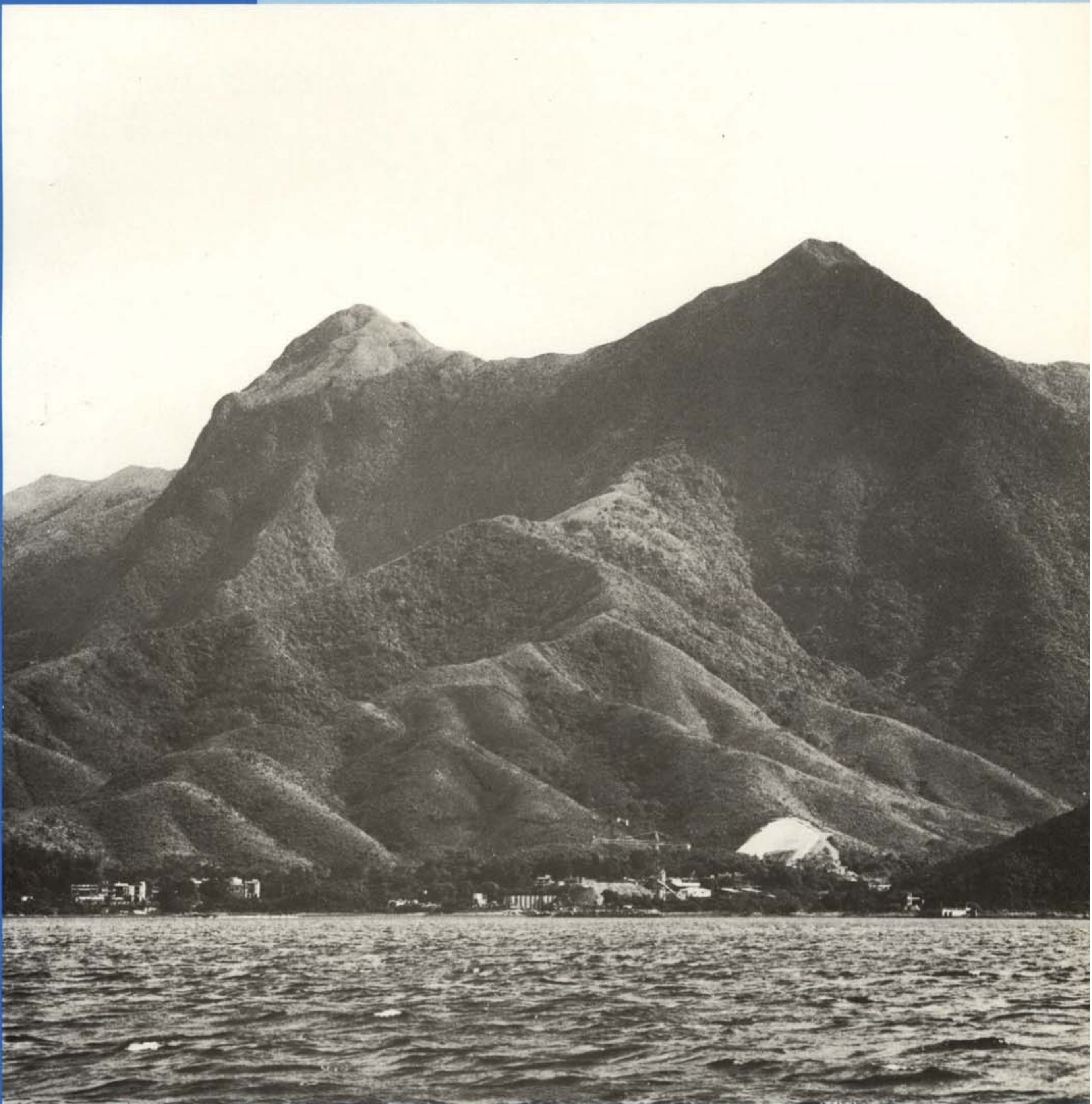
HONG KONG GEOLOGICAL SURVEY *MEMOIR No. 1*

Geology of Sha Tin



Geotechnical Control Office
Civil Engineering Services Department
HONG KONG

HONG KONG GEOLOGICAL SURVEY *MEMOIR No. 1*

Geology of Sha Tin

1:20 000 Sheet 7

R. Addison

Geotechnical Control Office
Civil Engineering Services Department
HONG KONG June 1986

Foreword

This Memoir describes the geology of the Sha Tin area as depicted on Sheet 7 of the 1:20 000 Geological Map Series of Hong Kong. Together with the map sheet, it represents the first published results of a new programme of systematic geological mapping which is being undertaken by the Geotechnical Control Office (GCO). The programme will permit the study of the geology of the Territory, both on land and offshore, in considerably greater detail than has been possible hitherto. It will enhance our understanding of Hong Kong's stratigraphy and structure, and it will contribute significantly to the establishment of a geological database necessary for the continuing economic development of the Territory. The mapping programme is being undertaken by the Geological Survey Section of the Planning Division of the GCO. The Section is led by Mr R. S. Arthurton and the Division is under the direction of Dr A. D. Burnett.

The Geological Survey of Sheet 7 was undertaken in 1983–84 by Dr R. Addison of the British Geological Survey (BGS) in partial fulfilment of the consultancy agreement between the Government of Hong Kong and the Natural Environment Research Council, UK. The marine geology was compiled by Mr R. J. Purser of the GCO, who also drafted the sections of this Memoir which deal with offshore deposits. The chapter of the Memoir on mineralisation and mining was compiled by Mr P. J. Strange.

The survey of Sheet 7 benefitted from the generous co-operation of various organisations and many individuals. The Royal Hong Kong Auxiliary Air Force and the Marine Department helped in gaining access to remote areas, and the Water Supplies Department arranged access to water tunnels. Valuable comment and advice was obtained from staff and research students at the Hong Kong Polytechnic and the University of Hong Kong, in particular Mr C. M. Lee and Dr D. R. Workman. Dr J. D. Bennett (BGS) gave general guidance during the mapping as well as assisting with fieldwork. Dr. J. Cobbing (BGS) made important contributions to the interpretation and classification of the granites. Many members of the GCO staff also contributed during the mapping and compilation phases of the work.

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

E. W. Brand
Principal Government Geotechnical Engineer
June 1986

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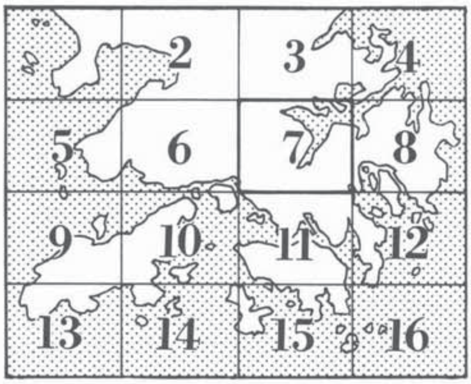
Map and Memoir Series Notes

• This Memoir describes the geology of the Sha Tin area, and should be read in conjunction with the 1:20 000 Geological Map Sheet 7 – Sha Tin.

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



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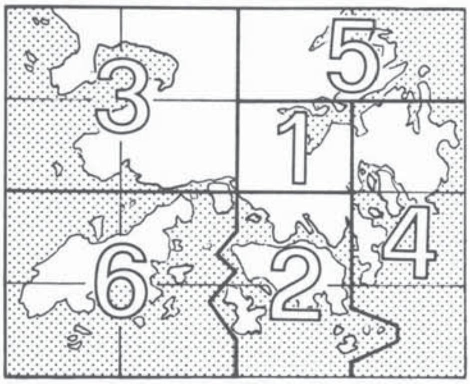


memoirs

• Grid References cited in this account are those of the Hong Kong 1980 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. (4130 2925). Six-figure references indicate positions to the nearest 100 metres, e.g. (370 268).

• Samples in the Territory-wide rock collection archived by the Hong Kong Geological Survey are referred to using the prefix HK followed by a serial number, e.g. (HK 227).

• The system used in this memoir for grainsize description and classification is summarised in the table below.

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

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

Chapter 1
Introduction

Location and Physiography

The area covered by this map sheet is referred to in this account as the district (Figure 1). The land area of the district amounts to about 140 sq km, lying north of the Kowloon hills around Tide Cove and Tolo Harbour, and including the peaks of Tai Mo Shan, Buffalo Hill, Ma On Shan and Tai To Yan. Three major conurbations lie within the district; Tai Po, Sha Tin and Tsuen Wan. The more mountainous terrain has mostly been designated as country parks, including those of Tai Mo Shan, Shing Mun, Kam Shan, Lion Rock and Ma On Shan, as well as the Tai Po Kau Nature Reserve.

The district is formed of two blocks of mountainous terrain divided by the deep linear northeast-trending valley of Sha Tin and Tide Cove. The northwestern block includes the highest peak of the Territory, Tai Mo Shan (957 m), as well as Grassy Hill (647 m) and Needle Hill (532 m). This block is dissected by further important northeast-trending valleys such as those through Shing Mun, Lead Mine Pass and Tai Po, and the Lam Tsuen Valley, which separates Tai To Yan, with its knife-edge southwestern ridge, from the Tai Mo Shan massif. Approximately at right-angles to the main valleys is a complementary set of drainage features. This includes the lower Shing Mun River, and the streams that drain southeastwards from Grassy Hill and Needle Hill into the Sha Tin valley. Perhaps the most significant northwest-trending line is that from Tai Po to the Chinese University, dividing the Tai Mo Shan and Grassy Hill massifs from the Tolo Harbour basin. The embayment of Tsuen Wan and Gin Drinker's Bay in the southwest lies on the line of Lead Mine Pass, although drainage of the Shing Mun River has been captured and diverted to Sha Tin.

The southeastern block includes the peaks of Ma On Shan (702 m), Buffalo Hill (604 m) and Tate's Cairn (577 m), that, though not as high as Tai Mo Shan, are more rugged. The peaks form a general ridge which, like the terrain of the northwestern block, is dissected by northwest-trending features such as Grasscutter's Pass, Heather Pass and Tai Shiu Hang, and the Ma On Shan Tsuen valley. Though not individually extensive, several northeast-trending valleys lie along a line from Tai Che to Ma On Shan and divide granitic from volcanic terrain. Southeastward drainage from the main ridge is into Hebe Haven by short northwest-trending valleys.

The two mountainous blocks described form respectively the southwestern and southeastern flanks of the Tolo Harbour basin. This basin floor lies generally at a level of 5 to 10 m below Principal Datum (PD), although in the area immediately south of Harbour Island, the floor lies at as much as 27 m below PD. Low ridges with intervening alluvial valleys form the northern margin of Tolo Harbour, and similar ridges protrude above sea level forming the islands of Ma Shi Chau, Yim Tin Tsai, Centre Island, Harbour Island and Bush Reef. Coastal plains fringe the southern shore of Tolo Harbour around Nai Chung and Wu Kai Sha.

Previous Work

The most comprehensive descriptions of the geology of the district are those by Williams (1943), Williams et al (1945), Ruxton (1960) and Allen & Stephens (1971). The first three of these publications dealt with the geology in fairly general terms, although Ruxton (1960) included stratigraphical descriptions of strata on Ma Shi Chau and on Centre Island in Tolo Harbour. The work by Allen & Stephens has remained the only detailed work based on thorough, systematic, Territory-wide field observation.

Bennett (1984b) has reviewed published work on the stratigraphy of Hong Kong as a whole. The earliest works on the stratigraphy of this district were by Brock & Schofield (1926) and Uglow (1926), who established the names of the Repulse Bay Volcanics and the Tolo Channel Formation respectively. Brock & Schofield (1926) used the term Tai Mo Shan Formation for a rock unit described by Uglow (1926) and Williams et al (1945) as an intrusive formation within the Repulse Bay Volcanics. The names Bluff Head Formation and Tolo Harbour Formation were introduced by Ruxton (1960).

Following Ruxton's work, several workers have reassessed the stratigraphy and structure of the sedimentary rocks of Tolo Harbour. Lam (1973) reported the discovery, by Dr C. J. Peng, of ammonites in strata underlying tuffs at the southern tip of Ma Shi Chau, thus confirming the presence there of Jurassic strata. Nau (1980) suggested that these ammonite-bearing strata should be correlated with the sedimentary rocks of the Tolo Channel Formation as described by Heanley (1924), and in the same work he reported the occurrence of Permian/Carboniferous fossils from strata on Ma Shi Chau which were designated as Bluff Head Formation by Allen & Stephens (1971). He proposed that all the pre-volcanic strata of Ma Shi Chau should be included in either the Tolo Harbour Formation or the Tolo Channel Formation. Lee (1982) discovered Devonian placoderm fish remains on Harbour Island in strata of the Bluff Head Formation, formerly assigned by Allen & Stephens (1971) to the Jurassic. Since the type locality of the formation is continuous with the Harbour Island outcrop, no re-definition of the formation is necessary, although its original allocation to the Jurassic system must be revised.

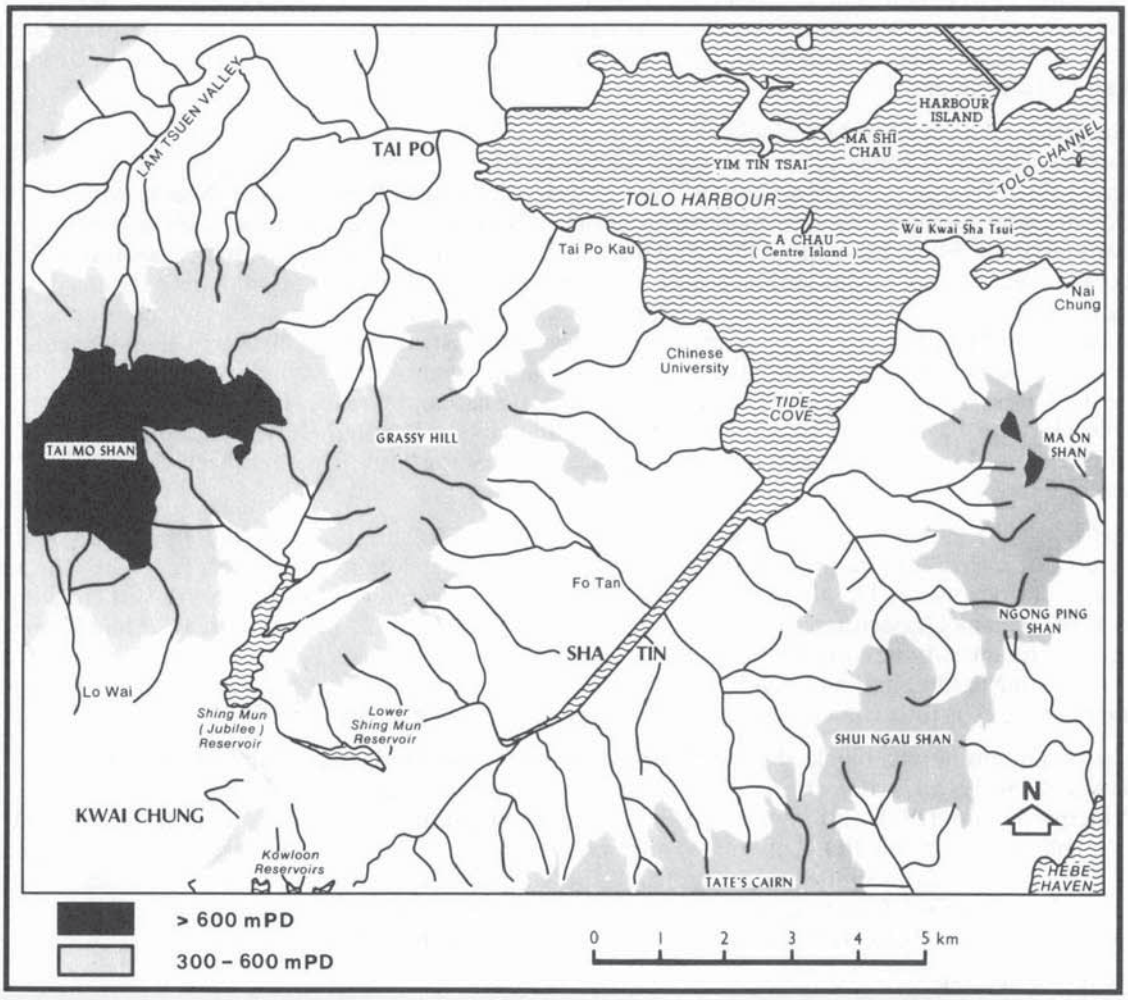


Figure 1 – Principal Topographical Features of the District

The definitive work on the igneous geology of Hong Kong is that of Allen & Stephens (1971), which superseded all previous work while adopting the main pre-existing names of the intrusive rock masses; these included the Hong Kong Granite and the Tai Po Granodiorite porphyry of Uglow (1926), Brock & Schofield (1926) and Williams et al (1945). There has been no more recent attempt at further classification of the intrusive rocks.

Ruxton (1957) reviewed the structural interpretations of the Territory, including the recognition of the Tolo Channel Anticline by Heim (1929). Ruxton himself recognised the importance of the Tide Cove – Lai Chi Kok Fault. Later, the structural geology of the district was dealt with thoroughly by Allen & Stephens (1971), Lai (1976; 1977) and, especially, Lai et al (1982). Papers by Nau (1980) and Ou Yang (1982) considered aspects of the structure of the Palaeozoic rocks of Ma Shi Chau. A review report by Bennett (1984c) embraced the tectonic history, structure and metamorphism of the Territory as a whole.

A number of publications have been produced on the mineralisation and mine workings of Ma On Shan and Needle Hill. The most important are those by Davis (1961a, 1961b), Shibata (1961) and Hui (1978). Other references to mineral deposits in the area were made by Weld (1915), Tegengren (1923) and Peng (1978).

Few works have dealt specifically with the superficial deposits of the district, although the works by Huntley & Randall (1981), Lai (1982) and Lai & Taylor (1983) have a bearing on the interpretation of the debris flow deposits. Whiteside (1984) described the sequence of superficial (Quaternary) deposits of Tide Cove and recognised Pleistocene alluvial deposits beneath marine clays in a sequence now regarded as typical of the Tide Cove – Tolo Harbour area. Bennett (1984a) reported on the superficial deposits and the processes and products of weathering in Hong Kong.

The Present Survey

The ground survey was carried out at a scale of about 1:10 000, mapping directly on to aerial photographs before transferring data to base maps. Traverses were made of most ridge-lines and, where possible, intervening stream sections. In practice, however, it was found that vegetation made many stream sections difficult and time-consuming to follow so that effort was concentrated on obtaining an even coverage of more closely spaced traverses on interfluves. Traverse spacings were maintained at distances of not more than 1 km, and generally around 0.5 km. Selected geological information was subsequently compiled at the 1:20 000 scale.

Tunnel records were obtained from Water Supplies Department for all the major water tunnels, and brief access was obtained to the Shing Mun – Tai Po tunnel. Borehole records for many major engineering projects were obtained from the Geotechnical Information Unit of the GCO, including the Tai Po by-pass, the Kwai Chung – Sha Tin trunk road, the Plover Cove to Sai Kung water supplies tunnel and the Tsuen Wan area records of the Mass Transit Railway site investigation. Geotechnical Area Studies reports of the Planning Division of GCO were consulted for additional information on superficial deposits. The borrow areas were mapped in 1982 and 1983, and these sites may have been subsequently modified. Limits of reclamation shown on the map are updated to October, 1985.

Geochemical analyses were carried out by the Analytical Chemistry Research Group, BGS, using chemical methods or Inductively Coupled Plasma Atomic Emission Spectroscopy for major elements, and XRF Spectroscopy for trace elements.

All records of the survey, including aerial photographic map overlays, manuscript maps, specimens, thin sections and analytical data, are retained in the Geological Survey Section of the GCO as part of the geological data archive of the Territory.

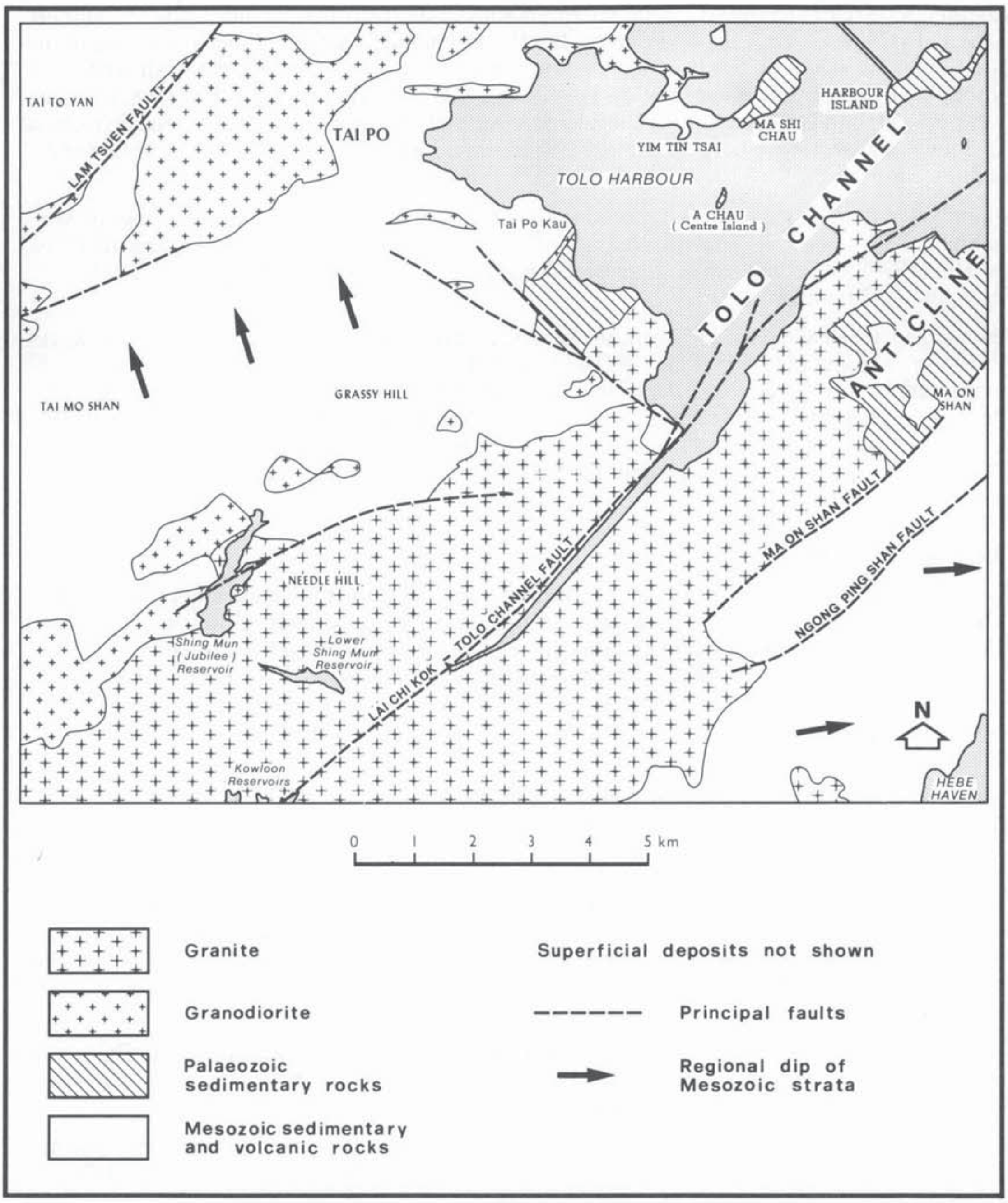


Figure 2 – Principal Features of the Solid Geology of the District

Chapter 2
Outline of Geology

The superficial deposits and solid rocks of the district and their respective ages are listed in Table 1.

The district is formed mainly of Mesozoic volcanic and sedimentary rocks intruded by granitic igneous rocks, also of Mesozoic age (Figure 2). In the Tolo Harbour area there are outcrops of Palaeozoic rocks. Quaternary superficial deposits form a patchy cover on land but are extensive in lowlying coastal areas and offshore.

The Mesozoic succession comprises the impersistent Tolo Channel Formation marine siltstones, from which Lower Jurassic fossils have been recovered, and, overlying these, the Repulse Bay Volcanic Group, a complex succession consisting mainly of crudely stratified pyroclastic rocks (tuffs) and including four distinctive formations.

The Mesozoic strata are folded into a broad, northeast-trending anticline, the Tolo Channel Anticline, with its axial zone extending along the Sha Tin valley, through Tide Cove and into Tolo Channel. The core of the Tolo Channel Anticline, in the Tolo Harbour – Tolo Channel area, is formed of Palaeozoic sedimentary rocks, including sandstones of the Devonian Bluff Head Formation and siltstones and sandstones of the Permian Tolo Harbour Formation. These are the oldest rocks of the district and are generally steeply inclined and more highly deformed than their Mesozoic cover.

The Palaeozoic and Mesozoic strata are intruded by a complex granite pluton, which crops out in the Kwai Chung – Sha Tin valley – Tide Cove area. The host rocks are locally altered by contact metamorphism. Coarse-, medium- and fine-grained varieties of granite are recognised, the coarse-grained granite being the oldest and forming the core of the pluton. The strata are also intruded by granodiorite, which pre-dates the granites and crops out extensively in the Lam Tsuen Valley and along the northwestern flank of the granite pluton. Quartz monzonite occurs in sheets along the southeastern contact of the pluton and, elsewhere, tends to intrude along fault lines. There are minor intrusions of porphyritic rhyolites, quartz latite and basalt, mostly in the form of dykes, which occur both in the stratified and in the plutonic rocks; but also, in the case of one variety of rhyolite, as more substantial bodies. Like the major intrusives, the minor intrusives are of Mesozoic age with the possible exception of the basalt dykes that may be Tertiary.

The axial zone of the Tolo Channel Anticline is also a fault zone and includes the Lai Chi Kok – Tolo Channel and Ma On Shan faults (Figure 2). Another major fault of similar trend extends along the Lam Tsuen Valley. The stratified rocks and granodiorite on the flanks of the granite pluton are also heavily faulted and some of these faults are mineralised.

An impersistent cover of superficial deposits on the land areas of the district includes debris flow deposits on the hilly ground and alluvium in the main valleys. In the low-lying, coastal and offshore areas, the superficial deposits are extensive and comprise older alluvial gravel, sand and mud of Pleistocene age, covered by a layer of marine mud with subordinate sand, of Holocene age. Over much of the district the solid rocks are weathered at outcrop, or under a cover of superficial deposits. A mantle of completely weathered rock, with or without corestones, may be many metres thick; some rock types, notably granodiorite, have been particularly susceptible to weathering.

Table 1 – Solid Rocks and Superficial Deposits of the District

Superficial Deposits

	Age	Genetic Classification
Quaternary	Holocene	Fill (made ground) Marine sand Marine mud Estuarine mud and sand
	Holocene and Pleistocene	Alluvium Debris flow deposits Talus (rockfall) deposits Mixed debris flow and talus deposits Slide deposits

Solid Rocks

	Age	Named Sedimentary and Volcanic Divisions		Principal Rock Types
Mesozoic	Upper Jurassic	Repulse Bay Volcanic Group	Tai Mo Shan Formation	Crystal tuff with biotite
			Ap Lei Chau Formation	Vitric tuff
			Shing Mun Formation	Lithic and crystal tuff and tuff-breccia; tuffite
			Yim Tin Tsai Formation	Crystal tuff with hornblende
	Lower Jurassic	Tolo Channel Formation		Siltstone
Palaeozoic	Permian	Tolo Harbour Formation		Siltstone, sandstone
	Devonian	Bluff Head Formation		Sandstone

		Major Intrusive Igneous Rocks
Mesozoic	Jurassic-Cretaceous	Fine-grained granite Medium-grained granite Coarse-grained granite Quartz monzonite Granodiorite
		Minor Intrusive Igneous Rocks
Tertiary		Basalt
Mesozoic	Jurassic-Cretaceous	Quartzphyric rhyolite Feldsparphyric rhyolite Quartz latite

Chapter 3
Palaeozoic Rocks

Distribution and Classification

Two rock units of Palaeozoic age occur within the district. The older unit, the Bluff Head Formation, is Devonian in age (395–345 million years (ma)) while the younger, the Tolo Harbour Formation is Permian (280–230 ma). Together they form the structurally complex basement on which the Mesozoic rocks were deposited and through which the granitic rocks were intruded.

The Bluff Head Formation was first defined by Ruxton (1960) and was originally thought to be Jurassic. More recent discoveries (Lee, 1982) indicate a Devonian age for the strata of the type area, while rocks on Ma Shi Chau previously classified as Bluff Head Formation (Allen & Stephens, 1971) have been re-classified as Tolo Harbour Formation (Nau, 1980). The Bluff Head Formation crops out in the northeastern part of the district where it forms Harbour Island, Tung Tau Chau and Tang Chau. The main islands represent the southwestern end of a substantial ridge of the formation extending along the entire length of Tolo Channel from the type section at Bluff Head. P'an Jiang is reported by Atherton (1983) as comparing the Bluff Head Formation with the Guitou (Kwei-tou) Formation (Devonian) of northern Guangdong Province.

The Tolo Harbour Formation was defined by Ruxton (1960) on Ma Shi Chau and on Centre Island in Tolo Harbour. He described a 150 m sequence of banded siltstones and shales cropping out on the southeastern coast of Ma Shi Chau. His assignment of these strata to the Permian, on palaeontological evidence, has been accepted by subsequent workers. The present geological survey also includes within the formation those dark siltstones and sandstones cropping out north of the Chinese University, and a substantial sequence of the remaining strata of Ma Shi Chau described by Ruxton as plant-bearing but undifferentiated older sediments, in part following Nau (1980).

Bluff Head Formation
Stratigraphy

Harbour Island. The formation consists of interbedded pale grey, medium- and coarse-grained, quartzitic sandstones (orthoquartzites) and slightly darker, fine-grained sandstones and siltstones (protoquartzites) with occasional beds and lenses of white, quartz-pebble conglomerate. About 800 m of strata are exposed on Harbour Island but account has not been taken of the possibility of these strata being repeated by strike-slip faulting or isoclinal folding. The base of this formation is not seen within the district.

The formation is best exposed on the southern shore of Harbour Island between 4348 3448 and 4475 3510. In this section the strata are dominantly fine- and coarse-grained quartz-rich sandstones. At 4348 3448 strata show cross-stratification and this feature, along with graded bedding at 4440 3492, indicate a northwestward younging direction. Farther north, at 4454 3496, vertically disposed lenses of quartz-pebble conglomerate display further younging evidence (Plate 1). At the southern tip of Harbour Island (4350 3452) siltstones interbedded with quartzitic sandstones have yielded fossils identified as placoderm fish remains of probable late Middle Devonian age (Lee, 1982) (Plate 2).

Sai O and Ma On Shan. A sequence of sedimentary rocks at least 300 m thick underlies the volcanic rocks which form the summits of Ma On Shan and The Hunch Backs. No fossils have been recovered from these strata and thus their age and assignation remain in doubt. However, grouping with the Bluff Head Formation is favoured on lithological and structural grounds.

The rocks are not well exposed except at the following localities: on the western ridge of The Hunch Backs (4280 3040); in a stream southwest of Sai O (4373 3150); and in Ma On Shan Mine (4130 2925), where they are much altered by thermal metamorphism and mineralisation. However, a water tunnel that was being driven southwards from a portal near Sai O (4410 3205) in 1985 has provided excellent sections of fresh rock. The rocks of this outcrop are rather poorly bedded and comprise white quartzite, purple siliceous siltstone and quartz-pebble conglomerate (4390 3165). Records from Ma On Shan Mine refer to limestones inferred by Davis (1964) to be of Permo-Carboniferous age. C. M. Lee (oral communication) considers that there are magnetite-bearing, metamorphosed sedimentary rocks in the mine that are Devonian in age.

Sedimentary Environment

The sediments of the Bluff Head Formation are mature to very mature quartzitic sandstones and conglomerates resulting from the recycling of detritus from deeply eroded basement rocks. The strata were deposited in high energy conditions, and sedimentary features (cross-bedding, channel-lag grits and graded beds) indicate a fluvial to deltaic environment.

Plate 1 – Sandstone and Conglomerate in Bluff Head Formation on Harbour Island (4454 3496)

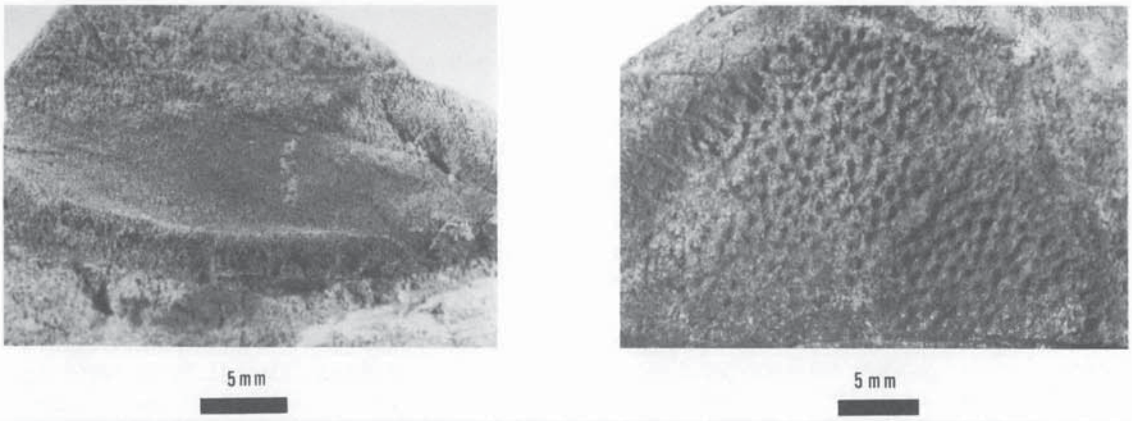


Plate 2 – Fossil Plates of Placoderm Fish in Siltstone of the Bluff Head Formation, Harbour Island (4350 3452); Specimens Courtesy of Mr. C. M. Lee

Tolo Harbour Formation

Stratigraphy

Ma Shi Chau (type area). The strata on Ma Shi Chau are structurally complex, and the interpretation of stratigraphic relations within the formation is extremely difficult. The strata are involved in syndepositional slump folds as well as a series of northerly plunging minor anticlines and synclines, the limbs of which are often sheared and overturned (Plate 3).

The northeastern coast demonstrates the most complete sequence although the succession, which youngs to the northwest, is cut by faults at the eastern end of this section. A sequence of some 500 m thickness is estimated on Ma Shi Chau, although the tectonic structures make this figure somewhat speculative. The formation is uncomformably overlain by tuffs and sedimentary breccia of the Repulse Bay Volcanic Group which crop out along the western shoreline; the contact has not been observed.

The sequence is divided into two lithofacies following Nau (1980). However, the outcrop is considered to be structurally too complex to warrant formal sub-division. The lower facies consists of a sequence of pale grey, pink-weathered, slightly calcareous siltstones, dark grey mudstones, siltstones and sandstones (4215 3428). The sandstones form layers up to 0.5 m thick. They are moderately even-bedded and persistant along strike, except where faulted. The dark grey mudstones and siltstones are occasionally ferruginous and contain pyrite nodules and, according to Nau (1980), in places contain plant remains. The pink-weathered, pale grey calcareous siltstones contain assemblages of poorly preserved marine fossils including molluscs, corals, bryozoans, brachiopods and crinoids (Plate 4). Interbedded strata have also yielded plant remains (Nau, 1980) (Plate 4).

On the northern coast of Ma Shi Chau these beds pass upwards with gradual increase in sand content into an upper facies consisting of more thickly bedded siltstones and sandstones, with beds up to 1 m thick. Conglomerates occur within the sandstones near the top of the exposed succession. Boulders which occur on the northwestern shore of the island show signs of tectonic or in-situ brecciation. Where they crop out on the eastern coast of the island, Nau (1980) recorded plant fossils, crinoid remains and corals in places within these beds. The strata there are occasionally contorted in syndepositional slump folds. At one locality (4172 3464) slumped, folded siltstones are overlain by planar-bedded, limonitic fine-grained, sandstone.

Dolomite has been proved under Quaternary deposits in offshore boreholes between Ma Shi Chau and Harbour Island. The assignation of this dolomite is uncertain; limestones and dolomitic limestones are known from the Devonian, the Carboniferous and the Permian in Guangdong.

Centre Island. Complexly faulted, contorted strata of similar lithologies to those of Ma Shi Chau occur across the entire island. Thin quartzitic sandstones are interbedded with dark siltstones at the southern tip of the island, while sandstones in beds up to 1.6 m occur in the north. About 150 m of strata are estimated to crop out on the island. Plant remains have been found in dark argillacous siltstones cropping out on the northeastern shore; no marine fossils have been found. Strata on the northwestern coast (4090 3342), which dip NE at 50°, display a younging direction to the northeast. Farther south (4094 3324) strata dipping W at 58° also young to the northeast. These attitudes are similar to those displayed on Ma Shi Chau.

Chinese University. The sedimentary rocks cropping out to the north and west of the Chinese University were included by Allen & Stephens (1971) within their Repulse Bay Volcanic Formation because of the reported presence of intercalated volcanic beds. Of the exposures cited by Allen & Stephens, that at the Chinese University has not been located during this survey, while

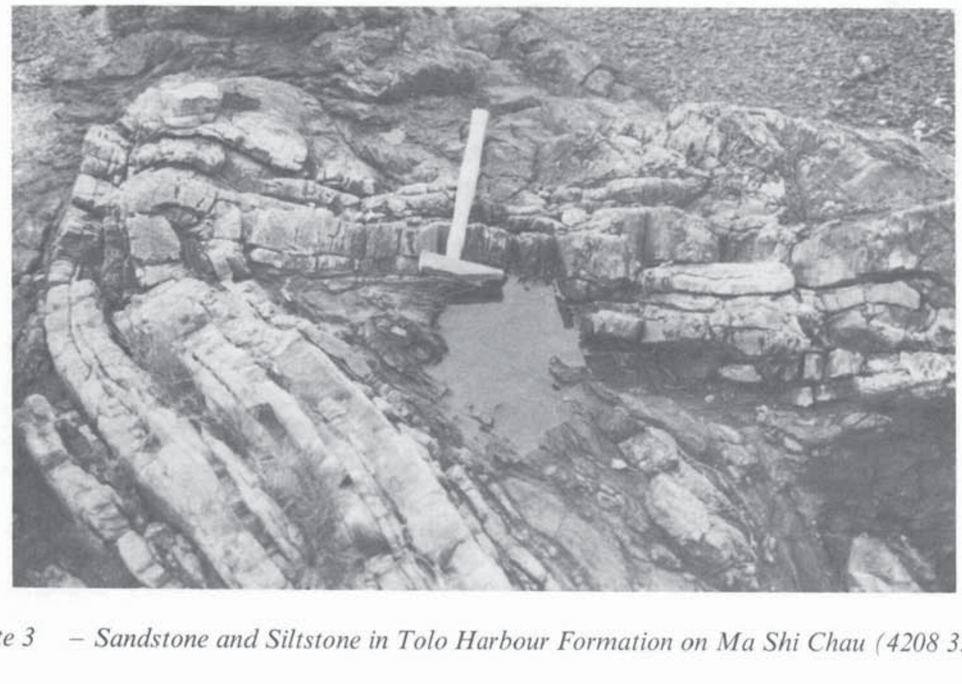
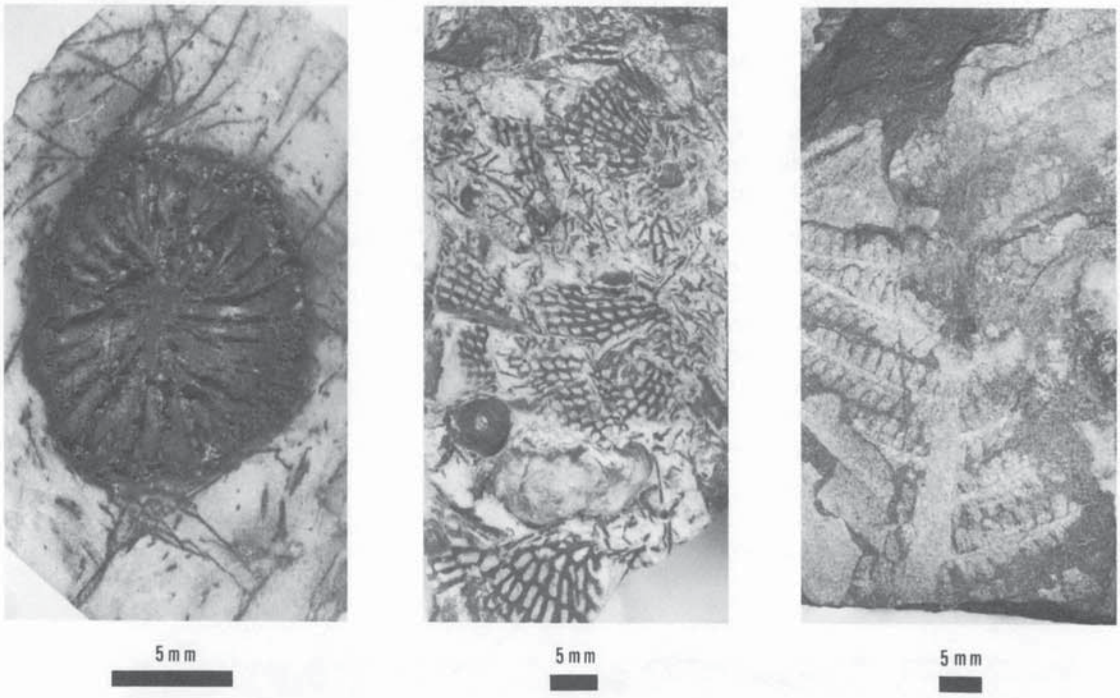


Plate 3 – Sandstone and Siltstone in Tolo Harbour Formation on Ma Shi Chau (4208 3539)

that above Po Min is regarded here as part of the volcanic succession of the Repulse Bay Volcanic Group, unconformably overlying the sedimentary rocks. The lithologies are dominantly grey to dark grey, fine- to medium-grained sandstones and laminated sandy siltstones. No fossils have been found but the laminated siltstones commonly show signs of intense bioturbation (3876 3158). Results of examinations for pollen and spores were negative.

In the stream section above Tai Po Mei (3814 3136) easterly dipping, faintly laminated sandstones up to 2 m thick occur, while upstream, close to the intrusions which separate Permian and Jurassic rocks, westward dipping, well-laminated sandstones show ripple marks and flaser-bedding. These features indicate a younging direction to the west. Elsewhere in the area, dips are generally around 70–80° to the E or S, and sedimentary features (worm burrows and flaser-bedding) indicate a younging in the direction of the dip, that is, away from the contact with the gently NW dipping Jurassic volcanic rocks lying to the west. From the general dip and the width of the outcrop, a thickness of up to 1 000 m of strata might be inferred, but the possibility of structural repetition of the sequence should be taken into account when estimating the overall thickness.



(a) (b) (c)

Plate 4 – Fossils in Siltstones of the Tolo Harbour Formation;
(a) the Coral ?Duplophyllum mikron (Yim et al, 1981);
(b) the Bryozoan Fenestella sp. and Crinoid Stems;
(c) Pecopteris (Asterotheca) norinii Halle; Specimens
(a) and (b) Collected on Ma Shi Chau by Mr. P. S. Nau;
Specimen (c) Collected on A Chau by Mr. C. M. Lee

Palaeontology

The age of the Tolo Harbour Formation is based on macrofossil occurrences in Ma Shi Chau. All examinations of samples for microfossils have proved negative. The fossils of Ma Shi Chau were first described by Ruxton (1960) who reported determinations by Dr Helen Muir-Wood of the British Museum. Dr Muir-Wood considered productoid brachiopods to be most probably of Permian age. Later discoveries by Lam (1973), Nau (1980) and Yim et al (1981) have confirmed a general Permian age for the strata. None of the assemblages of marine or plant fossils is entirely diagnostic.

Sedimentary Environment

As indicated above, the fossils include marine shelly remains as well as fragmentary plant debris. The two assemblages are not found in the same bed but in interbedded strata. The marine fossils are sparse, very poorly preserved, broken and abraded, and appear to have been transported. Interbedding of strata bearing marine and terrestrial fossils implies an environment that received detritus from both sources. A deltaic shallow marine environment is favoured. Re-deposited fossiliferous sediments and slumped beds are common features of the distal portions of the pro-delta; laminated, bioturbated, or flaser-bedded sandy siltstones occur either in pro-delta or tidal channel environments.

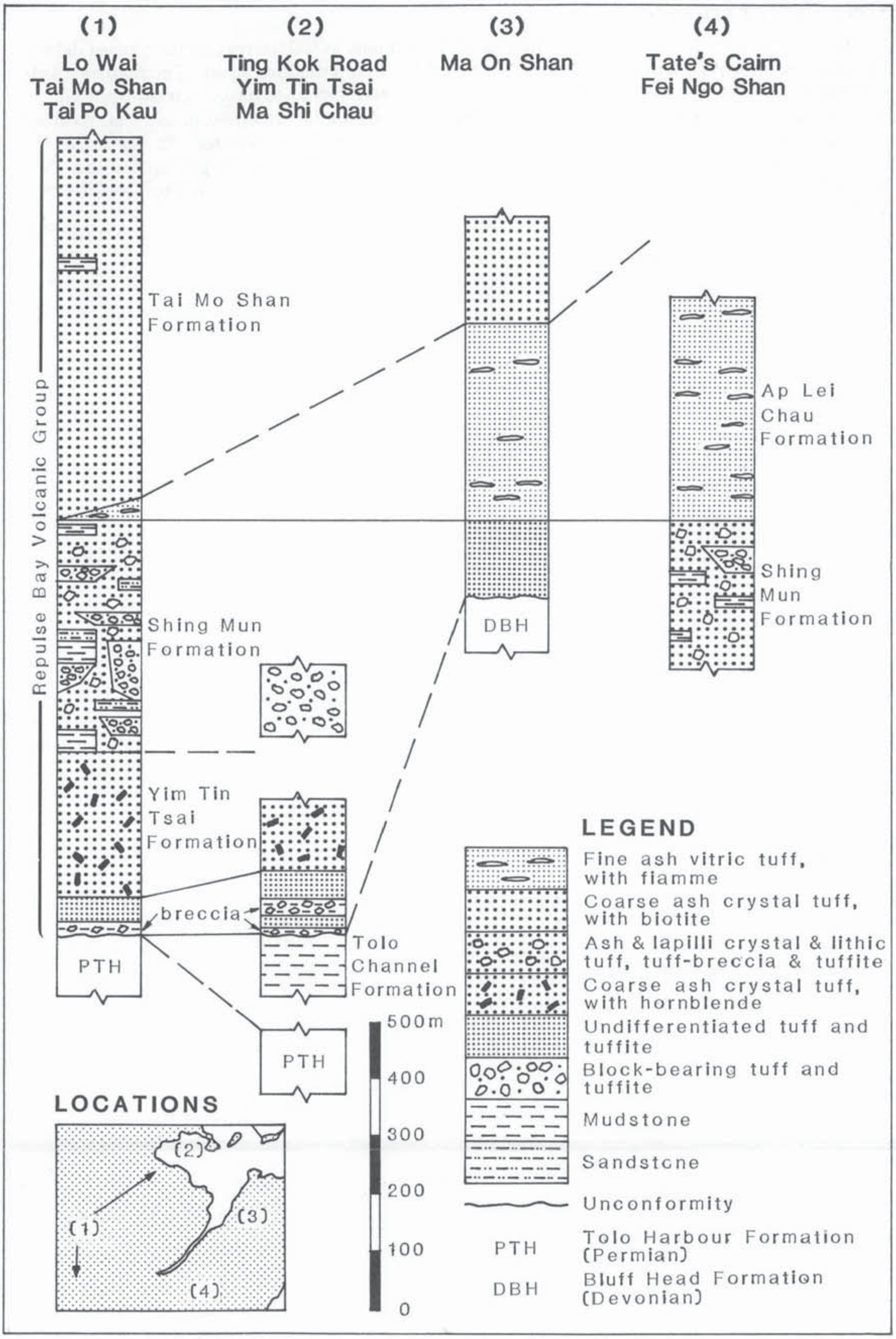


Figure 3 – Generalised Sequences of Mesozoic Sedimentary and Volcanic Rocks

Chapter 4
Mesozoic Sedimentary and Volcanic Rocks

Distribution and Classification

The Mesozoic succession is illustrated in Figure 3. In the Tolo Harbour area, it rests on the structurally complex sedimentary rocks of the Tolo Harbour Formation (Permian), while on Ma On Shan it rests on sandstones and siltstones assigned to the Bluff Head Formation (Devonian).

The oldest of these Mesozoic rocks within the district are mudstones and siltstones of the Tolo Channel Formation, of Lower Jurassic age (Lee, 1984). The strata form small outcrops on Ma Shi Chau and at Nai Chung, north of Ma On Shan. The Tolo Channel Formation is overlain or, to the southwest of Tolo Harbour, overlapped, by the Repulse Bay Volcanic Group, a complex succession dominated by tuffs that form sequences up to 1 200 m thick. C. M. Lee in Anon. (1985) regarded the Repulse Bay volcanic rocks as equivalent to the Upper Jurassic Gaojiping Group of central-eastern Guangdong Province.

Four named formations have been recognised in this survey within the Repulse Bay Volcanic Group. Each is characterised by a laterally extensive, distinctive lithofacies. Also included in the group are lithostratigraphic units of tuff and sedimentary breccia of local distribution, forming the basal part of the group but not given formational status.

Allen & Stephens (1971) recognised a number of distinctive lithologies within the volcanic succession, but chose to assign the entire succession to one formation, the Repulse Bay Volcanic Formation, with a type section at Repulse Bay on Hong Kong Island. They did not recognise the existence of the Tolo Channel Formation within the district. However, they assigned an additional formation, the Bluff Head Formation, to the Mesozoic succession. The Bluff Head Formation in its type outcrop is now known to be Devonian in age (Lee, 1982), while an outcrop of Bluff Head Formation mapped by Allen & Stephens (1971) on Ma Shi Chau in Tolo Harbour is now classified partly as Tolo Harbour Formation and partly as Tolo Channel Formation (Nau 1980).

The development of the names Tolo Channel Formation and Repulse Bay Volcanic Formation was reviewed by Allen & Stephens (1971). The name Repulse Bay Volcanic Group is introduced for the present survey. Although only one of the new formations in the group occurs in the Repulse Bay type-section of Allen & Stephens, the name Repulse Bay is retained on the grounds that it is well established and familiar.

Tolo Channel Formation
Stratigraphy

As described by Allen & Stephens (1971), the Tolo Channel Formation was restricted to a small outcrop of ammonite-bearing mudstones just beyong the eastern boundary of the district on the northwestern side of the Tolo Channel. Ammonites have since been found in siltstones at the southern tip of Ma Shi Chau (Lam, 1973), and in carbonaceous siltstones and mudstones at Sham Chung just to the east of the district in Three Fathoms Cove (Lee, 1984; Nau, 1984). Besides, Lower Jurassic fossils are reported by C. M. Lee and P. S. Nau (oral communication) in siltstones and mudstones at Nai Chung. The rocks of all these outcrops are assigned to the Tolo Channel Formation.

Details

Ma Shi Chau. The Tolo Channel Formation is exposed on the foreshore at the southern tip of Ma Shi Chau (4108 3451), where it consists of pinkish-brown weathered, laminated, micaceous siltstones, dipping steeply to the west. About 150 m of strata are estimated, but the contact with the Permian strata to the southeast (4120 3445) is faulted. The strata are unconformably overlain to the northwest (4105 3453) by sedimentary breccia that forms the base of the Repulse Bay Volcanic Group. The outcrop has yielded an ammonite fossil (Lam, 1973) indicating a Jurassic age. Apart from their steep dip, these strata are generally only weakly deformed, in marked contrast to the strata of the adjoining crop of Tolo Harbour Formation.

Nai Chung. At the jetty at Nai Chung (4422 3280) highly contorted, dark and pale grey siltstones and mudstones appear to underlie heterolithic conglomerates which crop out on the ridge immediately to the west. The siltstones and mudstones are reported to contain fossils of Jurassic age (C. M. Lee and P. S. Nau, oral communication).

Repulse Bay Volcanic Group

The Repulse Bay Volcanic Group of the district is divided on a lithostratigraphic basis into four main units (Figure 3). In this survey the descriptive nomenclature and classification of the pyroclastic rocks (tuffs) is based on Schmid (1981), and Fisher & Schmincke (1984). At the base of the group there are thin acidic welded tuffs interbedded with fine-grained tuffites classified as undifferentiated tuffs and tuffites. On Ma Shi Chau, Yim Tin Tsai and near Tai Po Kau a basal conglomerate or sedimentary breccia is present.

The oldest of the differentiated formations is the Yim Tin Tsai Formation. It is composed of welded ash-lapilli crystal tuffs and it appears to be restricted to areas north and west of Tide Cove. The Shing Mun Formation is an extremely variable assemblage of lapilli, coarse ash and fine ash tuffs and tuffites, any of which may be block-bearing; also conglomerate, sandstone, siltstone and mudstone. It occurs northwest of Tide Cove and the Sha Tin valley on Tai Mo Shan and around Tai Po. Southeast of the Sha Tin valley it is restricted to the area of Tsz Wan Shan and northeast of Shui Ngau Shan. It is absent from Ma On Shan and The Hunch Backs.

The welded fine ash crystal tuffs of the Ap Lei Chau Formation are best developed to the southeast of the Sha Tin valley. To the northwest of the valley, on the flanks of Tai Mo Shan, the formation is attenuated, and it is absent from the succession on Grassy Hill (Tso Shan). The Tai Mo Shan Formation is developed as a thick homogeneous unit of welded ash-lapilli crystal tuffs on Tai Mo Shan, and also around Pak Kong on the opposite side of the Sha Tin valley.

Yim Tin Tsai Formation and Underlying Rocks of the Repulse Bay Volcanic Group

Stratigraphy

The Yim Tin Tsai Formation is the oldest widespread tuff division within the group which has a distinctive appearance and mineralogy. Units of tuff and breccia underlie the formation (Plate 13) but are not considered sufficiently distinctive or widespread to warrant recognition as a separate formation. The formation crops out in the area north and northwest of Tide Cove, the type area being on Yim Tin Tsai in Tolo Harbour where about 200 m of strata are estimated. Farther west the formation is found around Tai Po Kau and Island House, Cove Hill, Fo Tan and Lo Wai (Kwai Chung).

The main lithology is a medium or dark grey, lapilli-ash crystal tuff. Occasionally it contains lithic blocks, usually up to 0.15–0.20 m, of crystal-rich, aphanitic volcanic rock. Crystals within the tuff are normally of feldspar, with lesser amounts of quartz, biotite and euhedral magmatic hornblende. Weak alignment of crystals and flattening of occasional fiamme and pumiceous lithic clasts indicate that the tuffs are welded. A chemical analysis of tuff from the Yim Tin Tsai Formation is given in Table 2.

Details

Ma Shi Chau and Yim Tin Tsai. Two thin lithostratigraphic units underlie the Yim Tin Tsai Formation and form the basal part of the Repulse Bay Volcanic Group. On Ma Shi Chau (4105 3451) the Tolo Channel Formation is unconformably overlain by about 5 m of sedimentary breccia. The magnitude of the break in sedimentation is not known although the dip of the breccia beds is less steep than that of the underlying siltstones and the change is sediment type is marked.

The breccia consists of angular clasts of pink or purplish siltstones, fine-grained sandstones and occasional vein quartz in a matrix of pale pinkish brown sandstone. It is trough-bedded in places and appears to be water deposited; however, elsewhere the layers of breccia are irregular and slumped. The clasts within the breccia are cleaved in some cases; in other instances they contain quartz veins and were probably derived locally from the Tolo Harbour Formation. The breccia is overlain by about 20 m of pale greenish grey tuffite and in turn by more breccia. The lowest few centimetres of the tuffite contain clasts of pink and red sandstones, identical to those in the breccia. The outcrop extends along the northwestern coast of Ma Shi Chau but, except for the most southerly part of the section where the base of the tuffite can be seen, exposure is poor.

Southwestwards, some 35 m of the upper breccia are well exposed on the shore at the eastern end of Yim Tin Tsai (Plate 13); these are succeeded by about 50 m of pale grey, lapilli-ash crystal tuff. This tuff is exposed on the peninsula that projects from the southern shore of Yim Tin Tsai (4038 3425). Here a cross-bedded sandstone forms a 0.5 m thick parting which can be traced for 40 m along the shore, within the tuff. In thin section the tuff from the eastern end of Yim Tin Tsai (HK 35, 4086 3453) is seen to be composed of lithic clasts and crystals in a fine ash matrix. Crystals constitute about 40% of the rock, with quartz and plagioclase (oligoclase) in subequal proportions and more abundant than alkali feldspar (microperthite). Biotite is rare and usually converted to muscovite. The matrix of the rock is composed of fine, recrystallised volcanic dust and lithic clasts showing occasional fiamme-like structures. Lithic clasts are of sandstone, or, more commonly, fine ash tuff.

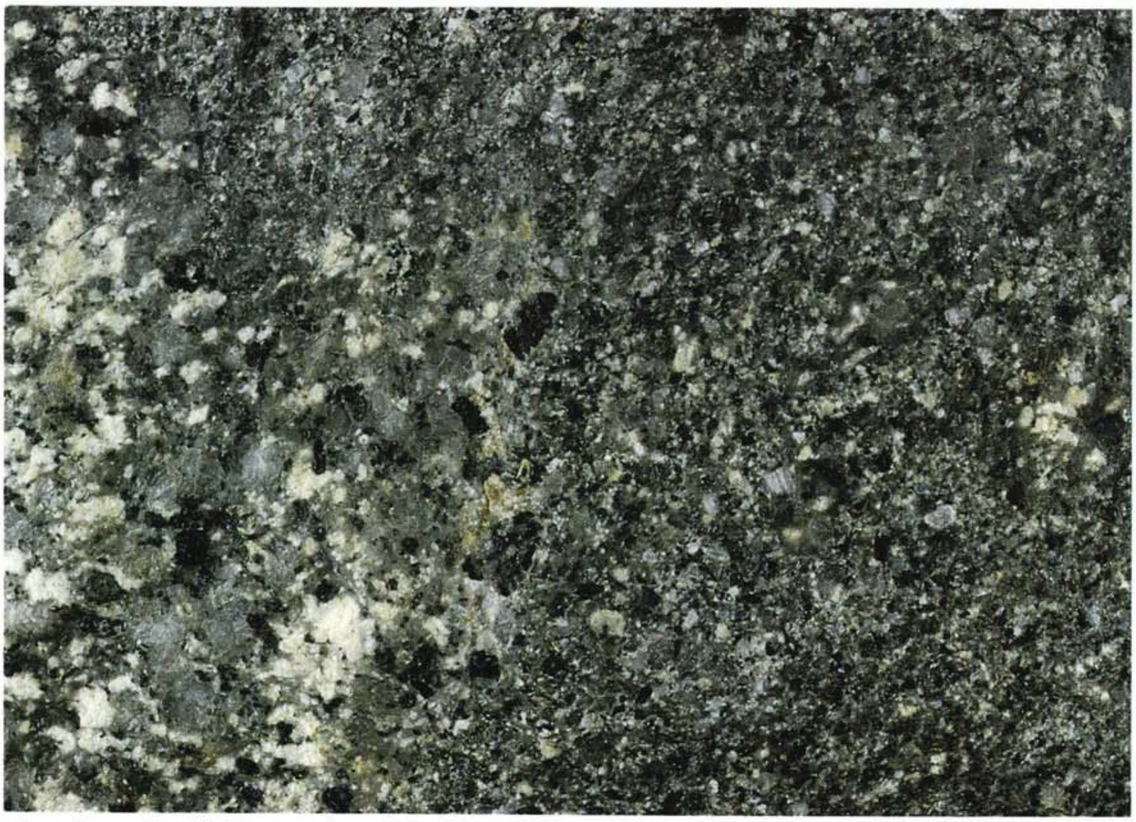
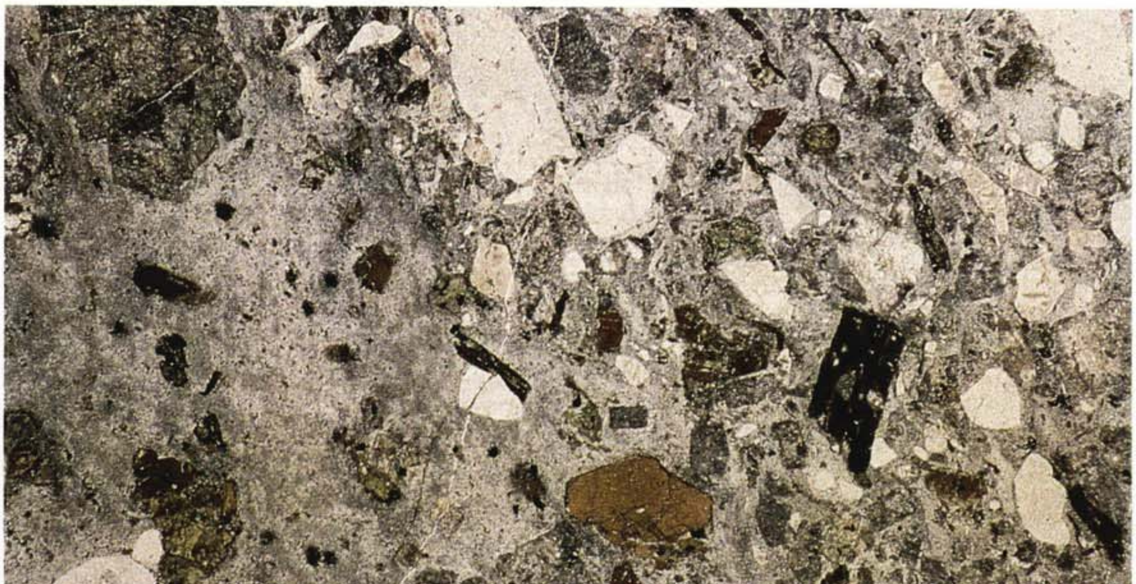


Plate 5 – Lapilli-bearing Crystal Tuff (HK 4952); Yim Tin Tsai Formation on Yim Tin Tsai (4054 3474); Note Diffuse-bounded Lithic Clasts; Natural Scale

Plate 6 – Thin Section of Tuff (HK 108); Yim Tin Tsai Formation at Tai Po Kau (3572 3356); PPL × 10



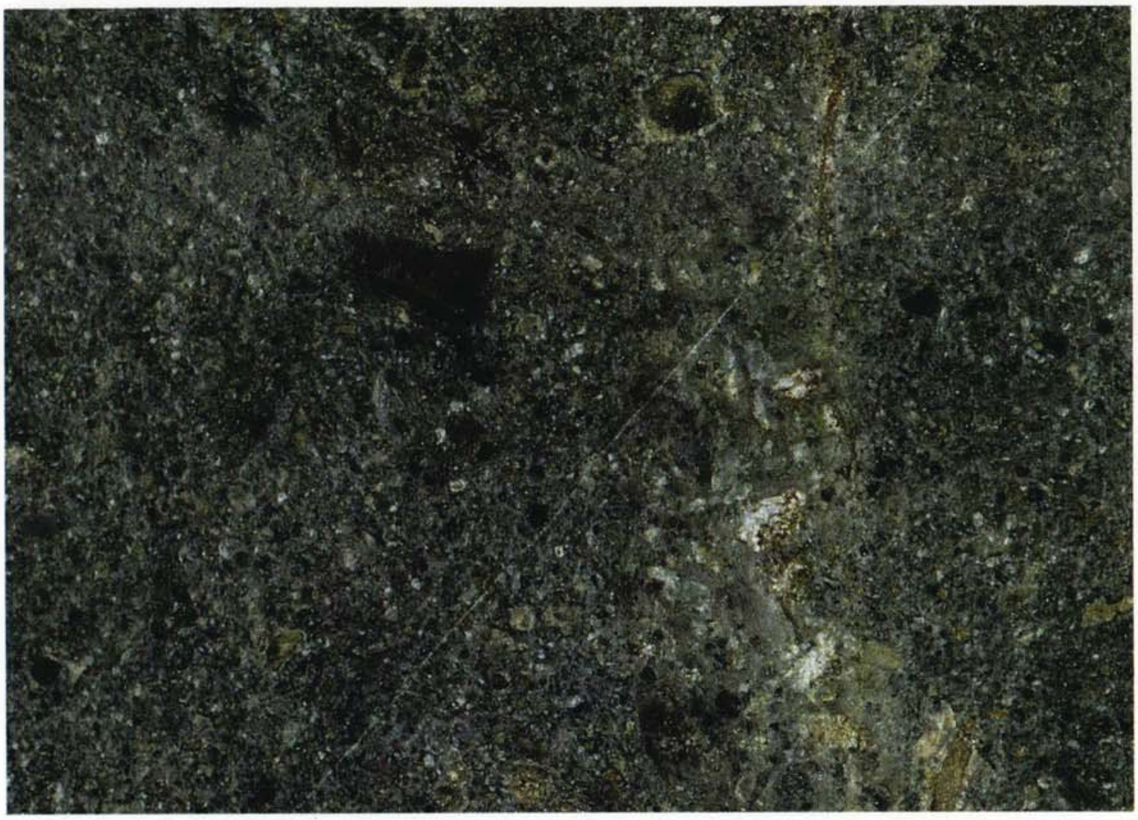
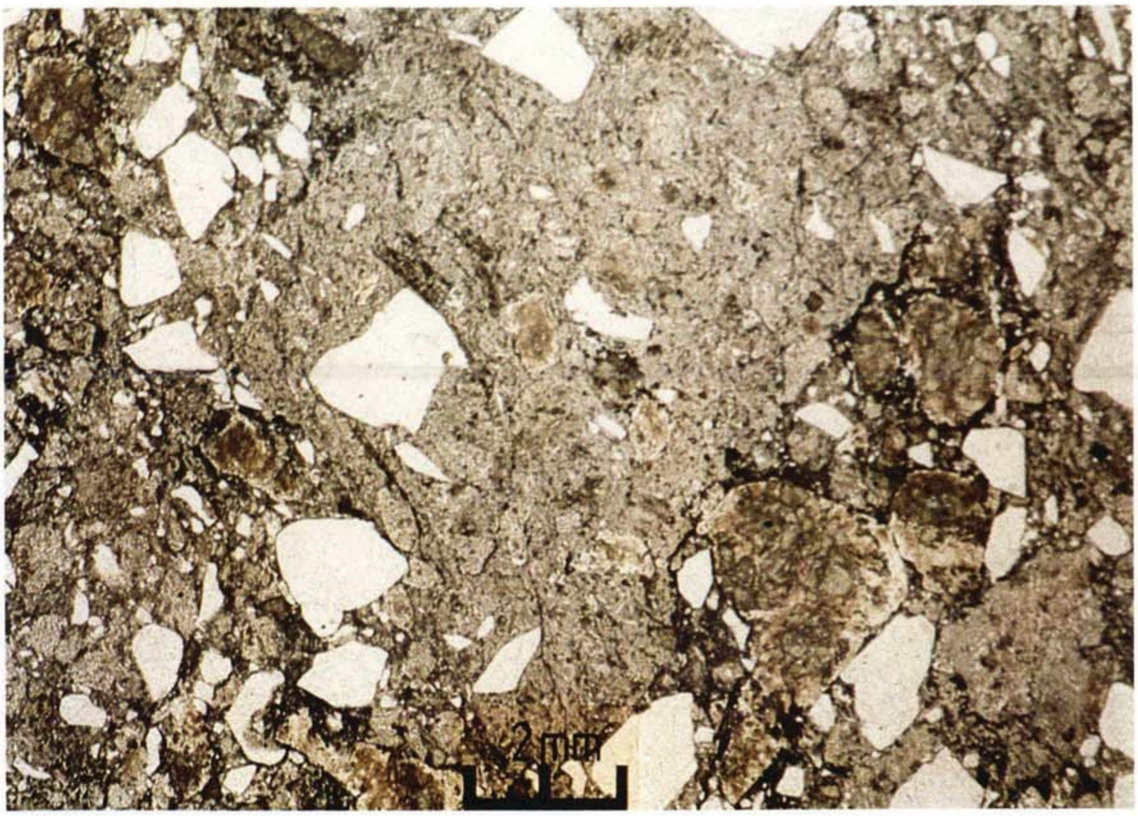


Plate 7 – Lapilli-bearing Ash Crystal Tuff (HK 4950); Shing Mun Formation on Grassy Hill (3518 3024); Natural Scale

Plate 8 – Thin Section of Tuff (HK 146); Shing Mun Formation on Grassy Hill (3479 3061); PPL × 10



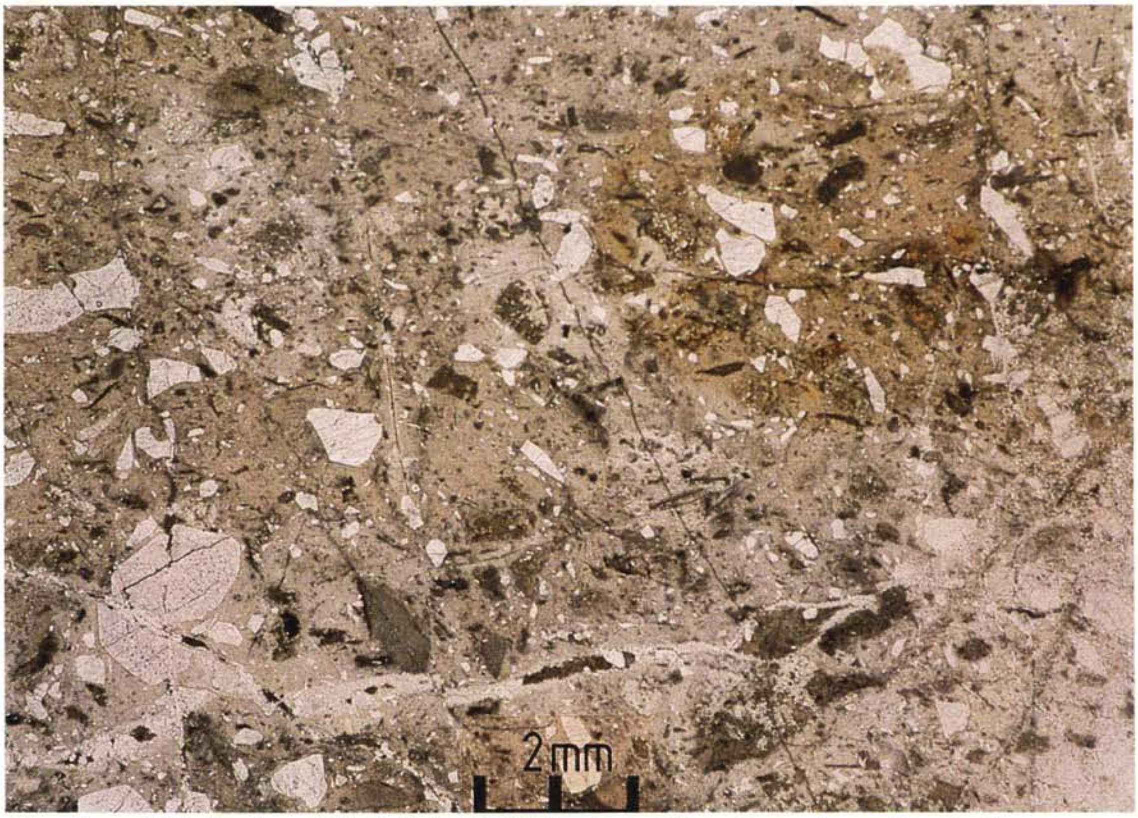


Plate 9 – Thin Section of Vitric Tuff (HK 822); Ap Lei Chau Formation on Ma On Shan (4416 2940); PPL × 10

Plate 10 – Lapilli-Ash Crystal Tuff (HK 4951); Tai Mo Shan Formation on Tai Mo Shan (3006 3018); Natural Scale

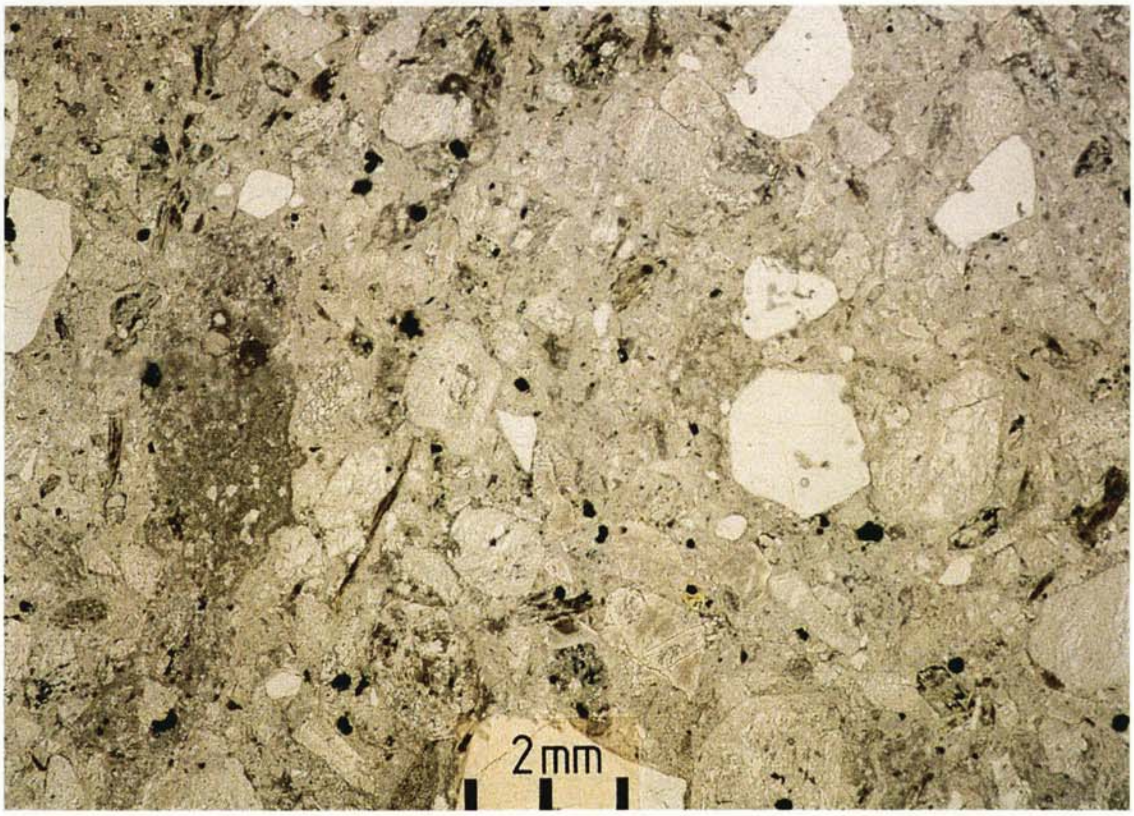


Plate 11 – Thin Section of Lapilli-Ash Crystal Tuff (HK 817); Tai Mo Shan Formation near Pak Kong (4477 2815); PPL × 10

Plate 12 – Thin Section of Granodiorite (HK 227) from near Tsuen Wan (3035 2630); XPL × 10

Tuffs of the Yim Tin Tsai Formation are particularly well exposed on the southwestern shore of Yim Tin Tsai, where they form low cliffs. The lowest rocks crop out on the peninsula described above (4044 3431), overlying the pale grey tuff. The precise contact is unexposed but appears to be lithologically sharp and conformable; the same lithological change can be seen at the eastern end of Yim Tin Tsai (4082 3453). The basal 20 m or so comprise dark grey, ash tuff with a faint, fine, crystal alignment and welding fabric. Thin sections (HK 37) show this rock to be a quartz-poor, biotite-rich, welded vitric tuff with a parataxitic texture of elongate, recrystallised, siliceous shards and fiamme. The contact of these lowest beds with the overlying main body of the Yim Tin Tsai Formation appears to be gradational. It is exposed at the eastern end of the island (4079 3461), where weak welding fabrics dipping N at 30–40° indicate superposition. These overlying rocks are grey to pale grey, lapilli-ash crystal tuffs, which are block-bearing in places. Crystals of feldspar are conspicuous, as are those of mafic minerals, biotite and hornblende. Two varieties of lithic clast are distinctive; small clasts of dark grey, fine-grained sandstones or siltstones, and lapilli and blocks (to 0.2 m) of dark, aphanitic volcanic rock with conspicuous aligned phenocrysts of feldspar (Plate 5). Welding fabrics have been recorded, e.g. at 4073 3464, but are not well developed. The top of the formation is cut out on Yim Tin Tsai by an intrusion of granodiorite.

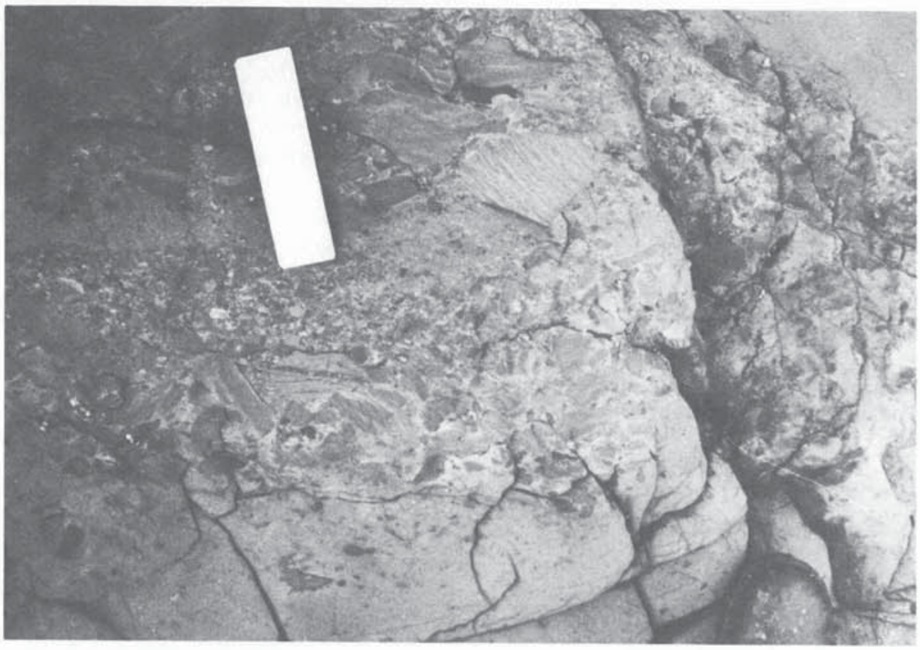


Plate 13 – Sedimentary Breccia in Basal Part of Repulse Bay Volcanic Group on Yim Tin Tsai (4088 3444); Scale 150 mm long

Island House (Yuen Chau Tsai) and Tai Po Kau. Tuffs of the Yim Tin Tsai Formation are well exposed along the shore of Tai Po Hoi from Island House (3625 3405) to Tsiu Hang (3860 3280). Around Island House the welding fabric is subhorizontal and, on the south of the island, common small lapilli of sedimentary rocks are also arranged in a subhorizontal fabric.

The basal strata of the Repulse Bay Volcanic Group, intruded by granodiorite and rhyolite, are exposed in the vicinity of St Christopher's Orphanage (3840 3253). A section seen in the road cutting (3815 3233) at Tsiu Hang showed a basal sedimentary breccia overlying sandstones assigned to the Tolo Harbour Formation. The breccia includes clasts of quartzite and phyllite and resembles that at the base of the Group on Ma Shi Chau and Yim Tin Tsai. The breccia grades upwards to tuffite with scattered lithic clasts and this tuffite is overlain in turn by lapilli-ash crystal tuff of the Yim Tin Tsai Formation (Table 2). This mixed sedimentary and volcanic sequence also crops out in the borrow area at Cove Hill (3880 3070), where it is similarly intruded by irregular bodies of granodiorite. The top of the Yim Tin Tsai Formation is seen on the western flank of Cove Hill (3755 2979) where it comprises mafic-rich, ash-lapilli crystal tuffs, overlain sharply by block-bearing, ash tuffs of the Shing Mun Formation. The top of the formation also crops out on the hill above Tai Po Kau (3619 3269), where the mafic-rich, lapilli-ash tuffs are overlain by flat-lying mudstones and siltstones of the Shing Mun Formation. The contact is not exposed.

Lo Wai and Shing Mun Reservoir. Minor outcrops of Yim Tin Tsai Formation flank the northern margin of the granites of Needle Hill, in places overlain by block-bearing tuffs of the Shing Mun Formation (3660 2920), while, further west around Lo Wai (3090 2690), there are more extensive outcrops comprising about 250 m thickness of strata, intruded at their base by granodiorite and overlain (3020 2714) by coarse ash tuffs of the Shing Mun Formation. The formation is best exposed in cut faces at the southern end of

Shing Mun Road (3140 2680) and along the Shing Mun Reservoir catchwater (3048 2698). Outcrops of tuff around Shing Mun Reservoir (3300 2760) are difficult to assign to a particular formation because thermal metamorphism by the adjacent granodiorite has destroyed original textures and recrystallised primary minerals. However, it seems likely that the Yim Tin Tsai Formation crops out in this vicinity.

Petrography

The tuffs of the Yim Tin Tsai Formation are distinctive in the field because of their colour, lithic clast content and crystal content. They are equally distinctive in thin section.

A typical specimen of the formation from Tai Po Kau (HK 108, 3572 3356, Plate 6) contains crystals of plagioclase (c 15%), quartz (c 12%), alkali feldspar (c 7%), biotite (chlorite) (c 7%) and hornblende (c 5%) in a matrix of quartz and sericite (Figure 4). Plagioclase crystals are up to 5 mm, euhedral but broken, and generally altered; when fresh they are clear, slightly blue under crossed-polarizers, twinned and occasionally strongly zoned, with extinction angles indicating compositions in the andesine range. Quartz occurs as crystals up to 5 mm which are rounded and resorbed, or occasionally small and splinter-like. Alkali feldspars are microperthite in large, broken euhedral crystals up to 4.5 mm; they are slightly clouded but otherwise fresh. Albitic feldspar can occasionally be distinguished by twinning within exsolution lamellae of the microperthite. Occasional small broken crystals of microcline microperthite occur. Biotite occurs as ragged and distorted laths up to 2 mm, which are pleochroic from dark brown to reddish brown, and commonly altered to chlorite. Hornblende up to 2 mm occurs as small, broken, euhedral crystals that are pleochroic from yellow to yellowish brown, and commonly show simple twinning. Lithic clasts up to several centimetres occur in hand specimen; in thin section these comprise a fine-grained matrix of recrystallised felsic platelets enclosing euhedral, unbroken crystals of the same species as those in the rock as a whole, with the addition of minor clinopyroxene. The matrix of the tuff is finely recrystallised quartz, sericite and iron ore.

Table 2 – Major Element Analyses of Tuff Samples from the Repulse Bay Volcanic Group

	Yim Tin Tsai Formation	**Shing Mun Formation**	**Tai Mo Shan Formation**
	St Christopher's Orphanage (3817 3230) HK 216	**Tai Po Kau Reserve (3630 3185) HK 215**	**Tai Mo Shan (3091 3033) HK 228**
SiO_2	71.04	73.61	68.96
TiO_2	0.45	0.36	0.60
Al_2O_3	13.67	12.59	13.89
Fe_2O_3	2.73	1.19	1.44
FeO	0.73	1.77	2.92
MnO	0.07	0.06	0.09
MgO	0.79	0.73	1.32
CaO	2.41	2.65	2.93
Na_2O	2.46	1.80	1.69
K_2O	4.69	4.77	4.92
H_2O^+	0.96	0.74	1.40
H_2O^-	0.14	0.09	0.14
P_2O_5	0.09	0.07	0.14
CO_2	—	—	—
Total	100.23	100.43	100.44

Volcanic Environment

The Yim Tin Tsai Formation is welded throughout its outcrops and must have been deposited from incandescent ash flows of considerable size. The onset of volcanism represented by the tuffs at the base of the Group appears to have been abrupt. It transformed what had been an erosive environment, with outcrops of Lower Jurassic and Palaeozoic sedimentary rocks, to one of major accumulation of pyroclastic deposits.

Shing Mun Formation

Stratigraphy

The Shing Mun Formation is the most complex formation of the Repulse Bay Volcanic Group in terms of individually mappable lithotypes. This variability is a characteristic of the formation, and lithologies include lapilli, coarse ash and fine ash tuffs and tuffites, any of which may be block-bearing (Plate 14); also conglomerate, sandstone, siltstone and mudstone. These lithotypes form mappable deposits in many outcrops but the members so mapped are rarely of great extent and have not been individually named.

The type area lies on the southern flanks of Tai Mo Shan, west of the Shing Mun Reservoir, where the formation is about 400 m thick. From there its outcrop extends northeastwards to Grassy Hill then northwards to Tai Po. It crops out again in the Lam Tsuen Valley. Unlike the Yim Tin Tsai Formation, the Shing Mun Formation extends into the area southeast of Tide Cove and the Sha Tin valley but it has not been recognised in the succession cropping out on Ma On Shan.

A chemical analysis of tuff from the Shing Mun Formation is given in Table 2.

Plate 14 – Block-bearing Tuff in Shing Mun Formation in Grassy Hill-Needle Hill Area (3570 2935)

Details

Tai Po and Hong Lok Yuen. In borrow areas south and east of Tai Po and around Hong Lok Yuen (3460 3590), complexly faulted and intruded sequences are composed predominantly of block-bearing tuffites of presumed laharic origin. The sedimentary rocks in these borrow areas (3600 3550 and 3790 3590) are extremely complex and it is possible that they represent large dislocated or slumped blocks within a lahar deposit. Large (up to 3 m) rounded blocks of skarn, composed of chlorite, tremolite and grossular, with carbonate nodules, are another feature of these borrow areas.

Kadoorie Farm and Tai To Yan. The Repulse Bay Volcanic Group outcrops of the Kadoorie Farm area are difficult to correlate lithologically since hand specimens and thin section (HK 341) invariably show some degree of thermal metamorphism or cataclastic deformation (3067 3183). The assemblage of rocks, however, includes tuffites, sandstones, siltstones and coarse ash tuffs; some tuffites are block-bearing (3165 3300) and correlate best with the Shing Mun Formation. This correlation is consistent with the interpretation of a syncline through Tai Mo Shan (Figure 9). The occurrence of granodiorite in this area may also be taken as supporting this broad correlation; granodiorite in other parts of the syncline intrudes as sills and dykes, consistently to the same general stratigraphic level. The Shing Mun Formation is recognised on the southeastern flank of Tai To Yan, northwest of the Lam Tsuen Valley. The succession there is dominated by lapilli-ash crystal tuffs but includes block-bearing tuffites (HK 352, 3040 3460) and at least two horizons of siltstone and fine-grained sandstone (3175 3549). The tuffs and tuffites are rich in secondary calcite, which forms plates and veins. The boundary between the Shing Mun Formation and the overlying Tai Mo Shan Formation appears to be transitional.

Grassy Hill and Tai Po Kau. The assemblage of block-bearing lapilli-ash tuffs, tuffites and sedimentary rocks (Plates 7 and 14) is well exposed on the ridges between Grassy Hill and Needle Hill (3570 2935) and on the hill south of Tai Po Kau (3742 3196). In this area the base of the formation can be placed at 3700 2942, where mottled, grey-green and brown, lapilli-bearing ash tuff overlies a massive ash-lapilli crystal tuff of the Yim Tin Tsai Formation which is rich in euhedral biotite and hornblende. The overlying succession is dominated by block-bearing tuffs (3570 2935) with subordinate sandstone and siltstone. A number of contacts of block-bearing tuff resting on lapilli tuff or sandstone illustrate the complex, variable nature of the formation. A chemical analysis of tuff from the Shing Mun Formation near Tai Po Kau is given in Table 2.

Tai Mo Shan. The succession cropping out on the southern flanks of Tai Mo Shan (3120 2734) is typical of the formation and is shown in Figure 3. The base crops out on the ridge north of Fu Yung Shan (3020 2714), Kwai Chung, where pale grey, lapilli-ash crystal tuff, poor in mafic minerals, (HK 388) overlies an ash-lapilli tuff of the Yim Tin Tsai Formation rich in mafic minerals (biotite and hornblende) and conspicuous feldspar (HK 389). Boulders from strata higher up the ridge line are of various lithologies, including interbedded tuffaceous sandstones and conglomerates in beds up to 3 m thick. Conglomerates are occasionally rich in limestone clasts up to 0.3 m set in a tuffaceous sandstone matrix (3025 2761). Elsewhere, rounded cobbles of quartzitic sandstone are more common (3042 2807) and the matrix is more clearly tuffaceous. A fossil from one of the limestone cobbles from the conglomerate has been identified as a brachiopod, probably a chonetacean of Carboniferous or Permian age (C.H.C. Brunton, written comm). The implication of this occurrence is that Carboniferous or Permian limestones underlie the volcanic source area. About 100 m thickness of conglomerates, siltstones, and lapilli- and block-bearing tuffs are estimated on the southern ridge of Tai Mo Shan, with coarse, block-bearing deposits occurring at two or possibly more levels (3022 2732 and 3056 2832).

On the southeastern ridge of Tai Mo Shan the lithotypes are more clearly defined. Block-bearing deposits with limestone clasts form crags above the catchwater (3144 2728). They are about 50 m thick and dip gently northwards. At their top they are bedded and are considered to have been alluvially re-worked; lower down they are composed of a chaotic assemblage of rounded and angular blocks of volcanic and sedimentary rock types, and are probably laharic in origin. The block-bearing deposits form a distinct shoulder on the ridge crest, above which siltstone and overlying quartzitic sandstone crop out (3154 2769). The siltstone may be continuous with the siltstone seen on the southern ridge of Tai Mo Shan (3020 2787) and in the valley of the Shing Mun River (3300 2900), where it can be seen to be interbedded with siliceous tuffites. The siltstone and quartzitic sandstone total some 40 m thickness and are overlain by pale grey, lapilli-ash and ash tuff which typifies the tuff deposits of the formation. In places, e.g. 3160 2805, these tuffs include lenticular layers rich in angular blocks of tuff and rounded cobbles of quartzitic sandstone.

The uppermost beds of the formation are ash-lapilli tuffs with occasional small sandstone clasts, as seen for example at 3154 2818, and these are overlain at 3164 2842 by about 20 m of pale buff, ash crystal tuff which contains common biotite flakes and small fiamme in a faintly aligned, probably welded, fabric. This latter lithology, which crops out also on the southern ridge of Tai Mo Shan (3024 2870) is considered to be a thin representative of the Ap Lei Chau Formation, a unit that appears to thin out altogether farther north.

Southeast of the Sha Tin Valley. The Shing Mun Formation crops out on the ridge of Tate's Cairn (4020 2408) and on the ridges north of Wong Ngau Shan and Shui Ngau Shan where outcrops are complexly faulted and intruded. The lithologies represented are generally dark, bluish grey, ash crystal tuffs with common thin (up to c 5 m) units of laminated, dark grey mudstones and crystal-bearing mudstones. These units of sedimentary rock are discontinuous and disturbed, probably syndepositionally, as can be seen at Tate's Pass (4095 2400).

Petrography

The volcanogenic deposits of the Shing Mun Formation may be considered in two classes for purposes of petrographic description. Those rocks of primary volcanic origin and those of secondary or reworked origin including the laharic deposits and the tuffites. The rocks of primary volcanic origin are mainly lapilli-ash crystal tuffs. Point counts on thin sections show 13 to 23% quartz crystals, 5 to 15% alkali feldspar crystals and 6 to 12% plagioclase feldspar crystals. Variations in total percentages of crystals are dependent upon the grain size of the deposit, the relative proportions of the three minerals within the coarser-grained rocks being more consistent and plotting in a relatively small field on a ternary diagram (Figure 4).

Figure 4 – QAP Diagram Showing Relative Proportions of Minerals in Tuff Samples from the Yim Tin Tsai and Shing Mun Formations (based on point counts of thin sections)

The tuff (HK 146) from the northern side of Grassy Hill (3479 3061) is typical of these primary pyroclastic lithologies. This rock (Plate 8) comprises quartz grains up to 4 mm (21%), alkali feldspar crystals up to 3 mm (15%), and plagioclase crystals up to 3 mm (13%). Quartz grains are euhedral, but broken and often deeply embayed. Alkali feldspar grains are broken, euhedral but clouded and commonly replaced in part by epidote; they show uneven extinction and are cryptoperthitic. Plagioclase grains are broken or in small clusters and, like the alkali feldspars, are usually altered, replaced in this case by sericite. Measurements on twin-plane extinction angles indicate compositions in the range of oligoclase. Mafic minerals are sparse, consisting of pale chlorite which is probably an alteration product of biotite. Iron ore minerals are finely scattered throughout the fine felsic matrix and form a distinct coating to most crystal and lithic grains. Lithic clasts up to 10 mm are recrystallised ash tuff, porphyritic, with all the crystal phases noted as crystals in the matrix. Flattening of some of the smaller lithic clasts may represent a welding fabric although no such fabric was noted at the outcrop.

The tuffite from Lead Mine Pass (HK 247, 3380 2982) is typical of rocks of mixed pyroclastic and re-worked volcanogenic debris. The rock is composed of quartz (c 18%) up to 3 mm in large angular broken crystals, small splinter-like fragments and sub-rounded grains. Plagioclase (c 8%) up to 2 mm occurs as euhedral but broken clasts, occasionally fresh, with multiple twinning and extinction angles indicative of oligoclase; alkali feldspar (c 6%) up to 2 mm is usually euhedral, broken and altered to epidote and sericite. Chloritised biotite is sparse; lithic fragments are common (c 10%) up to 5 mm, usually irregular or sub-rounded and consisting of siltstone, mudstone, volcanic glass, welded tuff and microlitic, porphyritic lava; the matrix is composed of comminuted crystal and lithic debris and is commonly replaced by large patches of epidote.

Beside these main lithologies there are also tuffaceous siltstones (tuffites) such as those cropping out south of Tai Po (HK 68, 3448 3329). This particular thin section is significant in that the plagioclase feldspar grains, although fragmentary, exhibit zoning and twinning extinction angles indicative of andesine compositions. These crystals, as well as occasional grains of magmatic hornblende, may be re-worked from the Yim Tin Tsai Formation. Alternatively they may represent minor influxes of tuffaceous material from a different source than that providing the bulk of the debris of the formation. Occasional, thin, discontinuous horizons of tuff bearing magmatic hornblende and zoned andesine plagioclase have been noted within the Shing Mun Formation (HK 189, HK 383).

Two other outcrops within the Shing Mun Formation are petrographically significant. Both rocks are microcrystalline, dark grey and porphyritic, and are believed to be andesite lavas. The outcrop at Au Pui Wan (3585 2936) is small and has not been traced laterally, while that at Ma Wo (3442 3343) is a unit approximately 5–10 m thick. Thin sections of both rocks (HK 66 and HK 273) show complexly zoned phenocrysts of feldspar of andesine to labradorite composition, along with euhedral phenocrysts of clinopyroxene and iron ores in a recrystallised felsic and chloritic matrix.

Sedimentary and Volcanic Environments

The Shing Mun Formation is lithologically the most variable formation of the Repulse Bay Volcanic Group but to an extent the variability allows a clear evaluation of the depositional environment of the unit.

It can be assumed that the general environment remained stable throughout the time of the deposition of the formation; there was no catastrophic uplift or submergence. Siltstones, sandstones and conglomerates are water-lain, fluvial, lacustrine or shallow marine in origin. A shallow, low-lying intermontane basin is envisaged. Pyroclastic rocks, including block-bearing tuffs, would accumulate in this environment mainly by ash-flow from adjacent volcanic vents or fissures. The tuffaceous conglomerates are clearly not directly vent related but are re-deposited, sheet or lobate bodies of chaotic debris. These probably accumulated as lahars or mudflows and blocky debris flows derived from an adjacent volcanic edifice. Thick ash deposits containing large blocks may be transported many tens of kilometres from their source area by pyroclastic flow or laharic flow (Fisher & Schmincke, 1984). The crystal-bearing mudstones found at Tate's Cairn (4095 2406) are subaqueous deposits which were probably deposited by slumping of unlithified, interbedded, air-fall crystal tuffs and dark grey mudstones.

The skarn blocks recorded in the Tai Po borrow areas (3600 3550 and 3850 3580) have developed a grade of metamorphism which must have been induced prior to their inclusion within the laharic deposits in which they occur. It is inferred that limestone or calcareous siltstones could have been metamorphosed in subvolcanic chambers or vent walls. This metamorphism is clearly earlier than any induced by the intrusion of the late Jurassic granites.

Ap Lei Chau Formation

Stratigraphy

The Ap Lei Chau Formation is described here but its formal definition awaits the description of the thick, distinctive successions of the type area near Aberdeen on Hong Kong Island. The lithology there is dominated by fine ash vitric tuff, with crystals and pumice fragments. In most exposures pumice and vitric clasts are flattened and stretched within a welded eutaxitic or parataxitic fabric (Plate 15). Elsewhere pumice fragments or fiamme are absent and the rock is a pale buff weathering, grey to dark grey, coarse-ash bearing fine ash vitric tuff. These homogeneous tuffs may contain slender welded vitric shards which may be visible with hand lens or naked eye. The Ap Lei Chau Formation is the only unit in which these features are known to occur.

Within the district the formation occurs mainly in the area south and east of the Sha Tin valley, on the high ridges of Ma On Shan, Shui Ngau Shan and Wong Ngau Shan, and on Tung Yeung Shan. It is estimated that the formation there is up to 300 m thick but most outcrops are complexly faulted and this figure may be inaccurate. The outcrops on the summits of Ma On Shan and The Hunch Backs, northwest of the northeast-trending fault which passes by the summits, have been included tentatively in the Ap Lei Chau Formation on lithological grounds and because of their structural and geographical association with rocks more easily recognisable as Ap Lei Chau Formation southeast of that fault.

On Tai Mo Shan there are outcrops of a pale buff, ash vitric tuff with small fiamme, which, although thin, is traceable around the southern flanks of the mountain. This tuff lies at the level of the change from the mixed tuff and tuffite assemblage of the Shing Mun Formation to the almost exclusively pyroclastic ash flow assemblage of the Tai Mo Shan Formation. For these reasons it is regarded as an attenuated representative of the Ap Lei Chau Formation.

Chemical analyses are available for the formation, and its composition is indicated to be rhyolitic (Tables 3 and 8, Figure 8).

Plate 15 – Vitric Tuff in Ap Lei Chau Formation on Shui Ngau Shan (4210 2624)

Details

Tung Yeung Shan. The best exposures of the Ap Lei Chau Formation within the district are those in the upper part of the sequences on Tung Yeung Shan ridge, immediately east of Tate's Pass. The rocks here are generally pale grey, lapilli-bearing ash vitric tuffs. Lapilli are usually flattened pumice fragments (fiamme) which may be porphyritic. Crystals of quartz and feldspar 2–3 mm long are common. Vitric shards are commonly visible in hand specimen as grey-brown, flattened vermiform shapes up to 2 mm long. The welding fabric represented by the flattened fiamme dips generally to the east at around 35° (4111 2473).

Wong Ngau Shan, Shui Ngau Shan. The outcrops of these hills are structurally complex. Measurements of welding fabrics are steep and the outcrops are cut by northeast- and northwest-trending faults, and are intruded by dykes. Exposures of clearly recognisable welded fiamme and shard-rich, ash tuffs occur (HK 1065, 4210 2624, Plate 15) but stratigraphic relations with the similarly complex outcrops of the Shing Mun Formation, which form the lower slopes of the hills, are not clear. No contact with the overlying Tai Mo Shan Formation has been observed.

Ma On Shan. The outcrops on Ma On Shan are divided by a major northeast-trending fault which downthrows stata to the southeast. Exposures of tuffs on this downthrow side are pale grey, coarse ash-bearing fine ash tuffs which contain common vitric shards, sometimes visible in hand specimen. Crystals are mainly of feldspar, some of which show a blue iridescent schiller effect. Welding is well developed and in places (4400 2950) columnar jointing can be seen. Welding fabric develops into a strong parataxitic fabric which resembles flow-folding (4418 2940) but thin sections can be used to distinguish these tuffs (HK 822, Plate 9) from adjacent flow-banded rhyolite intrusions (HK 823, 4451 2915). Dips of the welding fabric are not consistent across the area and mappable contacts are either faulted or intruded by rhyolite, making interpretation of the succession difficult.

Northwest of the major northeast-trending fault on Ma On Shan the outcrop of the volcanics is disturbed by subsidiary faults and folds. Lithologies are difficult to correlate but closest resemblances are with tuffs of the Ap Lei Chau Formation. Fiamme-rich welded tuff (HK 829) crops out on the ridge north of the summit of Ma On Shan (4405 3001). The base of the Repulse Bay Volcanic Group on Ma On Shan can be seen on the ridge southwest of the summit (4385 2962), where thin tuffs, up to 2 m thick, are interbedded with dark grey argillaceous sandstones. However, lithologies are all somewhat altered and identification of rock types is problematical.

The Ap Lei Chau Formation also crops out on dissected ridges above Mau Ping Lo Uk (4320 2786), where it is intruded by aphanitic rhyolites, and to the south, where it is faulted against tuffs of the Tai Mo Shan Formation lying to the northwest.

Tai Mo Shan. A few exposures of a relatively thin (20–30 m) pale buff coloured, ash vitric tuff occur on the southern flanks of Tai Mo Shan (3154 2818 and 3024 2870). Mapping indicates that these outcrops consistently lie between the mixed pyroclastic-epiclastic lithologies of the Shing Mun Formation and the entirely pyroclastic, ash flow, ash-lapilli tuffs of the Tai Mo Shan Formation. Because of similarities between the lithologies found at these localities (HK 319, 374) and tuffs of the Ap Lei Chau Formation, and because of the position of the outcrops in the Tai Mo Shan succession, the correlation has been sustained. The implications of the correlation are that the Ap Lei Chau Formation shows dramatic thinning northwards across the Sha Tin valley.

Petrography

Specimen HK 822, from the ridge southeast of Ma On Shan (4418 2940), is typical of the Ap Lei Chau Formation tuffs of that area. In hand specimen the rock is dark grey fine ash with conspicuous crystals of feldspar. In thin section crystal phases consist of alkali feldspar (c 8%) up to 2 mm, quartz (3–4%) up to 1.5 mm and plagioclase feldspar (3–4%) up to 2.5 mm. All the crystal phases are broken and resorbed, originally euhedral, grains. Alkali feldspar is normally fresh or slightly clouded without exsolution of albite or microcline twinning. Plagioclase is oligoclase and is moderately fresh with multiple twinning; it is usually present as slightly broken euhedral crystals, occasionally as fine splinters. Quartz often occurs as deeply resorbed, skeletal grains and fine splinters. The matrix is composed of fine vitric shards, flattened in a eutaxitic fabric with distinct cuspate shapes, but recrystallised in part in an axiolitic texture, elsewhere in anhedral felsic plates. Occasional drawn-out fiamme of porphyritic glass occur with phenocrysts of quartz, plagioclase, orthoclase and biotite.

Specimen HK 783 is a tuff from Tung Yeung Shan (4112 2436) and shows slight differences from the previous thin section. The crystal content is slightly higher, although the form and nature of the species are the same. The matrix is finely recrystallised and welding has advanced to the stage that shards are indistinguishable, a fine parataxitic banding being the only evidence of welding. Lithic clasts are similar to the previous sample being felsic, recrystallised and porphyritic, with quartz, two species of feldspar and biotite.

Specimen HK 1065, from Shiu Ngau Shan (4210 2624), is a good example of a tuff showing a well developed eutaxitic fabric. Crystals constitute about 30% of the rock and are dominated by alkali feldspar (c 15%) in altered, fractured, clear grains up to 3 mm, some of which show minor perthitic exsolution. Plagioclase (oligoclase) occurs as broken euhedral crystals to 2 mm showing fine twinning but often deeply altered to sericite. Quartz grains are euhedral, broken and up to 2 mm, or more generally rounded and up to 1 mm. Lithic clasts of felsic recrystallised porphyritic glass up to 8 mm long are flattened, distorted and welded along with smaller stretched fiamme. The matrix is composed of recrystallised fine ash.

Volcanic Environment

The Ap Lei Chau Formation tuffs of this district are distinctive because of their generally fine ash grain size and low crystal content. Lithic clasts, when present, are usually porphyritic glass flattened to a eutaxitic welded fabric. In places these welded fiammé are extremely conspicuous and form the most important field character for the recognition of the formation.

Welded tuffs of the lithologies described originate as incandescent ash flows which may issue from a central vent, in which case the flows are small and usually linear to lobate. Larger volume sheets of welded tuff have been generally related to calderas (Smith, 1979), although Fisher & Schmincke (1984) also suggest the possibility of the eruption of large volume ash flows from central-vent type eruptions by collapse of a Plinian eruption column as described by Sparks & Wilson (1976). The Shing Mun Formation, which underlies the Ap Lei Chau Formation, is believed to have been deposited mainly by ash flows and laharic debris flows, presumably derived from a major volcanic edifice. It is likely that the tuffs of the Ap Lei Chau Formation originated from a similar source.

In thickness and extent the deposits of the Ap Lei Chau Formation would be classified as large volume flows although the asymmetry of the occurrence of the formation on opposite sides of the Sha Tin valley would apparently be inconsistent with this view. However, penecontemporaneous activity on the Lai Chi Kok – Tolo Channel Fault, causing uplift on the northwestern side, could have resulted in non-deposition or erosion of the Ap Lei Chau Formation from that region. Alternatively, original asymmetry of the eruption might have been responsible for the attenuation of the formation on Tai Mo Shan.

The site of the fissure or vent which produced the tuffs is not known. However, it is possible that it lies in the region of Shek Nga Shan. This hill is composed of a dark grey, flow-banded, porphyritic rhyolite, here considered to be of magmatic origin. This rock body was mapped by Allen & Stephens (1971) as part of their Repulse Bay Volcanic Formation but the evidence of irregular flow-banding and geometry of the body, which forms a plug-like mass at least 300 m high would imply an intrusive origin. The occurrence of similar bodies further to the northeast on Ngong Ping Shan (4410 2861) and at Mau Ping Lo Uk (4330 2774), in rather different geological settings, would support this conclusion. In addition, it may be significant that feldspars showing blue schiller effects noted in the Ap Lei Chau Formation at Ma On Shan (4438 2973) are also present in the rhyolite on Shek Nga Shan (4187 2734). The weight of evidence thus indicates a volcanic source in this area.

Tai Mo Shan Formation

Stratigraphy

The Tai Mo Shan Formation is the youngest and most widespread of the formations recognised within the Repulse Bay Volcanic Group in the district. The name Tai Mo Shan Formation was originally applied by Brock & Schofield (1926) and Uglow (1926), although both publications described the formation as being of intrusive origin. However, from their descriptions it is clear that the rocks to which they refer in their type area are in fact the welded, lapilli-ash crystal tuffs which form the summit and main mass of Tai Mo Shan. In view of this, the name Tai Mo Shan Formation has been revived in this survey.

The formation is best exposed on Tai Mo Shan, where it is disposed in an open broad northeast-trending syncline, and on the ridge that extends eastwards from Tai Mo Shan towards Lead Mine Pass. The base is not well exposed but crops out on the southern and southeastern ridges of Tai Mo Shan where the formation overlies a thin development of the Ap Lei Chau Formation. The sequence on Tai Mo Shan is approximately 600 m thick although the top is not seen. The Formation also occurs in extensive outcrops around Pak Kong Tsuen and Ho Chung, southeast of Ma On Shan Tsuen, and on Tai To Yan.

The massive tuffs of the Tai Mo Shan Formation weather to an orange to reddish brown saprolitic soil with large corestones. On summit areas, corestones form large fields of cuboidal blocks and toppled tors, some of which are 3–4 m high. These block or boulder fields are to an extent characteristic of outcrops of the formation. The rocks are generally massive and rather uniform in composition. They vary from pale to dark grey and from lapilli to coarse ash tuffs (Plate 10). The coarse ash tuffs are more common, but lapilli of quartz, feldspar and volcanic glass (fiamme) are the most conspicuous field characters. Pale grey sandstone clasts up to 20 mm and dark green biotite crystals are also common components. Volcanic lithic clasts are commonly flattened to form fiamme and aligned in a eutaxitic fabric. Chemical analyses of tuff from the Tai Mo Shan Formation on Tai Mo Shan are given in Tables 2 and 3.

Details

Tai To Yan. The Tai Mo Shan Formation crops out on the summit and northwestern flank of Tai To Yan, where it consists mainly of lapilli-ash and coarse ash crystal tuffs. The tuffs usually contain scattered, small, sub-angular lithic lapilli of mudstone and siltstone. Secondary calcite and biotite characterise the tuffs seen in thin section.

Tai Mo Shan. The base of the formation is exposed on the southern (3020 2880) and southeastern (3155 2843) ridges of Tai Mo Shan where lapilli-ash crystal tuffs overlie the ash vitric tuffs which are considered to be the attenuated representatives of the Ap Lei Chau Formation. The Tai Mo Shan tuffs, besides being coarser, and rich in crystals and clasts of volcanic glass, are more homogeneous and weather more massively into cuboidal blocks, which in places form boulder fields. Proportions of different crystals vary, as does the state of preservation of crystal phases. This is particularly obvious with respect to feldspars and biotite, which are more conspicuous in certain exposures (3360 3055). Lithic clasts of porphyritic volcanic glass, are common, generally 2–3 mm in length, although occasionally up to 30 mm and these are usually flattened in a moderately well developed eutaxitic fabric. Other lithic fragments, notably small clasts of pale grey sandstone and dark grey siltstone, are locally conspicuous. Despite the lithological variation within this sequence, none of the variants has proved to be mappable. The formation is very similar in its development on the ridge east of Tai Mo Shan (3220 3095) and on the ridge enclosing the valley of Yuen Tun Ha. As on Tai Mo Shan, the tuffs commonly form fields of large tors and lag boulders surrounded by deep residual soils.

Pak Kong and Ma On Shan Tsuen. The formation forms two outcrops on either side of the Ngong Ping Shan Fault. To the east and southeast of Ma On Shan Tsuen (4375 2912 and 4320 2855) the outcrop is bounded by faults and intrusions. Southeast of Ngong Ping Shan the outcrop forms a thick southeasterly dipping sequence, the top of which is not seen, and the base of which is faulted. The lack of unambiguous stratigraphical contacts makes the interpretation of the succession in this area difficult. From the geometry of the outcrops it is inferred that the lapilli-ash crystal tuffs of Pak Kong overlie the fine ash tuffs of the Ap Lei Chau Formation on Tung Yeung Shan, which in turn overlie the Shing Mun Formation on Fei Ngo Shan (Kowloon Peak) to the south of the district. For these reasons the lapilli-ash crystal tuffs of Pak Kong are taken to belong to the Tai Mo Shan Formation.

As on Tai Mo Shan, the outcrop of the Pak Kong area is of grey or dark grey, lapilli-ash crystal tuff rich in quartz, feldspar, biotite and flattened lithic fragments of volcanic glass. Horizons of dark grey tuff conspicuously rich in mafic minerals (biotite and hornblende) are moderately common in the lower part of the succession exposed on Fu Yung Pit hill (4260 2589) and on the ridge extending northwards from there to Ngong Ping (4400 2785). To the southeast the tuffs are paler grey and less rich in mafic minerals, although still containing conspicuous crystals of quartz and feldspar. Little variation was noted across this area either in field characters or thin section.

Northwest of Ngong Ping, east and southeast of Ma On Shan Tsuen (4375 2912 and 4320 2855), are two hillsides which differ from surrounding terrain in that they are capped by tors and boulder fields. The lithology of the rocks in both cases is lapilli-ash crystal tuff, rich in conspicuous plagioclase and in places containing lithic clasts of pale grey sandstone and dark grey mudstone. Occasional lithic clasts of porphyritic volcanic rock up to 150 mm occur and some of these are welded. The top of these lapilli-ash tuffs does not crop out in these areas, and the basal contact of the main outcrop is faulted along most of its length.

The western contact of the tuffs cropping out east of Ma On Shan Mine (4363 2918) is taken to be faulted, since thin sections of the tuffs there show no sign of any biotite regrowth, normally the first indication of metamorphism of such tuffs. The sedimentary rocks in the mine immediately west of the fault, on the other hand, are quite strongly baked by the granite. The contact at the southern end of this crop is intruded by the porphyritic rhyolite (4285 2816) or faulted against pale grey, welded fine ash tuffs of the Ap Lei Chau Formation (4335 2807).

Petrography

In thin section the tuffs of the Tai Mo Shan Formation show considerable variation in proportions of crystals and in the relative proportions of the main crystal types present. Point count studies indicate that quartz varies from 8 to 16%, plagioclase from 7 to 22%, alkali feldspar from 4 to 13%, and biotite from 3 to 6%, while total crystal content varies from 22 to 42%. Quartz is always less abundant than combined feldspar percentages. This helps to distinguish the Tai Mo Shan Formation tuffs from the Shing Mun Formation tuffs in which quartz is more abundant than the combined feldspar percentages. Shing Mun Formation tuffs also generally have a lower biotite content.

The plot (Figure 5) of point counts of quartz, alkali feldspar and plagioclase showing the overlap of counts of tuffs from the Pak Kong area with counts from the Tai Mo Shan area supports the correlation of the tuffs of the two areas. Yim Tin Tsai Formation tuffs also plot in this area of the diagram (Figure 4) but, while tuffs of the Tai Mo Shan Formation do occasionally contain hornblende, the mineral is not as widespread in its occurrence as it is in the Yim Tin Tsai Formation.

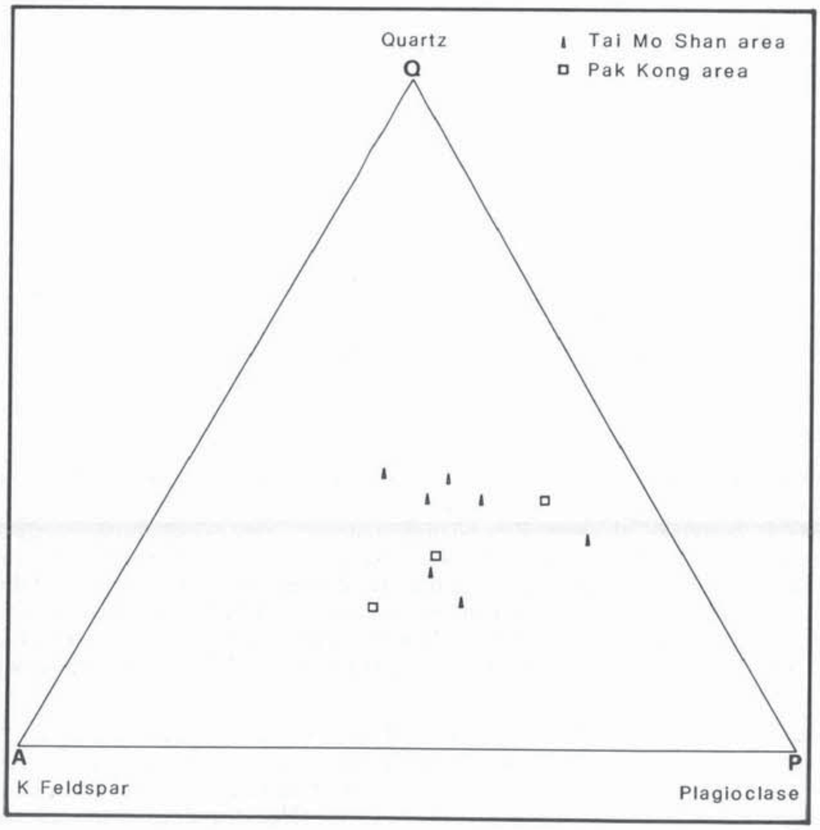


Figure 5 – QAP Diagram Showing Relative Proportions of Minerals in Tuff Samples from the Tai Mo Shan Formation (based on point counts of thin sections)

Tuffs from the eastern ridge of Tai Mo Shan are typical of the formation in the type area. Specimen HK 156 (3092 3062) contains quartz to 4 mm (12%), plagioclase to 6 mm (c 22%), alkali feldspar to 2 mm (c 4%) and biotite to 2.5 mm (c 4%). Quartz grains are euhedral, rounded to broken and angular, occasionally deeply resorbed. Plagioclase normally takes the form of somewhat altered, broken, euhedral twinned crystals with extinction angles indicative of oligoclase. Alkali feldspars are usually euhedral or broken crystals which are strongly clouded and generally show a slight microperthic albite exsolution. Biotite grains are usually partially chloritised and occur either as plates or stacked crystals. Lithic clasts are large (over 10 mm) and composed of dark, microcrystalline, recrystallised volcanic glass with small phenocrysts of plagioclase and biotite. Distinct flattening of the glass indicates welding. Clasts of mudstone and fine-grained sandstone are also present. The matrix is composed of comminuted rock and crystal debris, epidote and iron ores.

Specimen HK 817 (4477 2815) from the Pak Kong area is typical, containing quartz to 3 mm (c 9%), plagioclase to 3 mm (c 12%), alkali feldspar to 3 mm (c 10%) and biotite to 2 mm (c 6%) (Plate 11). Quartz crystals are large and resorbed or smaller, broken and angular. Plagioclase crystals are usually sericitised, euhedral or broken. Measurements on twin-plane extinctions indicate oligoclase composition. Alkali feldspar is usually clouded with minor traces of microperthitic exsolution. Biotite occurs in euhedral thin laths which are altered to pale chlorite. Lithic clasts of porphyritic microcrystalline igneous rock occur, as well as fiamme of dark, porphyritic volcanic glass. The matrix consists of comminuted rock and crystal fragments, and very finely recrystallised welded glass shards which are evident now only from a fine parataxitic fabric which can be seen enclosing the larger fragments.

Volcanic Environment

Evidence of welding fabric from the Tai Mo Shan and Pak Kong outcrops indicates deposition from incandescent ash flows. As with the Ap Lei Chau Formation the ash could have been erupted either from fissures or from a central vent. It is not known, however, whether the Tai Mo Shan Formation and the Ap Lei Chau Formation originated from the same fissure or vent. The change in crystal proportions and increase in proportion of mafic minerals would seem to indicate a change in the original magma chemistry, but it has been shown that a single volcanic vent can produce quite different magma types in successive eruptions (Fisher & Schmincke, 1984).

Chapter 5
Major Intrusions

Classification

The intrusive rocks of the district fall into two broad classes; the plutonic granitoid rocks, and the hypabyssal, generally porphyritic, aphanitic dykes and sills of rock types chemically related to the plutonic rocks. The plutonic rocks include coarse-, medium- and fine-grained granites, quartz monzonite and granodiorite, and these form the major intrusions described in this chapter. The hypabyssal rocks include rhyolites, quartz latite and basalt, and are described in the following chapter entitled Minor Intrusions.

Previously, most of the intrusive rocks of the Territory have been named and defined in terms of their lithological characters and their position in an inferred sequence of intrusive events. Thus Schofield & Phemister (*in* Williams et al, 1945) introduced the terms Tai Po Granodiorite Porphyry and Hong Kong Granite. Allen & Stephens (1971) adopted the terms Tai Po Granodiorite (strictly for the *plutonic* rock type) and a redefined Hong Kong Granite. They introduced many other named intrusive classes, including Needle Hill Granite, Ma On Shan Granite, Cheung Chau Granite and Sung Kong Granite. Furthermore, they showed grain size and porphyritic variants of certain named classes, such as medium-grained phases of the Hong Kong and Sung Kong granites and a fine-grained phase of the Hong Kong Granite.

In this survey the classification of the plutonic igneous rocks into principal rock types is based on Streckeisen (1974), and is identical to that of Allen & Stephens (1971). However, the detailed classification adopted is considerably simpler than that used by Allen & Stephens. The new classification has been chosen partly because of a re-interpretation of the intrusive sequence (Strange, 1985) and partly out of a need to convey clear lithological information for engineering purposes. The scheme divides the plutonic rocks on the basis of grain-size (British Standards Institution (BSI), 1981).

Coarse-grained rocks are taken to be those with a general grain-size exceeding 6 mm, with medium-grained rocks between 6 mm and 2 mm and fine-grained rocks less than 2 mm. In order to conform with the grain-size category boundaries used in engineering practice (BSI, 1981) the boundaries have been modified from the 5 mm and 1 mm dividers used by Allen & Stephens (1971). It is regarded as neither necessary nor desirable to apply geographical names to the plutonic classes at this stage of the resurvey of the Territory as a whole.

Granodiorite
Distribution and Lithology

The granodiorite of the district is fine- to medium-grained, mesocratic and porphyritic. Its colour varies with the proportion of the mafic minerals, biotite and hornblende. Phenocrysts are of white plagioclase or, occasionally, pink alkali feldspar and quartz (Plate 16). The granodiorite generally forms low-lying terrain. This is primarily because of its susceptibility to chemical weathering. It weathers to a thick saprolitic soil which, because of the low quartz content of the parent rock, is relatively fine-grained and rich in clays.

The main outcrop covers an area of over 7 sq km around Tai Po. It is concealed in the west by the superficial deposits of the Lam Tsuen Valley and is probably continuous beneath the alluvium with the outcrop around Kadoorie Farm. Granodiorite extends as thin discontinuous sills from Tai Po to the area around St Christopher's Orphanage, where there are more substantial northward-dipping sheets. It forms complex outcrops in the borrow area at Cove Hill and, westwards from there, isolated outcrops occur on the hills northwest of Fo Tan. Still further west, in Shing Mun Country Park, on the south-eastern flanks of Tai Mo Shan and around Sheung Kwai Chung and Kwai Shing, it occurs as extensive sills or laccoliths adjoining the granite or in the strata above it.

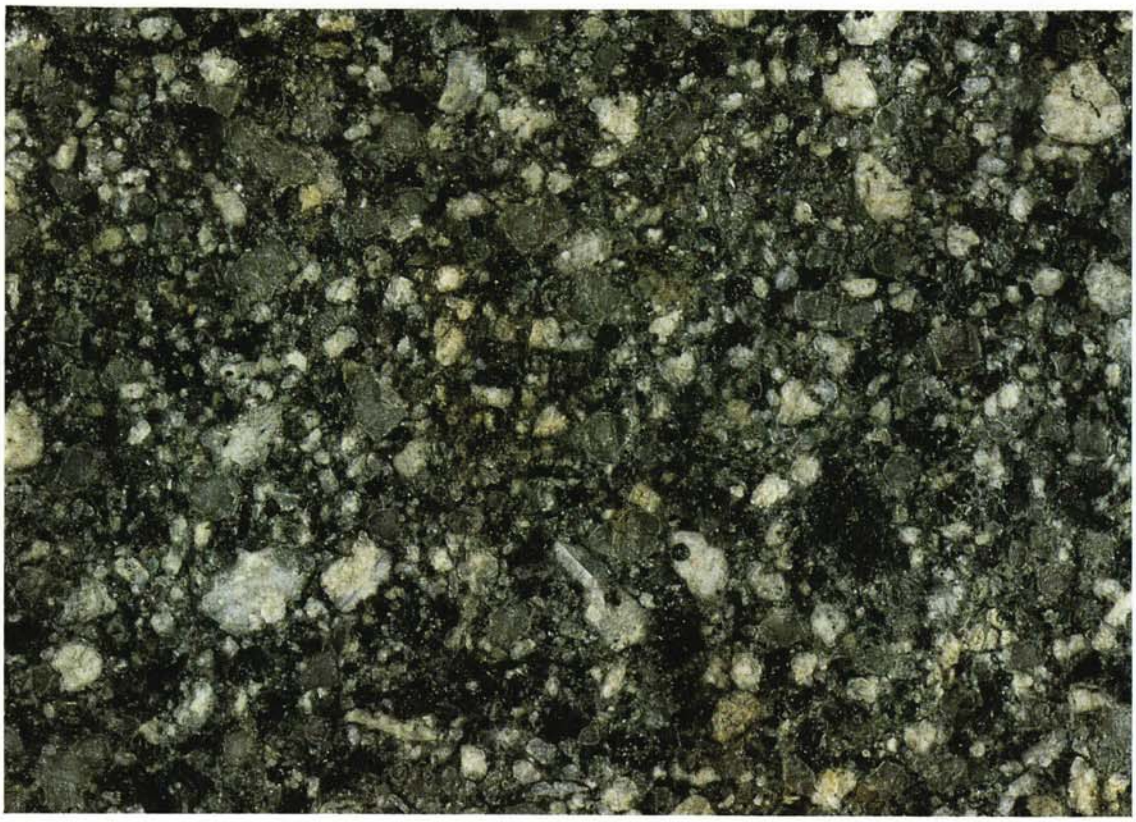


Plate 16 – Porphyritic Fine-grained Granodiorite (HK 4953); Tai Po By-pass (3404 3336); Natural Scale

Plate 17 – Coarse-grained Granite (HK 4955) at Sun Tin Wai Estate (3716 2583); Natural Scale

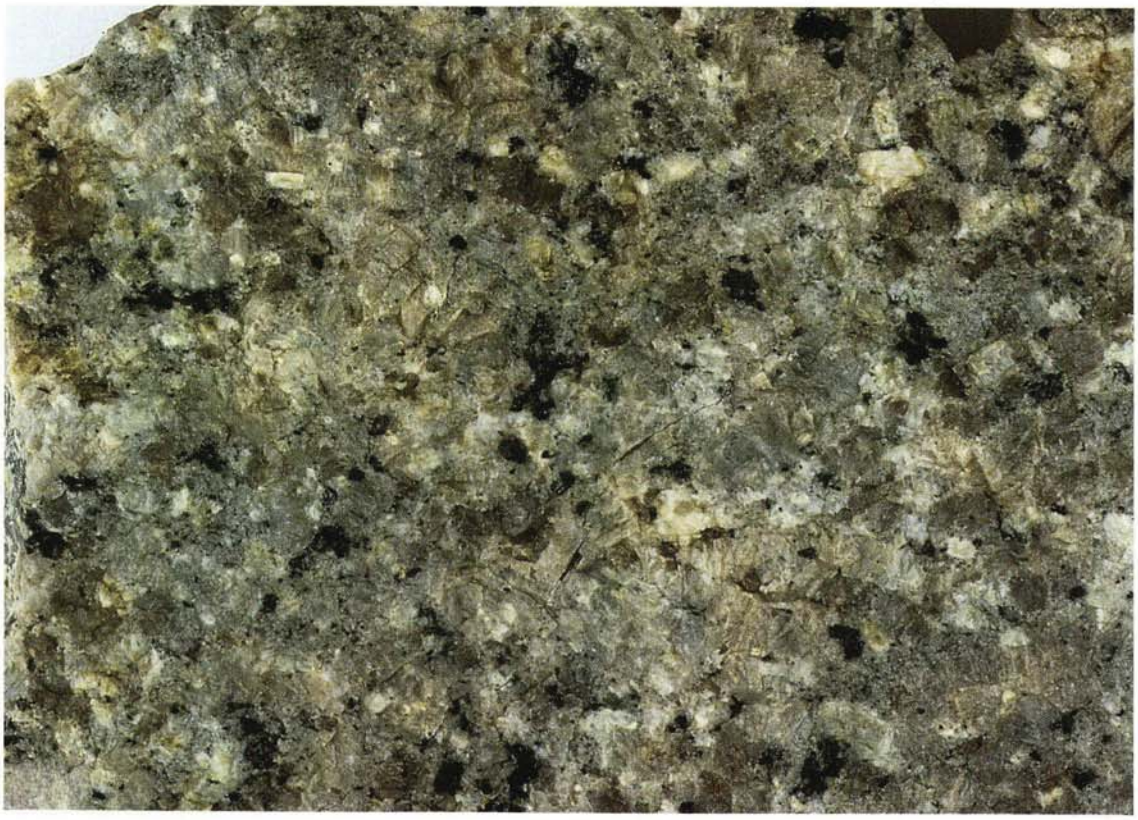


Plate 18 – Thin Section of Coarse-grained Granite (HK 620) near Sheung Keng Hau (3603 2465); XPL plus ¼λ plate × 10

Plate 19 – Thin Section of Coarse-grained Granite (HK 807) near Tsang Tai Uk (3762 2587) Showing Fine-grained Interstitial Texture; XPL × 10

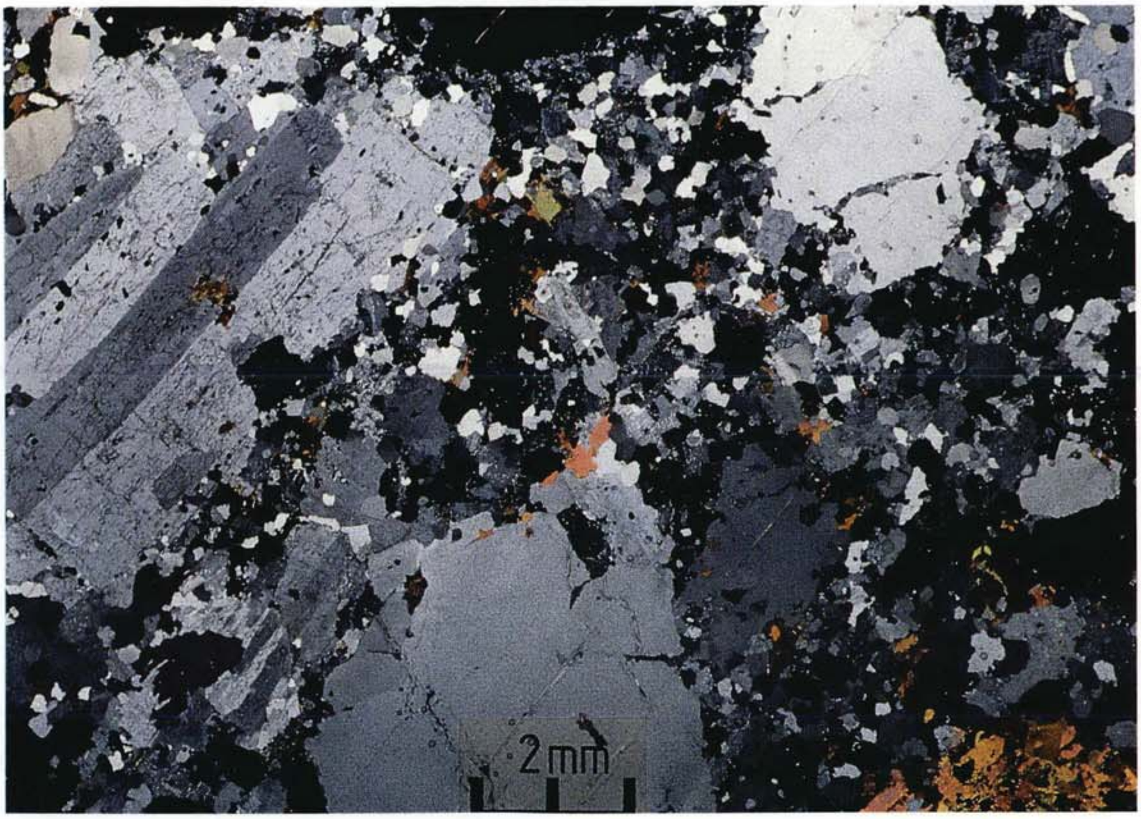


Plate 20 – Medium-grained Granite (HK 4954) at Turret Hill Quarry (4006 2750); Natural Scale

Plate 21 – Thin Section of Medium-grained Granite (HK 520) at Fo Tan (3712 2805); XPL plus $\frac{1}{4}\lambda$ plate × 10

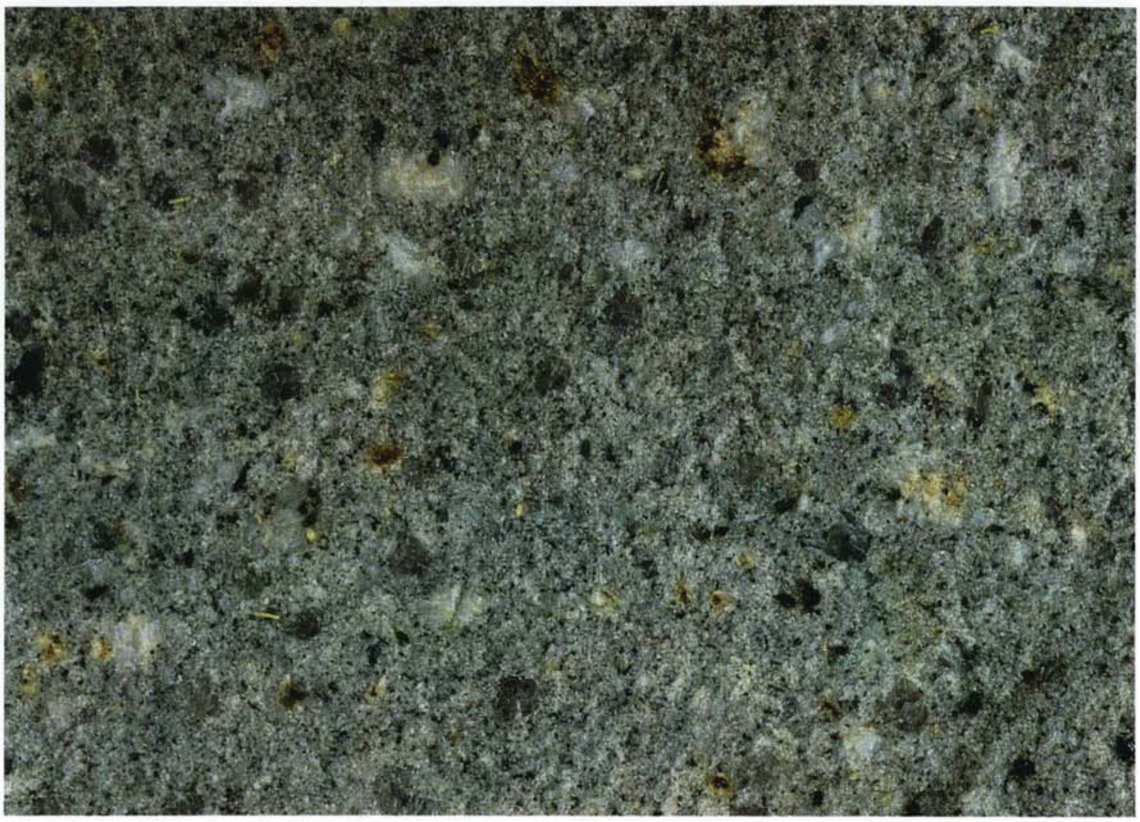
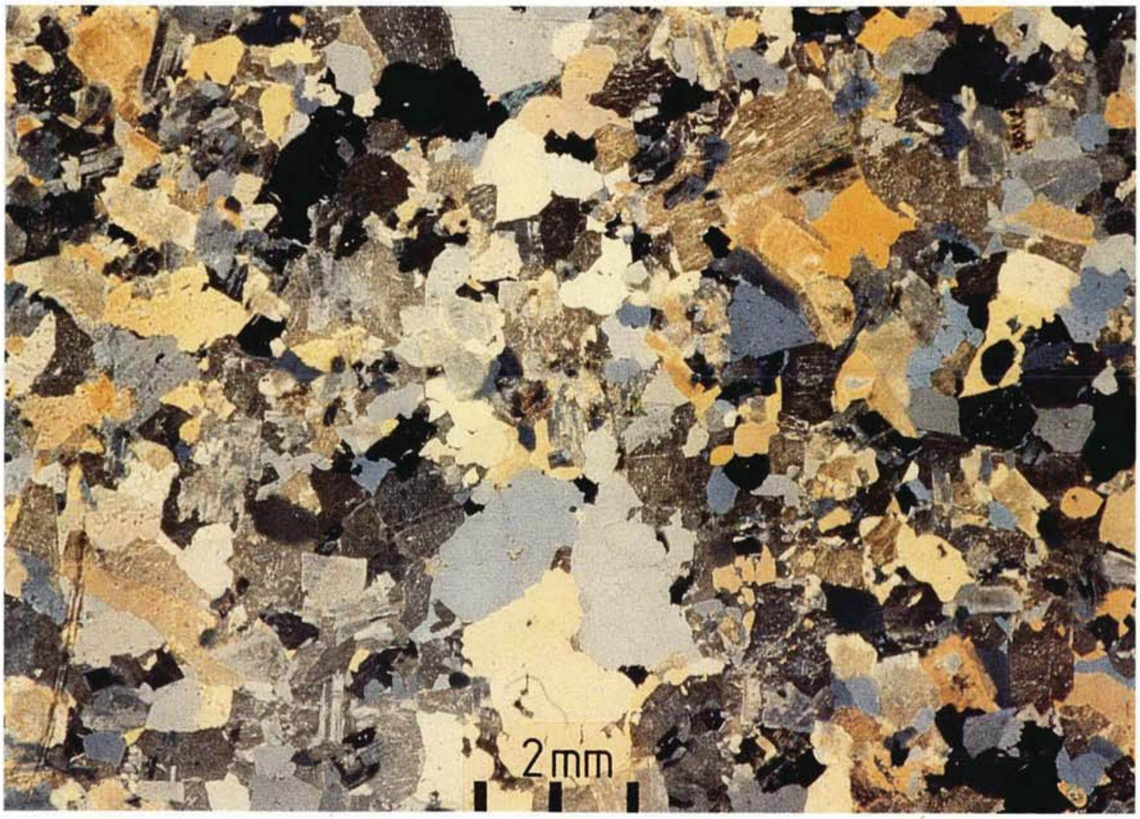


Plate 22 – Megacrystic Equigranular Fine-grained Granite (HK 761) near Sha Tin Wai (3857 2602); Natural Scale

Plate 23 – Thin Section of Fine-grained Granite (HK 219) at Shek Lei Quarry (3230 2472); XPL plus $\frac{1}{4}\lambda$ plate × 10



Details

Tai Po. The main mass of granodiorite at Tai Po is exposed only as structureless residual soils with corestones. These soils grade downwards into saprolite with relic quartz veins and joints (3436 3396). In some deeper valleys, and on some of the steeper slopes, relatively fresh rock may occur (3410 3425). From the corestones and the saprolitic soil the granodiorite can be seen to be fairly uniform in grain-size and mineralogy, but is veined and spotted with epidote in most exposures. Contacts are rarely seen in natural exposures but have been recorded in road cuttings in a number of places. They show little chilling of the granodiorite but are sharp, irregular and commonly sheared (3438 3359). Exposures in the borrow area at Nam Hang (3620 3550) show complex relations between granodiorite and the tuffs and tuffites of the Shing Mun Formation; a series of major and minor granodiorite bodies are cut by northeast- and northwest-trending faults.

The outcrops around Yim Tin Tsai are generally homogeneous, but occasionally have feldspar phenocrysts as at 3972 3544. South of Yim Tin Tsai there is a small outcrop of granodiorite on Centre Island (4095 3334). An exposure of red saprolitic soil on Harbour Island (4405 3542) is inferred to be deeply weathered granodiorite. Granodiorite is recorded in submarine boreholes drilled for the Tolo Channel aqueduct in the channel between Harbour Island and Tang Chau.

West of Tai Po, granodiorite is sporadically exposed in the Lam Tsuen Valley, for example as fresh rock in road-cuts near Kadoorie Farm (3003 3267). An exposure in the river bed north of Chung Uk Tsuen indicates the possibility of an extensive crop under the alluvial deposits of the area. Southeast of Kadoorie Farm, on Kwun Yam Shan (3036 3190) the granodiorite has been deeply and extensively chloritised to form a rock which consists of stringers and coarse blebs of quartz in a chlorite matrix (HK 332, 333). On the western slopes of Kwun Yam Shan rock types transitional between unaltered granodiorite and quartz-chlorite rock can be seen (HK 339, 340).

South of Tai Po, granodiorite occurs as dykes and sheets. One intrusion can be traced from the ridge above Sheung Wong Yi Au (3580 3298) to Tai Po Kau (3680 3299). Around Tsiu Hang (3850 3245) and in the Tai Po Kau Nature Reserve (3676 3197) sheets of granodiorite intrude the lower part of the Repulse Bay Volcanic Group. Similar outcrops are better exposed in the Cove Hill borrow area (3870 3034), where irregular masses of granodiorite with outcrops from a few metres to 180 m wide are complexly faulted, and intruded by quartzphyric rhyolite.

Shing Mun Reservoir – Kwai Chung. The granodiorite of this area is more variable than around Tai Po. In places the matrix is fine-grained; elsewhere it is medium-grained. The proportions of feldspar and quartz phenocrysts also vary considerably. However, these variations have not proved to be laterally continuous and have not therefore been delineated on the map.

There is an extensive but faulted outcrop of granodiorite in the vicinity of the Shing Mun Reservoir. Contacts exposed in Shing Mun River indicate that the granodiorite body dips to the NW at about 15° (3323 2886). The thickness of this intrusion is inferred to be over 100 m. A similar sized, lopolith-shaped body extends from the southern part of the Shing Mun Reservoir area through Sheung Kwai Chung (3260 2676), Sam Tsuen (3060 2575) and Kwai Shing (3072 2504). This body is also cut by faults, which are well exposed around Sam Tsuen and Kwai Shing, where granodiorite alternates with numerous sheets of fine-grained granite, and feldsparphyric and quartzphyric rhyolites. The contact with the granite on the south-eastern flank of the granodiorite demonstrates the younger age of the granite, which penetrates the granodiorite as minor dykes.

Small exposures of what is probably an extensive body of granodiorite concealed beneath alluvium occur around Ho Chung (4278 2407 and 4208 2466).

Petrography and Geochemistry

The petrography of the granodiorite (Plate 12) has been described fully by Allen & Stephens (1971) and no further details are given here. Full silicate analyses of three samples of granodiorite are given in Table 7. Silica (SiO_2) varies from 66 to 70%, and lime (CaO) from 1.24 to 3.83%. The sample with high silica and low lime is a porphyritic fine-grained variety and it might be questioned whether it is justifiable to classify it as granodiorite. However, on an ACF plot (Figure 7), its analysis groups with the granodiorites; trace element analysis (Table 3, Figure 8) confirms this link, analyses of the granodiorites and the volcanic rocks showing numerous similarities, particularly in the abundances of Ti, Sr, Zr, Rb and Ba.

Age Relations

The granodiorite is presumed to be the oldest of the granitoid intrusives. It is cut by fine-grained granite, and quartzphyric and feldsparphyric rhyolites in the Kwai Shing and Sam Tsuen areas, and by dykes of quartzphyric rhyolite on Yim Tin Tsai (4036 3508) and on the northern coast of Tolo Harbour (3842 3531). West of Tai Po numerous small northwest-trending dykes of basalt cut the granodiorite, as seen at Kam Shan (3410 3452) and as recorded in water tunnel site investigations between Mui Shue Hang (3342 3539) and Lin Au (3338 3390). At Wai Tau Tsuen (3322 3583) the granodiorite is cut by a northwest-trending basalt dyke, 30–40 m wide.

Table 3 – Trace Element Analyses of Samples of Tuff from the Repulse Bay Volcanic Group (RBVG) and of Major and Minor Intrusive Rocks

Element	Tuffs (RBVG)			Grano-diorite		Qtz. Mon-zonite	Granites Coarse-	Granites Medium-		Granites Fine-grained			Rhyo-lites
	Tai Po Kau Reserve (3630 3185)	Ngong Ping Shan (4407 2854)	Tai Mo Shan (3091 3033)	Tai Po Borrow Area H (3607 3596)	Tai Po By-pass (3417 3399)	Ngong Ping Shan (4415 2835)	Sha Tin Heights (3568 2603)	Wu Kwai Sha Tsui Quarry (4286 3288)	Ma On Shan Tsuen (4206 3071)	Turret Hill Quarry (4014 2756)	Shek Lei Quarry (3230 2472)	Chinese University (3945 3149)	Sai Kung Road (4619 3007) (Sheet 8)
	HK 215	HK 202	HK 228	HK 9	HK 209	HK 200	HK 223	HK 207	HK 218	HK 213	HK 219	HK 226	HK 217
Ti	1960	640	328	2690	4000	1880	1180	430	190	100	140	170	1530
V	30	0	60	50	70	20	0	0	0	0	0	0	0
Rb	249	204	298	201	153	216	232	372	534	643	673	532	220
Sr	123	50	147	142	236	345	113	52	17	4	4	16	106
Y	26	50	29	36	33	32	31	31	127	162	179	86	37
Zr	151	202	211	180	230	441	189	88	114	72	124	113	395
Nb	8	20	11	10	12	8	12	14	52	55	59	30	15
U	8	8	7	9	6	2	6	13	17	19	22	28	8
Ba	530	190	700	610	700	860	530	70	10	0	0	10	430
La	30	60	30	30	40	80	40	0	10	10	0	0	60
Ce	80	130	80	90	110	170	120	40	60	60	60	50	130

Coarse-grained Granite

Distribution and Lithology

The coarse-grained granite forms a fairly distinct mappable lithotype which crops out between Fo Tan and Sha Tin Heights. This outcrop has an elongate, oval form, with its long axis along the Sha Tin valley. A series of minor outcrops occurs along a line from Man Tau Tun to Ngau Au Shan. These are probably either fault-slices from the margins of the main body of coarse-grained granite or screens of coarse-grained granite at the contact with the country rock, dislocated from the main coarse-grained body by the subsequent intrusion of sheets and masses of fine- and medium-grained granites.

The lithology of the granite is generally uniform. It consists of coarsely interlocking crystals of alkali feldspar, plagioclase and quartz (Plates 17 and 18). Alkali feldspar is grey or pinkish grey and commonly forms phenocrysts up to 20 mm. Plagioclase feldspar is white and not usually developed as phenocrysts. The coarse-grained granite is rich in biotite, which forms large, dark brown, felted clots, often over 10 mm in diameter, as well as scattered, small, fresh flakes of around 1.2 mm diameter. Quartz forms large clustered groups of crystals around 10 mm in diameter. Molybdenum has been noted at a number of localities. In some areas the original coarse-grained texture of the rock appears to have been partially recrystallised (Plate 19).

Interstitial patches between the larger feldspars are fine-grained. The development of this modified texture is gradational and may reach a stage where the fine-grained matrix becomes dominant and the crystals of the original coarse-grained granite are reduced to isolated megacrysts.

The coarse-grained granite described here was named by Allen & Stephens (1971) as Sung Kong Granite. However, these authors also included within the Sung Kong Granite large outcrops of medium-grained granite which is quite different in texture and which has different major and trace element chemistry.

Details

Northwest of the Sha Tin Valley. North of Kowloon Reservoir the coarse-grained granite is homogeneous and equigranular, but deeply weathered and poorly exposed. The southern contact with fine-grained granite strikes E-W just north of the reservoir and is complex, with sheets of fine-grained granite intruding the main mass of coarse-grained granite. The fine-grained granite contacts are seldom exposed, but a contact dipping at 70° roughly to the N is recorded northeast of the reservoir (3454 2452). Immediately to the east of this locality the contact is displaced to the southwest on the Lai Chi Kok – Tolo Channel Fault.

The northwestern contact trends northeastwards through the Lower Shing Mun Reservoir. From there it can be traced in road sections to Fuk Lok Tsuen (3560 2738). The contact is complex, consisting of somewhat discontinuous interleaves of fine- and coarse-grained granites. In some of these outcrops the megacrystic fine-grained granite may be modified from coarse-grained granite (3495 2676). Thin sheets of fine-grained granite dip SW at 25°–30° (3496 2662) but these clearly diverge from the main granite contact. Further northeast, at Yau Oi Tsuen (3625 2779), lenses of coarse-grained granite up to 2 m thick, surrounded by fine-grained granite, are probably xenoliths adjacent to the margin. West of Fo Tan (3720 2815) there are similar complex outcrops of fine-grained granite with common megacrysts of feldspar and quartz, adjacent to coarse-grained granite and containing interstitial fine-grained quartz and biotite. Similarly at Tai Wai (3590 2629) the coarse-grained granite shows signs of recrystallisation of quartz and biotite (HK 525); in places the rock grades to a megacrystic fine-grained granite.

The coarse-grained granite is occasionally quartz-poor, pink and syenitic in appearance, but only minor occurrences of this lithology are recorded, at Ha Wo Che above Fo Tan, (3752 2814), on the shores of Lower Shing Mun Reservoir (3427 2588), and near San Tin Wai (3741 2560).

Southeast of the Sha Tin Valley. The coarse-grained granite here is generally equigranular, occasionally bearing phenocrysts of pinkish grey feldspar, and characterised by large felted clots of biotite, precisely as seen northwest of the Sha Tin valley. Occasional quartz-poor syenitic zones are seen (HK 806). The southern contact can be traced from above the Lion Rock Tunnel entrance (3594 2412) to Amah Rock (3656 2450). Northeastwards from Kak Tin the contact extends south of Tsang Tai Uk (3794 2596) to Sha Tin Wai (3856 2624), where it passes beneath the alluvium. Numerous intrusions of fine-grained granite and quartz monzonite form outcrops parallel to the contact, separating the coarse-grained granite on the northwest from medium-grained granite on the southeast. These are well exposed in outcrops at the entrance to Lion Rock Tunnel (3582 2418) and in the catchwater which contours the hills south of the Lion Rock Tunnel Road. Much of the coarse-grained granite here is iron-stained and altered, and the quartz : feldspar ratio may be lower than normal; the feldspars are commonly discoloured brown (HK 612). These features are particularly marked where screens of coarse-grained granite are enclosed by quartz monzonite and fine-grained granite as at 3471 2465, 3630 2407 and 3662 2405 near Amah Rock.

The contact zone is well exposed in road-cuts at Sha Tin Wai (3850 2640). Here vertical sheets of quartz monzonite up to 100 m wide intrude the coarse-grained granite and separate it from the medium-grained granite to the south. The monzonite includes xenoliths of, and is chilled against, coarse-grained granite. The coarse-grained granites in these outcrops show signs of recrystallisation, with interstitial fine-grained quartz and biotite. These textures are better developed further west, around San Tin Wai (HK 621, 3707 2562).

An isolated body of coarse-grained granite crops out on Nui Po Shan (Turret Hill), at 4115 2800, northeast of the main outcrop. This minor body appears to be steep sided, faulted on its southwestern flank and almost entirely surrounded by medium-grained granite. Southeast of the main coarse-grained granite outcrop at Sha Tin lies a wide outcrop of medium-grained granite which is succeeded to the southeast by a zone of coarse-grained granite, fine-grained granite and quartz monzonite sheets. These bodies crop out on Man Tau Tun (3930 2461), at Kong Pui Tsuen (3966 2492), Ngau Au Shan (4060 2553) and in Shek Nga Pui (4140 2588). The coarse-grained granite sheets vary from 20 to 180 m wide and are identical in appearance to the altered and discoloured granite bodies, for example, near Amah Rock. The grain size of these sheets precludes the possibility that they cooled originally as thin minor intrusions. Moreover, it is known from outcrops to the north that the coarse-grained granite is older than the finer varieties. Thus it seems likely that these coarse-grained granite sheets were separated from the main body of coarse-grained granite by faulting or by the dilational intrusion of the medium-grained granite. The trend of the intrusions is parallel to known northeast-trending faults lying to the northeast, but none of these faults can be traced through these outcrops. In view of this, the intrusive separation of the sheets is thought more likely.

Petrography

Exposures around Lower Shing Mun Reservoir and the southwestern end of the Sha Tin valley, near Sheung Keng Hau, (3610 2500) provide the best examples of unmodified textures of the coarse-grained granite. The specimen HK 620 from Sheung Keng Hau (3603 2465, Plate 18) is typical. It consists of coarsely interlocking plates of quartz, alkali feldspar, plagioclase and biotite. Quartz (57%) forms individual plates of up to 7 mm which interlock with other grains in pools of over 12 mm width. The grains show signs of strain with slightly undulose extinction. Grain boundaries are sharp but angularly irregular. Alkali feldspars (20%) form large anhedral plates up to 7 mm which interlock with quartz. They are mainly microcline microperthite, and are fresh or only slightly altered. Plagioclase (18%) occurs in interlocking clusters of anhedral grains of oligoclase often associated with biotite. The grains are fresh or may have altered cores; they are twinned and weakly zoned. Biotite (4%) occurs as large plates to 4 mm interlocking with plagioclase and quartz, or as large clusters of smaller crystals which form felted masses to 0.5 mm. It is pleochroic from green to pale yellowish brown; hornblende (1%) is a common accessory of biotite. Apatite and sphene occur as accessory minerals. The primary texture of the rock is disrupted in places by thin veins of quartz and biotite.

Specimen HK 807, from the road southwest of Tsang Tai Uk (3762 2587), is a coarse-grained granite which has an interstitial fine-grained content. In thin section (Plate 19) the rock is composed of about 42% matrix and about 58% megacrysts of quartz, alkali feldspar, plagioclase and biotite. Quartz (c 20%) forms anhedral to subhedral crystals up to 6 mm diameter which have occasional inclusions of plagioclase, alkali feldspar or biotite and have variable extinction. Plagioclase (c 18%), the dominant feldspar, is euhedral oligoclase up to 7 mm, and is twinned and quite strongly zoned within the oligoclase ranges. The alkali feldspar (14%) is usually in anhedral crystals up to 5 mm which are microperthitic, or occasionally in zoned orthoclase. Scattered anhedral crystals of microcline occur. Both the plagioclase and the alkali feldspars enclose blebs of quartz in cross-cutting or concentric arrays which, in some instances, are granophyric in appearance. Biotite (6%) forms large enhedral plates up to 4 mm, pleochroic from dark brown to straw yellow, which contain inclusions of quartz and iron ores. Biotite also occurs as patches up to 6 mm of interlocking laths. The matrix of the rock consists of interlocking euhedral crystals of 0.25 to 0.5 mm of quartz, orthoclase, microcline plagioclase and biotite. Apatite is a common accessory mineral.

The syenitic variety (HK 806) from near San Tin Wai (3741 2560) is markedly coarse-grained, with the dominant mineral, alkali feldspar, forming crystals over 20 mm in length. Alkali feldspar, normally microperthite but with some microcline, forms approximately 80% of the rock as interlocking anhedral to euhedral crystals. Plagioclase is generally smaller, up to 5 mm, and forms around 12% of the rock. It is twinned and zoned but usually sericitised. Quartz (c 6%) forms euhedral clusters to 5 mm or fills interstices between feldspar grains.

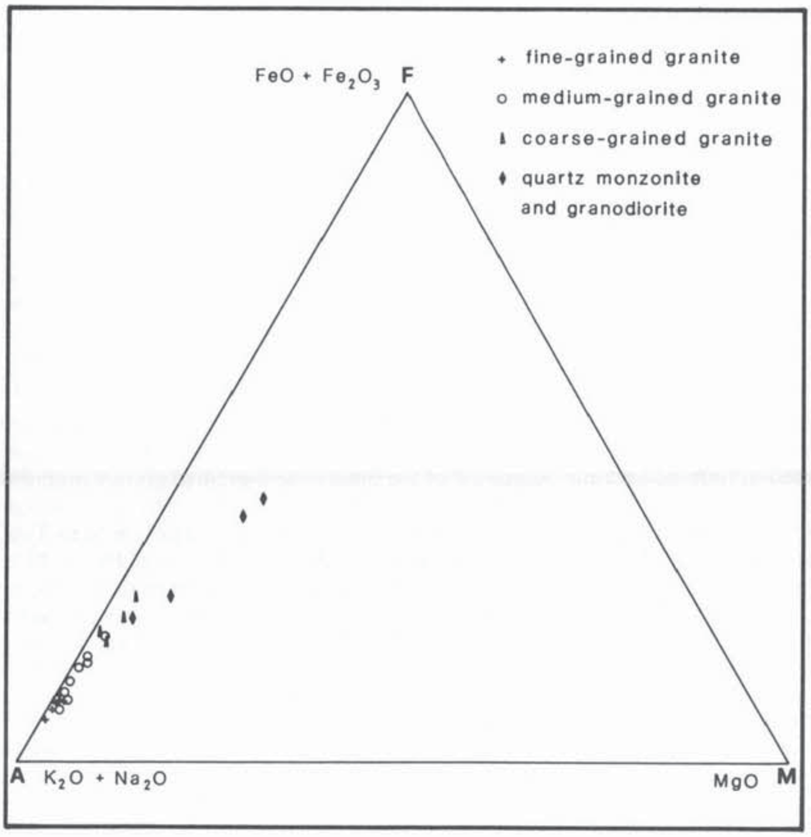


Figure 6 – AFM Diagram Showing Relative Proportions of Alkalis, Iron Oxides and Magnesia in Samples of the Major Intrusive Rocks

Geochemistry

Analyses have been made of two samples of coarse-grained granite; HK 223 from Sha Tin Heights (3568 2603) and HK 2357 from Fo Tan (3765 2813). Results are listed in Tables 3 and 4. These analyses are clearly granitic (cf Cox et al, 1979) but are slightly richer in silica (SiO_2) and potash (K_2O), and poorer in soda (Na_2O) than the average granite. Potash, soda and lime (CaO) contents differentiate the coarse-grained from the medium-grained granites (Figures 6 and 7), differences which are described in subsequent sections. Trace element chemistry (available only for HK 223) also serves to distinguish the coarse-grained from the medium-and fine-grained granites, (Table 3, Figure 8).

Table 4 – Major Element Analyses of Coarse-grained Granite Samples

	Sha Tin Heights (3568 2603) HK 223	**Fo Tan (3765 2813) HK 2357**
SiO_2	74.00	75.58
TiO_2	0.21	0.10
Al_2O_3	13.04	12.33
Fe_2O_3	0.68	0.32
FeO	1.36	1.05
MnO	0.04	0.03
MgO	0.22	0.06
CaO	1.31	0.76
Na_2O	2.82	2.90
K_2O	5.48	5.21
H_2O^+	0.46	0.35
H_2O^-	0.18	0.23
P_2O_5	0.05	0.01
CO_2	—	—
Total	99.85	98.93

Age Relations

The coarse-grained granite can be demonstrated to be older than most other phases of granite. It occurs as xenoliths in quartz monzonite at Sha Tin Wai (HK 777, 3852 2627). Beside the Lion Rock Tunnel Road (364 248) it is cut by both quartz monzonite and fine-grained granite. The fine-grained granite is the youngest lithotype and carries patches of resorbed coarse-grained granite and swathes of crystals, probably xenocrysts, from the coarse-grained granite. The coarse-grained granite is intruded by fine-grained granite bodies in a number of other areas, particularly around Sha Tin Heights and Tung Lo Wan (3680 2684), northwest of the Sha Tin valley; and to the southeast on Nui Po Shan (4150 2795). Feldsparphyric rhyolite dykes are common in the Lower Shing Mun Reservoir area (3550 2600) and northeast of there, around Pak Tin (3550 2690).

The coarse-grained granite clearly pre-dates at least some of the movements on the Lai Chi Kok – Tolo Channel Fault as seen from exposures at Kowloon Reservoir (3450 2434). At Sha Tin Wai (3846 2625) narrow zones of granite with a schistose fabric indicate shear deformation while the granite was still hot.

Medium-grained Granite

Distribution and Lithology

The medium-grained granite almost entirely surrounds the coarse-grained granite at outcrop, forming a concentric shell. This shell is broken in the southwest by an intervening intrusion of fine-grained granite while, in the northeast, borehole data from Tide Cove indicate that the outcrop is cut by graben outliers of sedimentary rocks. To the northwest of the Sha Tin valley medium-grained granite crops out discontinuously between Kwai Chung and the Chinese University. On the southeastern side of the Sha Tin valley, it forms an almost unbroken outcrop from near Amah Rock to Wu Kwai Sha Tsui.

The medium-grained granite is the least variable of the mapped granite classes and is consistent both in grain size and mineral content. In hand specimen it consists of subhedral interlocking grains of quartz, feldspar and biotite (Plate 20). The maximum grain size is around 7 mm while the average is around 4–5 mm. Quartz forms anhedral crystals or aggregates up to 7 mm. Alkali feldspar is sometimes grey but more usually pink and may form euhedral crystals up to 8 mm long. Plagioclase is normally white and forms smaller crystals up to 5 or 6 mm. Biotite occurs as fresh, individual, euhedral flakes to 3 mm, or as clusters of crystals to 5 mm, generally evenly scattered through the rock. As with the coarse-grained granite, in places the medium-grained granite includes fine-grained quartz and biotite interstitially between the large grains. Gradual transitions from unmodified medium-grained granite to megacrystic fine-grained granite have been noted.

The medium-grained granite in this district was assigned by Allen & Stephens (1971) mainly to the Cheung Chau Granite, but also to the Ma On Shan Granite and to two phases of the Sung Kong Granite. Geochemically the samples from the outcrops concerned are alike and distinct from the Sung Kong Granite.

Details

Northwest of the Sha Tin Valley. The medium-grained granite here forms one northwesterly dipping sheet which attains its maximum thickness of about 300 m south of Needle Hill (3480 2740). Northeast of Needle Hill the sheet splits into two or three leaves, intercalated with fine-grained granite. Contacts with the fine-grained granite to the north are sharp. They show no evidence of chilling of either facies, and dip NW at angles of around 25° (3465 2740, 3590 2843). At the latter locality coarse- and fine-grained granites are interbanded along the contact. Further northeast, around Ho Tung Lau (3880 2940) and the Chinese University (3960 3100), the medium-grained granite is cut by a number of minor sheets of fine-grained granite. Sections recorded in water tunnels northwest of Ho Tung Lau indicate that the contact of this body dips gently to the northwest. Around the Chinese University contacts are steep.

Southwest of Needle Hill, around the Lower Shing Mun Reservoir, contacts between the medium-grained granite and the enclosing fine-grained granite are steep, while on Kam Shan (3330 2510) and on Ma Tsz Keng (3320 2600) medium-grained granite forms a pair of lenticular bodies which are sub-horizontal or dip gently southeastwards. These changes in attitude along strike are interpreted as original intrusive, as opposed to tectonic, features.

Southeast of the Sha Tin Valley. The outcrops here are more continuous than those northwest of the Sha Tin valley and contain fewer fine-grained granite intercalations. In typical exposures the granite forms large well-rounded corestones and is free from all but very minor quartz veins and aplite dykes (3910 2504 and 3955 2600). The contact with the coarse-grained granite south of Sha Tin is steep and complex, striking east-northeast. It is interrupted by numerous sheets of quartz monzonite and fine-grained granite.

In the area south of Tsang Tai Uk (3820 2590) and at To Shek (3890 2615) the medium-grained granite includes an interstitial fine-grained matrix, particularly in the vicinity of intercalations of fine-grained granite. South of Tsang Tai Uk xenoliths of medium-grained granite occur within the fine-grained variety. At To Shek, sharp, chilled margins of fine-grained granite occur at the contacts. A fine-grained matrix is also seen west of Tai Che (4060 2667). There are sheets of fine-grained granite on the southeastern contact of the medium-grained granite. However, whereas on the northwestern contact the fine-grained granite is chilled against, and clearly younger than, the medium-grained granite, on the southern contact the interbanding of the two lithologies could be a normal marginal feature of the medium-grained granite. Sheets of quartz monzonite run parallel to the contact and are younger than the granites.

The medium-grained granite around Nui Po Shan (4050 2850) and northeast of Tai Shui Hang (4180 2960) is generally homogeneous and equigranular. In Turret Hill Quarry (4010 2755) it is intruded by thin sheets and dykes of fine-grained granite, and in places has an intersitial fine-grained texture. Northeast of Tai Shui Hang the medium-grained granite is cut by fairly flat-lying sheets of fine-grained granite. Although the medium-grained granite shows few signs of grain-size modification, the contacts are rarely sharp; patches of fine-grained granite occur within the medium-grained granite (4173 2993). Around Wu Kai Sha (4250 3150) and Wu Kwai Sha Tsui (4300 3300) the medium-grained granite is homogeneous and equigranular.

Petrography

Specimen HK 520 from Fo Tan (3712 2805, Plate 21) is typical of the medium-grained granite of the district. Alkali feldspar is the most abundant mineral (c 40%) and this forms anhedral interlocking plates of fresh microperthite up to 7 mm. Quartz (c 38%) also forms anhedral inter-locking plates with a general diameter of 2–4 mm. Plagioclase (c 20%) forms euhedral to subhedral crystals up to 3 mm long and euhedral interstitial patches, all of which are somewhat sericitised. They show multiple twinning and measurements of the extinction of twin lamellae indicate an oligoclase composition; most crystals show weak to moderate zoning. Biotite (c 3%) forms small clusters of euhedral laths up to 2 mm which are pleochroic from pale brown to deep green. It is normally interstitial along with plagioclase and quartz. Sphene and apatite occur as accessory minerals.

Specimen HK 776 from Sha Tin Wai (3840 2618) is typical of the medium-grained granite which includes interstitial fine-grained textures. The textures appear as graphic intergrowths of quartz in alkali feldspar or plagioclase. These intergrowths are not, however, always related to crystal margins and do not appear to have been formed by eutectic crystallisation of quartz and alkali feldspar.

Table 5 – Major Element Analyses of Medium-grained Granite Samples

	Lower Shing Mun Reservoir (3427 2622) HK 225	**Turret Hill Quarry (4011 2754) HK 211**	**Ma On Shan Tsuen (4206 3071) HK 218**	**Wu Kwai Sha Tsui Quarry (4286 3288) HK 207**
SiO_2	76.43	76.42	76.18	77.93
TiO_2	0.09	0.02	0.05	0.08
Al_2O_3	12.60	12.24	12.76	12.35
Fe_2O_3	0.64	0.18	0.07	0.39
FeO	0.73	0.56	1.07	0.48
MnO	0.03	0.03	0.10	0.03
MgO	0.05	0.03	0.03	0.12
CaO	0.55	0.44	0.76	0.57
Na_2O	3.43	3.64	3.39	3.39
K_2O	4.94	4.83	4.74	4.70
H_2O^+	1.13	0.59	0.49	0.50
H_2O^-	0.13	0.11	0.12	0.28
P_2O_5	0.01	<0.01	<0.01	0.01
CO_2	—	—	—	—
Total	100.76	99.09	99.76	100.83

Geochemistry

The major element chemistry for four medium-grained granites is shown in Table 5. These granites are from four widely separated outcrops referred by Allen & Stephens (1971) to two different granite types. HK 207 from Wu Kwai Sha Tsui Quarry (4286 3288), HK 218 from Ma On Shan Tsuen (4206 3071), and HK 225 from the Lower Shing Mun Reservoir (3427 2622) were all designated as Cheung Chau Granite, while HK 211 from Turret Hill Quarry (4011 2754) was mapped by Allen and Stephens as a medium-grained phase of the Sung Kong Granite. AFM and ACF plots of the granite analyses (Figures 6 and 7) show a moderately close grouping of these analyses. The grouping corresponds with that of fine-grained granites but is distinctly separate from the analyses of the coarse-grained granite.

Trace element analyses (Table 3, Figure 8) show similar, though less marked, grouping of the medium- and fine-grained granites, separate from the coarse-grained granite, granodiorite and quartz monzonite.

Age Relations

The medium-grained granite south of the Sha Tin valley intrudes the coarse-grained, dividing the central Sha Tin outcrop from minor screens to the southeast around Kong Pui Tsuen (4000 2500). The medium-grained granite on Needle Hill (3470 2748) is interleaved with fine-grained granite without signs of chilling. The implied close chemical and time relationships are confirmed by analytical results. Around Tsang Tai Uk (3818 2595) and To Shek (3896 2617), however, medium-grained granite shows signs of recrystallisation by the formation of a fine-grained intersitial matrix and is intruded by fine-grained granite. It is inferred that the medium-grained granite is coeval with some of the fine-grained granite (e.g. on Needle Hill) but pre-dates other intrusions of fine-grained granite.

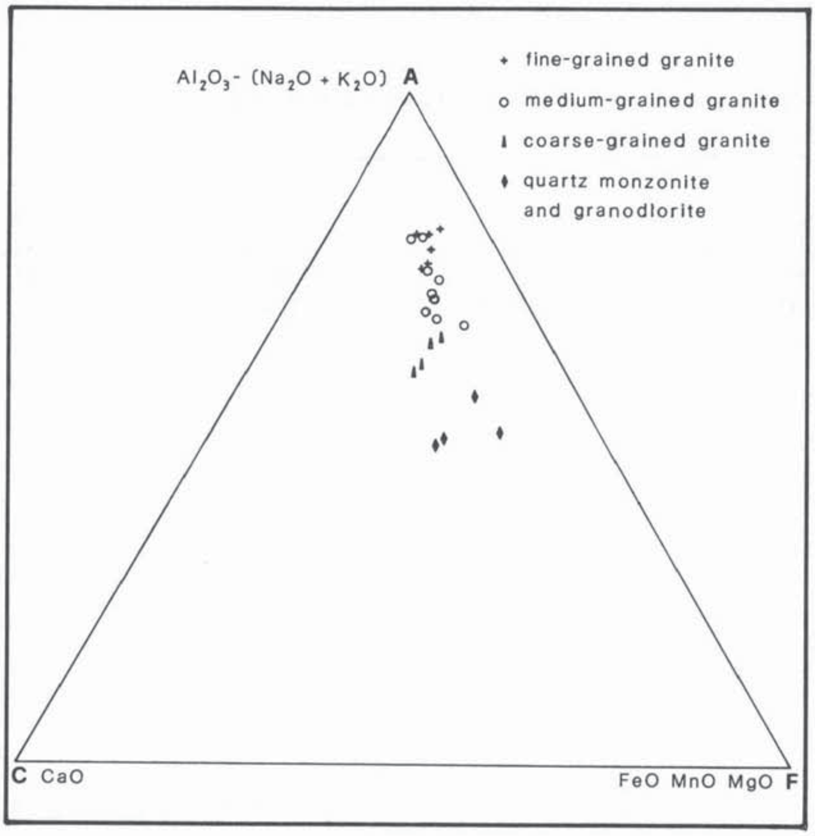


Figure 7 – ACF Diagram Showing Relative Proportions of Alumina minus Alkalis, Lime and Combined Ferrous and Manganese Oxides and Magnesia in Samples of the Major Intrusive Rocks

Fine-grained Granite

Distribution and Lithology

The fine-grained granite crops out in two main tracts; northwest and southeast of the Sha Tin valley. Northwest of the valley the fine-grained granite extends from Kwai Chung through Needle Hill to the Chinese University, essentially flanking the medium-grained granite. Southeast of the Sha Tin valley the fine-grained granite flanks the medium-grained granite at Amah Rock and further northeast near Wu Kwai Sha Tsui. Outcrops in the south, however, are complex, and relationships are difficult to interpret. In places, as on Ma On Shan, the fine-grained granite is a marginal facies to the medium-grained granite; elsewhere, the fine-grained granite can be seen to intrude the medium-grained granite.

The fine-grained granite is typically a pink, equigranular and subhedral, with subequal proportions of quartz and feldspars and minor biotite as at Shek Lei and Kwai Chung. Variations include a megacrystic variety with a fine-grained equigranular matrix which contains crystals of feldspar up to 10 mm long, quartz to 7.5 mm, and biotite as individual crystals to 2 mm and clusters up to 7.5 mm (Plate 22). Another widely occurring megacrystic variety has large crystals of quartz, feldspar and biotite in an inequigranular matrix.

Details

Northwest of the Sha Tin Valley. The main outcrop of fine-grained granite lies between Kwai Chung, Needle Hill and Ho Tung Lau. Around Needle Hill and further north the granite forms northwesterly dipping sheets at the margins of, and within, the medium-grained granite. Dips of the main contacts with the Repulse Bay Volcanic Group are gentle, as can be judged from the effect of topography on the outcrop pattern around Fo Tan, and as is confirmed by the position of the contacts in water-supply tunnels beneath Fo Tan. Contacts of fine- and medium-grained varieties also dip gently to the northwest, as seen at 3469 2740 on Needle Hill. The granite in these outcrops is almost exclusively megacrystic. The Needle Hill outcrops are continuous with those at Kwai Chung but the lithology further south is more variable with both equigranular and megacrystic varieties occurring.

Around Sam Tsuen (3100 2590) and Kwai Shing (3090 2490) the fine-grained granite intrudes granodiorite and, in the contact zone, forms vertical dykes up to 20 m wide parallel to the main contact. At Sheung Kwai Chung (3260 2670) the contact is simple. The contacts with the medium-grained granite east of Kwai Chung on Kam Shan (3320 2510) and Ma Tsz Keng (3320 2590) are irregular but generally sub-horizontal. North of the Kowloon Reservoir the main mass of fine-grained granite intrudes coarse-grained granite and, northeastwards from there, sheets of fine-grained granite up to 100 m thick intrude the coarse-grained granite around Sha Tin Heights (3570 2550) and Tung Lo Wan (3680 2672).

Southeast of the Sha Tin Valley. The main outcrops of fine-grained granite in this area separate medium-grained granite from sedimentary and volcanic rocks. Around Tate's Cairn and Mau Tso Ngam (4066 2500) the outcrops are complex, with numerous sheets of fine-grained granite, screens of tuff and coarse-grained granite, and sheets of quartz monzonite. The fine-grained granites are poorly exposed but appear to be mainly equigranular with scattered megacrysts. The granite which crops out on Tate's Cairn (4050 2429) is very pale grey and strongly recrystallised. The granite here is very close to the roof of the intrusion and it is likely that this recrystallisation is an autometasomatic effect.

Around Ma On Shan and Wu Kai Sha the intrusive relationships are simpler, with fine-grained granite forming two undulating sheets, generally parallel to the contact with the overlying sedimentary rocks. The granite in these outcrops is variably megacrystic.

South of Sha Tin, fine-grained granite forms a sheet-like body striking east-northeast between medium- and coarse-grained granites. However, around To Shek (3900 2620) and Tsang Tai Uk (3820 2580) the granite has more complex field relations. It contains xenoliths of medium-grained granite and intrudes the medium-grained granite with sharp contacts. Adjacent to the contacts, the medium-grained variety has developed a fine-grained matrix, and the fine-grained granite has absorbed megacrysts from the medium-grained granite.

Petrography

Specimen HK 219 from Shek Lei Quarry (3230 2472, Plate 23) is typical of the equigranular fine-grained granite. It comprises closely interlocking grains of quartz, plagioclase and alkali feldspar, with minor amounts of biotite in single isolated grains. Quartz, the most abundant mineral (c 38%), forms anhedral to subhedral grains usually around 1.5 mm diameter, but occasionally grains may be composite and up to 4 mm diameter. Quartz is often interstitial to the other minerals. Alkali feldspar (35%) is microperthite and forms euhedral to anhedral grains (c 2 mm) which are clouded by alteration. Besides albitic exsolution lamellae, the microperthite commonly contains euhedral, angular inclusions of plagioclase, and some grains have overgrowths of oligoclase. Plagioclase feldspar (27%) of oligoclase – andesine composition is slightly sericitised and forms euhedral to anhedral grains up to 2 mm in length but usually smaller. These show complex combined Carlsbad and albite twinning and, occasionally, weak zoning. Biotite (2%) forms single anhedral intersititial grains up to 1 mm across; in most instances it is substantially altered to muscovite with iron ores. Small anhedral grains of fluorite are moderately common and sphene is a rare accessory mineral.

Specimen HK 761 from the borrow area south of Sha Tin Wai (3857 2602) is a typical megacrystic fine-grained granite. The matrix forms about 70% of the rock and has an anhedral granular texture, generally around 0.3 mm, of quartz, plagioclase, alkali feldspar and biotite. The minerals are mostly polygonal although, commonly, many of the smaller quartz grains are rounded. Quartz forms about 40% of the matrix. It occurs as discrete crystals but also as groups of inclusions showing optical continuity within plagioclase or alkali feldspar. Alkali feldspar is microperthite, slightly clouded, with small rounded blebs of quartz up to 0.2 mm as inclusions. Plagioclase is oligoclase to andesine, slightly sericitised and exhibiting complex twinning; it occurs both within the matrix and as inclusions within quartz phenocrysts. Biotite is pleochroic from brown to very light brown and anhedral; it is occasionally altered to chlorite.

The megacrysts include all four main minerals and form about 30% of the whole rock. Alkali feldspar, the commonest megacryst type, occurs as euhedral crystals of microperthite up to 6 mm long. The margins of the crystals commonly contain small rounded blebs of quartz, groups of which may exhibit optical continuity. Plagioclase, which occurs as crystals or crystal groups up to 5 mm long, also has rounded, marginal inclusions of quartz. The quartz megacrysts, which are rounded and up to 6 mm diameter, may be free of inclusions or may contain polygonal inclusions of alkali feldspar and plagioclase up to 0.3 mm. Biotite clusters are up to 2 mm diameter, usually intergrown with quartz. Fluorite is a moderately common accessory mineral. It appears that two types of textures and grain relations are present. The original texture is one of polygonal intergrowth of quartz, feldspar and biotite. This has an overprinted texture of rounded blebs of quartz and feldspar which appear to have penetrated both matrix and megacrysts alike.

Geochemistry

Analyses have been made for major elements for four samples of fine-grained granite; HK 219 from Shek Lei Quarry (3230 2472), HK 2358 from Tai Che (Sha Tin) (4053 2669), HK 213 from Turret Hill Quarry (4014 2756) and HK 226 from a quarry northeast of the Chinese University (3945 3149). They all show close similarity in their proportions of major elements (Table 6, Figures 6 and 7). Trace element values for HK 219, HK 213 and HK 226 are also similar (Table 3, Figure 8). It is noteable that major element plots for both the fine-grained and the medium-grained granites show a certain amount of overlap.

Table 6 – Major Element Analyses of Fine-grained Granite Samples

	Shek Lei Quarry (3230 2472) HK 219	Tai Che Sha Tin (4053 2669) HK 2358	Turret Hill Quarry (4014 2756) HK 213	Chinese University (3945 3149) HK 226
SiO_2	75.85	75.42	77.46	77.88
TiO_2	0.03	0.02	0.02	0.03
Al_2O_3	12.86	12.66	13.09	12.18
Fe_2O_3	0.09	0.11	0.12	0.14
FeO	0.77	0.52	0.70	0.71
MnO	0.06	0.02	0.04	0.06
MgO	<0.01	0.02	<0.01	0.03
CaO	0.62	0.43	0.44	0.54
Na_2O	3.98	4.07	4.28	3.58
K_2O	4.81	4.99	4.42	4.70
H_2O^+	0.27	0.19	0.30	0.29
H_2O^-	0.13	0.03	0.12	0.13
P_2O_5	0.01	<0.01	<0.01	0.01
CO_2	—	—	—	—
Total	99.48	98.48	100.99	100.28

Age Relations

Around Kwai Chung, at Sam Tsuen (3100 2590) and at Kwai Shing (3090 2490), fine-grained granite clearly intrudes the granodiorite, and is itself intruded by quartzphyric and feldsparphyric rhyolites. In the Sha Tin valley around Sha Tin Heights (3570 2550) and Tung Lo Wan (3680 2672) the fine-grained granite intrudes the coarse-grained granite. South of Sha Tin Water Treatment Works thin veins of fine-grained granite intrude quartz monzonite sills (3504 2402); conversely, south of Sha Tin Wai northward-dipping sheets of quartz monzonite intrude fine-grained granite. On Needle Hill and around Ma On Shan Tsuen there is a close relationship between interleaved fine- and medium-grained granites, whereas around To Shek and Sha Tin Wai the fine-grained granite intrudes, and includes xenoliths of, medium-grained granite.

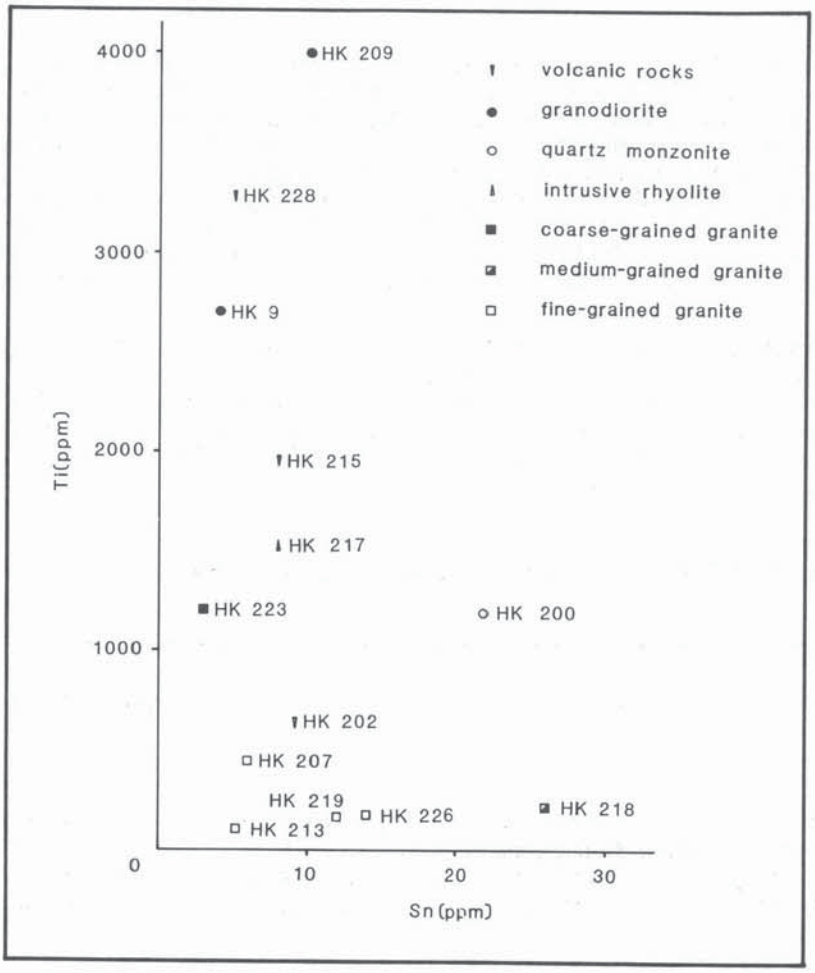


Figure 8 – Plot of Titanium Against Tin in Parts per Million (ppm) in Volcanic and Intrusive Rocks

Quartz Monzonite

Distribution and Lithology

Intrusions of quartz monzonite are restricted to the area southeast of the Sha Tin valley. They are sheet-like bodies which parallel pre-existing intrusive units or faults and have outcrop widths in the range 10 to 100 m.

The main occurrences lie along the contact of the medium- and coarse-grained granites between Kowloon Reservoir and Sha Tin Wai. Minor sheets occur within the medium-grained granite, and more extensive sheets intrude the southeastern contact zone of the medium-grained granite between Man Tau Tun and Mau Tso Ngam. At Shek Kwu Lung the quartz monzonite forms a large sheet intruded between fine- and medium-grained granites. This intrusion can be traced to Turret Pass from where a possible associated sheet of quartz monzonite extends between the Jurassic volcanic rocks and the rhyolite of Shek Nga Shan. Similar intrusions within the volcanic rocks occur at Mau Tso Ngam and on the northwestern ridge of Wong Ngau Shan. Northeast of Shek Nga Shan quartz monzonites occur along the northeast-trending fault lines which pass through Ma On Shan Mine and to the east of Ngong Ping Shan.

The quartz monzonite varies from dark grey and fine-grained to pale grey and medium-grained (Plate 24). The two varieties can be seen as a marginal and core facies of the intrusion at Sha Tin Wai. Both varieties are characteristically porphyritic with slender, rectangular, white phenocrysts of feldspar up to 7 mm, usually flow-aligned, in a darker matrix which contains conspicuous biotite flakes up to 3 mm.

The quartz monzonite is distinctive in its weathering characteristics. Like the granodiorite it weathers to a red saprolitic soil with abundant round corestones up to 2 m which, in extensive outcrops as at Ngau Au, form boulder fields.

Details

Kowloon Reservoir – Sha Tin Wai. Quartz monzonite is well exposed in the catchwater between the reservoir and Amah Rock, and in roadside outcrops by the entrance to Lion Rock Tunnel. Contacts are rarely seen and when exposed are usually sheared. However, at Lion Rock Tunnel the quartz monzonite can be seen intruding coarse-grained granite with an irregular contact. The quartz monzonite here is itself intruded by a dyke of feldsparphyric rhyolite. At Sha Tin Wai the quartz monzonite intrudes coarse-grained granite with a vertical contact. The monzonite is chilled against the granite with a darker grey, biotite-rich marginal facies. In roadside exposures farther south the quartz monzonite contains xenoliths of coarse-grained granite. In borrow areas southeast of Tsang Tai Uk (3815 2580) and south of Sha Tin Wai (3850 2594) a 10 m thick sheet of dark grey, porphyritic, fine-grained quartz monzonite intrudes fine-grained granite, dipping N at about 40°.

Southeast of the Sha Tin Valley. In the areas around Man Tau Tun (3900 2460), Mau Tso Ngam and Wong Ngau Shan (4130 2615), contacts have rarely been observed and outcrops have been plotted from the occurrence of corestones. This is also the case around Ngong Ping. In Ma On Shan Mine (4358 2921) the quartz monzonite forms an irregular vertical dyke 4 m thick intruding chloritised, altered sedimentary rocks which form abundant xenoliths within the dyke. Nearby outcrops show very irregular thin dykes of quartz monzonite cross-cutting quartz veins, brecciating the country rock and carrying rounded blocks of garnetiferous skarn.

Table 7 – Major Element Analyses of Granodiorite and Quartz Monzonite Samples

		Granodiorite		Quartz Monzonite
	Tai Po By-pass (3417 3399) HK 209	**Nam Hang Borrow Area (3607 3596) HK 9**	**Route Twisk Tsuen Wan (3035 2630) HK 227**	**Ngong Ping Shan (4415 2835) HK 200**
SiO_2	67.69	70.31	66.00	65.64
TiO_2	0.70	0.47	0.74	0.33
Al_2O_3	14.37	13.63	14.34	16.42
Fe_2O_3	1.36	0.68	2.13	1.57
FeO	3.62	2.60	2.92	1.50
MnO	0.08	0.09	0.11	0.13
MgO	1.49	0.92	1.46	0.60
CaO	3.83	1.24	3.12	1.38
Na_2O	2.66	3.33	2.94	3.66
K_2O	3.55	4.52	4.41	7.23
H_2O^+	1.26	1.28	1.10	1.03
H_2O^-	0.15	0.17	0.18	0.42
P_2O_5	0.18	0.13	0.17	0.11
CO_2	—	—	—	—
Total	100.94	99.37	99.62	100.02

Petrography

Specimen HK 537 from Man Tau Tun (3912 2445, Plate 25) is typical of the quartz monzonite. It contains 40–45% phenocrysts in a fine-grained matrix. Phenocrysts are of both plagioclase feldspar and alkali feldspar in roughly equal proportions, with additional smaller phenocrysts of biotite and hornblende. Alkali feldspar phenocrysts are up to 8 mm, slightly clouded and euhedral, but with slightly irregular margins. They are

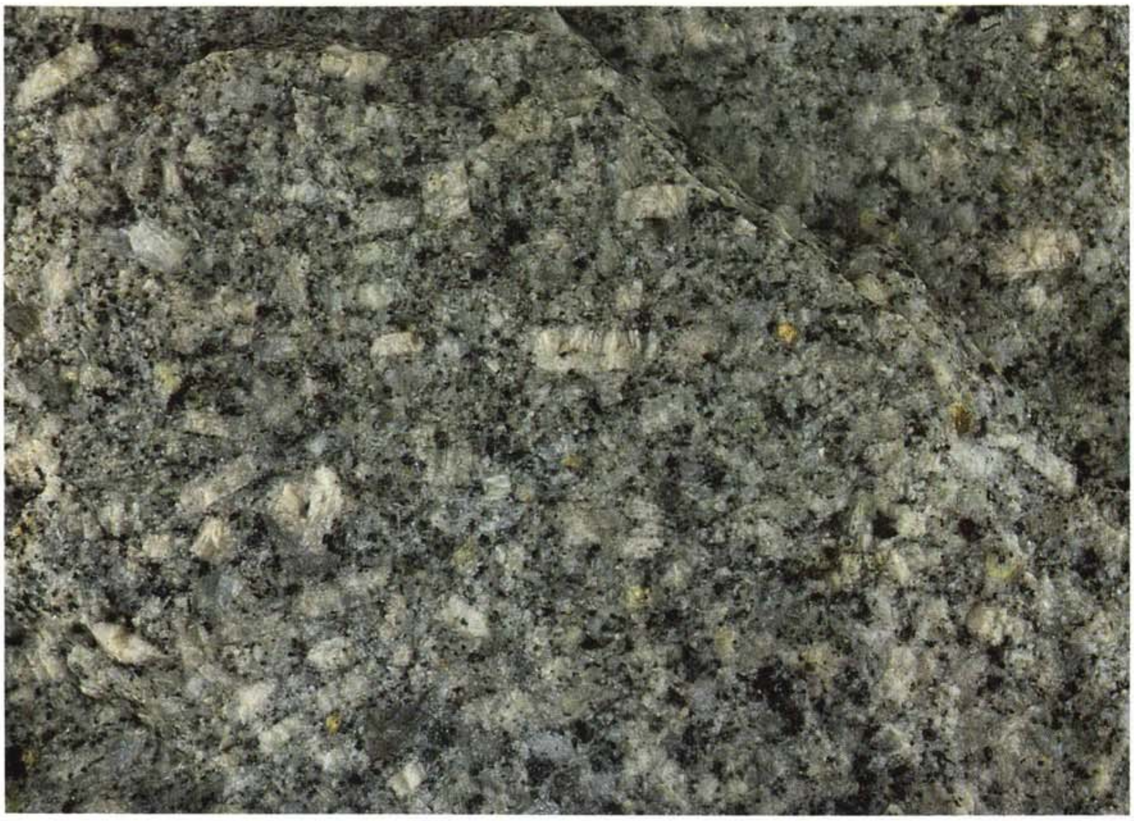


Plate 24 – Medium-grained Quartz Monzonite (HK 3835) at Sha Tin Wai (3852 2646); × 1.5

Plate 25 – Thin Section of Quartz Monzonite (HK 537) at Man Tau Tun (3912 2445); XPL × 10

Plate 26 – Thin Section of Quartzphyric Rhyolite (HK 272) in Dyke on Grassy Hill (3584 2930); XPL × 10

Plate 27 – Thin Section of Feldsparphyric Rhyolite (HK 1245) on Shek Nga Shan (4243 2707); XPL × 10

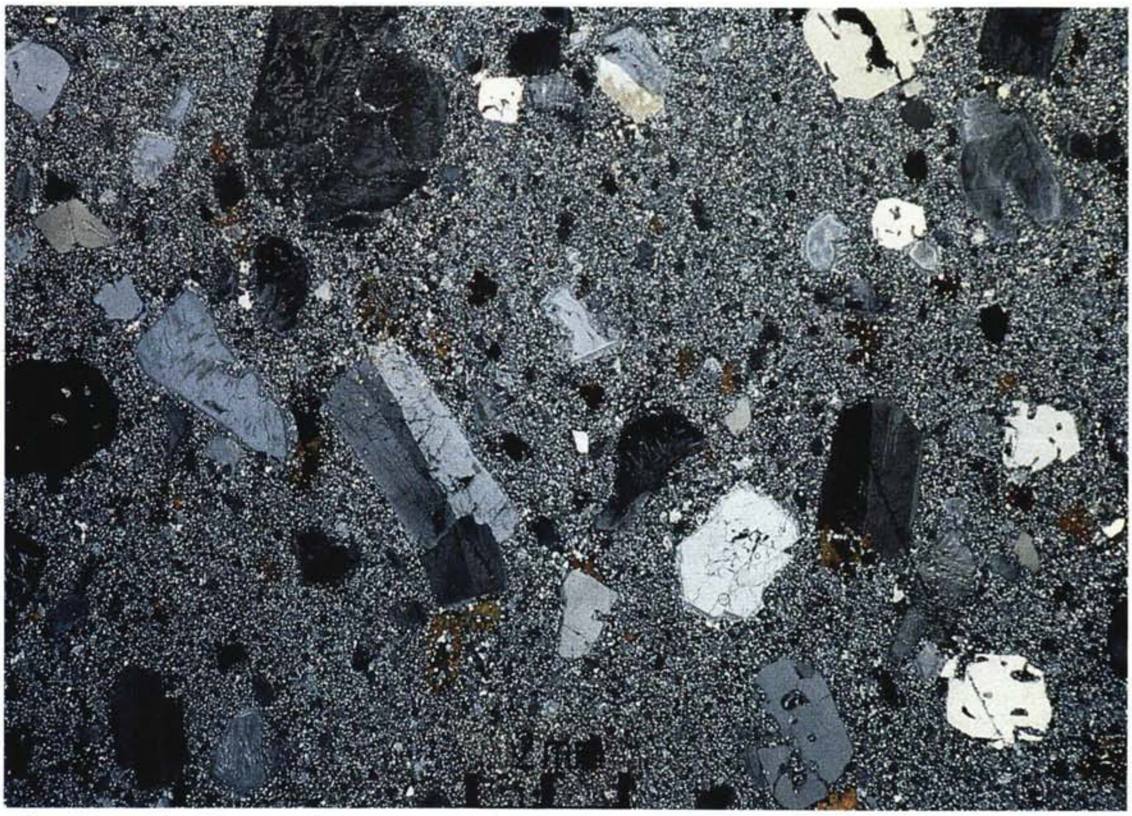
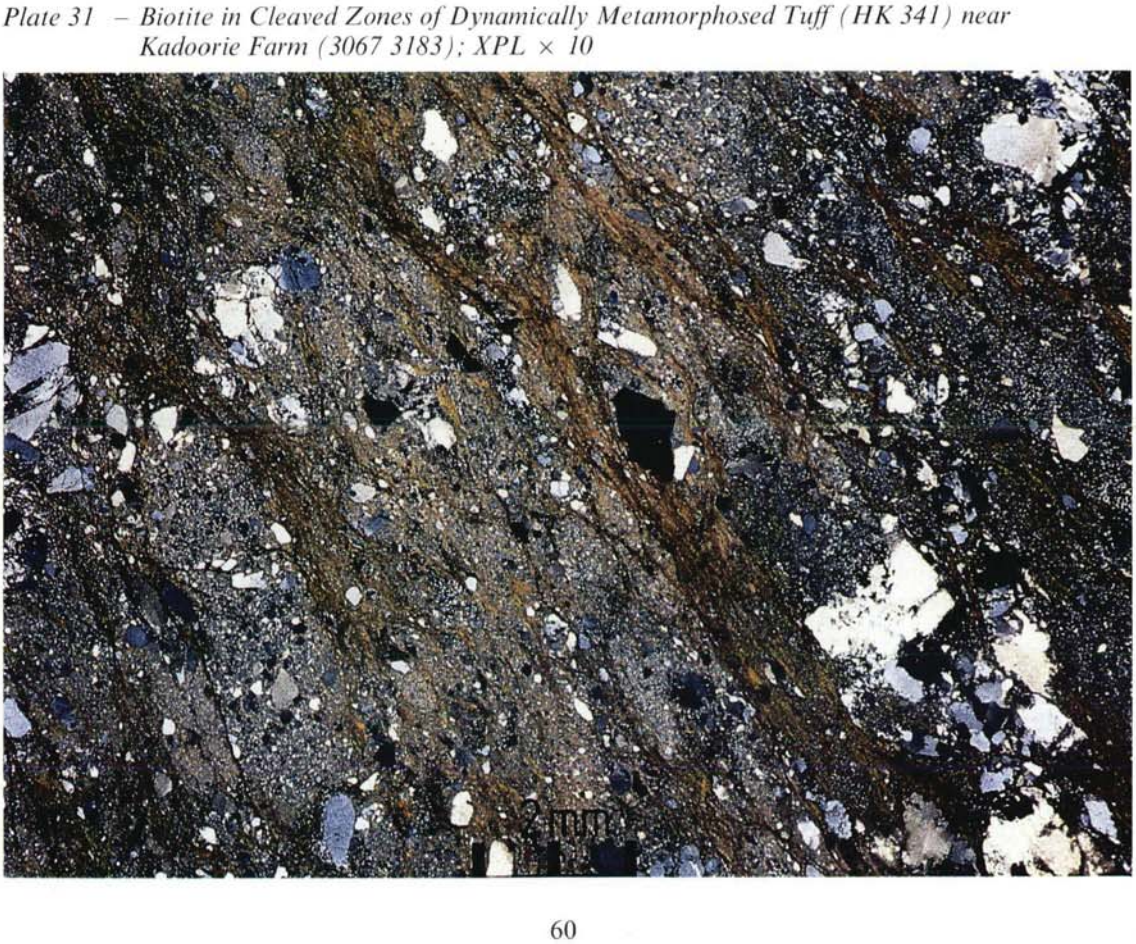


Plate 28 – Thin Section of Quartz Latite (HK 788) at Tsim Mei Fung (4134 2547); XPL × 10

Plate 29 – Thin Section of Basalt (HK 412) in a Dyke at Wai Tau Tsuen (3322 3580); XPL × 10

Plate 30 – Crystals of Cordierite in Thermally Altered Siltstone (HK 89) in Tolo Harbour Formation near the Chinese University (3945 3179); XPL × 10

Plate 31 – Biotite in Cleaved Zones of Dynamically Metamorphosed Tuff (HK 341) near Kadoorie Farm (3067 3183); XPL × 10



microperthite, and show marked signs of zonation or crystal overgrowth in some instances. Plagioclase crystals are usually smaller, up to 4 mm, and slightly sericitised; they are also euhedral and are partially twinned, measurements of extinction angles indicating compositions in the range of oligoclase to andesine. They are commonly strongly zoned. Biotite forms anhedral to euhedral plates up to 1.5 mm; it is pleochroic from light to dark brown, and is usually fresh. Hornblende, like the biotite, forms crystals of up to 1.5 mm; it is pleochroic from light to dark green, and occasionally forms euhedral twins. All of these crystal phases occur also within the matrix of the rock, which is fine-grained. In addition, quartz forms anhedral interstitial growths, making up about 3–5% of the matrix.

Geochemistry

One sample of quartz monzonite has been analysed for major elements. The results are given in Table 7 and plotted in Figures 6 and 7. Major element plots indicate an affinity with the granodiorite, the coarse-grained granite and the volcanic rocks, rather than with the fine- and medium-grained granites. A similar relationship is apparent from trace element chemistry (Table 3, Figure 8).

Age Relations

The quartz monzonite intrudes all of the major plutonic rocks, Veins of fine-grained granite have been found within sheets of quartz monzonite near Kowloon Reservoir, but the relationship between these veins and plutonic bodies is not known.

Chapter 6
Minor Intrusions

Classification

The minor intrusions of the district fall into four categories; quartzphyric rhyolite, feldsparphyric rhyolite, quartz latite and basalt. The intrusions are almost exclusively dykes, and these trend mainly in northeasterly or northwesterly directions.

Allen & Stephens (1971) classified these minor intrusions as either quartz porphyry, feldspar porphyry or dolerite. In this survey the porphyries of Allen & Stephens correspond variously to the feldsparphyric rhyolite, quartzphyric rhyolite and quartz latite, depending on the assessment of their mineralogical composition, and their dolerites are mapped as basalt. This system has been adapted from the recommendations of Streckeisen (1980).

Streckeisen (1974) makes no recommendations for the nomenclature of minor intrusions. However, Hatch et al (1972) recommend the use of the terms rhyolite, latite and basalt for such rocks on the grounds that the rock name is dependent upon grain size alone and not on mode of occurrence. Hence a rhyolite may be intrusive or extrusive. The value of this system is that the rock may be named correctly even if the field relations required to establish its mode of occurrence are obscure.

Quartzphyric Rhyolite
Distribution and Lithology

Quartzphyric rhyolites form dense swarms of northeast-trending dykes on Yim Tin Tsai around Tai Po, Pai Mun, Cove Hill and, to the southwest, around Sam Tsuen. Isolated occurrences are found on Ma On Shan and The Hunch Backs, and at Pak Wai. The dykes are up to 20 m wide, though usually only about 5 m. The rocks are pale grey to pale greenish grey, microcrystalline to sacharroidal, with common small phenocrysts up to 3 or 4 mm of quartz, and less common smaller phenocrysts of feldspar. The margins of the dykes are flow-banded (Plate 32).

Details

Yim Tin Tsai. The best exposed, densest swarm of quartzphyric rhyolite dykes occurs on and around Yim Tin Tsai. Individual dykes vary from 3 to 20 m wide, and strike generally in a northeasterly direction. Several dykes crop out on the northern coast of Yim Tin Tsai (4050 3472) where they intrude tuffs of the Yim Tin Tsai Formation. They occur either as single or as multiple intrusions. On Ma Shi Chau (4120 3443) quartzphyric rhyolite intrudes along the fault separating Permian rocks of the Tolo Harbour Formation and Jurassic rocks of the Tolo Channel Formation. North of Yim Tin Tsai (3977 3545) quartzphyric rhyolite dykes intrude granodiorite; the direction of strike in this area varies from northerly to easterly.

Tai Po – Chinese University. An easterly or east-northeasterly dyke trend is predominant in the area south of Tai Po. Here a group of quartzphyric dykes, although displaced by faults, can be traced for over 3 km. The outcrops above Sheung Wun Yiu (3480 3340) are deeply weathered to a white clay soil which, in the past, has been extensively excavated for use in the manufacture of pottery. Northeast of the Chinese University, near Tsiu Hang and Pai Mun (3880 3150), quartzphyric rhyolites intrude siltstones and sandstones of the Tolo Harbour Formation while, at the Chinese University itself, a rare instance occurs of quartzphyric rhyolite intruding medium-grained granite. As on Yim Tin Tsai the trend of these dykes is northeasterly. The dykes of the Tsiu Hang and Pai Mun outcrops appear to be offset sinistrally across the northwest-trending faults of Tai Po Mei (3845 3123). Dykes crop out in the Cove Hill borrow area (3890 3030), intruding granodiorite and tuffs of the Repulse Bay Volcanic Group, and similar dykes crop out again on Cove Hill (3780 2990).

Kwai Chung. Few instances of quartzphyric rhyolite occur southwest of Cove Hill until the outcrops of Kwai Chung are reached. Here, quartzphyric rhyolite intrudes granodiorite and fine-grained granite in faulted complexes at Sheung Kwai Chung (3264 2688) and Sam Tsuen (3100 2602).

Southeast of the Sha Tin Valley. Quartzphyric rhyolite is uncommon in the area southeast of the Sha Tin valley. One group of thin dykes intrudes tuffs of the Ap Lei Chau Formation on the ridge of The Hunch Backs and Ma On Shan (4395 3015), and a substantial, 15 m wide, northeast-trending dyke crops out in roadside exposures at Pak Wai (4444 2450) intruding tuffs of the Tai Mo Shan Formation.

Petrography

Specimen HK 272 (3584 2930) from the ridge southeast of Grassy Hill shows the features typical of the quartzphyric rhyolite (Plate 26). It comprises predominantly a matrix of closely intergrown, microcrystalline quartz, feldspar and minor biotite, with phenocrysts of the same minerals. Quartz is in the form of slightly rounded, but euhedral, crystals and crystal clusters up to 3 mm across, though more generally about 2 mm. The crystals show slight reaction rims but are not substantially embayed or resorbed. Feldspars are sparse, plagioclase up to 1 mm being most common; clouded, epidotised orthoclase is subordinate. Biotite, which is mainly altered to chlorite and iron ores, is scattered throughout as small flakes up to 0.2 mm with occasional larger crystals.

Age Relations

The quartzphyric rhyolite has been found as dykes intruding all of the granites northwest of the Sha Tin valley but, although present southeast of the valley, it has only been noted there intruding the Jurassic volcanic rocks. The dykes appear to be offset by northwest-trending faults around the Chinese University, but intrude along the northeast-trending faults of Ma Shi Chau.

Plate 32 – Dyke of Flow-banded Quartzphyric Rhyolite Intrudes Tuff of Yim Tin Tsai Formation on Yim Tin Tsai (4050 3472)

Feldsparphyric Rhyolite

Distribution and Lithology

The feldsparphyric rhyolite occurs in four main contexts; in sheets associated with the granodiorite in the areas around Shing Mun and Tsiu Hang; in northeast-trending dykes intruding granodiorite and all varieties granite between Kwai Shing and Fo Tan; in east-west or northwest-trending dykes intruding granites and tuffs of the Repulse Bay Volcanic Group in the south on Tsz Wan Shan and around Yuen Tun Ha, and in the Tai Po Kau Nature Reserve; and as large masses intruding tuffs of the Repulse Bay Volcanic Group on Shek Nga Shan, Mau Ping Lo Uk and Ngong Ping Shan. The dykes are generally up to about 20 m wide, though exceptionally they may attain 60 m.

The lithology is moderately uniform, comprising crystals up to 20 mm of euhedral feldspar, dominantly pink orthoclase, and euhedral quartz, commonly in bipyramids up to 10 mm, in a matrix which, when fresh, is dark and microcrystalline but which weathers to give a pale buff, sandy appearance. Biotite may sometimes be present in flakes up to 2 or 3 mm.

The rhyolite forming the large masses of the Shek Nga Shan area is strongly flow-banded and very similar to the welded tuff of the Ap Lei Chau Formation, but its petrography indicates a magmatic, rather than a pyroclastic, origin. Moreover, orientations of contacts and flow-banding, the general morphology of the outcrops, and the variety of the country rocks in which the different outcrops occur, all indicate that these rocks are of intrusive, rather than extrusive, origin.

Details

Kwai Chung – Yau Oi Tsuen. Feldsparphyric rhyolite is well exposed at Fu Yung Shan (3020 2670) and in stream sections north of Wo Yi Hop (3200 2800), where it contains conspicuous phenocrysts of feldspar and quartz. In the stream section north of the Shing Mun Reservoir (3322 2887) the top of the intrusion can be seen dipping gently northwards beneath bedded tuffites and siltstones of the Shing Mun Formation. Around Nim Au (3825 3090) and near Tsiu Hang (3795 3254) rhyolite dykes are sinistrally offset by the northwest-trending faults. The feldsparphyric dykes of Kwai Shing (3080 2500), around Kam Shan (3370 2500), Lower Shing Mun Reservoir (3540 2690) and Yau Oi Tsuen (3610 2775) are homogeneous in type with a generally uniform northeasterly trend. They intrude all of the plutonic rock-types of the area and cross-cutting relationships are recorded, although not exposed, as individual dykes clearly intersect the granite boundaries.

Tai Po Kau. The outcrops at Yuen Tun Ha (3400 3180) and in Tai Po Kau Nature Reserve (3700 3240) appear to represent a faulted, easterly-trending dyke. However, in stream sections above Tsung Tsai Yuen the same dyke appears to follow a northeast-trending fault for a short distance before resuming an easterly trend on the southeastern side of the fault.

Sha Tin Pass – Shui Ngau Shan. The dykes of Tsz Wan Shan (3910 2410) and Tiu Tso Ngam (3980 2410) are up to 60 m wide and strike in a northwesterly direction. Although they mostly have the normal aphanitic groundmass with scattered phenocrysts of quartz and feldspar (4005 2405), in some instances they are crowded with feldspar phenocrysts (3880 2413). At these localities the rhyolites intrude fine- and medium-grained granites, and tuffs of the Shing Mun Formation. At Shek Nga Pui (4140 2585) a feldsparphyric rhyolite dyke intrudes the coarse-grained granite, while west of there, on Fu Yung Pit (4270 2600) and Shui Ngau Shan, a group of small bosses of feldsparphyric rhyolite intrudes tuffs of the Ap Lei Chau Formation.

Plate 33 – Flow-banded Feldsparphyric Rhyolite on Shek Nga Shan (4237 2714)

Shek Nga Shan – Ngong Ping Shan. The rhyolites of Shek Nga Shan (4220 2700) and Ngong Ping Shan (4440 2920) differ from the more usual varieties of feldsparphyric rhyolite in being generally finer grained, darker coloured, sparsely porphyritic and flow-banded (Plate 33). In thin section the rocks have a finely recrystallised felsic matrix which in places develops perlitic cracking and spherulitic growths, and encloses resorbed quartz crystals and slender alkali feldspar crystals (sanidine). In hand specimen feldspar crystals show a blue schiller effect, a feature which has also been noted in welded tuffs of the Ap Lei Chau Formation on Ma On Shan. The lithological indentification of the rocks as rhyolites is clear; whether they are extrusive or intrusive in origin is less obvious. The fine grain-size and flow-banding are perhaps more consistent with an extrusive origin. Chemical analysis, and particularly trace element analysis, of this rhyolite from an exposure on the Sai Kung-Nai Chung road (adjacent to this district at 4605 3046) shows similarities with volcanic rocks (Table 8). However, other factors militate against an extrusive interpretation; interpreted contacts are mostly steep; the geological settings of the different outcrops are complex and varied; flow-banding is inconsistent; and blocky or autobrecciated textures, such as would be developed in extrusive flows, are absent.

Table 8 – Major Element Analyses of Rhyolitic Tuff and Rhyolite Samples

	Rhyolitic Tuff Ap Lei Chau Formation Ngong Ping Shan (4407 2854) HK 202	Intrusive Rhyolite Sai Kung Road Sheet 8 (4619 3007) HK 217
SiO_2	75.58	71.22
TiO_2	0.11	0.27
Al_2O_3	13.10	14.30
Fe_2O_3	0.69	0.76
FeO	0.89	1.56
MnO	0.06	0.11
MgO	0.05	0.20
CaO	0.58	1.16
Na_2O	3.70	3.39
K_2O	5.62	6.30
H_2O^+	0.33	0.42
H_2O^-	0.12	0.13
P_2O_5	0.01	0.05
CO_2	—	—
Total	100.84	99.87

On Shek Nga Shan (4230 2700) flow-banded rhyolite intrudes tuffs of the Shing Mun and Ap Lei Chau formations, but at Ngau Au (4170 2760) and on the ridges northwest and southeast of Shek Nga Shan a quartz monzonite sheet intrudes along the contact. Near Mau Ping Lo Uk (4300 2750) flow-banded rhyolite intrudes tuffs of the Tai Mo Shan and Ap Lei Chau formations, and, as on Shek Nga Shan, quartz monzonites are associated with the contact zones. Northeast of Mau Ping Lo Uk and on Ngong Ping Shan the rhyolite intrudes the Ap Lei Chau Formation. The southeastern flanks of the flow-banded rhyolite outcrops are defined by the Ngong Ping Shan Fault, which also forms the locus for intrusion of quartz monzonite. At Shek Nga Shan and at Shek Lung Tsai (4260 2830) the Ma On Shan Fault forms the northwestern margin of the rhyolite intrusion.

Petrography

Specimen HK 104 from the Lower Shing Mun Reservoir (3483 2593) illustrates the characteristic features of the feldsparphyric rhyolite. This shows euhedral crystals of orthoclase (up to 9 mm) showing simple twinning, occasionally intergrown with multiple-twinned plagioclase feldspar which usually forms euhedral crystals or crystal clusters up to 5 mm. Quartz is less abundant than the feldspars but forms euhedral bipyramids or clusters of crystals up to 3 mm diameter. Biotite occurs as small flakes up to 2 mm. The matrix comprises about 60–65% of the rock and consists of finely recrystallised feldspar and quartz.

Specimens HK 2 from Ngong Ping Shan (4449 2882) and both HK 1245 (4243 2707) and HK 1247 (4188 2733) from Shek Nga Shan illustrate the features of the flow-banded feldsparphyric rhyolite (Plate 27). In all three sections the rock has a microcrystalline, recrystallised quartzo-feldspathic matrix. In HK 2 and HK 1247 the matrix is banded, and in HK 2 it shows conspicuous perlitic cracks. Phenocryst assemblages are the same in all three cases, consisting of flow-aligned, rather slender crystals of alkali feldspar (sanidine) up to 8 mm long, which are euhedral but slightly resorbed. Quartz forms 1–2 mm euhedral grains which are commonly strongly resorbed. Plagioclase forms sparse equant grains which are strongly twinned and quite strongly sericitised. Specimen HK 1245 contains microlites of oligoclase-andesine feldspar in the matrix.

Age Relations

The feldsparphyric rhyolite dykes have been found cutting all major plutonic rock types. Near Tsiu Hang a dyke of quartzphyric rhyolite crops out within a dyke of feldsparphyric rhyolite and, in this instance at least, post-dates the feldsparphyric variety.

The petrography, field characteristics, outcrop form and geochemistry of the intrusions of Shek Nga Shan all indicate that these bodies may be high-level sub-volcanic intrusions. Their associated extrusive rocks could be the Ap Lei Chau tuffs or, possibly, younger formations of the Repulse Bay Volcanic Group not exposed in this district.

Quartz Latite

Distribution and Lithology

A group of minor aphanitic feldsparphyric dykes which crops out on Shui Ngau Shan, Wong Ngau Shan and Tsim Mei Fung are somewhat problematical. They are commonly flow-banded and contain small flow-aligned phenocrysts of feldspar and quartz; in places their texture resembles that of the quartz monzonite.

In hand specimen the rocks are rather indeterminate in appearance, weathering buff to grey, being aphanitic, with scattered small crystals up to 5 mm of feldspar, quartz and biotite; flow-banding is common but not ubiquitous. They have been termed quartz latites because of their petrography and their similarity and association with the quartz monzonites at outcrop, although they are much finer-grained than the monzonites.

Details

The intrusions on Tsim Mei Fung (4130 2556) are the most distinctive of the quartz latites, being markedly flow-banded with common flow-aligned feldspar phenocrysts up to 5 mm, patches of biotite flakes up to 2 mm and xenoliths of quartz monzonite. The dykes on Wong Ngau Shan and Shui Ngau Shan intrude tuffs of the Ap Lei Chau Formation, which have a superficially similar appearance, making geological boundaries unclear in places.

Petrography

A sample from Tsim Mei Fung (HK 788, 4134 2547) shows the main features of this lithology (Plate 28). The matrix of the rock is faintly flow-banded and comprises finely recrystallised, granular quartz and feldspar with minor biotite. Within the matrix there are euhedral to rounded and anhedral crystals of alkali feldspar, plagioclase and quartz. Alkali feldspars are the largest and most abundant crystals, up to 5 mm long, and consist of microperthite which often shows an uneven extinction, probably due to alteration as a result of instability within the matrix, since all grains have reaction rims. Some crystals, however, show signs of original zonation. Plagioclase grains, also occasionally up to 5 mm long, are multiple-twinned and their extinction angles indicate an oligoclase composition. All crystals show zonation and reaction rims, with some regrowth overprinting the reaction rims. Quartz grains are up to 2 mm long, rounded and very deeply embayed. Biotite forms ragged crystals up to 1 mm, which are pleochroic from mid-brown to dark brown. The crystals commonly overgrow minute quartz grains of the matrix.

Age Relations

This rock type is known only in the area around Shui Ngau Shan where it intrudes tuffs of the Ap Lei Chau Formation. Its association with quartz monzonite suggests that it is probably coeval with that rock type.

Basalt

Distribution and Lithology

The basic intrusions of the district are in the form of minor dykes generally up to 2 m thick. They have been termed basalts because they are microcrystalline; the use of this name does not imply an extrusive mode of origin.

The dykes occur in two main trends, northeast and northwest, usually with only one trend being represented in any one area. The dykes occur around Kwai Chung and around Tai Po, with minor occurrences at the Lion Rock Tunnel and Tai Shui Hang. In the field the rocks appear dark greenish grey and aphanitic, weathering to a fine reddish brown soil. The rock is usually non-porphyritic but one example at Kwai Shing contains xenocrysts of feldspar and quartz.

Details

The basalt dykes of Tai Po are not well exposed in natural sections but can be seen in road excavations. Near Kam Shan (3410 3453) deeply weathered, thin (c 1 m) dykes intrude saprolitic granodiorite. At Wai Tau Tsuen (3322 3580) bridge excavations revealed a dyke about 50 m wide which was homogeneously aphanitic

(HK 412). Thin dykes intrude siltstones and tuffs of the Repulse Bay Volcanic Group in borrow areas south of Tai Po (3540 3342) and in roadside exposures at Tai Po Kau (3686 3317). Numerous basalt dykes were encountered in tunnel works west of Tai Po, and inferred extensions of these dykes at crop are shown on the map.

Around Kwai Chung there are a few basalt dykes up to 2 m wide. North of Cheung Shan Estate (3124 2670 and 3166 2677) they intrude tuffs of the Repulse Bay Volcanic Group, whereas at Shek Lei they intrude fine-grained granite (3220 2474). At Kwai Shing, in road-cuts near the Texaco Road roundabout (3012 2478), a basalt dyke carries xenocrysts of quartz and feldspar up to 15 mm long. This dyke is also cut by quartz veins.

Thin dykes have been recorded intruding the medium-grained granite southeast of the Sha Tin valley in Tai Shui Hang (4198 2838), and at Wu Kai Sha (4250 3142).

Petrography

Specimen HK 412 is from the thick dyke at Wai Tau Tsuen (3322 3580, Plate 29). The rock is predominantly formed of fine laths, up to 0.2 mm, of biotite, feldspar and amphibole, with grains of pyroxene and iron ores, all closely interlocking; phenocrysts of clinopyroxene are common, as are chloritic pseudomorphs after feldspar phenocrysts. Carbonate-filled vesicles are also common.

Age Relations

The basalt dykes intrude all the main rock types of the district. The dykes which trend to the northwest follow a fault trend which cross-cuts the quartzphyric and feldsparphyric dykes north of the Chinese University. It is likely that the basalt dykes represent the latest magmatic event of the district. Indeed, it is probable that the basalt dykes belong to an entirely separate phase of intrusion related to extensional tectonics during the opening of the South China Sea Basin during the Tertiary (Holloway, 1982). However, basalt xenoliths are known within the granite at Sha Tin Pass (3863 2450), and it is to be expected that further evidence of earlier phases of basalt intrusion might be found.

Chapter 7
Structure

Bennett (1984c) reviewed the regional structural setting of Hong Kong and detailed the previous work on its structure and tectonic history. The principal structural elements within the district are shown in Figure 9.

Pre-Mesozoic Structures
Tolo Channel Anticline

Fold style. The form of the Tolo Channel Anticline as it affects pre-Mesozoic rocks is inferred from the attitude of the Devonian Bluff Head Formation on Harbour Island and Tang Chau and at Sai O, and the Permian Tolo Harbour Formation on Ma Shi Chau, A Chau (Centre Island) and around the Chinese University. The Bluff Head Formation on Harbour Island and Bush Reef dips steeply to the southeast but shows evidence of a northwestward younging direction. In the Sai O water tunnel (4410 3205) quartzites and siltstones assigned to the Bluff Head Formation dip generally to the northeast at 20°. On Ma Shi Chau northeast-striking strata young towards the northwest. It is inferred that the Tolo Channel Anticline is a tight fold with a northeast-trending axial trace and an overturned northwestern limb. The anticline is faulted along its axial zone by the Ma On Shan and Lai Chi Kok – Tolo Channel faults.

Minor folds. Minor folds are well displayed on Ma Shi Chau (Plate 3) and their trends are given in Allen & Stephens (1971). The anticlines are usually asymmetrical with north-northeast-trending axes which plunge steeply in the same direction. Western limbs are vertical or overturned, striking sub-parallel to the fold axes; eastern limbs dip northeast at about 60°. A tight, minor syncline on the northwestern shore (4174 3541) also plunges steeply to the north-northeast and has an overturned western limb. Other synclines are drag folds against faults which commonly trend parallel the fold axes. Similar minor folds have been noted on A Chau. Strong kink structures affect the Permian strata on the southwestern shore of Ma Shi Chau.

Faults. The Devonian strata of Harbour Island are cut by close shear-planes and minor faults on the southwestern coast (4348 3467). These structures strike at about 028°, dipping steeply southeast, and suggest the existence of a parallel major fault in the channel between Harbour Island and Ma Shi Chau. Faults are extremely common within the Permian strata of Ma Shi Chau, most often parallel to minor fold axes at strike angles of 015° to 030°. Faults on A Chau also affecting Permian strata strike north-south. The drag folds against these faults indicate a sinistral strike-slip movement.

Age of folding. The Jurassic Tolo Channel Formation on Ma Shi Chau is not involved in tight folding nor has it developed kink structures. Also, sedimentary breccia forming the lowermost beds of the Repulse Bay Volcanic Group on Ma Shi Chau contains clasts of siltstone which have quartz veins and penetrative shears and cleavage such as are seen in the Permian strata. Quartzphyric rhyolites which intrude folded strata at the northern end of the island have flow-banding which indicates intrusion after folding. All these features indicate an age of folding at some time between the late Permian and early Jurassic, i.e. between 230 and 195 ma. Reports of late Triassic – early Jurassic structural activity in China were quoted by Bennett (1984c).

Mesozoic Structures
Tolo Channel Anticline

Fold style. The Tolo Channel Anticline, as it affects the Mesozoic strata of the district, is a broad open fold with its axial zone extending along the Sha Tin valley, through Tide Cove and Ma On Shan and along Tolo Channel. The fold plunges northeastwards towards Tide Cove. The Mesozoic strata in the Tai Mo Shan and Grassy Hill areas, on the northern flank of the Anticline, dip northwest at about 20°. Southeast of the fold, strata are complexly faulted, but the pervading dip is to the southeast. In broad terms, this is also the disposition of the contact between the granite and its enclosing strata.

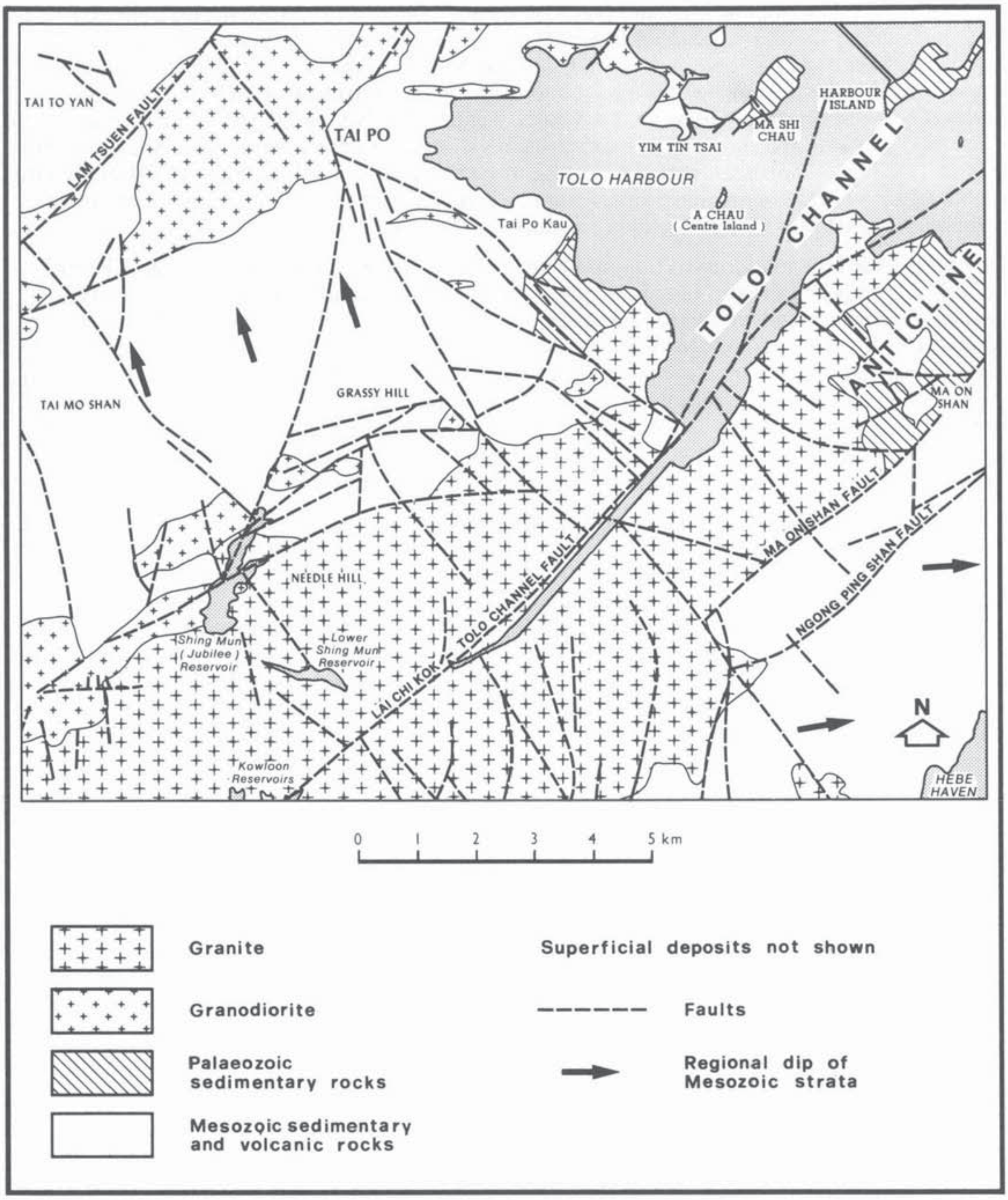


Figure 9 – Principal Structural Features of the District

Faults parallel to fold axis. The axial zone of the Tolo Channel Anticline is also a fault zone, and there are many faults parallel to the fold axis. A major structure, the Lai Chi Kok – Tolo Channel Fault, lies along the Sha Tin valley and is exposed north of the Kowloon Reservoir (3450 2434). Here the fault strikes 050° and has an associated wide breccia zone with slickensides indicating strike-slip movement. A splay from the main fault in Tide Cove may continue into the channel separating Ma Shi Chau from Harbour Island but the main fault itself is considered to pass southeast of Wu Kwai Sha Tsui. Strong jointing in granite on the shoreline east of Lok Wo Sha (4360 3258) is believed to have been developed in proximity to the main fault.

Faults subparallel to the Lai Chi Kok – Tolo Channel Fault can be traced from Ma On Shan to Tai Che (4090 2702), and from Ngong Ping Shan (4430 2846) to Shek Nga Pui (4130 2600), where they strike 050°. The Ma On Shan and Ngong Ping Shan faults downthrow strata to the southeast. These and similar faults are the main causes of minor fold deformation such as that seen on Ma On Shan at Shek Nga Pui, and on Ma Shi Chau and Yim Tin Tsai. It is possible that the Ma On Shan Fault extends southwestwards into the zone of complex intrusions which strike in a similar direction south of Sha Tin Wai to the Lion Rock Tunnel. The Ngong Ping Shan Fault may extend in a similar way into the zone of complex intrusions striking southwestwards from Shek Nga Pui to Man Tau Tun. A northeast striking fault has been mapped on Tsz Wan Shan (3890 2404). On Ma Shi Chau a northeast-trending fault separates Permian strata on the southeast from Jurassic strata on the northwest. A rhyolite dyke intrudes the fault line.

Between Needle Hill and Grassy Hill, on the northern side of the Lai Chi Kok – Tolo Channel Fault, is a group of faults striking about 060° to 080°. This group extends from the Cove Hill borrow area and Fo Tan westwards across Shing Mun Reservoir, converging near Cheung Shan Estate (3190 2685). Outcrops near Cheung Shan Estate show intensely brecciated and sericitised, granodiorite and tuff. Movement on the faults is relatively minor, their main effect being to form a minor graben on the northern side of the granite outcrops. Minor zones of mylonite occur in the coarse-grained granite at Sha Tin Wai (3847 2623) and in the medium-grained granite north of Sha Tin Pass (3861 2446 and 3842 2525). At the latter two localities (HK 1351 and 1359) narrow shear bands strike 075° and 065° respectively, dipping steeply northwards.

Relationship between major intrusions and Mesozoic structures. For the most part the shape of the major granite masses reflects the folds as seen in the Jurassic strata. The tendency towards closure of the granite outcrop northwards around Wu Kwai Sha Tsui corresponds with the northeastward plunge of the Tolo Channel Anticline along Tide Cove. The dip of the Jurassic strata on the northwestern limb of the Anticline, west of Sha Tin, is generally concordant with the layering observed in the adjoining granite outcrops. The attitude of the granite layering is considered to be an intrusive morphological feature rather than due to later tectonism, and thus it seems likely that the broad folding of the country rock is in part a doming effect over the granite pluton. The quartz monzonite bodies commonly coincide with fault zones and are believed to have been intruded preferentially along lines of contemporaneous structural weakness.

Cross faults. A significant number of faults occur with trends of about 130° and 180°–190°. They have vertical displacements of as much as 200 m, as seen on the northern flanks of The Hunch Backs (4350 3070), or horizontal displacements of up to 600 m sinistrally, as seen at the Chinese University (3920 3060).

The most important set of cross faults includes the two mentioned above and extends from northwest of Tai Po (3360 3500) to Tide Cove, and from there to Ma On Shan and along Tai Shui Hang to Mau Ping, south of the Cove. These faults intersect the Ma On Shan and Ngong Ping Shan faults and displace them slightly. Fault breccias associated with the fault at the Chinese University crop out near Ma Liu Shui (3967 3025). Between Shui Ngau Shan and Sha Tin Pass numerous cross faults cut the northeast-trending granite complexes. In a few instances basalt dykes are intruded along these faults, as they are along similar faults northwest of Tai Po.

A line of southeast-trending faults which lie en échelon extends from Kadoorie Farm through the headwaters of the Shing Mun River, across the southern ridge of Needle Hill and through the Lower Shing Mun Reservoir to the area of the Lion Rock Tunnel. Quartz veins with mineralisation are associated with these faults at Needle Hill Tungsten Mine. Another group of similar faults extends from Tai Mo Shan southwards to Sam Tsuen and Kwai Shing. On Tai Mo Shan a N-S fault has been the locus for intense alteration of tuffs of the Tai Mo Shan Formation (3042 2895).

With the exception of the fault on Tai Mo Shan mentioned above, most of the cross-faults described can be shown to be late structures. Northwest of the Chinese University the faults displace late feldsparphyric and quartzphyric rhyolites. South of Tide Cove the cross faults intersect and slightly displace the northeast-trending faults. In places, however, they are occupied by basalt dykes and quartz veins.

Chapter 8
Metamorphic Rocks

Contact Metamorphic Rocks

The most widespread metamorphic rocks of the district are thermally altered tuffs and sedimentary rocks associated with granitic intrusions. The contact or thermal metamorphism of the sedimentary rocks has resulted in the formation of spotted hornfels north of the Chinese University and skarns at Ma On Shan. Weak thermal alteration of the tuffs has resulted in the regrowth of biotite, quartz and albite. With more intense metamorphism the original textures have been lost and the rock may resemble a fine-grained igneous rock. The same effect has been noted in contact metamorphism of feldsparphyric rhyolite at Ma On Shan.

The Permian beds in the vicinity of the granite at the Chinese University show contact metamorphic spotting at a distance of up to 200 m from the contact (3938 3178). Closer to the granite, higher grade metamorphic rocks show cordierite porphyroblasts to 1 mm in a felt of aligned, pale orange-brown biotite crystals and quartz grains (HK 89, 3945 3179). Alignment of biotites implies high stress at the time of metamorphism, presumably due to the forceful intrusion of the granite (Plate 30).

The sedimentary rocks around the mine at Ma On Shan are generally intensely altered but this metamorphism may not be entirely due to thermal contact alteration against the granite. Since both the granite and a feldsparphyric rhyolite dyke (HK 1252, 4326 2985) show recrystallisation of biotite and intense quartz veining, it seems likely that some of the alteration of these sediments may be due to later mineralising fluids. The development of skarn rocks in the mine is likely to result from the alteration of carbonate-bearing sedimentary rock. It has been suggested (C. M. Lee, oral communication) that the strata involved are most likely to be Devonian in age, since strata of that age in Guangdong Province include sedimentary iron ores.

Contact metamorphism commonly affects tuffs cropping out east and west of the Shing Mun Reservoir. The metamorphism has caused the recrystallisation of quartz, biotite and albite, making it difficult to allocate the tuffs to a particular formation.

Dynamic Metamorphic and Related Hydrothermally Altered Rocks

Tuffs of the Repulse Bay Volcanic Group, mostly on Tai To Yan and Tai Mo Shan, are cut by steeply inclined bands of alteration, mostly not more than 5 m wide but extending in some cases more than 1 km. The alteration is believed to be the product of hydrothermal processes, and in some instances may be associated with the intrusion of material of subvolcanic exhalative origin.

The altered tuffs are remarkably uniform in appearance both in the field and in thin section. At outcrop the bands usually form sharp ridges of jagged crags which contrast with the smooth terrain and rounded or cuboidal boulders of the surrounding tuffs. The rock type is pale grey, buff weathering and fine-grained, with moderately common and conspicuous relict glassy quartz lapilli to 4 or 5 mm. Lithic lapilli of sandstone and microcrystalline volcanic rocks may occasionally occur. Volcanic lapilli may appear as fiammé which lie parallel to the margins of the body. In some examples, secondary biotite and deeply altered feldspar grains have been recorded. The specimen HK 134 (3257 3192) is an altered tuff typical of the outcrops north of Tai Mo Shan. It consists of free crystals of quartz up to 5 mm, forming about 12% of the rock, with occasional, very deeply altered crystals of mica and possible sericitic pseudomorphs of feldspar. The quartz grains are either large, rounded and embayed, small, broken and angular, or splintery. Lithic lapilli are almost exclusively of a porphyritic igneous rock which contains quartz phenocrysts and occasional biotite crystals in a granular recrystallised felsic matrix.

One particular altered band, on the southern ridge of Tai Mo Shan, is significant, extending as it does for over 1 km. It is well exposed at 3046 2892 (HK 375), where it is rich in lithic lapilli, some of which appear to be sedimentary. The margins of the band are sheared, and the altered tuff itself contains many quartz stringers. Immediately to the west of the band there are outcrops of sheared sediment a few metres wide and these are succeeded laterally by outcrops of lapilli-ash crystal tuffs which have a sub-horizontal welding fabric. The same fabric can be seen in tuffs immediately to the east of the band and these attitudes are consistent with the known structure of Tai Mo Shan. The band itself can be traced southwards downhill where it can be seen in stream sections at 3053 3860 and at 3062 2819 (HK 376); here it affects tuffs of the Shing Mun Formation some 300 m below its outcrop on the ridge.

Around Kadoorie Farm tuffs are cut by narrow shear zones and have developed a strong schistosity parallel to the fault planes. One such example, HK 341 (3067 3183, Plate 31), shows the development of fine biotite crystals in sheaves between unaltered tuff lenses. Here also the tuffs are affected by thin zones of intense chloritisation which, in some exposures, almost entirely obliterates the original texture of the rocks. Granodiorite seen in adjacent outcrops is also intensely chloritised, especially on Kwun Yam Shan (3032 3190), where a weak foliation is also developed.

Chapter 9
Mineralisation and Mining

Mineralisation in the Sha Tin area falls into two main categories; fissure veins containing quartz and metallic minerals, and contact metasomatic skarn deposits.

Fissure Vein Deposits

The most important deposits of this type crop out on the hillside immediately north of the Lower Shing Mun Reservoir. A total of 11 wolframite-quartz fissure veins have been worked, the workings being referred to collectively as the Needle Hill Tungsten Mine. The veins have an average strike of 300° and usually dip steeply to the south. They average only 0.4 m in width and extend over distances of 200 to 400 m. The average grade of the crude ore worked yielded 0.41% wolframite concentrates. One lode, vein A, extended over 450 m and had an estimated depth of 240 m with an average vein width of 0.41 m; it yielded an average wolframite content of more than 1% in crude ore (Hui, 1978). Between 1956 and 1967 a total of 216.4 tonnes of wolframite concentrate was produced at Needle Hill Tungsten Mine. The mining lease expired in 1978 and since that time no ore has been produced. The mineral veins cut both fine- and medium-grained granites and probably represent a late-stage injection of high-temperature hydrothermal mineralised fluids along parallel northwest-trending fractures. Other minerals present in the Needle Hill ore-bodies include minor amounts of galena, sphalerite, pyrite, molybdenite and fluorite (Peng, 1978).

At Ho Chung (4275 2428), in the southeast of the district, a wolframite-quartz fissure vein deposit similar to that at Needle Hill has been worked on a small scale. Here, the vein occurs within fine-grained granite.

Minor lead-zinc bearing fissure veins cut the Repulse Bay Volcanic Group in the area north of Tai Mo Shan. In the headwaters of the Lam Tsuen Valley (316 315) several abandoned adits were noted, and galena and sphalerite were present on the waste dumps. Molybdenite was noted within granite at 3635 2492, near Sheung Keng Hau.

Skarn or Tactite Deposits

The major deposit in this category occurs on the western slopes of Ma On Shan, where a large magnetite-bearing ore body has been mined both underground and in a large opencast pit. The crude magnetite ore contained an average iron content of 32%, and between 1957 and 1968 the average production rate was 98 000 tonnes of ore per year. The mine ceased operation in 1976. The ore body occurs at the contact between fine-grained granite and sedimentary rocks of the Bluff Head Formation. Contact metasomatism of the sedimentary rocks has resulted in large masses of magnetite enclosed in a skarn body containing tremolite, actinolite, diopside and garnet as the principal gangue minerals. In parts of the underground workings near the granite contact magnetite occurs in marble (Peng, 1978). Weld (1915) noted similar, but smaller scale, 'contact metamorphic iron deposits' south of Tai Po Hui, and around around Tai Mo Shan, but no details were given.

Pegmatite

Pegmatite patches are common within the fine- and medium-grained granites, and at Tung Lo Wan (370 268) in Sha Tin a large pegmatite body has been quarried for pure alkali feldspar that is used in the manufacture of ceramics and enamels, and in glassmaking. This pegmatite crops out over an area of 25 m by 15 m and has been worked to a depth of 10 m (Peng, 1978). A mining licence is still in effect for this working, which is the only active mine within the district.

Chapter 10
Superficial Geology

Bennett (1984a) gave a comprehensive review of published work on superficial deposits and weathering processes and products in Hong Kong.

Classification of Materials

Most of the data on superficial materials and weathering in the low-lying coastal and offshore areas of the district are derived from borehole records. The borehole sites are mainly in the Sha Tin, Tide Cove and Tai Po areas, and also in the vicinity of Harbour Island.

The superficial materials of the district are grouped into two main classes; the transported materials and the in-situ materials. The in-situ materials include boulder fields and saprolite mantles. The transported materials comprise marine, estuarine and alluvial deposits and the deposits of mass-wasting (colluvium), including debris flow, talus (rockfall) and slide deposits. The estuarine deposits are of mixed origin, formed by the interaction of marine and alluvial processes; similarly, deposits of mixed debris flow and rockfall origin are recognised.

Fill deposits (made ground) are mostly those of marine reclamation but include site formation fill and mining and sanitary dumps. The limits of reclamation shown on the map are updated to October, 1985.

Marine Mud and Marine Sand

As far as has been determined, there is only one layer of marine sediments in Tolo Harbour and its associated inlets. The marine sediments are divided into two broad classes; sand and mud (Figure 10). The mud is the more extensive and represents clays and silts deposited by settlement from suspended load in sea water. The sand appears to be closely associated with the near-shore environment and is most probably locally derived terrestrial material. Sand bodies have been noted at Tai Po, Tai Shui Hang, Wu Kai Sha, Nai Chung, Sha Tin and along the coast between Sha Tin and Tai Po. No surface sand deposits are known in the main body of Tolo Harbour. Geophysical investigations carried out at the southwestern end of Tolo Channel indicate that a large area around Tang Chau is devoid of marine deposits. Borehole data indicate that marine deposits are thin or absent in the area of a local bathymetric hollow immediately south of Harbour Island.

Based on radiocarbon dating evidence from similar deposits elsewhere in the Territory (Yim, 1984) these deposits are considered to be entirely Holocene in age.

Details

Tai Po. The marine deposits in the western part of the Tai Po inlet consist mainly of an upper 4–6 m layer of sandy materials over marine silts and clays of a similar thickness. The base of the marine sand is at about −5 m PD and the base of the marine mud is at about −10 m PD. The top of the marine deposits is notably smooth and regular, except where disturbed by reclamation. In the north of the inlet near Sha Lan, coastal sand appears to underlie the marine mud.

Wu Kai Sha, northern Tide Cove and Nai Chung. Offshore from Wu Kai Sha the marine sediments consist mainly of shelly silty clays with only a minor occurrence of sand. The uniform grey marine deposits are generally 10 m, though locally up to 15 m, thick. Their upper surface is smooth and regular, except where it has been disturbed by reclamation or dredging.

Close inshore the marine deposits consist primarily of sandy deposits. These sand bodies were deposited in two distinctly different environments. At the mouth of the river at Tai Shui Hang the marine sand rests on marine mud, whereas at Ma Liu Shui and to the west of Wu Kai Sha sand occurs beneath the marine mud. The underlying sand at Ma Liu Shui represents a littoral deposit that has been buried by the marine mud following a rise in sea-level. The sand deposits that overlie the marine mud are associated with major land streams and, as such, represent locally-derived terrestrial sands deposited in a marine environment. This could imply a recent increase in the rate of deposition of such terrestrially-derived sediment or that the extension of sand bodies over the marine mud is a result of a lowering of the sea-level, producing an offlap sequence.

Southern Tide Cove and Sha Tin. The marine deposits in this area have been greatly disturbed by reclamation and sand dredging. The original marine sequence appears to have consisted of sand grading into clays and silts in a fashion similar to that inferred at Tai Po. Prior to large-scale reclamation, parts of the Cove had been reclaimed by means of small dams and ponds. This has further complicated the stratigraphy. The deposits are noticeably thinner in this area than further north, with a thickness of about 8 m. In an excavation recorded by Whiteside (1984) at The Royal Hong Kong Jockey Club marine mud extended under fill to a depth of −10 to −12 m PD. The mud included a rich macrofauna, mostly bivalves and gastropods. Apart from the basal layer, the fauna was regarded as typical of relatively shallow marine conditions; gastropods from the basal mud, however, were considered to be typical of a soft sediment intertidal shoreline. The basal layer also contained quartz grit and plant remains, including wood, and was darker than the overlying mud.

Estuarine Mud and Sand

These are deposits of mixed alluvial and marine origin. They consist of silt, clay and medium- to fine-grained sand that are grey in colour and may be organic. Estuarine deposits have been mapped only in the Tai Po area where records of boreholes around Tai Po Tau, Tai Po Kau Hui and Kam Shan have been used to delineate them. Like the marine deposits, the estuarine mud and sand are regarded as Holocene in age.

Details

Northwest of Tai Po, numerous boreholes have been drilled through the deposits at the mouth of the Lam Tsuen River. West of Tai Po Kau Hui (3500 3480), the estuarine deposits consist of grey sand up to 5 m thick resting on probable alluvial gravel with cobbles. In places, the grey sand is overlain by up to 1.5 m of grey, organic clay. No marine shells are present in either the sand or the clay. Towards Tai Po Tau (3440 3495) and San Wai Tsai (3500 3526) the estuarine sand and mud are replaced laterally by alluvial sand and gravel. Similarly, close to the channel of the Lam Tsuen River between Shui Wai (3420 3470) and Tai Po, alluvial sands and gravels replace estuarine mud and sand. Areas of estuarine mud and sand were also encountered in boreholes on the southwestern side of the river near Shui Wai and near Kam Shan (3440 3448).

Alluvium

The alluvium comprises a diverse range of sediments from clay to boulders. Of these materials, sand and gravel are dominant. The alluvium may be light grey in colour but is more usually yellow or yellowish brown. On land the main areas of deposition are the Sha Tin valley, Tai Po and Lam Tsuen Valley, with minor areas in and around Kwai Chung, Ho Chung and in the valleys around Tolo Harbour.

Offshore and in certain low-lying coastal areas the alluvium can be subdivided on the basis of whether it overlies or underlies the Holocene marine deposits. The younger alluvium, consisting of poorly sorted sand and gravel, occurs southwest of the Sha Tin valley near Tai Wai. Elsewhere, streams flowing into Tolo Harbour have deposited small deltas of this younger alluvium which intercalates with the marine deposits.

The older alluvium is extensively developed beneath the marine deposits (Figure 10) but its detailed stratigraphy is laterally variable. The general succession of an upward-fining sequence of gravels and sands, as proposed by Holt (1962), is characteristic of only the inner portions of Tide Cove. Elsewhere, such as the area offshore from Wu Kai Sha, the succession is complicated, with many discontinuous gravel layers that appear to fill old channels within sequences of sand, silt and clay. The older alluvium usually rests on weathered bedrock.

The alluvium mapped onshore is entirely Holocene in age. In low-lying coastal and offshore areas the older alluvium, underlying the marine deposits, is regarded as late Pleistocene. Radiocarbon dating of a sample of wood from the upper part of the older alluvium near Sha Tin gave an age of 23 270 $\pm$ 720 yrs BP (Whiteside, 1984).

Details

Lam Tsuen Valley. The alluvium of Lam Tsuen Valley consists of bouldery gravel (Plate 34). These deposits have been eroded following rejuvenation of the river to form a complex set of dissected terraces, the scarp features of which range from 1–10 m in height. The terraces slope from southwest to northeast from a general level of about 80 m PD around Chai Kek (3130 3368) to a level of about 37 m PD around Hang Ha Po (3270 3536). The bouldery alluvium can be seen to rest directly on deeply weathered granodiorite near Wai Tau Tsuen (3338 3565) at an elevation of about 27 m PD and some 10 m above the present valley floor. Over most of its course in the Lam Tsuen Valley the river flows over alluvial deposits but in a few places, such as near Fong Ma Po (3236 3518), it flows directly on granodiorite; the terrace nearby this latter locality has an elevation of around 42–46 m PD, indicating a thickness of alluvium between 15 and 19 metres.

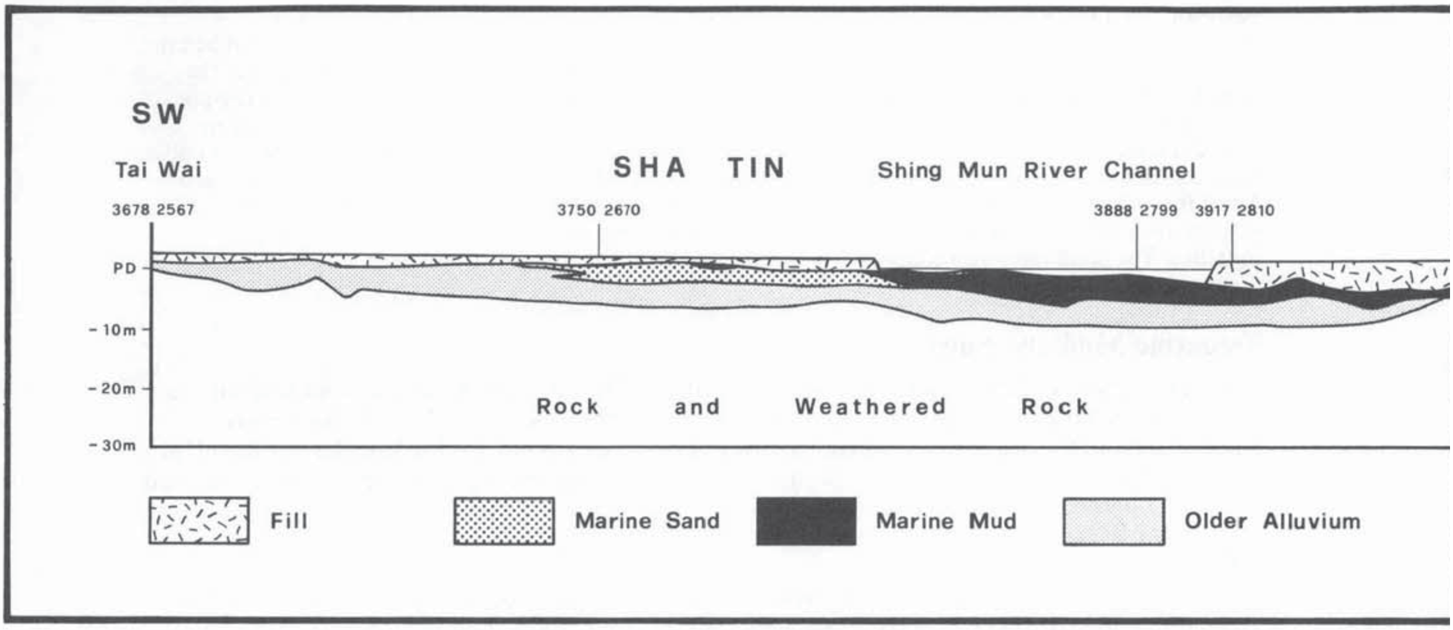


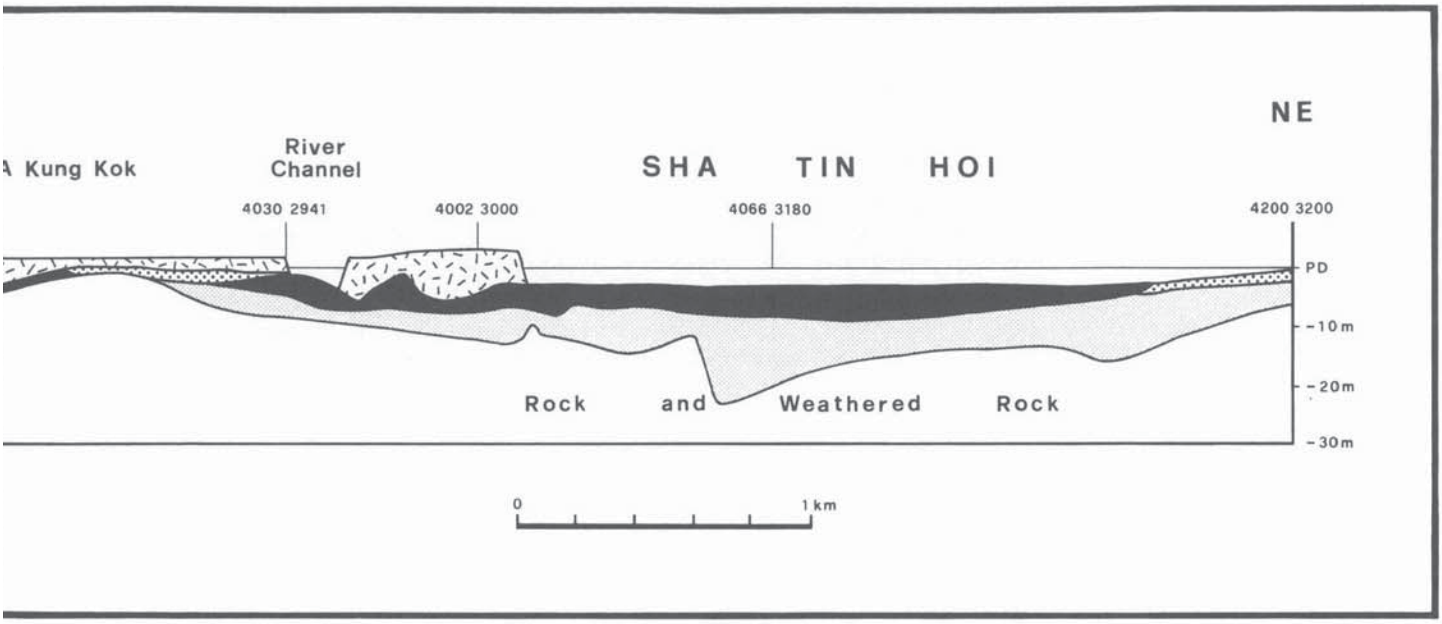
Figure 10 – Section showing the Quaternary Deposits of the Sha Tin Valley and Tide Cove

Tai Po. Alluvium flanks the present course of the Lam Tsuen River between Tai Po and Mui Shue Hang (3375 3516). Up to 5 m of sand and gravel are recorded resting on up to 8 m of gravel with cobbles. In the Tai Po inlet of Tolo Harbour the general level of the base of the older alluvium decreases eastwards to about −20 m PD. This is considerably higher than the levels encountered in the mouth of Tide Cove (see below). The sub-alluvium topography consists of a level shelf with an east-west trending channel connecting with the current position of the Lam Tsuen River. Except along the old channel line and nearshore areas, the cover of the older alluvium is thin compared to the Tide Cove sequence. About 3 to 4 m of older alluvium are normal; it consists mainly of sandy gravel near the shore, but grades into gravelly sand, silty sand and silty clay with increasing distance from the shore. The buried channel appears to be filled with fluviatile sand and gravel, some 10–20 m thick. The lack of offshore boreholes makes it difficult to determine the position of the probable eastward extension of this channel and its confluence with a deeper buried channel from Tide Cove. There is a large body of alluvial clay near Tai Po Sewage Treatment Works. It is over 12 m thick with a base at about −20 m PD. This clay occurs in a channel in weathered bedrock and is overlain by gravel approximately 4–5 m thick. On the southern side of the inlet the older alluvium thins to a veneer of clay or is completely absent, with marine deposits resting directly on weathered bedrock.

Wu Kai Sha, northern Tide Cove and Nai Chung. Beneath the marine deposits there are deposits of alluvium with a flat and regular upper surface. The alluvium comprises a thin layer of clay over sand and gravel. The sand and gravel are up to 20 m thick and, in the area offshore from Ma On Shan Tsuen, are underlain by up to 15 m of clay and silt which rest on weathered bedrock. The clay and silt are laminated and it is possible that they are lacustrine deposits. The base of the older alluvium off Nai Chung is relatively flat with a general level of −20 m PD out to Tang Chau. Farther north the base falls abruptly, forming a buried channel south and west of Harbour Island, extending to at least −50 m PD. An organic horizon within the alluvium has been proved at about −35 m PD between Ma Shi Chau and Harbour Island. Off Wu Kai Sha there is a persistent layer of alluvial clay beneath the marine deposits. This is underlain by fluviatile sand and gravel, with weathered boulders being reported in some boreholes. Contours of the base of the older alluvium show a considerable trough in the vicinity of the mouth of Tide Cove, extending to more than −49 m PD.

Southern Tide Cove and Sha Tin. Beneath the Holocene marine deposits the older alluvium consists of a persistent layer of alluvial clay with a thickness of about 5 m and a base at 10–16 m PD. This horizon is underlain by an impersistent deposit of sand and gravel, usually 3 to 4 m thick. In a temporary exposure at The Royal Hong Kong Jockey Club, Whiteside (1984) identified three main units in the alluvium under the marine deposits. The alluvium thinned out southwestwards against a rise of bedrock, which consisted of weathered granite. The upper unit, extending to −14 to −16 m PD, consisted of an upward fining sequence from grey silty sand to brown silty clay; a sample of wood from within this unit yielded a radiocarbon age of 23,270 ± 720 yrs BP. The middle unit comprised brown sand with an impersistent pebble bed at its base of about −19 m PD. The lowest unit, restricted to a local hollow, was a whitish silty clay up to 2 m thick and with wood remains at its top.

The younger alluvium of the Sha Tin valley is almost entirely concealed by fill, although small areas remain at surface around Kak Tin (3700 2555), Sha Tin Tau (3730 2595) and north of Hin Tin (3570 2490). Boreholes at Tin Sam (3650 2550) have revealed between 5 and 10 m of light grey to yellowish brown silty



sand and gravel resting directly on deeply weathered granite. The top of the bedrock beneath alluvium lies generally about −8 m PD to the west of Tai Wai.

Kwai Chung and Tsuen Wan. Boreholes drilled west of Ha Kwai Chung Village encountered a succession of up to 15 m of marine sands resting on up to 17 m of alluvium. These boreholes lie along the central part of a former river mouth at Ha Kwai Chung; laterally and upstream the shelly sands are replaced by sands without shells.

Debris Flow Deposits

Debris flow deposits are formed as accumulations of mass-transported, water-mobilised debris (Varnes, 1978). They are diverse in their composition. Their common feature is poor sorting, the term being used in the geological sense. Component material ranges in grain size from blocks and boulders to gravel and clay. Some deposits contain a full range of grain sizes while in others gravel, sand and clay may be the only components. More typically the deposits comprise boulders and cobbles supported by a gravelly clay matrix.

Debris flow deposits occur widely within the district. They are present in most small, upland valleys and form major spreads over the floors of some of the larger valleys. The most significant accumulations are in the valley around Yuen Tun Ha south of Tai Po, in the headwaters of Shing Mun River, in Lead Mine Pass, in the valley above Lo Wai near Kwai Chung, and at Siu Lek Yuen east of Sha Tin, Pak Kong and Nai Chung.

Debris flow deposits in some areas, such as around Yuen Tun Ha, are the youngest deposits in the valley fill successions. Elsewhere, as at Nai Chung, debris flow deposits underlie recent alluvium and extend offshore beneath marine mud. Despite the fact that some accumulations are clearly composite in nature it is not thought that an age calssification of debris flow deposits is warranted. It is considered unlikely that correlations between local successions of these deposits could be sustained.

Details

Yuen Tun Ha. The debris flow deposits of the valley around Yuen Tun Ha extend from above Ta Tit Yan (3475 3145) over 1.5 km downstream to Sheung Wun Yiu (3400 3296). The deposits are composite and about 5 m thick where seen in incised stream sections. The lowest deposits have a white gravelly clay matrix and rest on deeply weathered tuffs; they are overlain by a boulder deposit with a brown clayey silt matrix.

Shing Mun and Lead Mine Pass. In the upper reaches of the Shing Mun River the stream is incised into thick debris flow deposits (3300 2880) derived from the southeastern ridge of Tai Mo Shan, and, further upstream, (3230 3000) from the ridge west of Lead Mine Pass. In places the stream cuts through over 8 m of a deposit of boulders, generally up to 2 m diameter but exceptionally up to 4 m, set in a pale grey, pink or yellow gravelly clay matrix and resting on residual soils of tuffite or granodiorite. This deposit may be composite since some exposures contain relatively fresh boulders of tuff, while in others small boulders may be completely weathered or have weathered rinds up to 80 mm thick. Alternatively these variations could be due to local fluctuations in the groundwater table. Similar deposits occur in Lead Mine Pass.

Lo Wai and Kwai Chung. The debris flow deposits above Lo Wai (3087 2681), north of Kwai Chung, are derived from a number of sources lateral to the river and are therefore variable. North of the catchwater, at 3070 2795, the deposit consists of large subrounded boulders of tuff up to 2 m in a matrix support of mottled orange and white, gravelly, clayey sand.

Siu Lek Yuen. Sections exposed during site excavation at Siu Lek Yuen (4000 2700) revealed a deposit of smoothly-rounded boulders of volcanic rocks, some of which were fresh, others weathered. The boulders were set in a matrix of brown, silty, gravelly clay. The deposits were up to 8 m thick.

Pak Kong. Major debris flow deposits are common around Pak Kong (4470 2690), Kei Pik Shan (4350 2600) and Keng Pang Ha (4470 2815). Debris is derived mainly from the tuffs of the Tai Mo Shan Formation. At Keng Pang Ha a typical deposit is eroded into terraces by the stream. The deposit consists of subrounded boulders up to 0.7 m, with thin weathered rinds, set in a brown gravelly silt. Elsewhere, as around Pak Kong, boulders are larger (up to 3 m) and set in a gravelly clay matrix.

Nai Chung. The boulder deposits of Nai Chung (4460 3240) and Wu Kai Sha (4240 3200) differ from those described above. They form more gently graded distal slopes and generally contain smaller boulders in higher proportions. This may in part be a result of the variation in bedrock of the source area, which includes mainly sandstones and fine-ash tuffs. Boreholes around Nai Chung revealed between 3 and 6 m of cobbles and gravel in a silty sand matrix. The material is intermediate in appearance between alluvium and a debris flow deposit. Sorting is better than would be expected for the latter but not as good as would normally occur in alluvium. The morphology of the deposits as well-graded fans of valley fill is also more likely to have resulted form debris flow accumulation. The deposits can be traced offshore in boreholes, where they lie beneath the marine deposits and are thus clearly of pre-Holocene age. They pass northwards into older alluvium.

Debris flow deposits of upland areas. Almost all the high-level valleys in the district are choked by debris of angular blocks in a silty clay matrix. The deposits on the northern flanks of Grassy Hill (3478 3060) and on the ridge west of Lead Mine Pass (3355 3015) are typical. The deposits at the latter locality comprise up to 75% of mostly fresh, angular boulders up to 1 m in a matrix of clayey gravel.

Plate 34 – Alluvial Gravel in the Lam Tsuen Valley (3334 3570)

Talus (Rockfall) Deposits

Talus deposits are formed as accumulations of coarse, angular, block supported, gravity transported rockfall debris. They comprise angular, large and small blocks with a minor matrix of sand and silt. Older deposits may have a more clayey matrix but this is inferred to have been emplaced after the original deposition of the blocks. There are relatively few localities in the district where talus is currently accumulating. There are minor occurrences on Ma On Shan (4392 2956) and on and around Shui Chuen O (3910 2540) and Shek Nga Shan (4240 2676), where relatively simple but vegetated slopes of superficial deposits occurring beneath rock faces have been interpreted as being formed of talus deposits.

Mixed Debris Flow and Talus Deposits

These deposits are similar to the talus deposits, comprising angular blocks and fragments, very poorly sorted but with a larger amount of clay originating from the debris flow component. The deposits form steeply-sloping cones below rock faces but the cones show evidence of complex origins such as surface channels and levées.

Few examples of these deposits have been mapped, although undoubtedly areas mapped as debris flow deposits may include components of talus origin. Deposits occur on The Hunch Backs (4270 3000), on the northern slopes of Shek Nga Shan (4210 2780), on the southern slopes of Wong Ngau Shan (4190 2570); also on the slopes of Kam Shan above Shek Lei (3280 2495).

Slide Deposits

These deposits are formed as accumulations of matrix or clast supported, gravity transported landslide debris and are mapped only when they are clearly still closely related topographically to the site of the original failure. Where debris has been transported any great distance, the deposits concerned are more appropriately classified along with the debris flow deposits.

Relatively few large slides occur in the district although there are numerous small ones on the steeper slopes. The sites of these slides are indicated on the map as backscar features. The largest slides are those at Ma On Shan Mine where they have formed largely as a result of mining excavation, and in the valley south of Tai Po where one slide has occurred in a debris flow deposit and another in deeply weathered tuff (3475 3180 and 3495 3215). An area of instability southwest of Sheung Wun Yui, near Tai Po (3410 3270) has been interpreted as a re-vegetated slide area.

Weathering

The processes of weathering in Hong Kong were reviewed by Bennett (1984a). They have resulted, inter alia, in the formation of a mantle of in-situ, chemically weathered rock that may range up to several tens of metres in thickness.

The granitic rocks and the tuffs have been altered in varying degrees to clay with quartz grains by the in-situ breakdown of feldspars to kaolinite (Morgan, 1984). A classification of the material decomposition grades for weathered granite and volcanic rocks in Hong Kong is given in the Geotechnical Manual for Slopes (GCO, 1984).

Plate 35 – Weathered Granite in Borrow Area near Wu Kai Sha (4247 3137)

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