with a moderately inclined axial plane.

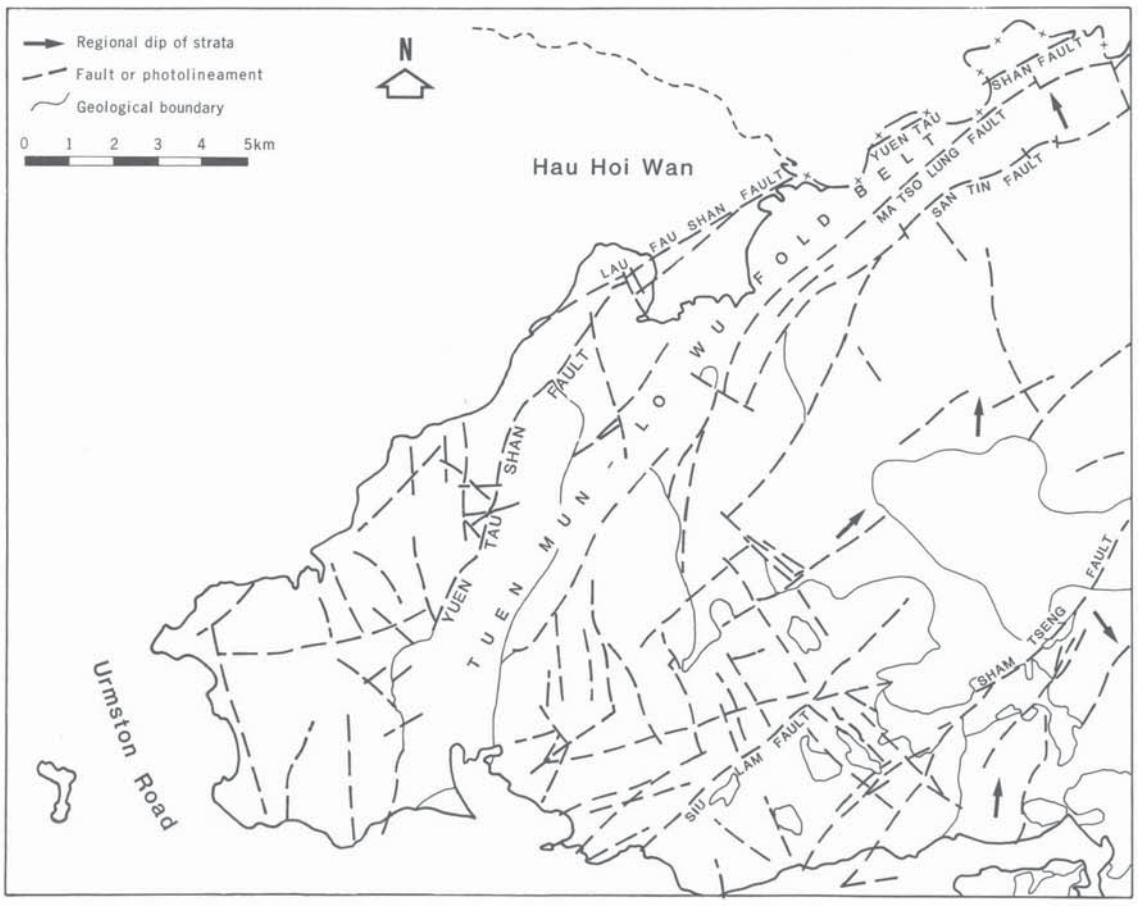


Figure 16 – Principal Structural Features of the District

Details

The Mai Po Anticline is a narrow, open to close fold with a length of 11 km. The axial trace is parallel to the adjacent northeast-trending thrust. Strata of the Lok Ma Chau Formation are exposed on the both limbs. The southeast limb is mostly cut out by the San Tin Fault. The strata of the northwest limb are well exposed between Ho Sheung Heung and Mai Po Hill, dipping at 30 to 46°. The Yuen Long Formation forms the core of the structure at Fairview Park (226 380), where it is found only in boreholes.

A similar anticline lies parallel to the Mai Po anticline between Seung Ma Lei Yue (293 435) and Tam Kon Chau (232 394). In the northern part of the outcrop the strata are disposed in a faulted monocline. The Yuen Long Formation again forms the core of the structure as shown by boreholes at Ha Wan Tsuen (259 417) and north of Fairview Park (224 383).

The Yuen Long Anticline is entirely concealed beneath superficial deposits of the Yuen Long plain. An interpretation of borehole data reveals an asymmetrical fold with an axial trace trending 050° from Tai Wai (220 340) to Fraser Village (209 330). The Yuen Long Formation forms the core of the structure, with the Mai Po Member of the Lok Ma Chau Formation forming the limbs. The northwest limb dips at around 40 to 46° and is very broad with a series minor folds, whereas the southeast limb is narrow due to its displacement by a northeast-trending fault. Quartzphyric rhyolite and basalt dykes are intruded along the core.

The Shan Ha Tsuen Anticline has a northnortheast axial trend and extends from Shan Ha Tsuen (196 330) to Shui Pin Wai (199 338). The strata in the core belong to the Yuen Long Formation but are covered by superficial deposits, while sandstones of Mai Po Member form low hills on both limbs. The axial trace of the anticline extends to Yuen Long Industrial Estate to the northeast (205 358). The structure is cut by faults which trend both northeast and northwest. To the northwest the anticline is flanked by a syncline, the axial trace of which lies across the Wang Chau Service Reservoir (197 355).

The Tin Shui Wai Anticline is concealed beneath superficial deposits of the Tin Shui Wai plain. It is inferred from borehole data that the axial trace trends northnortheast between Tin Shui Wai and Ha Tsuen San Wai (185 349). There may be two en echelon folds or one structure displaced by a northwest-trending fault. The Yuen Long Formation forms the core of the structure, with Mai Po Member on both limbs. Boreholes indicate that the dip of the northwest limb is gentler than that of the southeast limb, and the axial plane is inclined towards the northwest. The anticline is dissected by northeast- and northwest-trending faults.

The Lam Tei Anticline lies in Tuen Mun valley, trending northnortheast between Shek Po Tsuen (177 336) and Fu Tei San Tsuen (173 299). To the southwest most strata involved belong to the Mai Po Member, but the succession is cut and foreshortened by a northeast-trending fault. The strata on the northwest limb belong to the Mai Po Member and to the Repulse Bay Volcanic Group.

Mesozoic folds. These folds affect the volcanic and sedimentary rocks of the Upper Jurassic and the red beds of the Upper Cretaceous; the fold styles are broad and gentle. The folds generally plunge towards the southwest and are affected by the intrusion of granitic plutons. The Cretaceous strata form a fault basin, cut by northeast- and northwest-trending faults.

Details

A synclinal structure trends northeast from Shek Lung Kung (270 269) to the peak of Tai Mo Shan. The strata in the core belong to the Tai Mo Shan Formation. The syncline is broad and gentle, and plunges southwestwards. The fold is intruded by granitic rocks and cut by northeast-trending faults.

North of Shek Kong Tsuen (297 330) is an anticlinal structure trending northeast along the Lam Tsuen-Kam Tin Road. The strata in the core belong to the Shing Mun Formation. The structure is broad and gentle, and is intruded by granodiorite along the axial zone and to the south. To the southwest, south of Ho Pui Reservoir, the anticline is flanked by a syncline with an axial trace trending eastnortheast.

A synclinal structure trends eastnortheast extending from Cheung Ngau Shan (230 318) through Tsat Shing Kong (267 342) to Ta Shek Wu (290 360). The strata in the core of the fold belong to the Tai Mo Shan Formation, with older strata on both limbs. The occurrence of Shing Mun Formation in the southwest indicates that the syncline plunges southwest. In the axial zone and the southwest of the fold, strata are dissected by northeast- and northwest-/trending faults respectively.

The Yuen Tau Shan syncline lies within the Lo Wu – Tuen Mun Fault Zone adjacent to the Tsing Shan (Castle Peak) granite pluton. The axial trace trends northeast from Yuen Tau Shan (156 324) to Fung Kong Tsuen (164 351), plunging towards the northeast and southwest. Tuff breccia of the Tuen Mun Formation forms the core of the structure, with younger tuffs on the eastern limb. The western limb of the fold is cut out by faults.

The Shan Shek Wan anticline is a narrow, close fold adjacent to the granite pluton, and is cut by a northnortheast-trending fault. The fold extends northwards from Shan Shek Wan (137 269) to 400 m west of Tuen Mun Service Reservoir (136 290). Strata of the Tsing Shan Formation form the core of the structure, with the Tuen Mun Formation on the east flank. This asymmetric anticline of approximate northerly trend is inferred west of the Shan King Estate; strata on the shallow western limb dip 25 to 38° west (1353 2860), while those on the eastern limb dip 85° east (1369 2886). Overturned strata at San Shek Wan San Tsuen are inferred to form the western limb of an anticline of similar trend. Inversion is indicated by sandstone strata that dip east at 70° (1384 2760) but include fining-upwards sedimentary units that young to the west.

Overturned strata believed to be in a similar structural context were found in a borehole nearby (1960D/8696, 1375 2725) which was inclined at 60° to the east; overturning was confirmed in this case by inverted cross-lamination in the sandstone cores.

Faults, Photolineaments and Dykes

The main faults and photolineaments of the district are shown in Figure 16. These traces are often covered by superficial deposits, particularly in the offshore areas; on the published geological map sheets they are only shown where they are not covered by superficial deposits. Circular histograms (Cheeney, 1983) of faults and photolineaments have been drawn for each map quarter sheet (Figure 17). The individual histograms all show a dominant northeast- to northnortheast-trend, with a secondary trend to the southeast. Some areas also have strong local trends, for example east in sheet 5NE, north in sheet 5SE and eastnortheast in 6SW. As well as a statistical analysis based on fault and photolineament trends in quarter sheets, these structures can be divided on genetic association.

The major faults trend northeast to eastnortheast, while other faults trend northwest to north. The northeast-trending faults include the Lo Wu – Tuen Mun and Lam Tsuen – Sham Tseng fault zones. The Lo Wu – Tuen Mun Fault is composed of at least four faults, bounded by the Lau Fau Shan Fault in the northwest and the San Tin Fault in the southeast. The displacement of the faults in this zone is believed to be vertical as well as horizontal. Fault activity has taken place since the Late Palaeozoic, the faults being rejuvenated during each subsequent orogeny. Belts of dynamic metamorphism, including brecciated, cataclastic, mylonitized and schistose rocks, are usually found within the fault zones.

Details

Northeast-trending Faults. The San Tin Fault is the major fault in the Lo Wu – Tuen Mun Fault Zone, and extends from Tuen Mun through Yuen Long to San Tin; it can then be seen further northeast at Lo Wu Camp (2960 4190). To the northeast of Yuen Long this fault trends eastnortheast, dipping northwest at angles varying from 35 to 50°. The Palaeozoic strata are thrust over from the northwestern side, and overlie metatuffs of the Tai Mo Shan Formation. This can be seen in outcrops 400 m northwest of Ho Sheung Heung (2910 4150), 300 m north of Pak Shek Au (2740 4090), and in boreholes at Mai Po Hill (2460 3923) and east of Yuen Long (2200 3368). To the southwest of Yuen Long the fault trends northnortheast. On the west side of the fault are strata of the Mai Po Member, and on the east side is granite. Along the San Tin Fault the sedimentary and volcanic rocks are metamorphosed to schistose rocks in a belt varying from 2 to 6 km wide.

The Yuen Tau Shan Fault begins 400 m east of Mong Tseng Wai, passing through the Sha Kong Tsuen, Yuen Tau Shan and Pak Kok. Borehole data clearly show that the fault extends northeastwards along the Shenzhen River from the river mouth to Lo Wu. To the northeast of Sha Kong Tsuen the fault trends eastnortheast, with the Lok Ma Chau Formation on the southeast side and granite on the northwest side. Along the fault there is a mylonitized granite zone varying from 60 to 100 m in width. Between Sha Kong Tsuen and Mong Tseng Wai the mylonite dips northwest at angles varying from 32 to 55° and may be parallel to the fault. At Ngau Hom (1690 3580) the Yuen Tau Shan Fault is displaced by a set of northwest-trending faults. Between Fung Kong Tsuen and Pak Kok the fault dips westnorthwest at angles varying from 47 to 50°; west of Wu Tip Wan the dip increases to 56°. A zone of mylonitized granite 20 to 80 m wide is exposed at the roadside south of Fung Kong Tsuen (1624 3500), at Yuen Tau Shan (1554 3270) and at Shan Shek Wan San Tsuen (1346 2698). The granite, thrust from the west over the volcanic rocks, can be seen in the outcrops 700 m northwest of Po Tong Ha (1485 3140), west of Wu Tip Wan (1314 2559) and in a borehole 100 m south of Kong Shan Tsuen (1423 2994). The fault coincides with the intrusive contact of the granite in some places, and xenoliths of tuff can be found in the fault zone, such as at Yuen Tau Shan (1554 3270) and 800 m north of Tsing Shan (Castle Peak) (1340 2850).

The Ma Tso Lung Fault trends eastnortheast and is situated between the San Tin and Yuen Tau Shan faults. It can be traced from south of Lut Chau, through Ma Tso Lung and Pak Hok Chau, to Lo Wu. Strata of the Mai Po Member and the Yuen Long Formation are thrust from the northwest over the younger strata of the Tai Shek Mo Member.

The Lau Fau Shan Fault lies within the granite, trending eastnortheast from Tsim Bei Tsui through Lau Fau Shan and into Hau Hoi Wan. The fault scarp is well exposed below the Lau Fau Shan Police Station (Plate 44) and at Tsim Bei Tsui; the fault surfaces dip northwest at angles varying from 54 to 75°. A 5 to 30 m wide quartz vein occurs along the fault zone, and a 5 m wide fault gouge occurs within a quartz vein 100 m southwest of Tsim Bei Tsui Police Station (1905 3840). On the both sides of the quartz vein the granite is mylonitized and silicified with reticulated quartz veinlets. At Lau Fau Shan (156 370) the fault has controlled the deposition in a minor fault basin; the strata in the basin comprise Upper Cretaceous Kat O Formation. The granite is intensely mylonitized on the southeast side of the fault, while on the northwest side is brecciated conglomerate of the Kat O Formation. The southern extension of the fault is inferred along the south coast of Hau Hoi Wan. Along the coast south of Sheung Pak Nai (130 336) the granite is intensely mylonitized, and a small northeast-trending fault passes through Tsang Kok (100 308) parallel to the inferred major fault. The Lau Fau Shan Fault is displaced by northwest-trending faults at Lau Fau Shan.

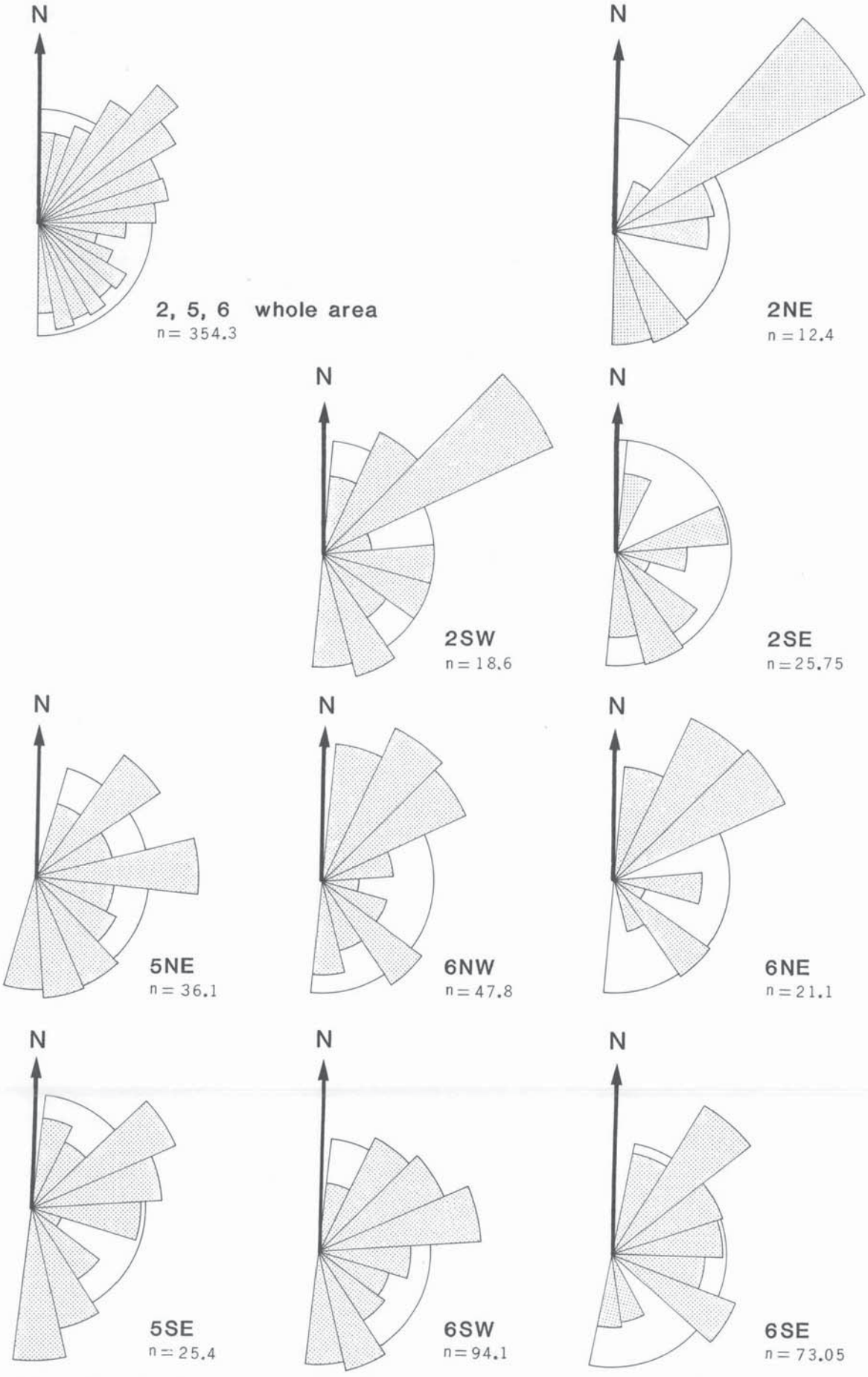


Figure 17 – Circular Histograms of Faults and Photolineaments for the District. Total Length Plotted in km = n (after Cheeney, 1983)

Plate 44 – Lau Fau Shan Fault Dipping Northwest at Lau Fau Shan (164 367)

The Lam Tsuen – Sham Tseng Fault Zone is composed of five major faults that trend northeast and dip 70 to 85° northwest. Along these faults is a zone of intense crushing and quartz veins varying from 5 to 30 m wide. The fault zone is part of the Starling Inlet – South Lantau Island Fault Zone. The Sham Tseng Fault (Plate 45) extends from Sham Tseng to Shek Kong Tsuen (296 320), dipping 85° northwest. The Ting Kau Fault (244 256) and Chuen Lung Fault (293 286) are parallel to this fault. The Chuen Lung Fault sinistrally displaces the Ap Lei Chau Formation. The Tsing Lung Tau Fault dips 70° northwest, and was well exposed in temporary excavations for the pier foundation of the Tsing Lung Tau Bridge (2292 2518) where a brecciated and crushed zone 5 to 20 m was noted; sub-horizontal striae occur on the fault surface. The Siu Lam Fault stretches from Siu Lam (196 256) through the Tai Lam Chung Reservoir to Ma On Kong (246 303). The outcrop at the catchwater southwest of Ma On Kong (2365 2955) shows that the fault dips 85° northwest with a crush zone in the granite more than 10 m wide and infilled by quartz veinlets. At the southern end of Tai Lam Chung Reservoir a number of major faults trending northeast traverse the area. Although there is little shearing or fracturing in the granite, there are numerous quartz veins and basalt dykes. Along the valley which extends northeast from Tai Lam Chung Reservoir the fine-grained granite and adjacent medium-grained granite are severely faulted, with the development of fault breccia, shattering and thick quartz veins (228 295).

Eastnortheast-trending Faults. These are generally less than 6 km long, with crush zones varying from 0.1 to 10 m wide and occasionally 20 m. In the northeast of the district these faults have formed schist zones; these can be found on Hadden Hill (272 397) and at Ngau Tam Mei (270 374). This eastnortheast-trending schistosity is superimposed on the schistosity trending northeast. A complex major shear belt occurs in the outcrop of the Tuen Mun Formation, although no specific faults have been identified. The foliation within the shear zones is steeply inclined and trends eastnortheast. About 2 km east of Ngau Tam Mei (270 374) there are four quartz veins along a fault zone. The fault passing through Lung Kwu Sheung Tan (094 295) also trends eastnortheast and contains several en echelon quartz veins varying from 0.2 to 2 m wide.

Northwest-trending Faults. The northwest-trending faults have high dip angles and displace the northeast-trending faults. Their crush zones are narrow and infilled by quartz veins or dykes. Northwest-trending faults are well developed in the granite plutons, for example the faults passing through Chung Shan (156 320), Kong Shan Tsuen (143 303) and Leung Tin Tsuen (136 300). In the north of the district these faults include the Ng Tung River Fault (297 430), which lies beneath the Sheung Shui alluvial plain, and Fung Kong Fault (283 413).

Plate 45 – Sham Tseng Fault Trending Northeast at Sham Tseng (245 255)

A fault has determined the course of a northwest-trending valley north of the summit of Tsing Shan (Castle Peak); it is well exposed in a stream (1294 2875) where it dips 50° southwest. The fracture is associated with schistose granite, mylonite and breccia, and separates fine- to medium-grained granite to the southwest from megacrystic fine-grained granite to the northeast. A feature of this fault, seen also further downstream (126 291), is the development of northnorthwest-trending splay faults on the northeastern side of the main fracture.

North-trending Faults. These faults mainly occur in the granite plutons. There is a narrow crush zone along the faults (Plate 46) which may be infilled with quartz veins or quartzphyric rhyolite dykes. For example, a 2 to 10 m wide schistose quartz vein trends from near Yuen Tau Shan (150 324) to near Ngau Hom Sha (150 340), and is cut by northwest- and eastnortheast-trending faults.

The principal valleys in the granite outcrop of the southern part of the Tsing Shan (Castle Peak) range follow faults that are in places associated with dykes or quartz veins. Three of these faults have a general northerly trend. The course of the most westerly, extending northnorthwest from Lung Kwu Tan, is largely covered by superficial deposits. The fracture is well exposed in a stream at Lung Kwu Tan (1022 2698) where a 2 m wide zone of vein quartz and tectonic breccia, including fragments of vein quartz, dips 60 to 70° west within a wider zone of schistose medium-grained granite. The same fracture is exposed northwest of Pak Long (0970 2858) where a 1 to 4 m wide, northerly-trending quartz vein is associated with tectonic breccia and schistose granite.

A northnortheast shear zone, presumed to be a fault, is mapped along the southern part of the valley passing through Tai Lang Shui (110 270). White mylonite or schistose granite is recorded where the zone cuts the granite outcrop, for example in the stream (1109 2708). Further south the structure affects the volcanic rocks that form a north-trending screen up to 50 m wide within the granite; the volcanics are in part strongly foliated (1096 2656). Exposures in the stream (104 263) display a north-trending fault and associated breccia; granite, basalt dykes and associated vein quartz are cut by the fault and brecciated. The granite to the west of the structure appears massive and sparsely fractured, while that to the east shows strong jointing, conspicuous foliation and quartz veins, all trending eastnortheast (1239 2666).

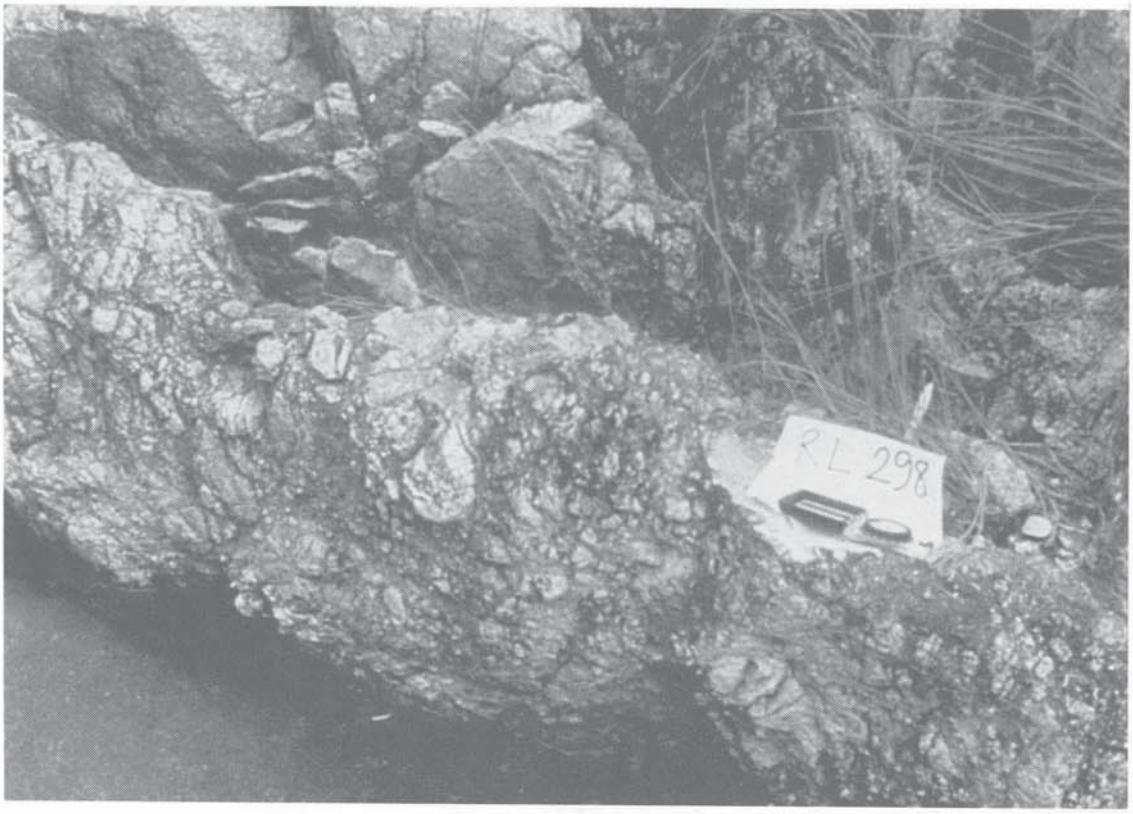


Plate 46 – Fault Breccia along North-trending Fault in Tai Lam Country Park (1825 2874)

The contact between the granite of the Tsing Shan range and the Repulse Bay Volcanic rocks is faulted along at least part of its outcrop, although the displacement may be regarded as related to the process of intrusion. Evidence of relative movement between the granite and the country rock is displayed in a shear zone typically 5 to 20 metres wide, parallel to and including the contact. Foliation in the granite and in the country rock increases towards the contact, and the foliated rock is commonly quartz veined. A temporary section at Leung Tin Estate (1420 2991) exposed andesite with a foliation dipping 75° southsoutheast, and a zone 1.5 m wide that included lenses of dark grey schist and irregular veins of quartz. The adjoining granite was mylonitized, with a network of minor quartz veins. Similar structural relationships are exposed in stream sections further south, near Shek Kok Tsui, although there the foliation is inclined to the west, towards the granite outcrop. Crenulate folds within the foliated volcanic rocks indicate a component of dextral displacement across the contact shear zone (1337 2617). The swarm of quartzphyric rhyolite dykes that intersects the contact near San Shek Wan Tsuen shows no evidence of appreciable lateral displacement, and a basalt dyke that cuts the contact on the coast further south (1316 2564) appears to be completely unaffected by faulting.

The main junction between the Tsing Shan and Tuen Mun formations west of Tuen Mun may also be faulted, although the evidence is inconclusive. The attitude of steeply inclined bedded tuffs within the Tuen Mun Formation near San Shek Wan Tsuen (138 269) is perhaps the strongest indication of a structural break at the contact; the strike of the tuffs differs markedly from that of the adjoining sedimentary rock of the Tsing Shan Formation.

Joints and Schistosity

The equal area point plots and density contours for joints and schistosity of the district (Figures 18, 19 & 20) give general indications of the trends of these structures in various rocks. Joints in the granite are often much more pronounced than in the older volcanic and sedimentary rocks, and have been treated separately. Furthermore, the joint pattern within the individual plutons of Tsing Shan (Sheet 5) and Tai Lam (Sheet 6) can be treated separately. Foliation and schistosity is much more pronounced in the volcanic and sedimentary rocks, particularly in the northwest of the district. The few measurements of bedding in these oldest strata are close to the observed foliation in orientation.

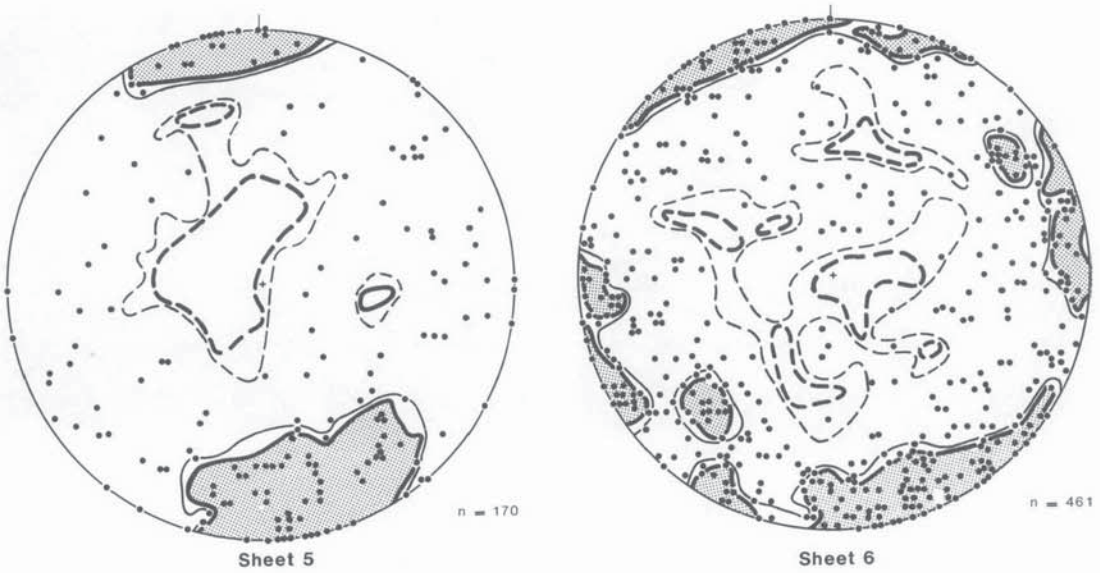


Figure 18 – Equal-area Point Plots and Density Contours for Joints in Granite of Tsing Shan (Sheet 5) and Tai Lam (Sheet 6). Concentration (solid lines) and Dispersion (broken lines) at 5% and 1% Significance Levels (Langford & Adlam, 1985)

Figure 19 – Equal-area Point Plots and Density Contours for Joints in Volcanic and Sedimentary Rocks of the District. Concentration (solid lines) and Dispersion (broken lines) at 5% and 1% Significance Levels (Langford & Adlam, 1985)

Details

Granite. The joint pattern in the granite of Tsing Shan (Castle Peak) is dominated by a set of steeply inclined fractures trending generally east to northeast (Figure 18). A subordinate joint set, steeply inclined and striking northnorthwest, is less commonly seen. Many joints of the northeast- to east-trending set are flanked by zones of schistose granite or mylonite, while associated quartz veins may themselves be shared and foliated. The joint pattern in the granite of Tai Lam is well developed and complex. There is a dominant east- to northeast-trend, but also a strong north- to northnorthwest-trend. This trend is parallel to major, generally northerly trending faults, well displayed in the northwest of the pluton. Shallow, southerly dipping sheeting joints are well displayed above the Tuen Mun Road to the east of Tai Lam; these joints have an associated microfracturing fabric. The dominant foliation in the granite (Figure 20) strikes northeast; this foliation is most pronounced in the Tsing Shan pluton, and to a lesser extent in the west of the Tai Lam pluton.

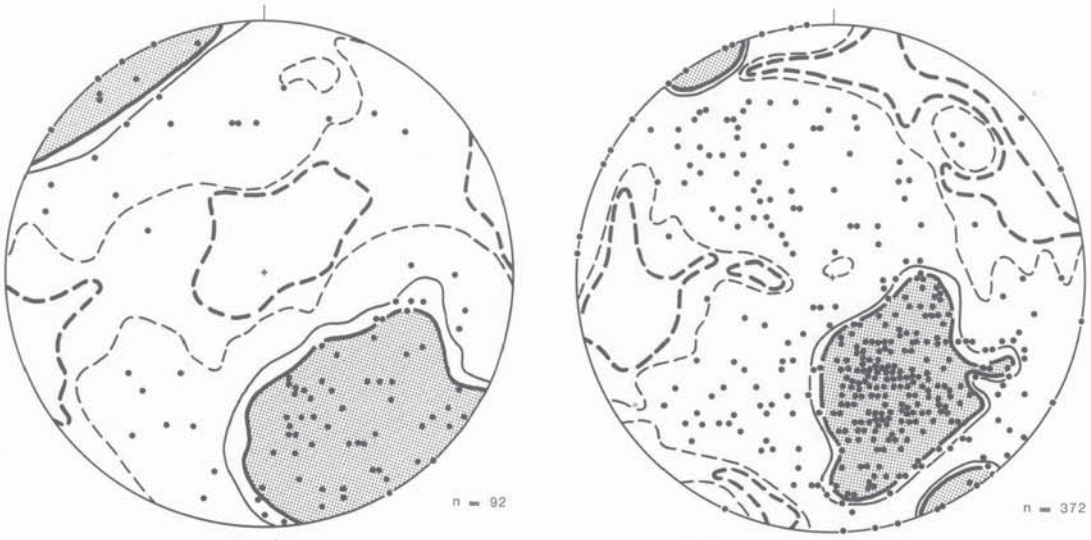


Figure 20 – Equal-area Point Plots and Density Contours for Foliation in Granite, and Volcanic and Sedimentary Rocks of the District. Concentration (solid lines) and Dispersion (broken lines) at 5% and 1% Significance Levels (Langford & Adlam, 1985)

Volcanic and Sedimentary Rocks. Joints in these rocks (Figure 19) appear to form a conjugate set, steeply dipping with trends of eastnortheast and southeast. This would be consistent with folding on northnortheasterly-trending axes, or compressive shear roughly east-west. However, there is also a significant proportion of joints trending northnortheast, and the overall joint pattern cannot be clearly linked to any known structures. At least some of the joints are likely to be closely related to those found in the granite intrusions. The foliation or schistosity in the volcanic and sedimentary rocks forms a very strong pattern (Figure 20), with a northeasterly strike and dip of about 45° north. This is consistent with the strong overthrusting seen in the major structures of the northwest of the district.

Chapter 8
Metamorphic Rocks

Most of the metamorphic rocks of the district are formed by the processes of dynamic and hydrothermal activity in a regional belt that extends across the district from Tuen Mun in the southwest to Shenzhen in the northeast. Schist and mylonite are extensively developed in the Palaeozoic and Mesozoic rocks of this area, and also in the adjacent granite outcrops, particularly over Tsing Shan. In addition, there are very restricted areas where metamorphic rocks have formed by metasomatic and thermal alteration at or near the contact of granitic plutons.

Davis (1952) reported the development of schists in rocks attributed to the Lok Ma Chau Formation between Tsing Shan Wan (Castle Peak Bay) and Yuen Long. However, he believed that the metamorphism was only local and not regional. Davis also reported metamorphism in the Tai Mo Shan Porphyry, now termed the Repulse Bay Volcanic Group, near Tsuen Wan. This is essentially epidotization, but he noted garnet and sulphides in places.

Allen & Stephens (1971) state that the Lok Ma Chau Formation comprises low-grade regionally metamorphosed rocks, and includes sericite schist, sericite-chlorite schist, phyllite and quartzite. They assigned the metamorphism to the greenschist facies, based on a mineral assemblage of sericite-chlorite-biotite-quartz-(albite). They cited the occurrence of xenoliths of schists within the granites east of Tuen Mun as proving that the regional metamorphism predated the intrusion of the granites. However, in the same publication Chandy & Snelling (1971) gave a mid-Cretaceous age for one metamorphic event, post-dating the granite intrusion. Allen & Stephens also recognized the effects of regional metamorphism on the tuffs adjacent to the Lok Ma Chau Formation in the northern New Territories. They recognized an intense cleavage, preferentially developed in parts of the volcanic and sedimentary sequences of the north and west New Territories. The metamorphic belt was thought to extend 7 km into the tuffs, with metamorphism dominant in a belt 2 to 3 km wide, suggesting that it is the margin of a broad belt of regionally metamorphosed rocks, and not the result of local shearing.

Bennett (1984c) reviewed metamorphism in Hong Kong, noting that Allen & Stephens (1971) had been the first to place an emphasis on regional metamorphism. He noted that there was evidence of regional prograde metamorphism in Devonian rocks in Shenzhen, but could not confirm that the Lok Ma Chau Formation was similarly affected. He stated that most workers in the field ascribed the metamorphism to dynamic effects in the vicinity of major northeast-trending faults.

There have been recent studies by Chan (1987) and Ho & Langford (1987) on the petrography of the metamorphosed sedimentary and volcanic rocks. Chan considered the Palaeozoic strata had experienced low-grade regional metamorphism of the greenschist facies. He also noted possible evidence of retrograde metamorphism from the epidote-amphibolite facies in the marble of the Yuen Long Formation, and noted that the rocks are metasomatized as well as metamorphosed. Ho & Langford (1987) classified the schists and metatuffs of the Tai Mo Shan Formation in a broad belt southeast of the thrust fault at the base of the overlying Palaeozoic strata. He found mineralogical evidence of hydrothermal alteration varying in intensity with proximity to the main fault and in relation to the development of narrow shear zones.

Thermal (Contact) Metamorphism

Thermal metamorphism has been noted in sedimentary rocks and tuffs close to granite contacts at Ho Pui and west of Ma On Kong. The rocks have a hornfelsed or spotted texture visible in hand specimen, but the exact mineral changes are often only visible in thin section.

Details

Ma On Kong. Thermally metamorphosed carbonaceous siltstone is exposed about 1.5 km west of Ma On Kong (235 311). The sedimentary outcrop, within the Shing Mun Formation, also includes siltstone and fine quartzitic sandstone; the siltstone is probably tuffaceous. The thermal metamorphism in the carbonaceous rock (HK 5133, 2345 3102) is shown by a fine speckling, which in thin section is sericitized chiastolite displaying the characteristic cross-shape.

Ho Pui. In the river bed just north of Ho Pui Reservoir, tuffs of the Shing Mun Formation are exposed in contact with fine-grained granite. The metatuffs are dark greenish grey and finely speckled with black secondary biotite. In thin section (HK 5042, 2555 3011) there is considerable recrystallization of quartz in the matrix.

Metasomatism

Metasomatism is the chemical alteration of rock by fluids that have emanated from a granitic intrusion. These fluids may affect the hot crystallized granite or granite which has already cooled, as well as the country rock. Within the granitic rocks the process results in either kaolinization or greisenization, while in the country rock only greisenization occurs.

Kaolinization affects granitic rocks in the Tsing Shan and Tai Lam plutons, and also affects rhyolite dykes on Tsing Yi; the kaolin commonly forms an economic or sub-economic resource. Patches of greisen are found within the granite of Tai Lam, and in rare instances at the contact with overlying rocks. The occurrence of greisen and the many outliers of tuffs in east Tai Lam Country Park indicate the shallow depth of present erosion into the roof of the pluton.

Details

Tai Lam. At Pak Shek Hang at the southwestern end of Tai Lam Chung Reservoir (195 265) (Plate 58) fine-grained granite is kaolinized and veined by quartz. The kaolinization is controlled by the local fracture system and the area has been deeply excavated for the kaolin along an east-west trend.

Greisenization occurs at Tin Fu Tsai (2446 2793) where granodiorite is intruded by fine-grained granite (2446 2793), and west of Ma On Kong where undifferentiated tuffs form a roof capping to fine-grained granite (2293 2973). The greisenized granite below the tuffs is hard, grey and siliceous, with hydrothermally altered biotite and a recrystallized groundmass. Greisen veins can be found in the same outcrop of fine-grained granite in a valley to the west (2224 2975). The greisen has the characteristic development of muscovite and occurs as thin veins. There are several thin greisen veins in the fine-grained granite west of Tsing Fai Tong. These occur in association with the roof capping of granodiorite and tuff in the area. The muscovite-rich fine-grained veins trend east and are up to 0.2 m wide (2391 2684).

Regional Metamorphism

A broad belt of low-grade regional metamorphism was previously recognized stretching from Tuen Mun, northeast to Lo Wu (Allen & Stephens, 1971). The present mapping programme has defined a larger area which is affected by both dynamic and hydrothermal metamorphism. Within this area, outcrops of sedimentary and volcanic rocks, granodiorite, granite and dykes are similarly affected. The dynamic effects of the regional metamorphism are prevalent in the granite of Tsing Shan, and to a lesser extent in the Tai Lam granite. Tectonically controlled hydrothermal metamorphism probably extends as far south as Tsing Yi.

The metamorphism is primarily associated with overthrusting of Palaeozoic basement onto Jurassic volcanics. The thrust zone extends from Tuen Mun, northeast into Shenzhen (Lai, 1977; 1981), and was termed the Lo Wu – Tuen Mun Fault Zone by Burnett & Lai (1985). The most marked mineralogical changes and structures lie within a belt 2 km wide extending from Lo Wu to San Tin. Shear belts similar in nature to the main zone, but smaller in scale, are developed within the Lok Ma Chau and Tuen Mun formations as far south as Tuen Mun, and within the Tai Mo Shan Formation at least as far southeast as Kadoorie Farm (Addison, 1986). Close to the main thrust, mylonitic schist and schist form narrow bands. The schistose tuffs grade through slightly schistose to non-schistose metatuffs to the south. Phyllite, graphite schist, and schistose sandstone and conglomerate occur to the north.

Details

Tuen Mun. The majority of the sedimentary rocks, tuffs and andesite lavas of the Tuen Mun valley are metamorphosed, but the development of a schistosity is confined to an impersistent northeast-trending belt. Schistose metavolcanics adjacent to phyllitic siltstones and quartzose sandstones of the Mai Po Member are exposed in a cut slope at Wong Fung Lek (1591 2962) (Langford et al, 1988). The schistose volcanic rocks are dark grey, with pronounced banding produced by the development of platy minerals (Plate 35). Temporary exposures of the siltstone showed the development of greenish grey or grey phyllite, with an irregular lustrous foliation (Plate 9).

A large part of the outcrop of the Tuen Mun Formation has been metamorphosed in a broad complex shear belt. The most extreme development of the metamorphism has resulted in the formation of sericite schist. Very light purplish or greenish grey sericite schist was exposed in temporary road cuts near Yeung Siu Hang (1473 2804) and further south in trial pits near Hung Lau (1421 2665). At the former locality the principal foliation trends northeast with a near vertical dip. Shearing of the volcanic rocks near the Shan King Estate (1447 2889) has produced a bluish grey recrystallized, laminated rock with pods of quartz and a foliation that dips 55° west.

Strongly foliated metavolcanic rocks, highly weathered and resembling siltstones, are exposed in a stream bed at Shek Kok Tsui (1391 2630) and were encountered in a fresh state in boreholes nearby at Pak Kok (1387 2614); the rock is greenish grey, foliated and fine-grained. In thin section, primary plagioclase is quite abundant, with secondary zoisite epidote, chlorite and muscovite. Similar strongly foliated and contorted metavolcanics are exposed at low tide on the shore west of Wu Tip Wan (Butterfly Beach) (1315 2565). A thin section from these metavolcanics (HK 3775, 1316 2562) shows an aphanitic texture consisting largely of sericite with abundant secondary quartz and patches of iron ore.

Au Tau. Crystal tuffs of the Tai Mo Shan Formation are metamorphosed to schists in a belt about 1 km wide extending from Au Tau (228 340), south across Ho Hok Shan (231 333); the schist dips steeply northwest.

Kai Keung Leng. Narrow, anastomosing zones of metatuff outcrop across Kai Keung Leng. The zones are usually around 10 to 50 m wide and are composed of pale brown weathering, fractured rock. The relict texture of the tuffs is sometimes visible, usually in the general disposition of quartz pyroclasts and the outline of lithic lapilli. The zones can often be traced as hard, resistant features in the surrounding more deeply weathered tuffs for at least 1 km. The zones of metatuff are dominantly quartz and sericite, and may be slightly schistose. The surrounding tuffs are slightly metamorphosed, with hydrothermal alteration only, giving secondary biotite, calcite, pyrite and sericite (Ho & Langford, 1987) (Plate 36). The more severe quartz-sericite hydrothermal alteration, although confined to narrow bands, affects intrusions within the tuffs. The metamorphism cuts a feldsparphyric rhyolite dyke on the southern slopes of Kai Keung Leng (2689 3515), with some parts becoming schistose. Further south, at the base of the hill (2720 3450), the alteration affects porphyritic granodiorite, resulting in a rock composed entirely of quartz and sericite.

In Tai Mo Shan Formation metatuff on Kai Keung Leng (HK 5341, 2669 3599) the metamorphic matrix of finely divided quartz and sericite is dominant (c. 50%), masking to a certain extent the presence of lithic clasts (c. 4%). The crystal pyroclasts are quartz (c. 18%), alkali feldspar, including microcline, (c. 19%) and plagioclase (c. 8%). The alkali feldspar is usually replaced in part or completely by secondary biotite and calcite.

Tai To Yan. On the eastern flanks of Tai To Yan, extending eastnortheast, is a broad belt of hydrothermal metamorphism with some schist development. There is abundant quartz veining, which in places has been commercially extracted (287 347), and resistant ribs of metatuff are developed in parts. The relict quartz pyroclasts sit in a fine quartz-sericite matrix with a weak preferred orientation. Exposures of this slightly schistose metatuff are well seen east of Ta Shek Wu Shek Tong (295 355). The ridge southwest of the summit of Tai To Yan (297 340) is composed of slightly metamorphosed tuff, and marks the edge of a metamorphic belt about 1 km wide extending towards Shek Kong. Similar pale-weathering, quartz-veined non-schistose metatuffs are exposed in the low hills adjacent to Kam Tin Road.

In thin section (HK 3375, 2970 3400) the Tai Mo Shan Formation metatuff that forms the hard ridge along the crest of southern Tai To Yan consists of c. 50% matrix, c. 46% crystals and c. 40% lithic clasts. The matrix, finely divided quartz and sericite, tends to obscure the lithics, but the crystal pyroclasts are still clear. Quartz (c. 19%) is not affected by the metamorphism, while alkali feldspar, including some microcline, (c. 20%) is altered in varying degrees to biotite and calcite (Plate 36). Plagioclase is generally only slightly altered, and there are secondary biotite, muscovite and opaques after biotite (c. 2%).

Shek Kong Village to Ngau Liu. A metamorphic belt up to 500 m wide extends from the flanks of Kwun Yam Shan southwest to Ngau Liu, and affects granite, granodiorite and tuffs alike. An aphyric siliceous rock which is believed to be hydrothermally altered fine-grained granite is exposed south of Kap Lung (2844 3058). In excavations south of Fan Kam Road (2946 3245) the coarsely porphyritic fine-grained granodiorite grades eastwards into a rock that is almost entirely altered to epidote, sericite and recrystallized quartz. Further south a cataclastic fabric commonly accompanies the hydrothermal alteration; foliated metatuffs of the Shing Mun Formation can be seen on Route Twisk (3000 3124), and foliated quartz-sericite metatuff of the Ap Lei Chau Formation is exposed near the Country Park Management Centre (2882 2972).

Tsing Yi. Hydrothermal alteration, epidotization, sericitization and associated quartz veining can be seen in tuffs and sedimentary rocks on northern Tsing Yi. The alteration occurs above the granodiorite intrusion, and may be related to a north-trending fracture zone.

Age of regional metamorphism

The regional metamorphism has a long history of development, starting with prograde metamorphism in a Palaeozoic basement (Bennett, 1984c; Chan, 1987). The main phase of movement, during which the schist belt was formed, took place after the deposition of the Repulse Bay Volcanic Group. Relatively minor dynamic and hydrothermal effects were associated with the end of the phase of regional metamorphism and the intrusion of the granites. The main age of regional metamorphism is Late Jurassic (Chandy & Snelling, 1971).

Chapter 9
Superficial Geology

Superficial deposits are those sediments that have not generally been lithified to form rocks. The superficial deposits of the district have been divided into onshore and offshore. Regardless of their mode of occurrence, the boundary between onshore and offshore deposits for the purpose of this memoir is taken at the pre-reclamation coastline. The estuarine deposits and mud flats of the intertidal region are treated as offshore deposits. The relationship between deposits of the onshore and offshore areas are shown schematically in Figure 21. All of the superficial deposits are believed to have formed during the Quaternary period.

The most important onshore superficial deposits in the district are mass wasting and fluvial deposits. Rare occurrences of organic material (peat) are found within alluvium. Offshore, these sediment types are also present, usually beneath marine deposits. This chapter also includes an account of the weathering products of both the common rock types and superficial deposits.

Onshore Superficial Deposits—Classification and Distribution

The onshore alluvium is known to be of Pleistocene age or younger, and like the stratigraphically related debris flow deposits is divided accordingly on the map. The alluvium is widespread in the west and north of the district, forming extensive floodplains. Debris flow deposits often occur upslope of the alluvium, and in isolated upland areas. Both deposits are composed of clay, silt, sand and gravel in varying proportions, while the debris flow deposits also commonly contain cobbles and boulders. Peat may occur within these sediments.

Beach deposits include sand and gravel extending inland from the low water mark. They are often found in sheltered areas of most rocky coastlines, but are absent in the north of the district where estuarine and alluvial deposits are dominant. In places it has been possible to differentiate a raised beach as a separate feature rising to 6 mPD. These probably formed during a period of slightly higher sea level. Talus or rockfall deposits have a very limited distribution, being found only near Tuen Mun, and are dominantly composed of angular blocks.

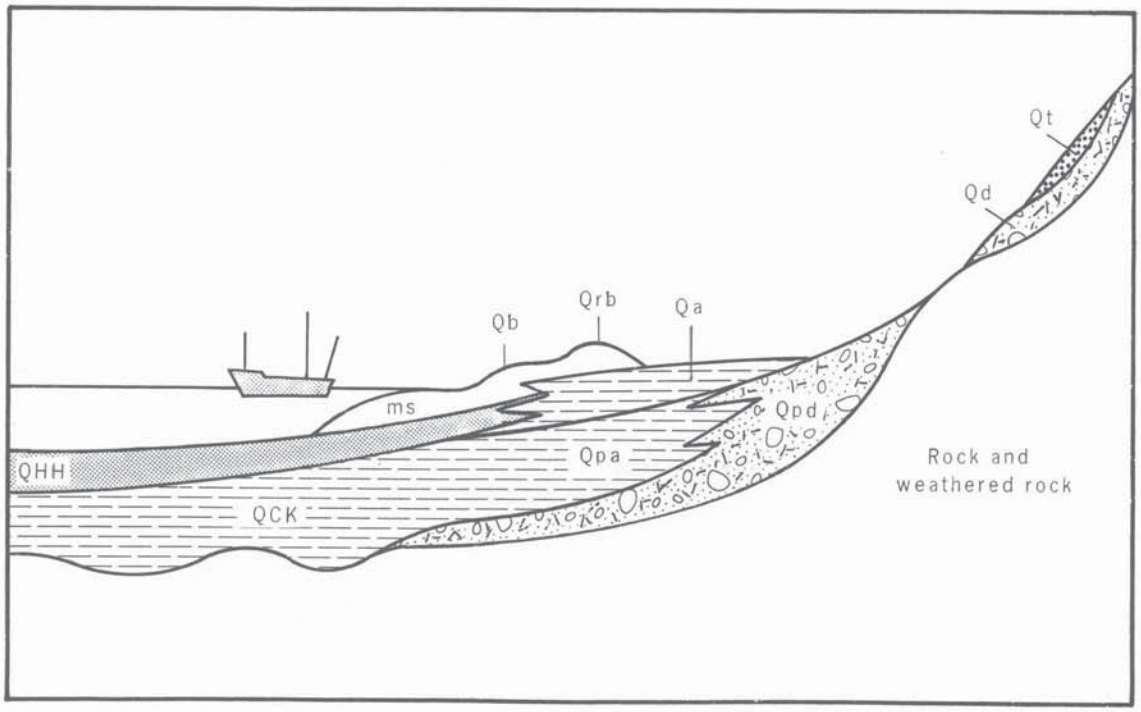


Figure 21 – Schematic Section Showing the Relationship between the Offshore and the Onshore Superficial Deposits

The onshore area has been progressively extended by reclamation, particularly in Tsing Shan Wan (Castle Peak Bay). Fill material has been mapped separately, both where it covers the pre-reclamation coastline, and where it is associated with major engineering projects such as dams and roads.

Alluvium

Stratigraphy

Alluvium is widespread on the Yuen Long, Kam Tin and San Tin plains, and in the Tuen Mun and Ngau Tam Mei valleys. It is rarely seen in section, and can usually only be described from site investigation boreholes and auger holes. The deposits consist mainly of well-sorted to semi-sorted clay, silt, sand and gravel. In colour the materials vary from grey to yellowish brown, depending on the nature and proximity of the bedrock source. Where the source is granite there is a predominance of sand-size material, while clayey, clast-rich alluvium derives from the volcanic rocks.

Two ages of alluvial deposits are recognized; late Pleistocene deposits are found in extensive fluvial terraces, while Holocene alluvium mainly occurs along the recent stream courses which are incised into the terrace surface by between 1 and 7 m.

The lithofacies of the late Pleistocene fluvial terrace deposits vary across the outcrop. Near the foot of hills the deposits consist mainly of semi-sorted yellowish brown to orange gravelly silty sand intercalated with layers of dark grey organic clay that may be lacustrine or marsh sediments (Plate 37). In the upper valley sections these deposits may pass laterally into Pleistocene debris flow deposits. In the distal plains the fluvial terrace deposits are characterized by mottled red to brick red, yellow, brown and white, well-sorted clayey sandy silt with some sand layers (Plate 38). The deposits have a thickness ranging from 5 to 12 m, with a surface elevation which falls from 27 mPD to below sea-level. Radiocarbon dating of organic clays from Shan Ha Tsuen (192 321) gave ages from 16 289 ± 831 to 33 575 ± 3 186 yr BP, indicating a late Pleistocene age (Appendix 2).

Most of the areas of Holocene alluvium (1 510 ± 70 to 1 630 ± 70 yr BP; Appendix 2) are relatively low-lying, being at most 10 mPD, and most are also narrow, cutting into the surrounding Pleistocene terraced alluvium. The deposits comprise semi-sorted subrounded boulders and gravelly sand in the upper stream courses, and yellowish brown, well-sorted clayey sand or silt in the lower courses. In places along the coast the streams are dammed by sand bars or spits, behind which lagoonal alluvial deposits form. Small patches of hill alluvium have been mapped from Tsing Shan to Lin Fa Shan, almost entirely on the granitic outcrops. This alluvium occurs in narrow, restricted areas, only rarely up to a kilometre long, and generally only 50 to 100 m wide.

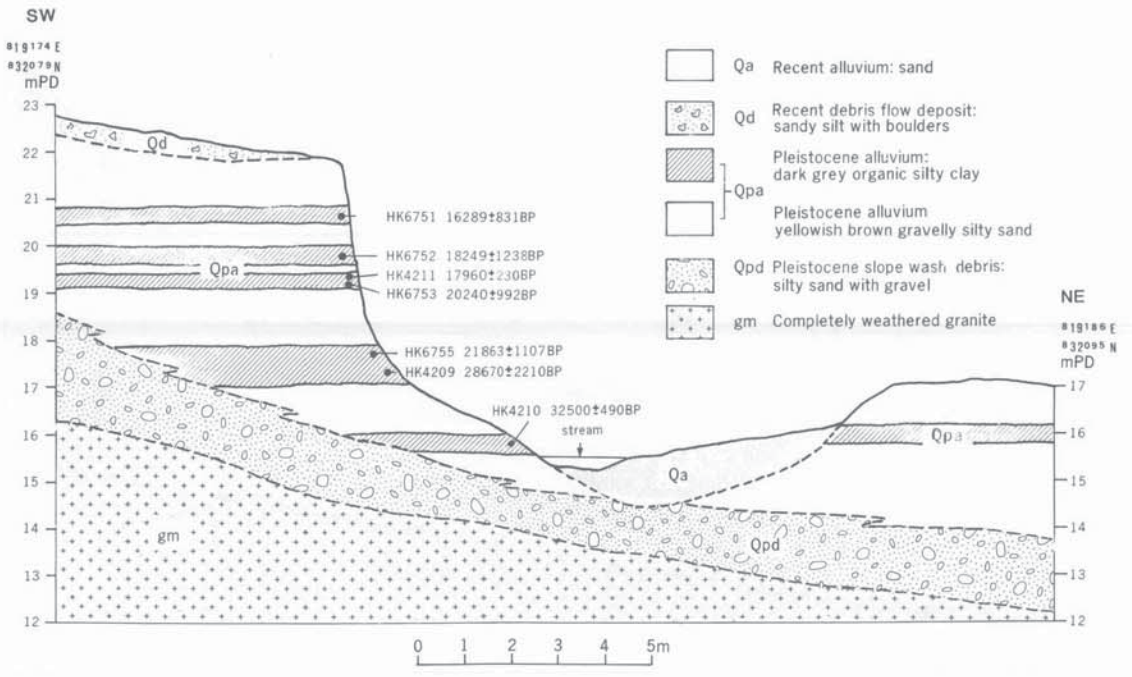


Figure 22 – C14 Dating and Soil Profile of Quaternary Deposits at Shan Ha Tsuen, Yuen Long (192 321)

Estuarine deposits are of mixed alluvial and marine origin. They consist of grey clayey silty sand with plant remains, and dark grey organic silty clay with shell fragments. These deposits mainly occur along the old coastline from Lo Wu passing through San Tin to Fairview Park. To the south the low lying areas north of Yuen Long and Tin Shui Wai may also be underlain by these deposits. The estuarine deposits are regarded as Holocene in age.

Details

Tsing Shan (Castle Peak). Deposits of alluvium are present in two contrasting situations in the southern Tsing Shan area; coastal and upland. The principal coastal alluvial tracts, formerly intensely cultivated, occur where streams draining the granite hill debouch onto the coastal plains of Lung Kwu Tan and the Tuen Mun valley, although at Tuen Mun the deposits are now largely masked by fill. At Lung Kwu Sheung Tan (095 292) (Plate 39) and Lung Kwu Tan (101 273) the alluvium forms swampy coalesced fans with surfaces in the range 10 mPD to sea-level. Augerholes sunk at Lung Kwu Tan (1010 2713) proved silty coarse sand to depths of about 1 m, the sand comprising sub-rounded to sub-angular quartz with some feldspar. While these deposits are considered to be of Holocene age, it is likely that they overlie older alluvium analogous to the Chek Lap Kok Formation offshore.

Formerly cultivated tracts of alluvium line some of the upland valleys of the Tsing Shan area, mostly in the range 120 to 190 mPD. These are generally bounded downstream by rock sills, while in places (1113 2919) streams flowing through them are rock-floored. It is likely that these deposits are thin, probably mostly less than 3 m.

Along the coast are infilled lagoons or deltas behind sand beaches containing deposits of light yellowish brown silty sand with thin layers of clayey silt derived from the weathered granite. On the southeastern coast of Hau Hoi Wan, small streams have been dammed either by sand bars as at Fuk Lo Tsuen (162 364), Ngau Hom Sha (146 346), Nim Wan (111 312), Tsang Tsui (101 310) and Yung Long (088 303), or by spits as seen on Sheung Pak Nai (134 344) and Tai Shui Hang (118 320). The thickness recorded by boreholes at the stream mouth of Tai Shui Hang varies from 4 to 6.5 m. To the east of Urmston Road, sediments have filled the lagoons behind the raised beaches at Lung Kwu Sheung Tan (092 293) and Lung Kwu Tan (099 275). The thickness of the deposits vary from 1.5 to 14 m.

Tuen Mun to Tin Shui Wai. Low-lying Holocene alluvium forms much of the low ground to the north of Tuen Mun. It forms in a series of narrow valleys incising Pleistocene debris flow deposits and alluvium. The valley floors are mostly 100 to 200 m wide, and extend up to 2 km north of the estuary. Similar narrow valleys drain northwards towards the estuary at Tin Shui Wai. This broad valley with a central watershed extends for 11 km from Tsing Shan Wan to Tin Shui Wai, draining south to Tuen Mun and north to Tin Shui Wai. Late Pleistocene fluvial terrace deposits underlie most of the low-lying land in the valley. The maximum elevation of the upper surface of the deposits is 20 mPD around Fuk Hang Tsuen (170 310). The sedimentary sequence in the Tin Shui Wai area can be divided into two parts. The lower part comprises 1 to 13 m of silty sand and gravel, and occurs in the eastern part of the area in the region of a buried stream channel. The upper part consists of reddish brown and grey silty clay with thin layers or pockets of clayey silt and silty sand. The deposits have a thickness ranging from 1 to 13 m, with the thickest deposits in the northwest, where they underlie Holocene marine deposits. South of Lam Tei, in the Tuen Mun valley, a relatively small outcrop of Pleistocene alluvium occurs that mainly comprises yellowish brown and grey clayey silty sand; sections show thin layers of gravelly coarse sand with boulders in the beds of buried former stream channels. In the main Tuen Mun valley the thickness of the terrace alluvium varies from 1.2 m at Lam Tei (162 310), to 16 m at Tin Shui Wai (191 367) and 8 m around Tuen Mun San Hui (157 288).

So Kwun Wat. Alluvium fills the narrow valley at So Kwun Wat, forming a generally waterlogged plain behind a sand bar. The alluvial flat is over 200 m wide and extends eastnortheast for over 2 km along the fault-controlled valley. On the flanks of the valley the alluvium grades into narrow debris-filled hollows. An auger hole sunk into the alluvium close to the beach (1759 2609) showed at least 2.4 m of pale, coarse and pebbly sand. This sand is well sorted, and may in part be an earlier, raised beach sand. At the upper end of the valley (1914 2656), near Pak Shek Hang, a 2.7 m auger sample recovered grey and mottled brown, gravelly sand and sandy clay. This material is clearly derived from the adjacent outcrops of deeply weathered granite, is poorly sorted and has been transported only a short distance. The surface of the alluvium is generally only 3 to 10 mPD.

Tai Lam Chung to Siu Lam. On pre-development aerial photographs a flat, extensive alluvial spread can be detected beneath Tai Lam Chung Reservoir. This outcrop is not continuous with those of Siu Lam and Tai Lam, but is separated from them by narrow gorges which formed the sites of the dams for the reservoir. The alluvium extending north into the valley at Tai Lam Chung forms a flat plain 100 to 200 m wide at 2 to 5 mPD. At Siu Lam the alluvium has accumulated behind a sand bar in a fault-controlled northeast-trending valley. It forms a flat spread rising steadily from about 3 mPD near the coast to 15 mPD inland.

The Holocene alluvial deposits mainly occur in narrow valleys within the drainage system. The deposits are composed of loose, light yellowish silty sand with thin layers of silty clay, and vary in thickness from less than 1 m up to 5 m.

Yuen Long Plain. The Yuen Long Plain is a broad alluvial valley surrounded by low hills, except at the northern end where it passes into the coastal mud flats. The valley is filled with late Pleistocene fluvial terrace deposits and Holocene alluvial deposits which line the recent streams courses 1 to 7 m below the terrace surface. The surface elevation of the Pleistocene fluvial terrace deposits grades from 23 mPD around Tai Tong (205 309) in the south to −2.5 mPD around Chung Hau Tsuen (213 349) in the north. At the same localities the base of fluvial terrace deposits is at 15 mPD and −9 mPD respectively.

The deposits are firm to stiff, mottled red and yellow clay with some sand. The deposits in the west and south of the plain are derived from granite and sandstone, and have high sand contents. The deposits in the east of the plain are derived from tuff, and have high silt and clay contents. In general, the sedimentary sequence in the deposit shows gravelly sand with quartz cobbles at the base. In the upper reaches of the stream at Shan Ha Tsuen (Figure 22) the alluvial deposits derived from granite mainly consist of gravelly sand with three to five thin layers of dark grey organic clay (Plate 37). The deposits derived from tuff south of Tong Tau Po mainly comprise yellowish brown clayey silt. Near Fraser Village (208 328) the deposits consist of yellowish brown sandy clayey silt with 2 to 5 layers of sand up to 3 m thick.

The thickness of the late Pleistocene fluvial terrace deposits varies markedly over the plain from 3 to 7 m near the margins to 15 m or more in the central part. Extreme thicknesses of up to 31.5 m were recorded in drillholes near the Yuen Long District Office (2044 3391), where there is a buried stream channel (Figure 23).

Holocene alluvial deposits occur mainly in the recent stream beds and in flood plains. They vary between a few metres and 100 m across, and form a delta beneath Yuen Long town. The thickness of the deposit varies from 1 or 2 m or less in the upper reaches to a maximum of 16 m near the Yuen Long District Office (2044 3391), where three streams converge. To the north of Yuen Long the deposits decrease in thickness. They are composed of gravelly sand with cobbles and boulders in the upper reaches of the valleys, and silty sand with thin layers of clay in the lower stream courses and delta. In the east part of the basin the clay content of the deposit is higher.

Kam Tin Plain. This is a broad alluvial valley which is lined with widespread late Pleistocene fluvial terrace deposits. The surface elevation of the deposits grades from 27.6 mPD around Shek Tau Wai (2800 3230) in the east to −3.9 mPD by the Castle Peak Road in the west. The composition of the deposits in the higher part of the valley near Shek Tau Wai is yellowish brown gravelly sand about 1 to 3 m thick, with thin layers of mottled red and brown silty clay. In the central part of the valley, around Shek Kong Camp (260 333), the deposits become thicker, averaging 8 m with a maximum 14 m (Figure 23). Boreholes show that the lower part of the deposit mainly comprises silty sand with gravel, with a layer of gravelly sand with cobbles at the base. The upper part is mainly mottled red, brown and grey sandy silt or silty clay. At the western end of the valley, where it grades into the mud flats described earlier, borehole records show that the deposits are up to 11.5 m thick and can be divided into three layers; the lower layer is 0.5 to 2.4 m thick and comprises gravelly sand with cobbles; the middle layer consists of 5 to 7 m of yellowish brown silty sand; and the upper layer consists of 3 to 4 m of mottled red yellow and grey silty clay.

Holocene alluvial deposits occupy the present stream courses and flood plains, and vary from 1 m of gravelly medium to coarse sand with some cobbles in the upper reaches, to 3 to 5 m of light yellow clayey silt with thin layers of sand near the stream mouths.

Ngau Tam Mei. In this narrow valley the surface elevation of the Pleistocene fluvial terrace deposits grades from 26 mPD in the east near Ngau Tam Mei (266 375) to −1 mPD by Castle Peak Road (240 375) in the west. Around Ngau Tam Mei these deposits consist of silty coarse sand with some boulders, with a thickness of 1 to 5 m. Near the valley mouth the deposits consist of up to 10 m of silty sand with thin layers of clay; coarse sand with quartz gravel and cobbles forms a thin layer at the base of a buried stream channel.

The Holocene alluvium is dominantly composed of sand, although to the west of Tam Mei Camp (246 376) the silt and clay contents are higher. Beyond the mouth of the valley a former deltaic deposit of light brown clayey silt overlies the dark grey silt and clay swamp deposits of the mud flat. The thickness of the Holocene alluvium varies from 1 m in the upper course to 6 m at the mouth of the valley.

At the mouth of Ngau Tam Mei Valley (240 378) the estuarine deposits consist of 2 to 5 m of light yellowish brown clayey silt with discontinuous lenses of sand. They are covered by deltaic silty, sandy deposits and rest on marine deposits.

Ng Tung Ho (River Indus) and Sheung Yue Ho (River Beas). In the upper course of Sheung Yue Ho the late Pleistocene fluvial terrace deposits comprise about 1 to 5 m of mottled red and brown gravelly sandy silt with highly to moderately weathered subrounded boulders. The boulders may form up to 40% of the deposit in the central part of the basin around Tsiu Keng Lo Wai and Chan Uk Po. Holocene alluvium flanks the present course of Ng Tung Ho and Sheung Yue Ho between Ta Shek Wu Shek Tong (284 354) and Lo Wu, from where the deposits connect with the alluvium of Shenzhen River through a narrow pass near Lo Wu railway station. The Holocene alluvium lies 2 m below the Pleistocene terrace surfaces. Along the middle course of Sheung Yue Ho at Hang Tau Tai Po (2830 3920) bedrock is exposed. In the lower stream course, near Sheung Shui, the Pleistocene fluvial terrace deposits consist of mottled red, yellow and white sandy clayey silt with a thickness varying from 5 to 12 m. The Holocene alluvium in the lower course is mainly a loose silty sand deposit overlain by a thin layer of silty clay; the maximum thickness is 7 m near Lo Wu.

At the mouth of the Ng Tung River and the lower course of Shenzhen River from Lo Wu to Ha Wan Tsuen (258 417), numerous boreholes have been drilled through the estuarine deposits. They comprise 2 to 7 m thick interbeds of alluvial silt or sand and marine clay which grade down into the underlying marine deposits.

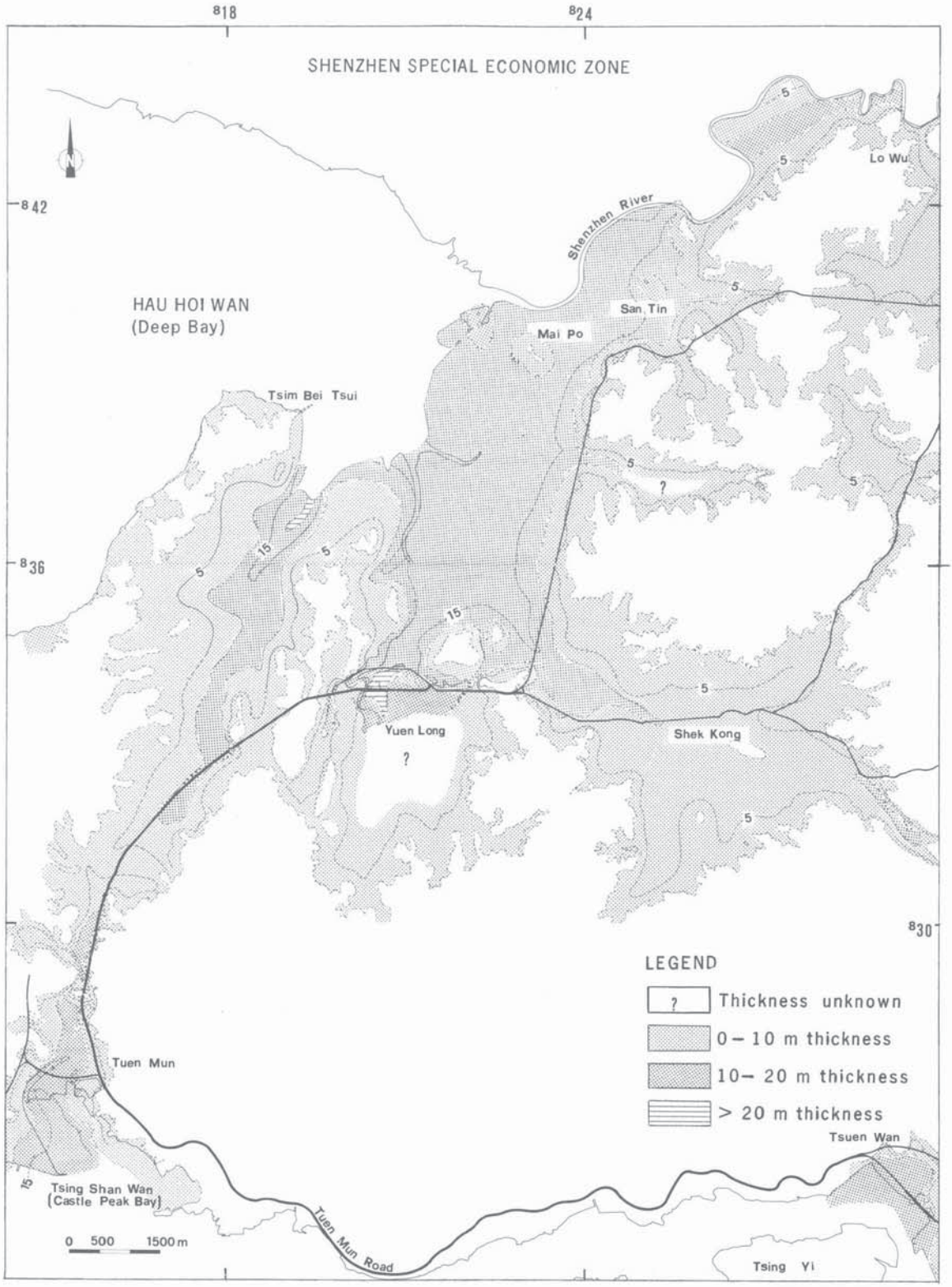


Figure 23 – Thickness of Quaternary Superficial Deposits between Tuen Mun and Lo Wu

Upstream, 1 km west of Hoo Hok Wai (265 425), the top layer of the deposits is river silt; downstream, the uppermost deposits are marine clay. Typical estuarine deposits appear in boreholes at Tung Chan Wai (2610 403). They consist of 2 to 6 m of interbedded yellowish grey clayey silt with mangrove remains and dark grey clay with shell fragments.

San Tin Plain. This area comprises the estuaries of Shenzhen River and Shan Pui River, and the San Tin mud flats. The surface of the area is very flat with an elevation varying from 1 to 5 mPD. Late Pleistocene alluvium is extensive in the plain beneath Holocene marine deposits and is composed of a widespread deposit of mottled red and yellow clayey silt up to 15 m thick with impersistent layers of sand (Plate 38).

Sedimentary Environment

Pollen analysis of samples from the third layer of dark grey organic clay at Shan Ha Tsuen (Figure 22) (K. B. Liu, written communication, 1987) gave a radiocarbon date of 17 960 yr BP. They contained a pollen assemblage indicative of an open woodland dominated by oak and pine, with a ground flora comprising abundant grasses and ferns. However, in the second layer, radiocarbon dated to 28 670 yr BP, pine pollen is virtually absent. Pollen analysis was also carried out on the first organic layer, radiocarbon dated to 21 649 yr BP. This larger is dominated by pine, with few oak pollen. The pollen assemblage suggests a significant vegetational change prior to the last glacial maximum.

Debris Flow Deposits

Stratigraphy

Debris flow deposits are accumulations of material transported by water mobilized gravitational processes. They have been generally referred to as colluvium in Hong Kong. They are diverse in their composition and usually poorly sorted. The grain size may vary between being predominantly silt, sand, gravel, cobbles or boulders, depending on the original topography, type of the parent rock and distance travelled. Generally, the fine debris occurs on the gentle slopes or the upper part of hillslopes, and the boulder deposits lie at the foot of steep slopes or fill the heads of valleys. Most commonly the debris flow deposits consist of boulders and cobbles embedded in a gravelly sandy silt matrix.

The deposits were recognized and studied by Berry & Ruxton (1960) and Grant (1960). Allen & Stephens (1971) noted the widespread deposits on Tsing Shan and at Shek Kong. The debris flow deposits were classified by Lai (1982) into three ages; early or middle Pleistocene, late Pleistocene and Holocene. The criteria for classification of these deposits were described by Lai and Taylor (1983), who cited field characters including colour, clay content and density of the matrix, degree of weathering, rind thickness of the boulders and cobbles, and contact relationships.

The largest areas of debris flow deposits are those at Shek Kong on the northwestern slopes of Tai Mo Shan, below Tsing Shan in the Tuen Mun valley, and around Tai To Yan, Kai Keung Leng and Tai Shek Mo, with the thickest accumulations at the base of the steep slopes, especially around the high, volcanic hills.

The Pleistocene debris flow deposits may occur as two varieties. The first is stiff to very stiff, mottled red to brick red, brown and white, or with reticulated streaks. The matrix is clayey sandy silt, and the clasts are the highly to completely weathered cobbles and boulders. The large clasts often have a rind with a thickness ranging from 20 to 50 mm or more. White streaks, consisting mainly of kaolinite, often form along relict joints through weathered boulders. These deposits may be overlain by deposits of slightly clayey sandy silt which is firm to stiff, reddish brown, or dark yellowish brown to orange red and slightly mottled. Since the younger part of these deposits can grade into fluvial terrace deposits they are believed to be of late Pleistocene age. The older part of these deposits may be at least middle Pleistocene. These subdivisions of Pleistocene debris flow deposits are not differentiated on the maps.

The Holocene debris flow deposits are soft to firm, light yellowish brown slightly clayey sandy silt to gravelly silty sand. The clasts are slightly to moderately weathered, subangular to angular cobbles and boulders. The rind on large boulders is never more than a few millimetres thick. These deposits overlie the fluvial terrace deposits (Figure 22) and fill valleys cutting the Pleistocene debris flow deposits.

Details

Tsing Shan (Castle Peak) and Tuen Mun. Debris flow deposits are extensive in western Tuen Mun, particularly over the outcrop of the Tuen Mun Formation. There are also substantial deposits on the western slopes of Tsing Shan, while elsewhere in the Tsing Shan uplands such deposits are largely restricted to valley linings. Except in southwestern Tuen Mun, it has not proved feasible to divide the deposits for mapping purposes. They are represented as debris flow deposits of Pleistocene-Holocene age despite the likelihood of various origins and complex histories.

The deposits in valleys and gullies in the Lung Kwu Tan area comprise trains of exhumed granite corestones which have accumulated by creeping and sliding. Some valleys are choked with the jumbled boulders of these deposits, the streams flowing below the deposit (e.g. 0980 2953 & 1040 2815).

Fans of debris flow material are present on the western flanks of Tsing Shan, notably to the southwest of the summit (124 273). These deposits includes conspicuous boulders of vein quartz several metres across and derived from the broad mineralized northeast-trending shear zone that cuts the summit ridge. The lower part of the fan complex includes terraces that reflect progressive incision by the main streams.

The deposits on the footslopes of the eastern side of Tsing Shan are demonstrably of two generations. The older, Pleistocene, division comprises debris flow deposits preserved as terraces that form interfluves to the contemporary drainage of these slopes; the terraces appear to be remnants of a once extensive apron, now 5 to 10 m thick. A former borrow pit near San Shek Wan San Tsuen (1420 2752) cut through 8 m of this material, which rests on completely weathered andesite; the deposit forms 4 m high vertical faces. It comprises ill-sorted boulders, cobbles and pebbles of sandstone, siltstone, granite and vein quartz in a matrix of sandy mud; the granite boulders are generally highly to completely weathered.

Where weathered the mud matrix is mottled red and ochre, as seen in the terraced deposits exposed in a small waterfall near San Shek Wan Tsuen (1383 2673). Contrasting depositional modes, indicating mud flow and alluvial torrent origins respectively, are illustrated in a 4 m section in a former borrow pit nearby (1383 2669). The lowest 2 m comprises debris flow deposits with ill-sorted, mud-supported cobbles and boulders up to 2.5 m across in a sandy mud matrix; the overlying material, forming the terrace surface, consists of relatively well sorted, clast-supported pebbles, cobbles and small boulders with a muddy sand matrix.

Other debris flow deposits of Pleistocene age may exist on the footslopes to the northwest of Tuen Mun, particularly those southwest of the Leung Tin Estate. In the absence of clear terrace features they have not been distinguished.

Between the terraced interfluves there are complex younger mass wasting deposits, in part of debris flow origin, in part the product of landslipping. The deposits include masses of weathered andesite, foundered Pleistocene debris flow deposits of the type described above, and younger, presumed Holocene, alluvial torrent and debris flow deposits. They have been encountered in many boreholes, generally less than 10 m thick, and are here regarded as Quaternary. A cut slope in the hillside above Tsing Shan Tsuen (1422 2792) shows 3 m of debris flow deposit resting on completely weathered andesite. The lower part of the deposit consisted largely of reconstituted weathered andesite boulders becoming increasingly abundant towards the top.

Where steep stream courses draining the eastern flank of Tsing Shan debouch onto the footslopes, fresh or slightly weathered rock debris, including blocks of granite more than 3 m across, has been incorporated by torrent and debris flow in the younger mass wasting deposits. This is well displayed at San Shek Wan San Tsuen (1385 2739) and farther south (1378 2719). At the latter locality the debris, which consists mainly of granite boulders, has slipped, leaving a backscar some 6 m high. Contemporary failures occurred during and after the excavation of a major borrow area in southwestern Tuen Mun (Area 19, 140 270); also during site formation farther north, near the Shan King Estate (Area 8, 141 284). In such instances where failures have occurred the bedrock consists of andesites of the Tuen Mun Formation.

Along the coastline from Tsim Bei Tsui, passing through Sheung Pak Nai and Nim Wan to Lan Kok Tsui, debris flow deposits occur on the foothills flanking the granite. They are mainly of Pleistocene age, consisting of subrounded, highly to completely weathered cobbles and boulders set in a stiff to very stiff, mottled red and brown gravelly sandy silt. The thickness varies from 1 to 3 m, with a maximum thickness of 6 m. Holocene alluvial deposits, consisting of large boulders set in the gravelly silty sand, fill the stream valley cut through the Pleistocene deposits.

At Lung Kwu Sheung Tan and Lung Kwu Tan the Pleistocene-Holocene debris flow deposits form elongate valley fill accumulations. Boreholes have revealed a maximum thickness of 11 m at the valley mouth (0911 2951).

From Pak Kok (136 262) to Yeung Shiu Hang (145 283) the deposits consist of moderately to completely weathered boulders and cobbles of metasandstone, metaconglomerate and granite in a matrix of mottled red, yellow and white clayey sandy silt. They can be traced in boreholes at Tsing Shan Wan (1380 2715), where they lie beneath the Holocene marine deposits. Younger debris deposits of Holocene age are composed of fresh to moderately weathered boulders set in a loose yellowish brown gravelly silty sand matrix. The thickness of the Pleistocene and Holocene deposits encountered in boreholes varies from 1.5 to 20 m (1400 2758).

From San Hing Tsuen to Fung Kong Tsuen (1670 3550), on the western flanks of the Tuen Mun valley, the deposits derive from tuff-breccia and fine ash tuff of the Tuen Mun Formation, and form a large fan-shaped body 6 km long by 0.5 km wide along the foot of the hill slopes. The deposits are mainly of Pleistocene age, containing highly to completely weathered materials, and are thickest in the lowest parts, varying from 1 to 3 m, with a maximum of 10 m. Along the east flank of Tuen Mun valley from Lo Fu Hang (170 305) passing Ping Shan to Ng Uk Tsuen (203 362) the debris flow deposits are mainly of Pleistocene age and are largely derived from metasedimentary rocks or, locally, from granite, as at Tan Kwai Tsuen. Since hillslopes are gentle, the deposits are relatively fine-grained, consisting of cobbles and gravel in clayey silt. The thickness varies generally from 0.5 to 2 m with a maximum of 8.5 m.

Tsuen Wan to Hadden Hill. The debris flow deposits of this area are mostly derived from volcanic rocks, and are well-developed along the footslopes of high hills. Surrounding the hills of Shek Lung Kung and Lin Fa Shan, north of Tso Kung Tam and at Chuen Lung the debris flow deposits form narrow elongate accumulations along the stream valleys. They comprise subangular boulders up to 5 m.

Excellent exposures of debris flow deposits are seen along Route Twisk in Shek Kong Village (190 318) (Plate 47). The deposits extend 2.5 km and are 0.5 to 0.8 km wide. The thickness varies from 2 to 8 m, with a maximum 18 m encountered in boreholes. Road cuttings and drillcores show the upper part of the deposit to consist of moderately to highly weathered cobbles and boulders of coarse ash tuff or tuff-breccia set in a

Plate 47 – Pleistocene Debris Flow Deposits at Shek Kong Village (2956 3144)

matrix of yellowish brown gravelly silty sand. The large boulders are up to 4 m in diameter and have a rind 2 to 10 mm thick. The thicknesses of the upper deposits vary from 0.5 to 3 m. The deposits grade into or underlie the late Pleistocene fluvial terrace deposits at Tsang Uk Tsuen (1771 3229), and it is inferred that they are of late Pleistocene age. The lower part of the deposits are reddish brown and mottled, with highly to completely weathered cobbles and boulders in a matrix of gravelly sandy silt with a thickness varying from 10 to 15 m.

On the footslopes of Kai Keung Leng and Hadden Hill the debris flow deposits are well developed. North of Kai Keung Leng the fan-shaped deposit is generally 2 to 10 m, with a maximum thickness of 18 m at the head of one valley (271 375) where it forms a boulder field. Large boulders of coarse ash tuff are up to 5 m across. Elongate accumulations of debris filling the stream valleys are up to 1.5 km long within the hill areas.

Along Ng Tung Ho (River Indus) and Sheung Yue Ho (River Beas) between Lo Wu and Tam Shui Hang the debris flow deposits occur on the both sides of alluvial plains and in the valley heads. The deposits are mainly of Pleistocene age and consist of highly weathered cobbles set in gravelly clayey silt. The thickness ranges from 1 to 4 m, occasionally up to 10 m.

Lok Ma Chau to Tai Shek Mo. In the area around Lok Ma Chau and Tai Shek Mo the debris flow deposits are entirely derived from metasandstone and quartzite of the Lok Ma Chau Formation. The deposits are widely distributed on the foothills but are relatively thin, generally 0.5 to 2 m. The maximum thickness encountered in boreholes is 6 m.

Beach Deposits

Stratigraphy

Beach deposits comprise the unconsolidated sediment that extends from the low-tide mark to the uppermost limit of wave action. They are usually composed of well-sorted gravelly, silty sand with shell fragments, and they form a narrow fringe around the natural coastline. Along the coast from Tsim Bei Tsui to Ting Kau, weathered granite provides an abundant sediment source for the beaches.

Raised beach deposits occur behind the contemporary sand beach and are composed of gravelly coarse sand with scattered pebbles at a height of up to 6.5 mPD. Archaeological evidence indicates a Holocene age and the radiocarbon dating gave ages from 1 370 $\pm$ 100 to 5 800 $\pm$ 500 yr BP (Appendix 2).

Details

Tsing Shan (Castle Peak). Holocene deposits of beach sand, generally intensively cultivated, are a feature of the Tsing Shan coastline. These deposits are continuous with the littoral and sublittoral sands of the Hang Hau Formation. They are preserved in bays between the rocky headlands of the western coast and in wave-dominated deltas on the southeastern shores of Hau Hoi Wan, where streams draining the heart of the Tsing Shan range discharge heavy loads of sand. Another deposit, north of Wu Tip Wan, was formerly fringed to seaward by a ridge of dune sand, a feature documented in the 1963 aerial photographs but now obliterated by construction earthworks.

Sand bars occur along the coast at Sha Kiu Tsuen (180 388), Fuk Lo Tsuen (161 363), Ngau Hom Sha (146 346), Nim Wan (111 312), Tsang Tsui (101 310) and Yung Long (088 303) (50, 1981). The sand bars are up to 1 km long and 150 m wide. The spits are also up to 1 km long and consist of medium to coarse sand; they are well developed between Sheung Pak Nai (134 344) and Tai Shui Hang (118 320). Borehole records show that the sand spit deposit at Tai Shui Hang is 6 m thick. Behind the beach are deposits formed by severe storm action rising to a height of 6.2 mPD. Late Neolithic archaeological material was found at Yung Long in the marine terrace underlying recent debris flow deposits.

An augerhole sunk on the platform at 5.6 mPD on Lung Kwu Tan (HK 2514, 1001 2753) encountered 2.06 m of coarse, well-sorted sand, with a pottery shard 1.5 m below surface; no shell debris was noted. The surface of the more seaward deposits corresponds to the level of the contemporary storm beach at 3.5 to 4.0 mPD. A temporary exposure in a pit (0995 2763) in these deposits at Lung Kwu Tan showed coarse sand with shell fragments to 1.5 m. The beach deposits form barriers to landstream drainage, and have impounded swampy alluvial tracts. At Lung Kwu Sheung Tan the more seaward beach sands are interrupted by an alluvial hollow, parallel to and just to landward of the contemporary storm beach.

On Lung Kwu Chau tombolo (0595 2620) a raised beach deposits connects the two islands. The sand bar is composed of light yellowish brown silty medium to coarse sand up to 5 m thick. Radiocarbon dating from an archaeological material found in these deposits gave an age of 5 800 $\pm$ 500 yr BP (Meacham, 1986).

Tuen Mun to Tsuen Wan. Beach deposits occur on both sides of the Tuen Mun valley. The deposits vary from 1 to 5.4 m thick. At an old lime kiln found in raised beach deposits at Shek Kok Tsui (1410 2640), radiocarbon dating gave an age of 1 370 $\pm$ 100 yr BP (Meacham, 1979), but the archaeological evidence implied a Neolithic age estimated at 3 000 to 3 500 yr BP (Peter & Bard, 1980).

There are small beach deposits at Castle Peak Beach, Ka Fei Wan, So Kwun Tan and Tsing Lung Wan. The coastline originally fringed by beach deposits has been concealed by reclamation projects at the mouth of Tai Lam Chung valley, at Sham Tseng and at Tsuen Wan. Borehole records show that the thickness of the beach deposits at Tsuen Wan varies from 2 to 5 m, and also show that the deposits overlie the marine mud and late Pleistocene alluvium.

Talus (Rockfall Deposits)

Stratigraphy

Talus comprises angular, large and small blocks with a minor matrix of sand and silt. Talus is formed by the accumulation of gravity transported rockfall debris at the base of a cliff or very steep rocky slope. The deposits occur at only a few localities in the district. They commonly overlie Pleistocene debris flow deposits and are still accumulating; as such they are entirely assigned to the Holocene.

Details

Tsing Shan. Talus mainly occurs on the east flanks of Tsing Shan. West of Po Tong Ha (146 309), talus forms a blocky fan at the base of a steep slope of the granite ridge. A second deposit occurs south of Yuen Tau Shan (155 320), where talus on the west side of the valley is composed of blocks and boulders of fresh to slightly weathered granite, tuff and tuff-breccia up to 2 m in diameter.

Offshore Superficial Deposits—Classification and Distribution

A systematic survey and classification of the offshore superficial deposits of Hong Kong has only recently commenced (Addison, 1986; Strange & Shaw, 1986). The oldest unit is the Pleistocene Chek Lap Kok Formation (Strange & Shaw, 1986), which commonly occurs beneath younger marine deposits. It consists of silt, clay, sand and gravel, largely of alluvial origin. The marine Hang Hau Formation (Strange & Shaw, 1986) is entirely of Holocene age and forms the sea bed over much of the district. It consists predominantly of marine mud with subordinate sand, becoming entirely sand in areas of stronger current activity and is stratigraphically related to both the estuarine muds and the beach sands.

Chek Lap Kok Formation

Stratigraphy

The Chek Lap Kok Formation has a widespread distribution but is concealed by the Hang Hau Formation in all but a few localities. The type section of the formation is a continuously sampled borehole at Chek Lap Kok, an island off northern Lantau (Shaw, 1985; Shaw et al, 1986). No radiocarbon dates are available for material from the formation within the district. However, evidence from elsewhere in Hong Kong suggests that the majority of the Chek Lap Kok Formation was deposited in the late Pleistocene (Kendall, 1975; RMP Encon, 1982; Strange & Shaw, 1986). Its thickness is generally in the range 10 to 30 m. It is absent from parts of the coastal fringe and from the east of the district adjacent to Ma Wan. Lithological details of the formation within the district are only available for the area of Hau Hoi Wan from continuously sampled Borehole CLP/E1 (Appendix 3).

The formation is lithologically diverse, consisting mainly of firm to stiff clay, with silt, dense sand and gravel, and occasional boulders. Some of the clays and silts are laminated, and some include grey or dark grey organic layers with wood fragments. The more typical colours are bluish grey to light grey, with sporadic yellow, brown and red mottling.

The formation has been extensively investigated by marine geophysical methods. Unlike the continuous sub-parallel reflectors that characterize the seismic signature of the marine mud of the Hang Hau Formation, the reflectors in the Chek Lap Kok Formation are generally impersistent or chaotic, though rather stronger than those in the marine mud (Plate 48). The unconformity between the Chek Lap Kok Formation and underlying rock or weathered rock is commonly poorly defined. The surface of unconformity is generally irregular (Plate 49), 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. The formation is estimated to lie at a maximum depth of −40 mPD at the mouth of Hau Hoi Wan. Seismic records in the Urmston Road area indicate that the surface of weathered rock there shelves to a depth of at least −50 mPD.

The top of the formation has been eroded over wide areas, and in parts of Urmston Road and north of Ma Wan the formation has been completely removed. In the Hau Hoi Wan area the top forms a gently undulating, gullied or channelled surface that falls gently northwestwards.

Details

Hau Hoi Wan (Deep Bay) and Shan Pui River (Yuen Long Creek). The predominantly alluvial deposits of the Chek Lap Kok Formation in Hau Hoi Wan comprise sand, gravel, silt and clay. Sand and gravel are mainly concentrated along the axis of the bay, occupying a valley eroded into the deeply weathered bedrock. The floor of this valley falls from about −28 mPD near Tsim Bei Tsui to about −40 mPD near the mouth of Hau Hoi Wan. Coarse channel deposits occupying the valley are contiguous with buried, dendritic channel deposits in the present Yuen Long plain below the ponds of Tin Shui Wai (Dutton, 1985). The sands and gravels are about 20 m thick within the offshore valley but thin laterally; they are all but absent from the nearshore successions. Away from the valley the sand becomes more muddy and is overlain by greater thicknesses of silt and clay. Sand lenses commonly occur within the overlying silt and clay units, particularly adjacent to the mouths of contemporary onshore drainage lines. At several locations, layers of sand in the overlying silt and clay are cemented by iron, silica or other minerals (Binnie & Partners, 1983).

The upper surface of the formation lies generally at between about −4 to −8 mPD. The surface commonly carries desiccation cracks filled with muddy sand of the Hang Hau Formation. Prior to the deposition of the overlying Hang Hau Formation sediments a deep valley was eroded into the surface of the Chek Lap Kok Formation. The valley falls rapidly from −8 to −16 mPD off Tsim Bei Tsui. It then assumes a more gentle gradient to reach a maximum depth of −24 mPD at the mouth of Hau Hoi Wan.

Urmston Road. The bedrock channel running southwest down the centre of Hau Hoi Wan continues southwestwards under the northern part of the Urmston Road channel. A series of depressions on this line extend to −46 mPD, the general level of the bedrock valley floor being at about −40 mPD. Southeastwards the bedrock surface rises to about −34 mPD off Lan Kok Tsui. The Chek Lap Kok Formation is thickest in this bedrock valley, ranging from 6 to 12 m thick, but with pockets up to 20 m thick. The formation thins southeastwards, reaching a minimum thickness of about 4 to 5 m over a bedrock threshold that appears to run approximately between Lung Kwu Chau and the minor headland south of Lan Kok Tsui. Hence the thick Chek Lap Kok Formation in Hau Hoi Wan is effectively excluded from the Urmston Road channel.

The surface of the formation is much more regular than its base. A shallow northeast-trending valley, continuous with the Hau Hoi Wan valley, is eroded into the top of the formation with a floor at between −21 and −26 mPD; the surface rises steadily towards Lan Kok Tsui and the southern shores of Hau Hoi Wan to a higher surface at around −13 mPD. Down the axis of the Urmston Road channel the surface of the formation slopes gently southeastwards. The underlying bedrock exhibits a series of pinnacles with intervening gaps that have a relief of up to almost 20 m. It is apparent that the formation filled-in and smoothed-out a very irregular bedrock topography prior to the deposition of the overlying Hang Hau

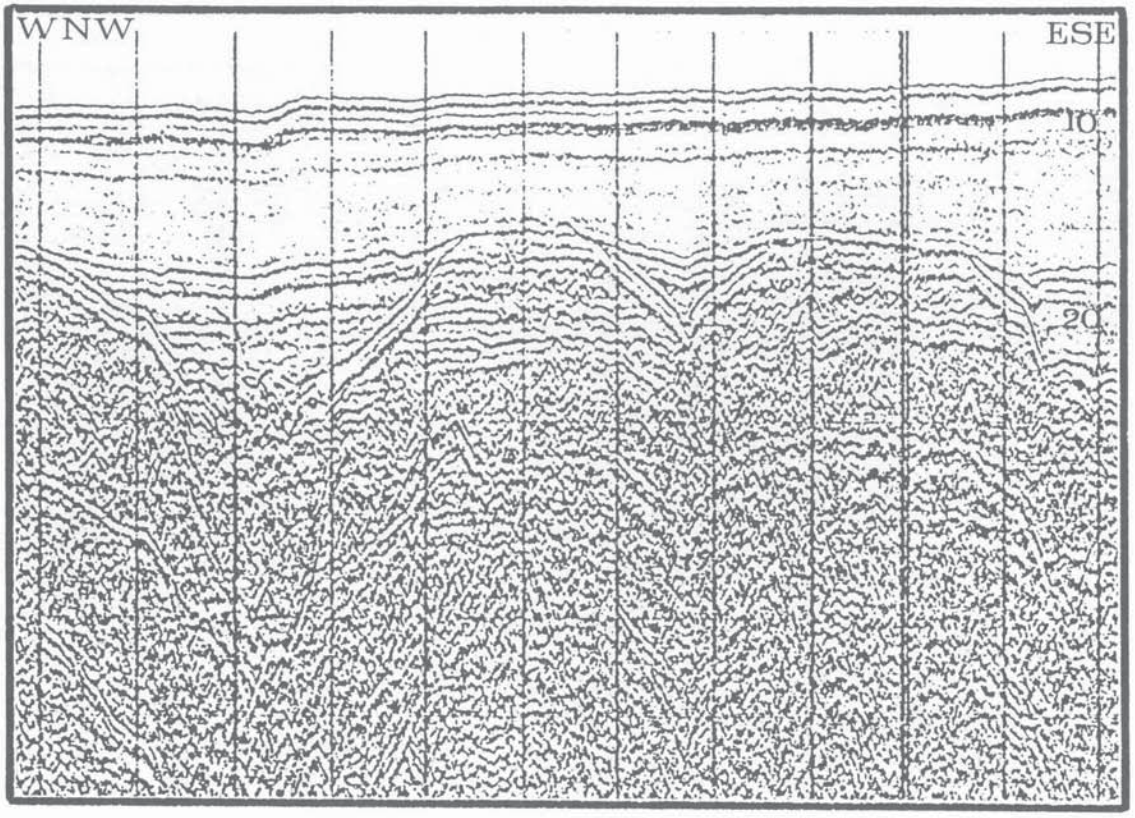
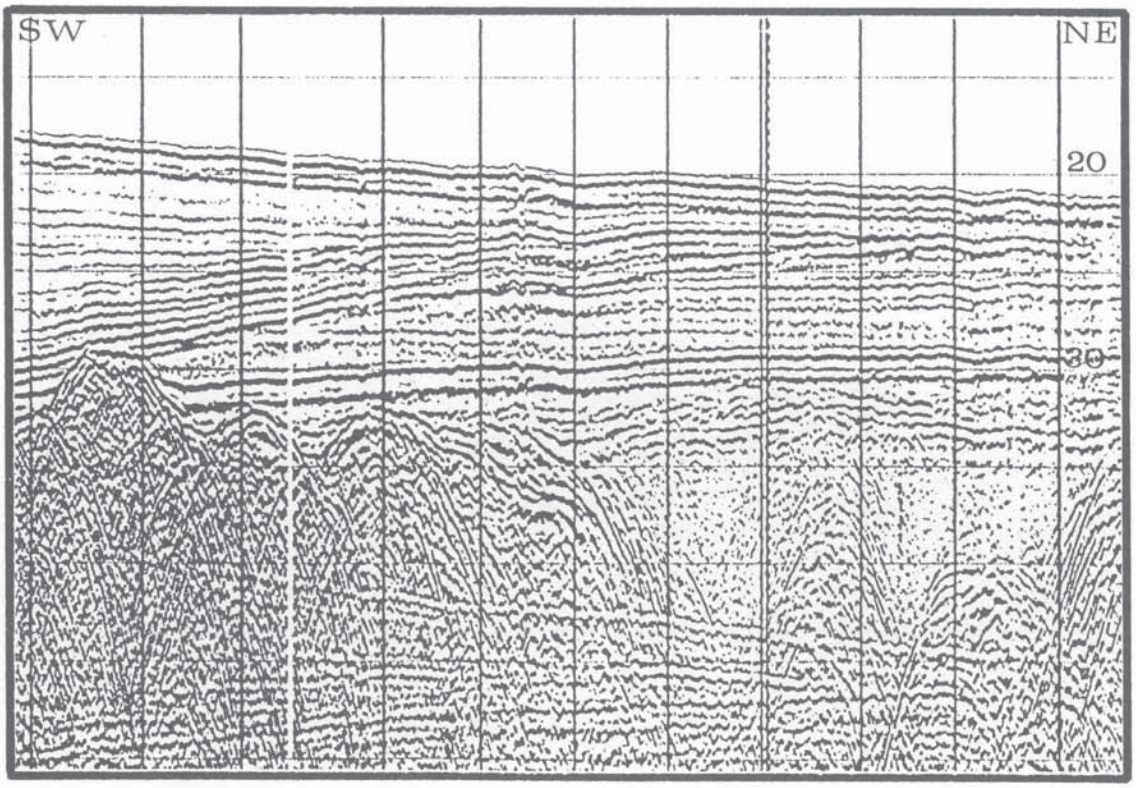


Plate 48 – Seismic Profile Showing an Unconformity at the Gullied Surface of the Chek Lap Kok Formation South of Tsing Shan Wan, Chaotic Seismic Signature of Chek Lap Kok Formation Contrasts with Regular Signature of Hang Hau Formation

Plate 49 – Seismic Profile Showing an Unconformity in the Hang Hau Formation in Urmston Road, Northeast of Lung Kwu Chau. Unconformity at the Top of the Chek Lap Kok Formation can also be seen



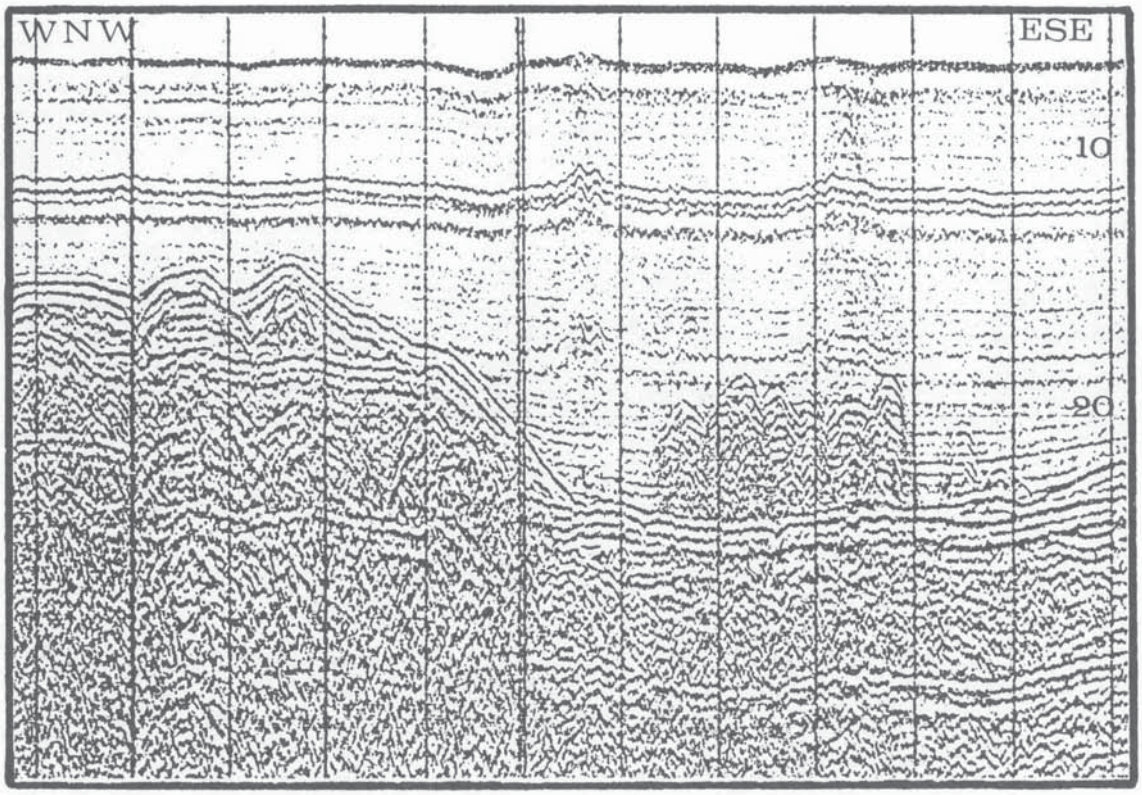
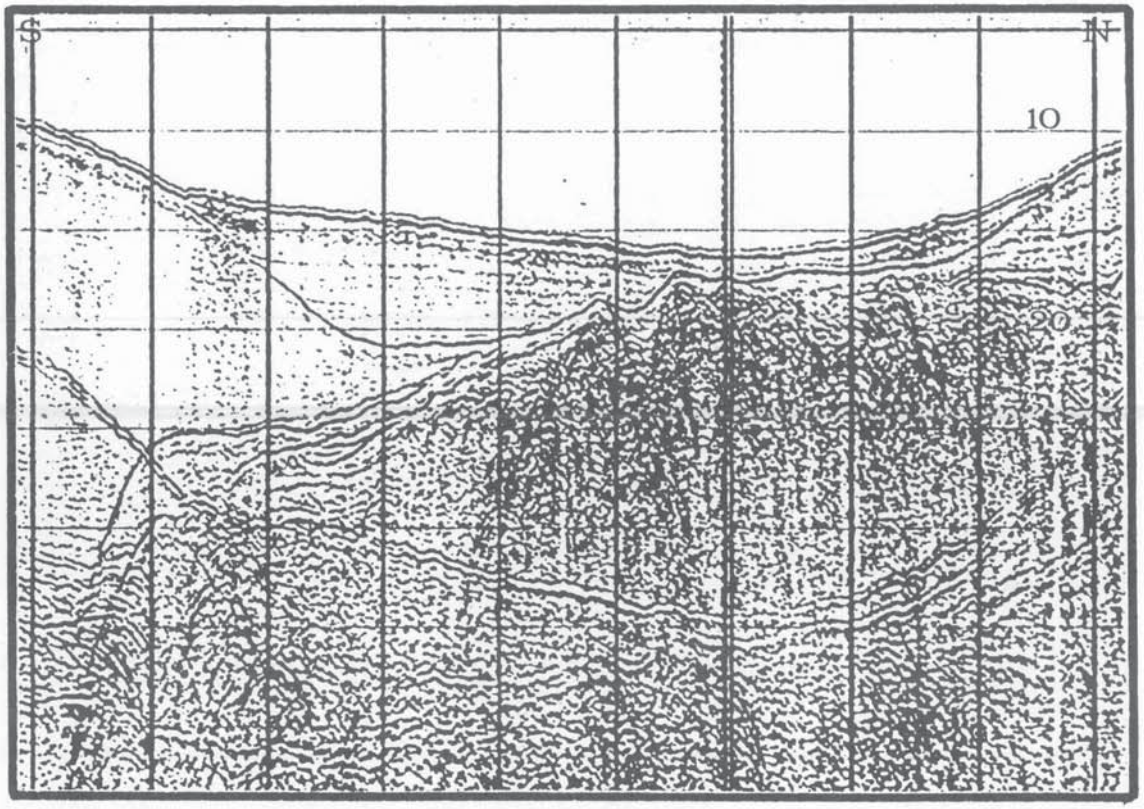


Plate 50 – Seismic Profile Showing Bedrock Terrace South of Tsing Shan Wan, Hang Hau Formation Displays Characteristic Continuous, Sub-parallel Reflectors

Plate 51 – Seismic Profile Showing a Channelled Discontinuity in the Hang Hau Formation South of Lung Chue To



Formation. In many cases it is not possible to distinguish the underlying weathered bedrock from the predominantly alluvial sediments of the Chek Lap Kok Formation, hence in many cases the true thickness of the formation may have been overestimated.

Tsing Shan Wan. Geophysical records indicate that the continuation of present Tuen Mun valley can be traced in a broad bedrock valley trending southeastwards. A steep rock terrace (Plate 50), approximately 15 m high, defines the western limit of the valley, in a line approximately south of the reclamation headland (0625 2583). The eastern slope of the valley appears to be more gradational. In the centre of the valley, at the southern limit of the district, Chek Lap Kok Formation sediments form a lens up to 15 m thick. Bedrock on the floor of this valley forms a smooth plain at about −35 mPD. The surface of the western rock terrace lies at a minimum depth of about −15 mPD, with a undulating relief of up to almost 10 m. Pockets of weathered bedrock remain in depressions between the bedrock pinnacles in this western area, whereas the valley floor appears to have been swept clean of any weathered mantle prior to the deposition of the overlying Chek Lap Kok Formation.

Southwards from the present typhoon shelter a bedrock step occurs near the southern boundary of the district. North of this step there are 12 m or more of Chek Lap Kok Formation sediments deposited on an irregular bedrock surface with a relief of up to 12 m. The top of the formation forms a regular surface, displaying little or no relief, that declines southwards from −17 to −22 mPD. South of the step the bedrock slope descends steeply to about −35 mPD; the slope is completely devoid of any Chek Lap Kok sediments.

Off Wu Tip Wan, bedrock occurs very close to the surface and slopes steeply southwards. A very undulating bedrock relief, with an amplitude of up to at least 20 m, is infilled by Chek Lap Kok Formation sediments to form a plain that declines gently southwards from about −5 mPD near the shore to almost −25 mPD at the southern boundary of the district.

Lung Chue To to Tsuen Wan. The Chek Lap Kok Formation has a limited development in this part of the district. Along the coast between Lung Chue To and Tsing Lung Wan, bedrock occurs close to the surface. Farther east the channel floor has been largely swept clean of any superficial cover, and several isolated outcrops of the formation remain along the channel margins. Only in the channel north of Tsing Yi does any extensive development of the formation exist. Over most of this portion of the district the formation is generally only a few metres thick. On seismic records it is difficult to distinguish the formation from the underlying weathered bedrock due to the lack of a well defined seismic reflector at the contact and the generally similar seismic character of the two units.

Bedrock rises steeply to the surface off Lung Chue To, and only a thin layer of superficial deposits can be identified on seismic records. The material is most probably weathered bedrock that has been reworked both by earlier mass movements and later marine action. Alluvium is only distinguished with certainty 800 m offshore, near to the southern boundary of the district.

North of Ma Wan the sides of the bedrock channel slope abruptly to around −20 mPD at the edges of a wide channel floor that grades to about −40 mPD. Near the centre of the channel a narrow slot is incised to about −55 mPD. Seismic records show that most of the channel is cut in bedrock with only thin, isolated patches of overlying material that may be outliers of Chek Lap Kok Formation.

In the channel north of Tsing Yi a more extensive but generally thin cover of Chek Lap Kok Formation sediments has been preserved. Borehole descriptions characterize the material as poorly sorted, stiff to firm, yellow and reddish-brown, sandy silty clay with gravel. These sediments occupy the central section of the channel as an almost continuous unit locally thickening to more than 25 m. The base of the formation is irregular, filling in hollows in the bedrock floor, but the upper surface is considerably smoother, ranging in elevation from about −35 to −25 mPD. Seismic records show that the alluvial plain was deeply gullied prior to the deposition of the overlying Hang Hau Formation (Plate 48), a phenomenon observed on the surface of the formation underlying Victoria Harbour (Strange & Shaw, 1986).

Sedimentary Environment

Palynological analyses (Strange & Shaw, 1986; Shaw et al, 1986; Shaw & Arthurton, 1987) suggest a dominantly fluvial origin for deposits within the formation, though a marine origin for some deposits has been proposed (Yim, 1984a; Wang & Yim, 1985; Howat, 1985). A lower sea-level existed at the time of deposition, although the presence of mangrove and possible lagoonal conditions indicates proximal marine conditions at various times prior to the Holocene marine transgression.

Hang Hau Formation

Stratigraphy

The formation is widespread, covering most of the sea-bed of the district. It is noticeably absent, or represented only by a thin veneer of sand, around Ma Wan. Locally it has been removed by dredging or disturbed by engineering works, particularly in the area of Tsing Shan Wan (Castle Peak Bay) and Nim Wan. The formation is also widely distributed in the area of former tidal flats and mangrove swamp from Tin Shui Wai through Yuen Long to San Tin, and at Tuen Mun. Organic material at the base of the formation in Borehole CLP/E1 (1020 3157) (Appendix 3) has been radiocarbon dated at 10 060 ±130 yr BP, confirming a Holocene age. The C14 dating of a

marine mud sample from Sheung Cheung Wai (1859 3426) gave an age of 3110 ± 185 yr BP and wood in deposits near Fung Chi Heung (2028 3430) was dated at 1900 ± 93 yr BP. Based on radiocarbon dating evidence from Tin Shui Wai, Yuen Long and San Tin plains which gave ages from 520 ± 112 to 6 760 ± 130 yr BP, these deposits are entirely Holocene in age (Appendix 2). Elsewhere in Hong Kong dates ranging from 6 520 ± 130 yr BP to 8 080 ± 130 yr BP have been obtained for deposits in the formation (Meacham, 1978; Strange & Shaw, 1986).

Lithologically the formation predominantly comprises soft to very soft, olive grey to bluish grey shelly mud (Plate 38), and is typically 10 to 20 m thick; its type section is a continuously sampled borehole in Junk Bay (Strange & Shaw, 1986). 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 dominant, and gastropods are locally abundant; sparse echinoid fragments have been noted (Plate 52).

Particle size distribution analyses of the mud plot in the clayey silt range. No evidence of structures or discontinuities within the mud are recorded from continuously sampled boreholes. However, well-marked and extensive, sub-parallel reflectors characterize the seismic signature (Plate 50), and in places, notably in Urmston Road, these reflectors indicate the existence of discontinuities within the mud (Plate 49).

The Hang Hau Formation is unconformable on the Chek Lap Kok Formation (Plate 48) and it locally overlaps it to rest on rock or weathered rock. Seismic records generally give a clear indication of the base of the Hang Hau Formation, and of stratification within it (Plate 50). Diachronism of the base of the formation has been demonstrated elsewhere (Strange & Shaw, 1986), and similar diachronism is to be expected, but remains unproved, in the district. Over large areas the Hang Hau Formation mud fills and overlaps, gullies or channels incised in the Chek Lap Kok Formation (Plate 48). Seismic records traversing Urmston Road demonstrate the existence of a younger sandy mud unit in a channel eroded in the older muds, separated by a well-defined discontinuity (Plate 51).

Sand or muddy sand is present within the formation as littoral or sub-littoral deposits fringing the present and pre-reclamation coasts. This marine sand appears to be closely related to the hillsides along the coast, fronting beach deposits, or exists in the marine mud as lenses or pockets. Sand is also associated with past and present tidal channels. Sand occurs on the floor of the contemporary channel at Ma Wan and a widespread sand body exists at the base of the formation below Urmston Road. At the base of the marine deposit there is often a layer of medium to coarse sand. Deposits at Tsing Shan and Tuen Mun are now incorporated into the reclamation.

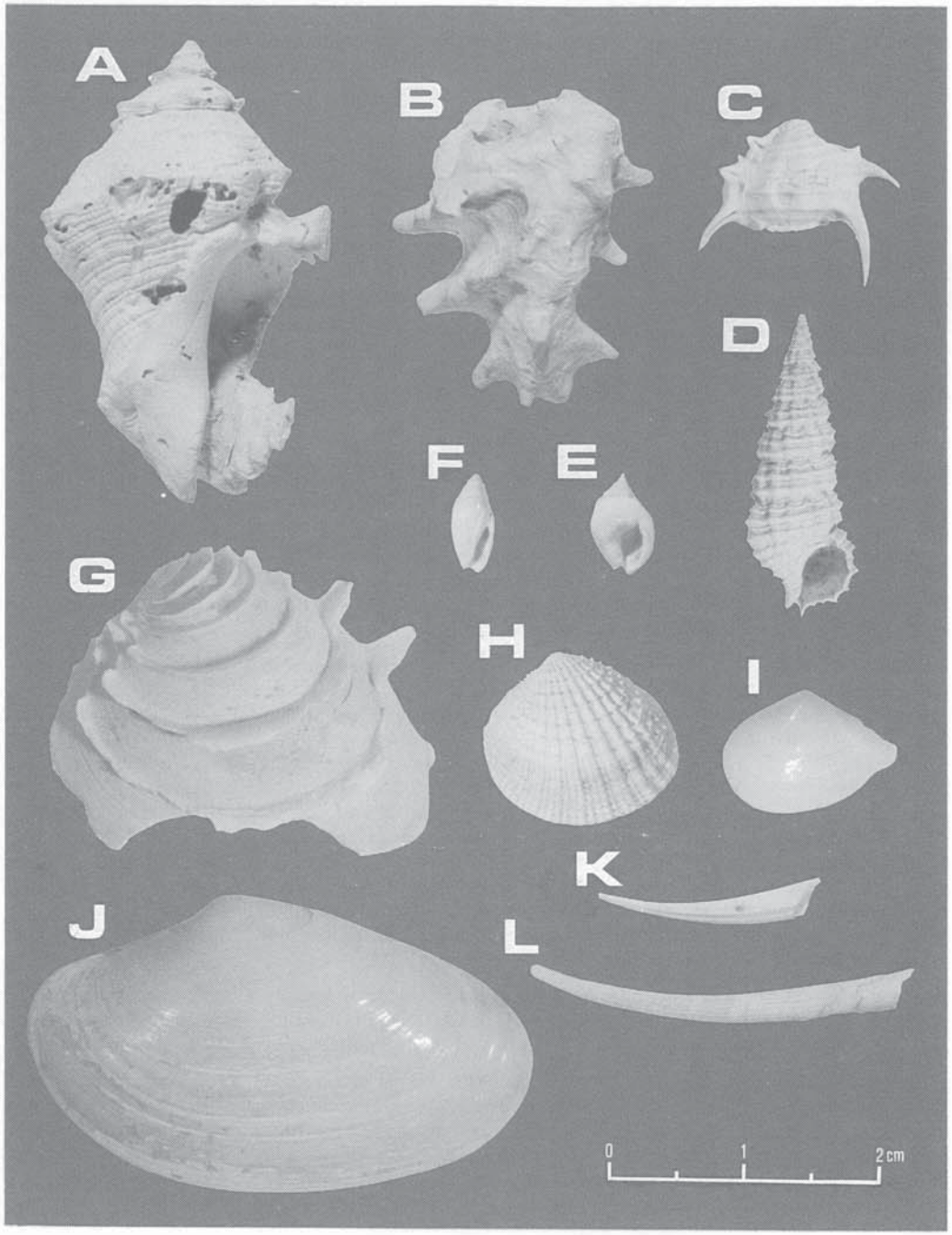
Details

Shenzhen River. Borehole records show that marine deposits similar to those at San Tin underlie estuarine deposits between Ha Wan Tsuen and Lo Wu. The 1913 topographic map indicates mangrove swamp in the area west of Hoo Hok Wai (270 437). At present, tidal influences reach east of Lo Wu bridge and along the Ng Tung Ho (River Indus) to near Lo Wu Camp. The thickness of the marine deposits increases along the lower course of the Shenzhen River from 2 to 3 m at Lo Wu to 5 m near Hoo Hok Wai and 14 m near Ha Wan Tsuen.

Yuen Long to San Tin. The 1913 topographic map shows tidal inlets reaching Mar Tin Road (208 334) and Nam Pin Wai (214 340) (Figure 24). Marine deposits occur north of Castle Peak Road in Yuen Long town, the predominant sediments being dark grey silty clay with sand partings, shell fragments and a 1.5 m thick silty sand with gravel near their base. Generally, the total thickness of the deposits is from 1 to 2 m, but in buried channels and at the mouth of the plain at Chung Hau Tsuen (214 350) the thickness reaches up to 6 m. The deposits rest on Pleistocene alluvium and are overlain by recent alluvial sand at the river mouth.

In the area around Yuen Long Industrial Estate, Fairview Park and Ha Wan Tsuen (256 417) a large expanse of tidal flats and mangrove swamp is shown on the 1913 topographic map. Outcrops confirm that marine deposits occur at the foot of former sea cliff by the side of the Castle Peak Road between Pok Wai (236 364), Wai Tsai (241 383) and Mai Po Lo Wai (243 394). At present, tidal influences along rivers reach Kam Tin Shi (243 333) in the south and Tsing Lung Tsuen (255 396) in the north. The marine strata form part of a typical transgressive sequence. At the base of the succession is a widespread quartz gravel up to 1 m thick underlying a 1 to 3 m thick greyish white silty sand which in turn underlies dark grey silty clay with shell fragments. Such sequences have be seen in excavations at Ha San Wai (238 368), Wai Tsai (241 383) and Lok Ma Chau Road (263 406). The deposits are unconformable on the Pleistocene alluvium (Plate 38) or on weathered rock. The total thickness of marine deposits is variable and increases with the distance seaward from the former coastline. The deposits are up to 1.5 m thick near the former sea cliff at Ha Chuk Yuen (239 373), 2 to 5 m thick around Fairview Park (228 375) and 10 to 15 m near the mouth of Shenzhen River. Radiocarbon dating gave ages from 5 093 ± 130 to 5 475 ± 155 yr BP for the lower part of the marine mud at Chau Tau (2658 4037), and 520 ± 112 yr BP for the upper part near Ha Wan Tsuen (2540 4189).

Tin Shui Wai. Marine deposits line a former embayment around Tin Shui Wai, between the headlands of Tsim Bei Tsui and Ng Uk Tsuen. On the 1913 topographic map most parts of the plain were shown as mangrove swamp (Figure 24). In the north, at levels below 1.5 mPD, the area is covered by marine deposits,



A	*Thais carinifera* Lamarck	G	*Bassina calophylla* (Philippi)
B	*Saccostrea* cf. *cucullata* (Born)	H	*Veremolpa micra* (Pilsbry)
C	*Murex* cf. *trapa* Röding	I	*Leptomya* cf. *minuta* Habe
D	*Proclava* cf. *kochi* (Philippi)	J	*Paphia undulata* (Born)
E	*Nassarius* cf. *bimaculosa* (A. Adams)	K	*Dentalium* cf. *octangulatum* Donovan
F	*Olivella* cf. *spreta* Gould	L	*Fissidentalium* cf. *hungerfordi* (Pilsbry & Sharp)

Plate 52 – Shells from Hang Hau Formation Mud in Borehole Deep Bay CLP/E1, Tsang Tsui (1020 3157)

and to the south these deposits occur at Hang Mei Tsuen (1870 3400). The deposits are predominantly dark grey silt and clay with shell fragments and occasional sand partings and lenses. Their thickness is variable, generally 1 to 3 m, but deposits which have accumulated in the former drainage channels (between Lo Uk Tsuen and Mong Tseng Wai) in the underlying late Pleistocene alluvium have a thickness of up to 14 m. On the both sides of the former embayment there is a thin layer of marine silty sand covering the marine mud; this can be seen south of Mong Tseng Wai (187 372) and north of Shing Uk Tsuen (196 362). At the base of the marine deposits is light grey silty fine to coarse sand up to 1.5 thick, with a trace of fine gravel and occasional carbonized plant remains.

Hau Hoi Wan (Deep Bay). The Hang Hau Formation forms a fairly uniform mud plain that slopes gently away from the present coastline to a depth of about −5 mPD near the mouth of Hau Hoi Wan. It forms a continuous cover over the floor of the bay, thickening from between 4 to 8 m near the coast to about 24 m towards the northern boundary of the district, where it fills a channel in the surface of the Chek Lap Kok Formation. Particle size analyses of samples of the mud plot out as silty clays (29:50) with a significant proportion (21%) of fine to very fine sand (Wong et al, 1987). More sandy muds occur at the surface in a zone that follows the deeper part of the bay extending out from the mouth of Shan Pui River. A basal sand, almost 2 m thick, was recorded in the continuously sampled offshore borehole at Tsang Tsui (CLP/E1) (Appendix 3). A similar thickness was recorded in other boreholes within the bay, except over the channel where up to 4 m was found to be present (Binnie and Partners, 1983).

Urmston Road. A seabed channel crosses the southern end of Hau Hoi Wan and from there through the Urmston Road channel, deepening southwards from about −12 mPD at the northern boundary of the district to −20 mPD between Lung Kwu Chau and the mainland. The Hang Hau Formation forms a continuous cover over the whole of this channel floor, infilling a palaeo-channel that runs southwestwards out from Hau Hoi Wan across the surface of the underlying Chek Lap Kok Formation. The Hang Hau Formation is, therefore, thicker in the northern part of Urmston Road and thins southeastwards as a result both of the declining upper surface and the rising base.

At the mouth of Hau Hoi Wan the formation reaches a maximum thickness of 25 m over the buried channel, thinning gradually to about 8 to 12 m over the Urmston Road channel and thickening to about 20 m over the western channel flanks. Southwards the formation thins locally to a minimum of about 5 m thick off Lan Kok Tsui. The pattern of thinning is irregular, as deeper pockets of the formation may be up to 15 m thick in depressions in the underlying Chek Lap Kok Formation. A cover of between 10 and 15 m of Hang Hau Formation muds is maintained along the length of the channel floor. Transverse geophysical profiles across the channel (Lan Kok Tsui to Lung Kwu Chau, and Tap Shek Kok to Lung Kwu Chau) show that the formation maintains a fairly constant thickness of about 15 m across the width of the channel, thinning only where bedrock pinnacles rise close to the surface (Plate 53), as southwest of Lan Kok Tsui (7167 8615) and west of Tap Shek Kok (9083 6397 and 8731 6410). These same profiles indicate an unconformity within the formation, similar to that observed in the channel north of Tsing Yi and in the East Lamma Channel (Strange & Shaw, 1986), suggesting that at least one erosional hiatus interrupted the otherwise regular deposition of marine mud during the Holocene.

The base of the formation comprises a fairly dense seismic reflector, indicating a sandy basal unit up to about 4 m thick over much of the Urmston Road. Its regular, sub-horizontal pattern of seismic reflectors are quite distinct from the more irregular reflectors characteristic of the underlying Chek Lap Kok Formation.

Tsing Shan Wan (Castle Peak Bay). Marine deposits occur extensively to the north of Tsing Shan Wan. They can be found in boreholes at Siu Hong Court (1580 3020) where the deposits can be divided into two parts. The upper part, of silty sand or sandy silt with shell fragments, is 1 to 5 m thick and occurs around the margins of the bay; it is absent south of Pui To Road (1530 2830). The thickness of the upper part is 1 to 7 m to the north of Tuen Mun San Hui, and 5 to 15 m to the south. The lower part consists of soft, dark grey silty clay with sandy lenses or pockets, and scattered shell fragments and organic matter. A thin sand layer with gravel can be found at the bottom, overlying the late Pleistocene alluvium.

Below the present typhoon shelter the formation has a thickness of about 8 m, thickening gradually southwards to 13 m at a point about 1.7 km south of the outer breakwater, where it rests directly on bedrock at the crest of a steep bedrock slope. A rapid southwards thickening then occurs, the formation reaching a thickness of 22 m at the southern boundary of the district.

When traced from the southwest shore of Tsing Shan Wan the formation thickens eastwards, indicating that it probably fills a former subaerial valley that extended southwards from the present Tuen Mun valley. South of Wu Tip Wan the formation thickens gradually, from a sandy near coastal unit about 2 m thick to almost 10 m thick at the southern boundary of the district. Off Mong Hau Shek a much more rapid thickening is apparent on a steeper bedrock surface.

Lung Chue To (Pearl Island) to Tsuen Wan. This part of the district constitutes the northern margin of a funnel-shaped channel lying between the northern shores of Lantau and the southern shores of the western New Territories. The channel is the only path for tidal flow between Hong Kong and the Pearl River Estuary. It narrows eastwards to a minimum width between Tsing Lung Tau and Ma Wan, and the associated concentration of tidal flow causes an increase in erosion and scour, with a marked thinning of sediments eastwards and an almost complete absence of sediments north and northwest of Ma Wan.

East of Tsing Shan Wan the formation forms a thick coastal sequence off Lung Chue To, but decreases in thickness further east towards Tai Lam Kok. The formation here consists of soft, dark olive grey structureless shelly muds. Seismic records show that a sandy basal sequence of the formation usually lies with marked

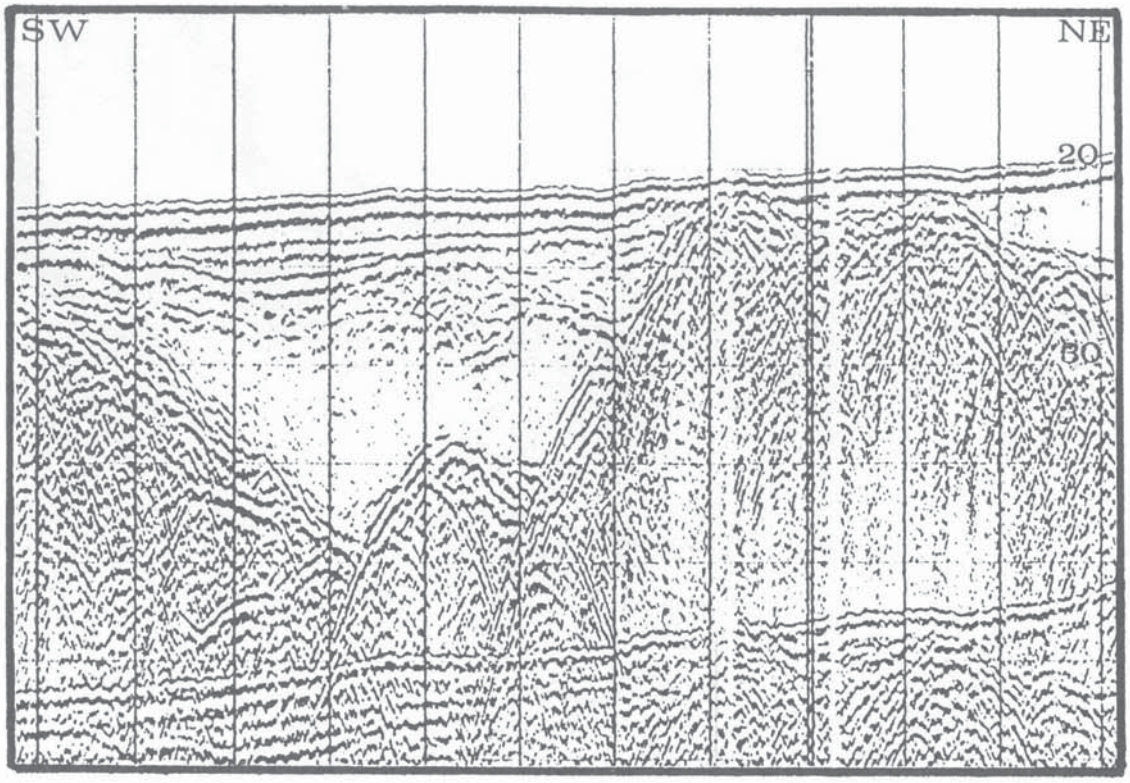
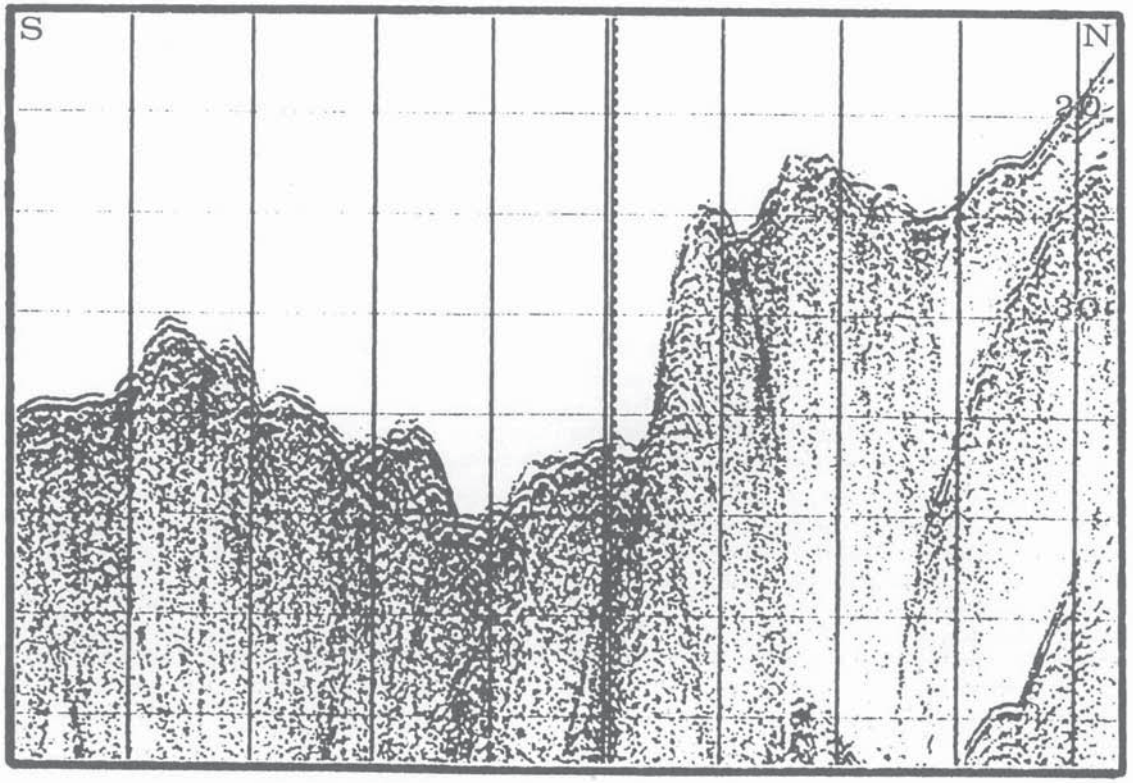


Plate 53 – Seismic Profile Showing the Irregular Bedrock Surface below Sediments in Urmston Road, Northeast of Lung Kwu Chau

Plate 54 – Seismic Profile Showing Bedrock Exposed on the Channel Floor South of Tsing Lung Tau



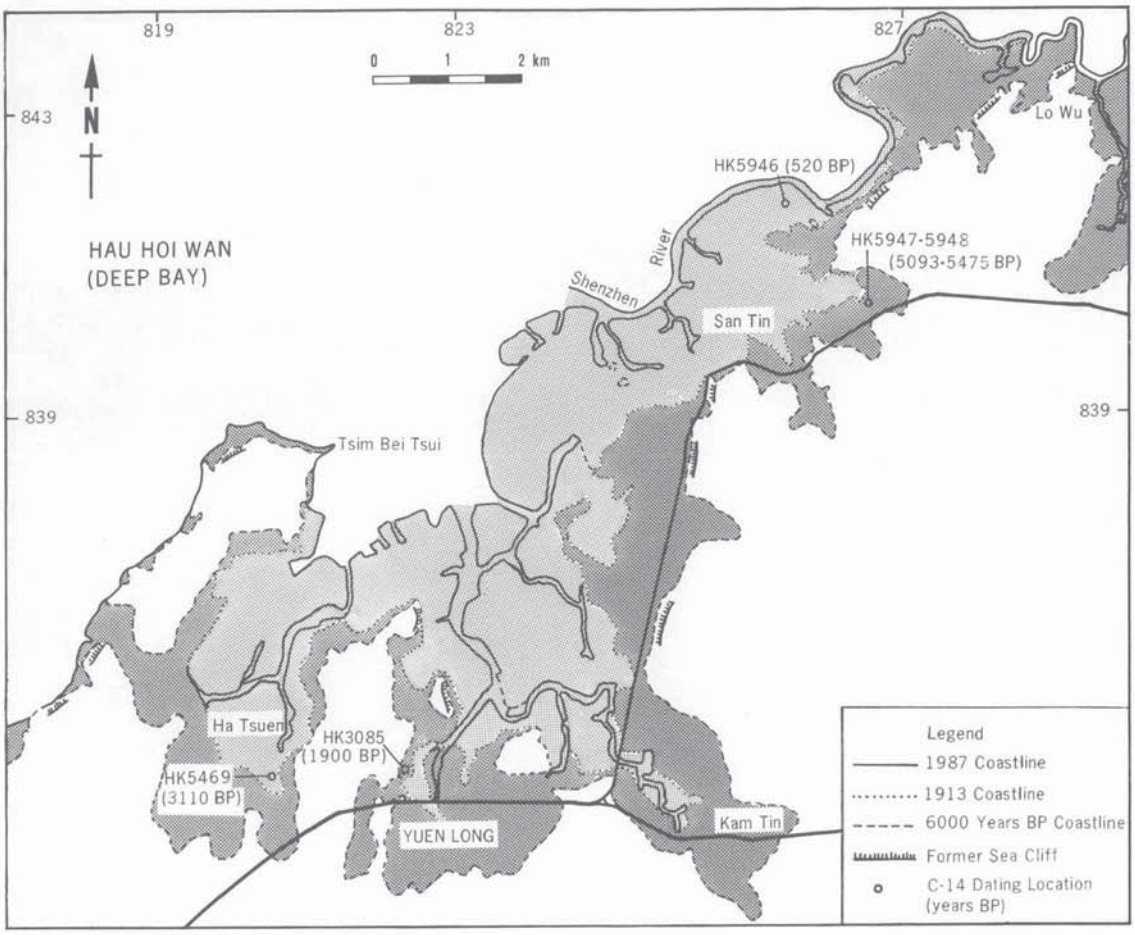


Figure 24 – Coastline Changes in the Yuen Long – Lo Wu Area During the Last 6 000 Years

unconformity on the underlying Chek Lap Kok Formation. Between Lung Chue To and Tai Lam Kok an almost complete cover of mud occurs, thickening away from the coast to almost 20 m at the southern boundary of the district. Seismic records show a discontinuity within the northern edge of the formation, suggesting a temporary increase in erosion. Between Tai Lam Kok and Tsing Lung Tau the marine muds are restricted to the shore, while further east only isolated patches remain and the seabed cover consists of a mobile layer of silty sand less than 1 m thick resting on bedrock. The main tidal channel turns sharply southwards between Ma Wan and Tsing Yi (Chalmers, 1984), with the result that the channel north of Tsing Yi is sheltered from the maximum tidal flows. Mud deposits in this channel thicken rapidly from 0 to 10 m within 100 m of the western threshold, reaching a local maximum thickness of a little over 25 m.

The well-defined western edge of these deposits demonstrates the abruptness of the increase in tidal velocity. Examination of the seismic traces of this area shows that the internal seismo-stratigraphic units pinch-out and prograde westwards (Plate 54), demonstrating that the slope is a depositional and not an erosional phenomenon, and that the tidal regime has always exerted a controlling influence in this zone.

Examination of the bathymetry in this channel reveals two minor channels, aligned west to east on the northern and southern edges of the main channel; they are probably ebb and flood channel features (Evans, 1987). The northern (ebb) channel extends for about 1 000 m and is up to 350 m wide and 15 m deep at its western end, shallowing gradually eastwards until it becomes indistinct. The southern (flood) channel extends for over 2 500 m and is about 300 m wide, with a depth of over 30 m off the northwestern corner of Tsing Yi. Seismic traces across this southern channel show that the Hang Hau Formation here comprises two units separated by an angular unconformity. The basal unit is characterized by faint, continuous, high amplitude horizontal reflectors truncated by an upper unit which displays steeply inclined reflectors that suggest a southward progradation. The unconformity is geometrically similar to that identified in the East Lamma Channel (Evans, 1986; Strange & Shaw, 1986).

The formation becomes sandy eastwards, with sand waves of 7 to 8 m wavelength and 0.5 m amplitude on the seabed off the north-eastern tip of Tsing Yi.

Sedimentary Environment

A recent study of sedimentation in Hau Hoi Wan (Wong et al, 1987) reported that the average sedimentation rate between 1898 and 1949, estimated from historical navigation charts, was 8 mm/per year. Pb-210 dating of core samples indicated a much higher rate of between 12.7 mm and 16.6 mm per year. The same study estimated that about 1 000 000 tonnes of dry solids were deposited in the bay each year. Of this total it was believed that approximately 90 000 tonnes were contributed by the Shenzhen River, 10 000 tonnes by the Shan Pui and other rivers and the remainder was derived from the Pearl River.

Palynological and micropalaeontological analyses of five samples from the Hang Hau Formation in Hau Hoi Wan (Borehole CLP/E1) (Appendix 3) have shown that, above the basal sand and gravel unit, the formation is rich in marine diatoms and terrestrial pollen, with lesser mangrove pollen and marine algae. Samples from the basal sand and gravel unit contained only rare marine algae and macroscopic shells; marine diatoms and mangrove pollen were absent. Terrestrial tree pollen contained in the samples indicate a gradual transition from more temperate associations in the lower samples to humid sub-tropical associations in the higher samples, reflecting the gradual post-Pleistocene climatic improvement. The Hang Hau Formation forms part of a typical transgressive sequence.

Weathering Rocks and Sediments

An extensive residual mantle of weathered rock overlies fresh rock in most of the district, effectively masking much of the solid geology. This mantle consists of a residue of minerals resistant to weathering, mostly quartz, combined with the weathering products of ferromagnesian and feldspathic minerals. The weathered mantle usually consists of material that retains the original structure and texture of the rock.

The majority of studies of rock weathering in Hong Kong have been confined to the granitoid rocks (Berry, 1962; Berry and Ruxton, 1959; Ruxton and Berry, 1957, 1959, 1961). Other lithologies, such as the sedimentary and volcanic rocks, have received less attention. Detailed chemical and mineralogical analyses of the weathering products of the commonly occurring rock types have been made by several workers (e.g. Brock, 1943; Knill Best, 1970; Lumb, 1962a, 1962b; Lumb Lee, 1975; Parham, 1969; Ruxton, 1968, 1980).

The processes of weathering were reviewed by Bennett (1984a), and an extensive discussion on weathering profiles is included in Strange & Shaw (1986). GCO (1988) offers guidance on the description and classification of weathered rocks and soils.

The effects of weathering upon the different lithologies are broadly reflected in their relief. Volcanic rocks tend to form higher and sharper peaks with fewer surface boulders, while granites form lower and more rounded peaks with surface boulders more common; in general, the fine-grained granites are more resistant to weathering than the coarser varieties. Exposures of large and extensive cut slope sections are less common in the district than in the more intensively developed urban areas of Hong Kong and Kowloon (Strange & Shaw, 1986).

Details

Volcanic Rocks. The tuffs of the area west of Tsuen Wan weather to form a clay and cobble-rich soil, with abundant corestones on hilltops (270 270). The weathered mantle is commonly redistributed in well-defined mass wasting deposits such as boulder fields and boulder streams. The corestones are usually fresh beneath a slightly weathered rind only a few millimetres thick. The corestones are cuboidal or sub-round, and are up to at least 4 m across.

Along the ridge west of Tai Mo Shan, core/stones are extensively developed in tuffs of the Tai Mo Shan Formation. These are up to 3 m across, of cuboidal form, with a thin weathering rind. As on Shek Lung Kung, the weathering products are commonly redistributed in well-defined mass wasting deposits such as boulder fields and boulder streams.

The tuffs outcropping on Kai Keung Leng and Tai To Yan consist of alternating bands, of varying widths, of slightly metamorphosed and strongly metamorphosed rock. The two rock types weather differently, with the slightly metamorphosed tuffs forming corestones and thin weathered profiles in a similar way to those rocks on Shek Lung Kung and Tai Mo Shan. The metatuffs generally form resistant ribs. Trains of debris are well developed below the summit of Kai Keung Leng.

Granite. In the areas of medium-grained and fine- to medium-grained granite outcrops, thick weathering mantles are usually best preserved over ridges and spurs, while fresher rock occurs closer to the surface on valley floors and steep flanks. Hilltop, ridge crest and spur-end tors commonly cap the higher relief, especially in the western part of the district such as at Lung Kwu Sheung Tan (091 294) (Plate 39), but valley-side tors are more common (Plate 40). Boulder sheets and streams drape the hillsides and choke the valleys downslope of upland tors (Plate 40). A fine example of a pedestal rock, an isolated rounded granite boulder surmounting a low smooth convex sheet of granite, occurs off Tap Shek Kok (0947 2671), forming a small island.

On the ridges and spurs the weathered granite mantle is prone to gullying. Several stages of gully development can be observed, from straight and subparallel shallow rills to deep and extensive dendritic systems of gullies. Gully development is especially well advanced in large areas of the Tai Lam Country Park, where a badlands landscape is developed (Plate 41). In many cases the headwalls of individual gullies may be up to 20 m high (e.g. 1190 2880) and headwall recession is achieved more by arcuate slip failure than by fluvial erosion.

A range of examples of different types of granite weathering micromorphology are displayed throughout the area. North of Pak Long a large isolated granite exfoliation shell forms an acuminate blade (0950 2880) (Plate 39). Nearby, on the beach north of Tap Shek Kok power station (0985 2720) an isolated granite boulder is perforated on its upper part by alveoles (honeycomb weathering) (Plate 55). In the Tai Lam Country Park are several examples of mineral boxworks, rectilinear quartz veins forming upstanding ribs on the surfaces of granite boulders (207 284) (Plate 56).

In Tai Lam Country Park the granite and granodiorite outcrops show deeper weathering than the adjacent outcrops of Jurassic tuffs. Around the northern end of Tai Lam Chung Reservoir (270 290) the outcrop of fine- and medium-grained granite is deeply weathered, with much gully erosion (Plate 42). The roof capping of undifferentiated tuffs to the north (225 300) stands out as a more resistant feature, surrounded by pale weathering granite ridges. Gullying in deeply weathered fine-grained granite is also well displayed at the southern end of Tai Lam Chung Reservoir. Here, the numerous thin quartz veins form resistant ribs, accentuating the pinnacles and ridges of the gullying. Basalt dykes and granodiorite stand out as areas of reddish brown clayey soil or saprolite.

The fine-grained granite is the least susceptible to deep weathering in the Tsing Shan area. It forms the highest ground, notably the summit of Tsing Shan. Over the ridges and spurs of the medium- and fine- to medium-grained granites the rock is deeply and completely weathered, with sheets of slightly to moderately weathered bedrock usually exposed on the flanks of the ridges and in valleys cut by streams. Gullies are common in the deeply weathered rock, same with backwalls up to 20 m high (119 288).

Granodiorite. Perhaps the most distinctive weathering product in the district is the reddish brown mantle, with corestones, that develops over the granodiorite outcrops. This is particularly well exposed in the Tsing Fai Tong—Tai Lam Chung Reservoir portion of the district, most notably at Kong A Leng (249 339) and adjacent to Yuen Kong Village School (2604 3179). The reddish brown or orange brown clay-rich mantle is

Plate 55 – Advanced Development of Alveoles in Granite on Lung Kwu Chau (0590 2633)

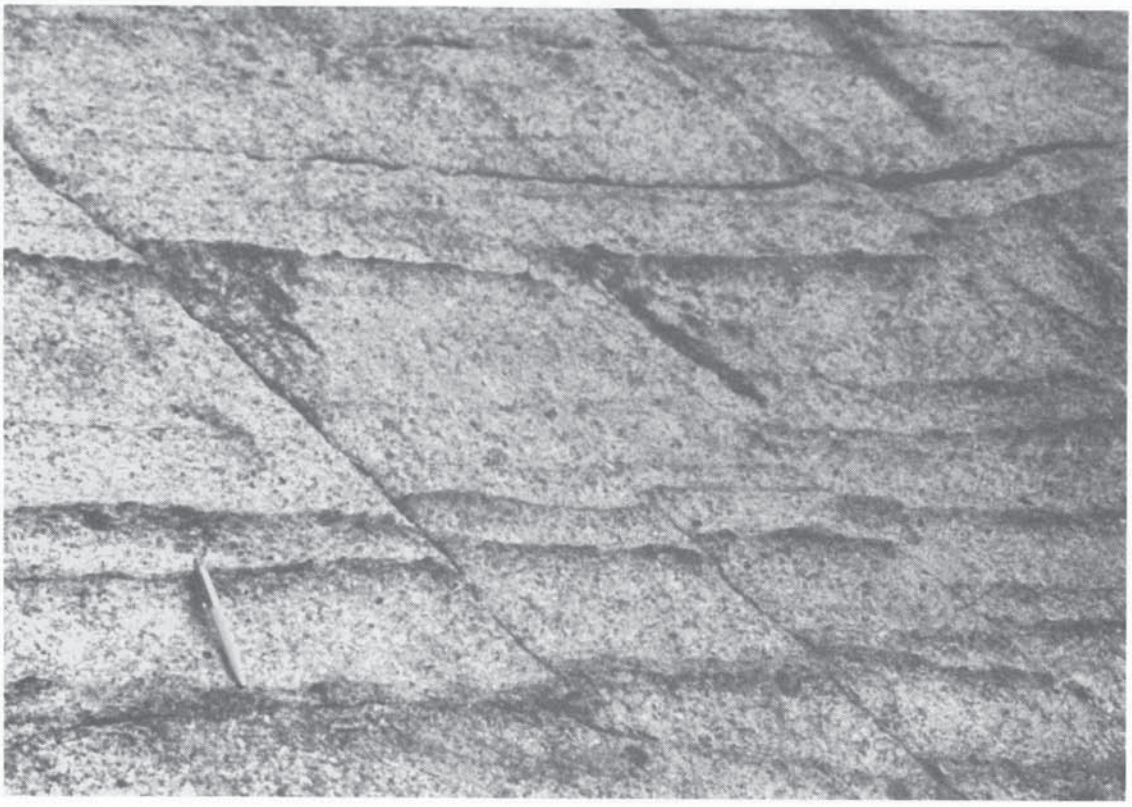


Plate 56 – Rectilinear Pattern of Upstanding Mineral Boxworks in Granite near Tai Lam Chung (2065 2823)

usually many metres thick and is easily distinguished from the pallid weathering residue overlying the granite outcrops. Conversely it can be confused with some of the weathered pyroclastic rocks, particularly the coarse ash crystal tuffs of the Tai Mo Shan Formation, as seen at Tai Lam (2291 2997), and tuffs of the Shing Mun Formation such as those occurring southwest of Ho Pui Reservoir (2555 3011).

North of Lin Fa Shan the bedrock is dominantly granodiorite. This always weathers deeply and evenly, producing few corestones. Weathering profiles exposed along a road on the ridge (274 288) near Pak Shek Kiu are up to 3 m high in moderately to highly weathered granodiorite, and thin quartz veins can be seen breaking up in the thin soil profile affected by downslope creep.

Andesite. The weathered andesites of the Tuen Mun Formation are also noteworthy. In general, the non-metamorphosed andesites are more deeply weathered than their dynamically metamorphosed counterparts. Corestone-free weathering profiles in non-metamorphosed andesites are commonly greater than 20 m thick. These rocks generally weather to brownish yellow silt flecked with white inclusions after feldspar phenocrysts and dark brown blotches after the mafic mineral. Profiles are exposed at Leung Tin Estate in northwest Tuen Mun and northeast of San Shek Wan Tsuen (Area 19). In some cases, superficial red to yellowish brown and yellow mottling may be developed in the uppermost part of the profile, a phenomenon well displayed at two sites in western Tuen Mun (1478 2828 and 1422 2792).

The andesite lavas of the Tuen Mun Formation are quartz deficient and metamorphosed to varying degrees in belts with pronounced foliations. In fault zones on the eastern side of the valley the depth of weathering is over 60 m. Over most of the valley the depth of weathering in the metamorphosed andesites and tuffs is over 20 m. Many of the site investigation boreholes in the area, commonly extending to 30 m depth, failed to intersect fresh rock. In their weathered state the foliated metamorphosed lavas resemble siltstones and sandstones, and have been recorded as such in many site investigation records. They are foliated yellowish brown, mottled red and yellowish white silt interrupted by sharply defined sheets of strongly sheared, very light grey or greyish green sericite schist.

Marble. Of particular weathering interest are the buried carbonate rocks of the Yuen Long Formation (Table 8). Carbonate rocks weather by solution in weakly acidulated groundwaters that attack not only the exposed subaerial surface but also penetrate and widen bedding planes, joints and other discontinuities. This process produces cavities of various sizes that reflect the relative resistance of the rock, the movement of groundwater and the duration of weathering. The carbonate rocks in Yuen Long are dominated by marble, with some dolomitic marble, dolomite and a few intercalations of pelitic rock. The dolomitic rocks are not so readily soluble as pure marble, and the pelitic rocks are insoluble. The impure marble also contains insoluble clayey, siliceous and ferruginous materials. The existence of cavities was first reported in 1981 (Ha et al, 1981) and despite subsequent reports (e.g. Siu & Kwan, 1982; Siu & Wong, 1984, 1985) the full extent and pattern of these features has not yet been determined.

Table 8 – Weathering Characteristics of Marble Material

	White marble	Black marble	Impure marble
VI V IV	Totally dissolved	Residue of black non-carbonate mineral grains	Soft residue of clay minerals and quartz; discoloured; may possess collapse structures due to removal of carbonate minerals
III	Usually discoloured; friable surface of powdery calcite grains	Friable surface; black or dark grey	Easily broken by hand; discoloured; may possess solution features such as cavities
II	Easily scratched with knife; may be slightly stained (near discontinuities)	Easily scratched with knife; pitted surface; black or dark grey	Easily scratched with knife; slightly discoloured; pitted surface
I	White or pale grey; crystalline	Black or dary grey; crystalline; banded	Grey or dark grey; finely or very finely crystaline

Sedimentary Rocks. Several other, less widespread, lithologies display diagnostic characteristics. Particularly distinctive are the conglomerates of the Tsing Shan Formation. These rocks, light greenish grey when fresh, weather to a multicoloured state, exhibiting light grey, greenish grey, white, light brown and yellow hues with dark brown and black limonitic or manganese joint coatings or cavity linings in the hemispherical hollows left as the clasts weather out from the matrix. Examples of this carious weathering can be observed on the hillside west of Shan King Estate (1369 2886), where 2 m thick beds have clasts up to 0.3 m in diameter weathering out.

Minor Intrusions. Quartzphyric rhyolite dyke swarms intruding granite on Tsing Shan weather from a very pale grey fresh rock to a pale yellowish green with a saccharoidal texture that locally becomes chalky. A 10 m wide feldsparphyric rhyolite dyke intruding the medium-grained granite at the Tap Shek Kok power station site (1005 2663) has a deeper weathering profile than the granite host, resulting in a shallow, linear depression. Conversely, quartz veins in the granite are generally more resistant to weathering than their host rock, resulting in white, blocky, upstanding ribs that frequently feed debris trails on the steeper declivities. Vertical sections through these features, usually in roadcuts (274 288), frequently display outcrop curvature indicating the direction and net movement of the uppermost layers.

Superficial Deposits. Subaerial weathering also affects the transported superficial deposits in the district. For example, the older, terraced debris flow deposits on the footslopes of Tsing Shan in western Tuen Mun are mottled dark red and yellowish white; the included granite boulders are themselves completely weathered.

The large spread of Pleistocene debris extending from the northwest flanks of Tai Mo Shan beneath Shek Kong Village shows few signs of weathering. The clasts have not been subjected to post-depositional in situ weathering. However, to the west, near Ho Pui Reservoir, a thin veneer of debris shows deep post-depositional weathering. The clasts are angular, but are also completely weathered (2648 2930).

Geophysical studies offshore have demonstrated that a mantle of weathered bedrock is commonly developed under the 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. Highly to completely weathered rocks and residual soil generally form moderate amplitude reflectors, while fresh to moderately weathered rocks form relatively high amplitude reflectors. The strongest seismic reflection usually occurs at the top of moderately weathered 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 elsewhere (Strange & Shaw, 1986) 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.

Examination of the Chek Lap Kok Formation sediments in the continuously sampled borehole in Hau Hoi Wan (CLP/E1) has shown that parts of the offshore superficial deposits have also been weathered. Similar observations have also been recorded from other continuously sampled offshore boreholes (Shaw, 1985, 1987; Shaw et al, 1986). In the Hau Hoi Wan borehole, weathering is apparent as yellowish orange mottles and streaks that grade downward into deep red mottling. The mottled sequence is abruptly overlain by the grey, unweathered deposits of the Hang Hau Formation, indicating that the period of weathering preceded the deposition of the marine deposits.

Chapter 10
Economic Geology

Classification

This account of the economic geology of the district has been divided into three sections; metalliferous mineral deposits, non-metalliferous mineral deposits and construction aggregates. Localities referred to are shown in Figure 25.

Metalliferous Minerals

These deposits usually occur as narrow fissure veins associated with late stage emanations of high temperature mineralized fluids from the Mesozoic granitic plutons. No major mines have operated within the district but numerous shallow workings formerly existed in the Lin Fa Shan area and also on the eastern slopes of Tsing Shan (Castle Peak).

The Lin Fa Shan deposits consist of a number of discontinuous narrow, wolframite-bearing fissure veins. In both the granite outcrop and adjacent granodiorite outcrop there are numerous small mining pits, mostly trending east-west along thin quartz veins (Plate 57). Galena, sphalerite, pyrite, scheelite, cassiterite, fluorite and beryl have also been recorded from the tailings (Peng, 1978). There are no production figures available for Lin Fa Shan, and no mine plans or details of the workings have been traced.

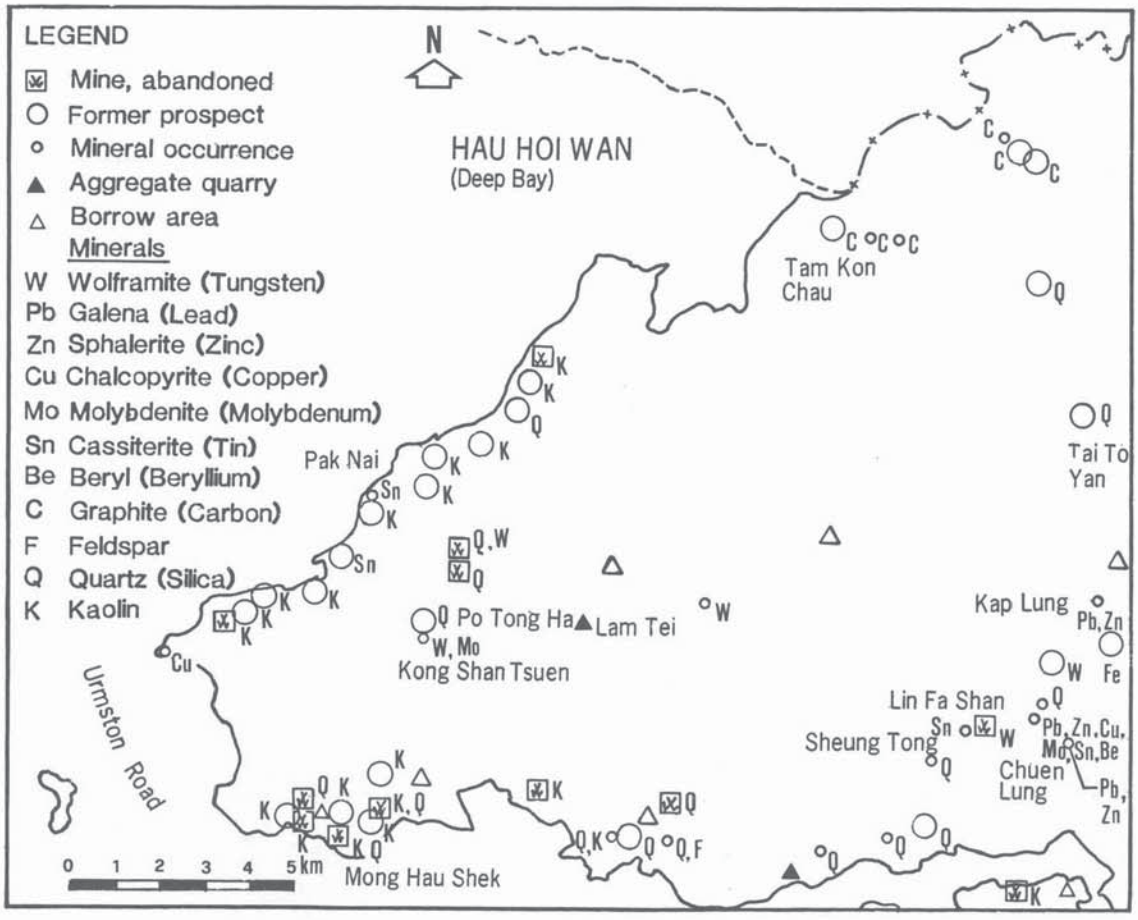


Figure 25 – Mineral Localities, Quarries and Borrow Areas in the District

Plate 57 – Small Abandoned Mining Pits Following Wolframite-bearing Veins at Lin Fa Shan (273 286)

Fissure veins containing economic quantities of wolframite and molybdenite have been mined in the vicinity of Kong Shan Tsuen on the eastern slopes of Tsing Shan.

Residual or eluvial placer deposits have been recognized by Davis (1952) in the vicinity of Sheung Tong (264 279), where weathered granitic bed-rock is said to contain significant cassiterite concentrations and has also yielded some gold. Davis (1952) also noted cassiterite bearing alluvial placer deposits in the Kam Tin plain but gave no specific locations.

Fissure veins containing galena and sphalerite, associated with actinolite, have been reported by Peng (1978) in the Kap Lung area (290 310); these are probably associated with a hydrothermally altered shear belt. Similar lead-zinc deposits have been noted by Nau (1977) near Chuen Lung (288 279).

Non-metalliferous Minerals

Fissure veins infilled with quartz are common, particularly in the granite areas, where shallow excavations along the strike of the veins characterize the workings (Plate 58). Numerous mining licences for quartz have been granted within the district, mainly in the Pak Kok – Mong Hau Shek, Siu Lam and Po Tong Ha areas. All licences have now expired and mining for quartz has ceased. The quartz was crushed and used in the manufacture of glass-ware, silica-ware and pottery. An average of 4 000 tonnes per annum of crushed quartz was produced by the Siu Lam working between 1955 and 1960. There is evidence of extensive workings for quartz on the northeast flanks of Tai To Yan. Here, the veins formed in metamorphosed tuffs close to a major northeast-trending fault zone. All the veins noted were small, and most trend parallel to the fault.

Kaolinized rhyolite and aplite dykes, and mylonitized granite have been worked for their clay content at a number of localities in the Mong Hau Shek area, Pak Nai area and on northern Tsing Yi. The kaolinization is probably due to late stage hydrothermal alteration along the dykes. The clay has been used in the local chinaware industry and as a rubber filler material. Completely weathered granite has been taken from shallow surface excavations in many locations, where the quartz has also been utilized. Davis (1952) noted a possible source of pure quartz beach sand, suitable for glass making, along the shore at Lau Fau Shan (170 370).

Plate 58 – Old Quartz Vein Workings in Kaolinized Granite near So Kwun Wat (195 265)

Graphitic siltstone, occurring within the Mai Po Member of the Lok Ma Chau Formation, has been prospected for its graphite content, but no mining has taken place. Several trial shafts into these deposits were sunk at Tam Kon Chau (233 394).

Allen & Stephens (1971) record the manufacture of bricks in Tuen Mun. Small quarries existed in the deeply weathered andesitic rocks, providing a source of clay for this industry. No record of production figures has been found.

Construction Aggregates

Bulk mineral production in the district is dominated by one major quarry at Lam Tei (176 306) producing stone for aggregates. This is the only working quarry within the district and ranks fourth in terms of quarrying output in the Territory. The rock type worked at Lam Tei consists of a uniform, sparsely megacrystic to non-megacrystic fine-grained granite. A number of quartzphyric rhyolite dykes intrude the granite and a small proportion of the aggregate consists of this rhyolite. Nearby abandoned quarries (176 310) are mainly in megacrystic fine-grained granite. The Lam Tei Quarry produces around 1 million tonnes of aggregate a year.

A rock crushing plant at Siu Lam commenced operation in 1984 and produced 578 740 tonnes and 492 940 tonnes in 1985 and 1986 respectively. Although much of the material crushed at this plant came from sites such as borrow areas within the district, some rock was brought in from as far as Diamond Hill, Kowloon.

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Appendix 1

Micropalaeontological Determinations of Carboniferous Samples from the San Tin Group in the District. Analyses by the British Geological Survey and Guangdong Institute of Geological Sciences (1)

SPECIES \ SAMPLE NUMBER & GRID REFERENCE	HK997, 1384 2760	HK3005, 2231 3181	HK3091, 2080 3526	HK3096, 2207 3455	HK3432, 2330 3940	HK4162, 2115 3055	HK4175, 2041 3011	HK5134, 2355 3118	HK5994, 2252 3490	HK6042, 2207 3455	HK6721, 2243 3176 (1)	HK6724, 2219 3446 (1)	HK6725, 2210 3438 (1)	HK6745, 2910 4163 (1)
Acanthotriletes parispinosus												●		
Acanthotriletes socrecticus											●			
Acanthotriletes sp.													●	
Apiculatisporis cf aculeatus			●						●					
Apiculatisporites cf variocorneus									●					
Botryococcus			●	●					●					
Calamospora microrugosa		●												
Calamospora nigratus													●	
Calamospora pallida		●	●						●					
Calamospora parva		●	●											
Calamospora pusilla													●	
Calamospora sp.	●											●		
Cinguilizonates loricatus									●					
Cinguilizonates sp.			●		●									
Convolutispora sp.									●					
Corbulispora sp.														●
Crassispora kosankei		●	●											
Crassispora sp.								●						
Cristatisporites indignabundus									●					
Cyclogranisporites sp.			●			●							●	
Densosporites anulatus		●	●			●		●	●	●		●		
Densosporites sphaerotriangularis		●							●					
Densosporites cf brevispinosus			●											
Densosporites cf pannosus			●											
Densosporites sp.									●		●		●	
Dictyotriletes bireticulatus		●	●											
Dictyotriletes minutus													●	
? Dictyotriletes sp.										●				
? Endosporites sp.				●										
Florinites pumicosus		●							●					
Granulatisporites granulatus								●						
Granulatisporites microgranifer		●												
Granulatisporites minutus												●		
Granulatisporites parvigranulatus														●
Granulatisporites sp.			●									●		
Grumosisporites varioreticulatus				●										
Knoxisporites seniradiatus							●							
Knoxisporites stephanephorus			●											
Knoxisporites sp.												●	●	
Laevigatosporites desmoninesensis		●	●					●						
Laevigatosporites vulgaris									●					
Laevigatosporites sp.				●										●
Leiotriletes sp.														●
Lophozonotriletes obsoletus														
Lophozonotriletes rarituberealatus											●		●	
Lycospora granulata		●							●					
Lycospora microgranulata														●
Lycospora orbicula											●		●	●
Lycospora pusilla		●	●					●	●			●	●	●
Lycospora subtriquetra									●					
Lycospora sp.												●		
Microreticulatisporites cf nobilis		●												
? Microreticulatisporites sp.						●		●						
Monilospora triungensis													●	
Punctatisporites sp.		●	●						●					●
Radiizonates striatus		●												
Raistrickia aculeata		●												
Raistrickia fulva		●	●						●					
Raistrickia sp.			●											
Reticulatisporites sp.													●	
Savitrisporites nux		●	●		●	●	●							
Schulzospora campyloptera		●												
Schulzospora sp.								●						
Secarisporites remotus			●	●										
Secarisporites sp.										●				
Stenozonotriletes rasilis													●	
Stenozonotriletes sp.													●	
Teicardisporites sp.													●	
Tumilospora malerkensis													●	
Tumilospora rarituberculata													●	

Appendix 2

Carbon 14 Dating of Quaternary Deposits in the District

No.	Sample number	Localities	Co-ordinates East North	Landform	Sample Type	Depth m	Elevation mPD	Laboratory Code	C14 age yr BP
1	HK6759	Shan Ha Tsuen Yuen Long	19270 32115	Terrace alluvial plain	Organic Clay	3.0	15.4	GF870009	33,575±3,186
2	HK4210	"	19180 32085	"	"	5.3	15.7	Beta	32,500±490
3	HK4209	"	"	"	"	3.8	17.2	Beta-18651	28,670±2210
4	HK6858	"	19345 32200	"	"	2.5	12.7	GF870302	27,770±540
5	HK6755	"	19180 32085	"	"	3.2	17.8	GF870016	21,863±1,107
6	HK6753	"	"	"	"	2.0	19.0	GF870008	20,240±992
7	HK6752	"	"	"	"	1.4	19.6	GF870017	18,249±1,238
8	HK4211	"	"	"	"	1.7	19.3	Beta-18652	17,960±230
9	HK6751	"	"	"	"	0.5	20.5	GF87006	16,289±831
10	HK5798	Nam Pin Wai	21440 34070	Mud Flat	Organic mud	3.0	−1.00	GF928	6,760±130
11	HK7607	Chuk Yuen	23900 37160	"	Rotten wood	3.0	1.3	GF932	6,670±130
12	*1	Tung Kwu (Lung Kwu Chau)	06000 26200	Tombolo (raised beach)	Pottery	1.0	3.7	ARL-239	5,800±500
13	HK5947	Chau Tau	26580 40370	Mud Flat	Roolet	3.0	0.4	SI86–123	5,475±155
14	HK5948	"	"	"	"	3.1	0.3	SI86–124	5,093±130
15	HK7600	Mai Po	24110 38330	"	Organic mud	1.9	2.49	GF927	3,220±95
16	HK7606	"	23925 37430	"	"	1.8	2.50	GF931	3,160±100
17	HK5469	Sheung Cheung Wai	18590 34260	"	"	2.5	0.2	SI86–122	3,110±185
18	HK3085	Fung Chi Heung	20280 34300	"	Rotten wood	1.5	0.9	SI86–109	1,900±93
19	HK7609	Shan Ha Road	19660 33157	Stream	"	10.5	−3.42	GF926	1,630±70
20	HK3714A	Yung Long	09561 30340	"	Organic clay	0.8	84.98	GF924	1,510±70
21	HK3714B	"	"	"	Rotten wood	0.8	84.98	GF929	1,510±70
22	EX7	Shek Kok Tsui	14150 26500	Raised beach	Charcoal	1.2	3.9	—	1,370±100
23	HK5946	Ha Wan Tsuen	25400 41890	Mud Flat	Organic mud	2.0	1.0	SI86–121	520±112

Notes:

*1 Meacham (1986)
EX7 Meacham (1979)
(The depth and elevation of samples *1 and EX7 are approximate)

Laboratory Codes:

GF Guangdong Institution of Geological Science, Guangdong, China
Beta Beta Analytic, Florida, U.S.A.
SI South China Sea Institution of Oceanology. Academia Sinica, Guangzhou, China
ARL Australian National University, Canberra, Australia

Appendix 3

Continuously Sampled Borehole through Offshore Superficial Deposits

The following is an abridged log of a borehole sunk for a private project. Continuous sampling of the borehole for detailed geological investigation was carried at the request of the Geotechnical Control Office.

Borehole	**Deep Bay CLP/E1**
Grid Reference	1020 3157
Surface Level	−1.99 mPD
Superficial Deposits	11.90 m thick
Bedrock	−13.89 mPD
Date Drilled	January, 1985

Geological Classification	Lithology	Thickness, m	Deepth in Hole, m	Reduced Level, mPD
Hang Hau Formation	SILT; clayey, olive grey, very shelly (many comminuted); increasingly sandy lower down	4.00	4.00	−5.99
	SAND; medium, silty, dark grey, shelly	1.35	5.35	−7.34
	CLAY; silty, sparse gravel, black; rich in plant fragments	1.14	6.49	−8.48
	SAND; medium to coarse with gravel, dark grey; silt lenses and plant fragments	1.87	8.36	−10.35
Chek Lap Kok Formation	CLAY; silty with sparse sand, pale grey mottled yellowish brown and spotted dark red	3.54	11.90	−13.89
Medium-grained Granite	GRANITE; medium-grained, creamy white rock, quartz and feldspar megacrysts; completely weathered	1.60	13.50	−15.49

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Index

Page numbers in **bold** refer to plates, figures and tables. Page numbers in *italics* refer to major sections on a topic.

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