Updating of Hong Kong Geological Survey 1:20,000-scale Maps

Major Findings and Revisions
Map Sheet 6 - Yuen Long

GEO Report No. 356

K.W.F. So & R.J. Sewell

Geotechnical Engineering Office
Civil Engineering and Development Department
The Government of the Hong Kong
Special Administrative Region

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Preface

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet.

Raymond WM Cheung
Head, Geotechnical Engineering Office
March 2022

Foreword

This report describes the major new findings on, and significant revisions to, Hong Kong Geological Survey 1:20,000-scale geological map Sheet 6 - Yuen Long, undertaken between 2010 and 2019. The work was carried out by the Hong Kong Geological Survey Section of the Planning Division as part of a programme continually to improve the reliability of the geological maps published by the Hong Kong Geological Survey. The updating exercise has taken into account the vast amount of new site-specific information, and advances in geological knowledge gained since the previously published map of 1988 was first surveyed. The map updating work for Sheet 6 has been implemented on a GIS platform using a standard GIS template, and the map has been made available for promulgation in ArcReader format.

Mr K.W.F. So (2015-19), Dr R.J. Sewell (2010-19) and Ms P.N.Y. Lau (2010-15), supported by Mr E.Y.H. Ng (2012-14), jointly managed the update of solid geology and offshore superficial geology of Sheet 6, while Messrs W.W.L. Shum (2006-07), J.S.Y. Ho (2007-08) and K.W.F. So (2018-19) undertook reinterpretation of the onshore superficial geology. Helpful advice on the updating of Sheet 6 were given by Messrs P.C.S. Ho and K.S.C. Mok. Comments on an earlier draft of this report were given by Messrs K.C.K. Tam and E.T.K. Tse and Dr D.L.K. Tang. Dr M. Smith of the British Geological Survey provided an overall review of the updated solid geology map (Series HGM20S) and the associated sections of this report. Mr J.C.F. Wong provided comments on the final draft of this report. Technical support was provided by cartographic and technical staff of the Section. All contributions are gratefully acknowledged.

Julian S H Kwan
Chief Geotechnical Engineer/Planning

Abstract

There have been new data available since the first edition of 1:20,000-scale geological maps were surveyed and published by the Hong Kong Geological Survey of the Geotechnical Engineering Office. Consequently, the Hong Kong Geological Survey Section of the Planning Division has embarked on a programme to update the 1:20,000-scale maps and to release them in both printed and digital forms. This programme will make these geological maps more easily accessible to the public, and more useful to engineers and planners.

The map updating work is being digitised on a GIS platform using a standard GIS template, and the maps are being published and disseminated in ArcReader format.

Sheet 6 - Yuen Long is the fourth map updated under the programme. The first edition of Sheet 6 was surveyed between 1984 and 1987, and was published in 1988. Reliability of the geological maps has been improved after incorporation of the vast amount of new information that has accumulated over the past thirty years, and advances in the understanding Hong Kong's geology since the published maps were first surveyed.

The key findings and revisions to Sheet 6 are described in this report. They include: new interpretation of the solid geology covered by superficial deposits, revision of the stratigraphy of the Carboniferous San Tin Group, reassignment of sedimentary units to Jurassic formations, revision of the nomenclature and classification of volcanic stratigraphy and intrusive rocks, improved accuracy of the alignment of concealed major faults and geological boundaries, revision of a fold model, revision of the type and extent of metamorphism, reinterpretation of onshore and offshore superficial deposits, and updating of the reclamation history. A whole-territory geodatabase has been developed, within which geological data of various aspects are arranged in multiple GIS data layers. A further major improvement is the addition of a solid-only GIS layer, which includes the first interpretation of the offshore solid geology based on geophysical and borehole data, and a large number of additional GIS layers containing geological and related information.

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1 Introduction

1.1 Background

The Geotechnical Engineering Office (GEO; then Geotechnical Control Office, GCO, until 1991) commenced a geological survey of Hong Kong in 1982. A series of fifteen Hong Kong Geological Survey (hereafter HKGS) 1:20,000-scale solid and superficial geology maps (Series HGM20) with six geological memoirs, and one 1:20,000-scale solid geology map (Series HGM20S), were published between 1986 and 1995 (Figure 1.1). The first edition of the 1:20,000-scale geological map Sheet 6 (hereafter Sheet 6) of Series HGM20 was published in 1988 (GCO, 1988a) with an accompanying geological memoir (Langford et al, 1989). It was based on field surveys carried out between 1984 and 1987. From 1989 to 1997, thirty-four 1:5,000-scale geological maps (Series HGM5, HGM5A and HGM5B) covering selected, mainly onshore development areas were also produced. In 2000, a series of ten 1:100,000-scale solid and superficial geology and thematic maps, and accompanying memoirs on the pre-Quaternary and Quaternary geology of Hong Kong, synthesising all of the available geological data at that time, were published (Sewell et al, 2000; Fyfe et al, 2000).

In the succeeding years since publication of the 1:20,000-scale maps, new geological information has become available and advances in knowledge and map publishing techniques have occurred. Hence, a geological map updating programme was initiated to improve the reliability of the geological maps. In addition, the updated maps will be available in printed and Geographic Information System (GIS) versions.

1.2 Scope and Objectives of the Project

The scope of the map updating project is comprehensive, including revisions of both the bedrock and superficial geology. The project is being conducted on a map-by-map basis (Table 1.1). The geology of the approximately 10 km^2 of offshore areas not previously surveyed (including part of Deep Bay, and areas northwest, west and southwest of Lantau Island), which have been included within the Hong Kong Special Administrative Region (HKSAR) since July 1997, is being incorporated within the update. Priority is also being given to establishing the locations of faults concealed by superficial deposits in both onshore and offshore areas, and to revising areas of complex geology. Several inconsistencies between individual map sheets, which have resulted from developments in terminology and interpretation that occurred during the preparation of the 1:20,000-scale maps between 1986 and 1996, are also being resolved. Sheet 6 includes a large onshore area covered by superficial deposits, much of which is underlain by marble and marble-bearing rocks that have not previously been surveyed. Therefore, for Sheet 6, both an updated solid and superficial geology map (Series HGM20) and a new solid geology map (Series HGM20S) will be printed. Major findings and revisions of Sheet 6 are reported here.

Nevertheless, the project is not a resurvey and relies heavily on desk studies of available information with only limited field confirmation. The desk studies involve integration of new data from ground investigations (both onshore and offshore boreholes and including results from recent geophysical surveys) from engineering projects together with a re-evaluation of the data collected during the original field survey. Other published maps and related publications will also be updated where necessary, including the 1:100,000-scale geological maps covering the whole of the HKSAR. The objective of the map updating project is to produce up-to-date, on-demand geological reports and maps, including legends, cross-sections and explanatory notes. Readers are recommended to refer to Langford et al (1989), Frost (1992) and Sewell et al (2000) for full descriptions and previous interpretations of the geology of Sheet 6.

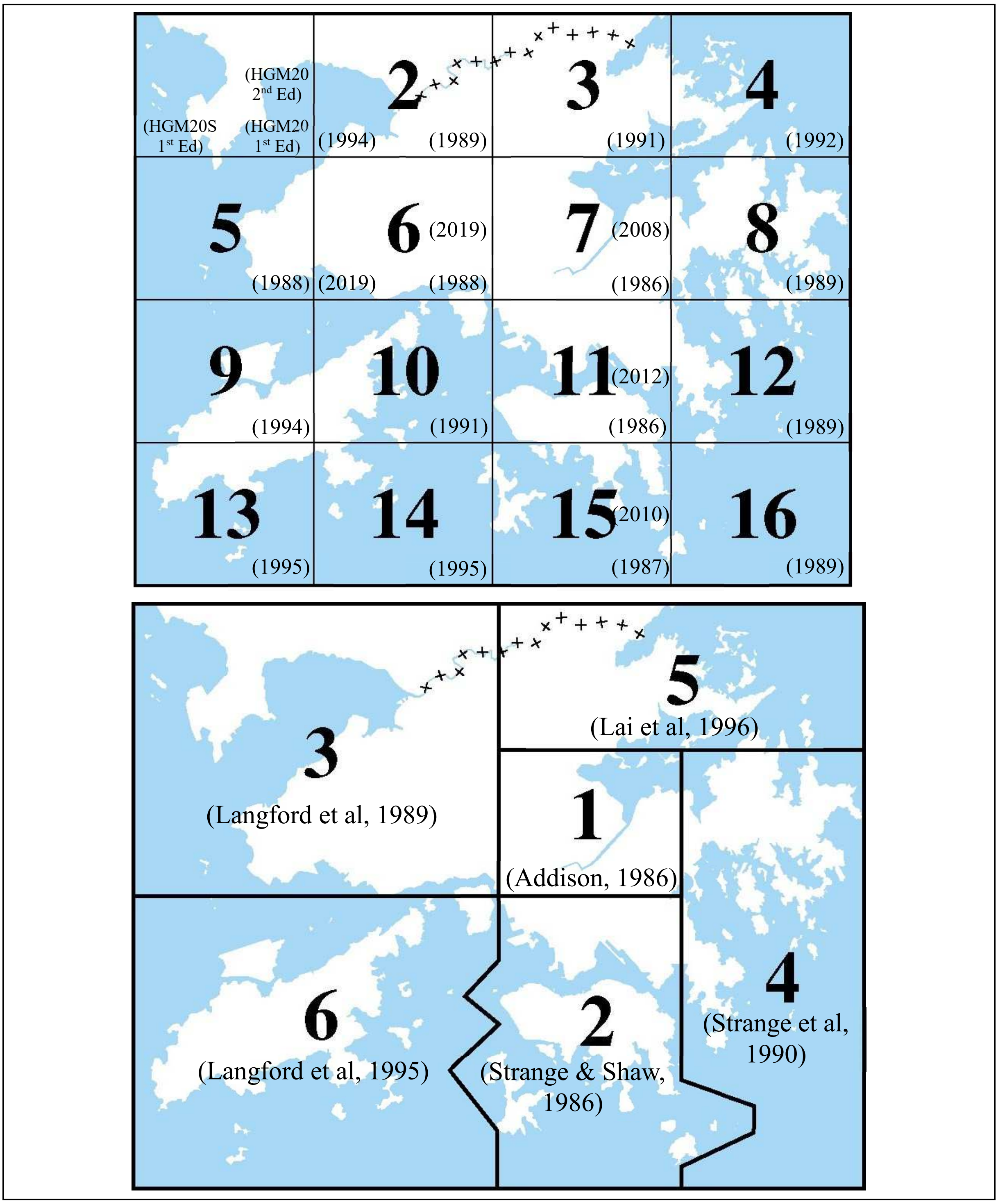


Figure 1.1 Published HKGS 1:20,000-scale Geological Maps (Series HGM20 Editions I and II, and Series HGM20S Edition I) and Geological Memoirs, with Year of Publication

Table 1.1 Revised 1:20,000-scale HKGS Geological Map Updating Programme

Sheet No.	Name	Period of Survey (Onshore* and Offshore#)	Year of Publication of First Edition Map	Priority for Revision	Year of Publication of Updated Map
7	Sha Tin	1983-84* #	1986	High	2008
15	Hong Kong South & Lamma Island	1985-86* 1986#	1987	High (north) Low (south)	2010
11	Hong Kong & Kowloon	1984-85* 1985#	1986	High	2012
6	Yuen Long	1984-87* 1986-87#	1988	High	2019
2	San Tin	1985-86* 1986-87#	1989	High	(in progress)
5	Tsing Shan (Castle Peak)	1984-86* 1986-87#	1988	High (east) Low (west)	(in progress)
3	Sheung Shui	1988-89* 1989-90#	1991	High (west) Low (east)	
9	Tung Chung	1989-92* 1991-92#	1994	High (north) Low (south)	
10	Silver Mine Bay	1985-89* 1990#	1991	High (north) Low (south)	
12	Clear Water Bay	1986-87* 1988#	1989	High (north) Low (south)	
8	Sai Kung	1986-88* 1988#	1989	High (west) Low (east)	
13	Shek Pik	1992* #	1995	Low	
14	Cheung Chau	1985-89* 1990-93#	1995	Low	
16	Waglan Island	1983-84* 1988-89#	1989	Low	
4	Kat O Chau	1989-90* 1989-92#	1992	Low	

2 Methodology

The original 1:20,000-scale geological maps relied heavily on conventional cartographic methods for publication, and paper maps were printed for distribution. In line with modern trends in map production, the updated 1:20,000-scale geological maps are being implemented on a GIS platform using a standard GIS template. The primary software is ArcGIS® Desktop Advanced (formerly ArcInfo® and ARC/INFO®). Multiple layers of geological information (Appendix A) are being developed within a whole-territory geodatabase that forms the basis of the data storage and retrieval system. Interrogation of geological datasets within the geodatabase will be possible using the latest GIS tools and Digital Elevation Models (DEM).

The updated geological maps will be published and disseminated as GIS publications in ArcReader (or equivalent) format making them accessible to the public, and useful to engineers and town planners. Paper maps of the updated edition of Series HGM20 and selected Series HGM20S will be printed and made available for purchase. Geological datasets that have been used for updating Sheet 6 represent available information up to 2018. The whole-territory geodatabase will be updated regularly, and new editions of the digital geological maps will be released from time to time along with updated datasets. The procedures and specifications for the HKGS digital geological maps, data model and geodatabase scheme diagram are contained in a separate internal report.

3 Data Sources

The primary data sources for updating Sheet 6 have included c. 23,000 ground investigation stations, over 2,400 rock hand specimen and core samples, rock thin sections, records of field notes, sketches and photographs, structural measurements and analyses. The ground investigation stations, which are contained in the Geotechnical Information Unit (GIU) of the Civil Engineering Library, exclude duplicated data, field and laboratory testing data, and those from too shallow excavation methods (Figure 3.1). The other data compiled during the original field survey are contained in the HKGS archive. In addition, whole-rock geochemical analyses (Sewell & Campbell, 2001b), absolute age data (Sewell & Campbell, 2001a), detrital zircon age data (Sewell et al, 2016, 2017), stream sediment geochemical analyses (Sewell, 1999 & 2008), seismic lines and selected scanned traces (Cheung & Shaw, 1993, HKGS archive), and reclamation histories have also been added to the geodatabase. Gravity and magnetic survey data used in the map update have principally come from onshore and offshore surveys conducted by Electronic & Geophysical Services Ltd. (EGS, 1991, 1993) and the summary by Sewell et al (2000). As-built tunnel records of West Rail Link and Express Rail Link projects have also been incorporated. All these records above have been compiled and are accessible within the geodatabase (Table A2).

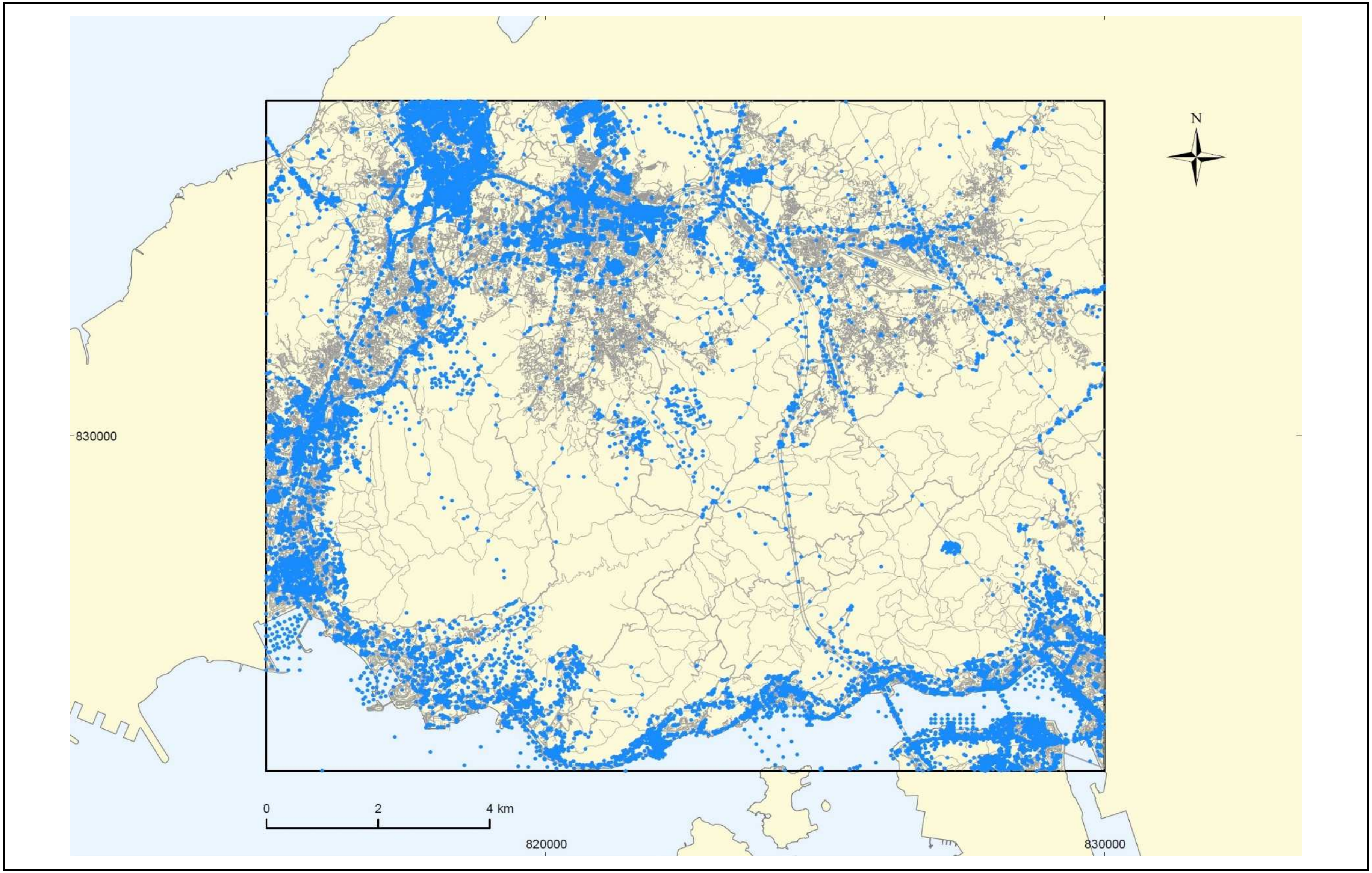


Figure 3.1 Distribution of Useful Ground Investigation Data for the Updating of Sheet 6

4 Major Findings and Revisions to Sheet 6

4.1 Rock Nomenclature

Rock nomenclature on HKGS geological maps generally follows the guidelines recommended in "Geoguide 3" (GEO, 2017). On the updated Sheet 6, the latest recommendations given by the British Geological Survey (Gillespie & Styles, 1999; Hallsworth & Knox, 1999; Robertson, 1999) and the International Union of Geological Sciences (Le Maitre et al, 2002; Fettes & Desmons, 2007) are also adopted to supplement the classification for pyroclastic, sedimentary and metamorphic rocks.

The first edition of the fifteen HKGS 1:20,000-scale geological maps (GCO, 1986a, 1986b, 1987, 1988a, 1988b, 1989a, 1989b, 1989c, 1989d & 1991; GEO, 1991, 1992, 1994a, 1995a & 1995b) assigned volcanic, sedimentary and metamorphic rocks to lithostratigraphic formations, whereas intrusive rocks were classified primarily on the basis of grain size and composition. Subsequent detailed petrographic, geochemical and geochronological analyses of the mapped units enabled a formation- and pluton-based nomenclature, which has been adopted for the major extrusive and intrusive units depicted on the 1:100,000-scale geological map (Sewell et al, 2000) and will be introduced in Sections 4.3 and 4.4. On the updated 1:20,000-scale geological maps (GEO, 2008, 2010 & 2012), formation/member/pluton names, together with rock type descriptors indicating dominant lithologies when necessary, have been assigned to all geological units. Thus it is possible to depict dominant lithologies alone, or to depict the formation and pluton nomenclature alone, on a digital map platform. As a result, several inconsistencies among the original 1:20,000-scale maps are now rectified, and the nomenclature is brought in line with the 1:100,000-scale geological map.

4.2 Map Legend

Among all published 1:20,000-scale geological maps, display of subcrop rocks is first introduced on Sheet 6 (Series HGM20S). Subcrops of the Yuen Long Formation immediately below superficial deposits are shown by solid colours, while inferred areas, or isolated borehole occurrences, of the Yuen Long Formation overlain by another solid geological unit at shallow depth is presented by dot patterns (Figure 4.1).

Following the practice of the previous 1:20,000-scale solid geology map (Series HGM20S; GEO, 1994b), key boreholes that reveal important geological features, structures or contact relationships in Sheet 6 area are denoted by symbols on the new map (Series HGM20S) and summarised in Appendix B.

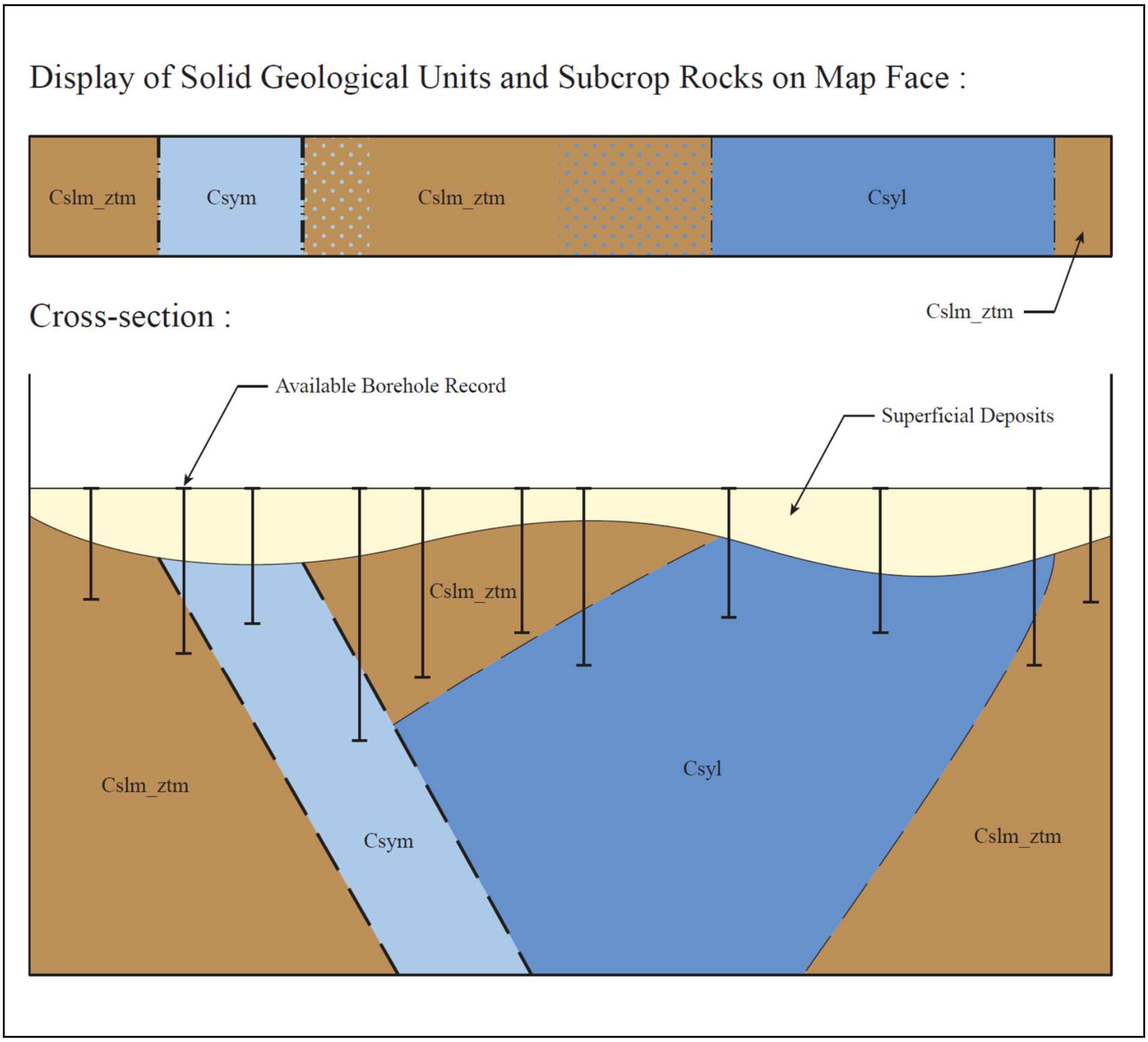


Figure 4.1 Schematic Diagram Illustrating the Display of Subcrop Rocks on Map Face and Cross-section (Not to Scale). Csym/Csyl: Ma Tin and Long Ping Members of Yuen Long Formation; Cslm_ztm: Mai Po Member of Lok Ma Chau Formation

4.3 Sedimentary and Volcanic Rocks

4.3.1 Nomenclature and Stratigraphy

On the first edition of Sheet 6, sedimentary and volcanic rocks were assigned to the Yuen Long and Lok Ma Chau formations of the San Tin Group, and the Tuen Mun, Yim Tin Tsai, Shing Mun, Ap Lei Chau and Tai Mo Shan formations of the Repulse Bay Volcanic Group respectively. Specific mappable lithological units within these formations were also depicted. The volcanic stratigraphy of Hong Kong was later reinterpreted by Campbell & Sewell (1998) and subsequently incorporated with further refinements on the 1:100,000-scale geological map (Sewell et al, 2000). On the updated Sheet 6, the stratigraphic nomenclature of sedimentary and volcanic formations is aligned with that on the 1:100,000-scale geological map. The updated stratigraphy is presented in Figure 4.2.

Age	Group	Formation	Member	Lithology	Thickness (m)
Cretaceous	-	Kat O	-	Sedimentary breccia, conglomerate, sandstone	?100
(non-conformity on intrusive rock)					
Middle Jurassic	Tsuen Wan Volcanic	Tai Mo Shan	-	Coarse ash crystal tuff, fine ash vitric tuff, tuffaceous sandstone	>600
		Shing Mun	Undifferentiated	Coarse ash crystal tuff, tuffite, tuffaceous sandstone/siltstone	400~600
			Shek Lung Kung	Tuff-breccia	
		Yim Tin Tsai	-	Coarse ash crystal tuff, tuffaceous sandstone	200~300
	(no contact with Tsuen Wan Volcanic Group)				
	-	Tuen Mun	Tuen Mun Andesite	Andesite lava, autobreccia, coarse ash crystal tuff	?1000
			Siu Hang Tsuen	Tuffaceous and epiclastic breccia/sandstone/siltstone	>1100
			Tin Shui Wai	Tuffaceous and epiclastic breccia/sandstone/siltstone	>300
(fault contact with Tuen Mun Formation, conformable with Shing Mun Formation)					
Early to Middle Jurassic	-	Tai O	-	(Meta-)sandstone, (meta-)siltstone, (meta-)mudstone	?
(inferred to be disconformity)					
Carboniferous	San Tin	Lok Ma Chau	Mai Po	Phyllite, metasiltstone, metasandstone, schist	>500
		Yuen Long	Long Ping	Grey to dark grey marble	200
			Ma Tin	White marble	>500

Legend :

- (solid line) conformable
- (dashed line) interbedded and gradational
- (wavy line) unconformable

Figure 4.2 Generalised Stratigraphy of Updated Sheet 6

4.3.2 San Tin Group

The Carboniferous San Tin Group in Sheet 6 area occupies a north-northeasterly belt of approximately 5.6 km long and 4 km in width. The extent of the San Tin Group is bounded to the south by the Tai Lam Granite, to the west by the East Tuen Mun Fault, and to the east by the San Tin Fault.

The San Tin Group comprises two formations: the lower, largely calcareous Yuen Long Formation (Lee, 1985; Langford et al, 1989) and the upper, mainly arenaceous/argillaceous Lok Ma Chau Formation (Langford et al, 1989). The Yuen Long Formation has no surface outcrop. Frost (1989, 1992) first divided the Yuen Long Formation into two member units: the lower Long Ping Member and the upper Ma Tin Member. The former comprises grey to dark grey, finely crystalline marble with sporadic metasandstone, dolomite and graphitic metasiltstone (e.g. at GIU no. 11187/BGS2), while the latter comprises massively bedded, white, crystalline marble (e.g. at GIU no. 11188/BGS3). The Lok Ma Chau Formation is divided into the lower Mai Po Member, comprising phyllite and metasiltstone, with metasandstone and graphite schist, and the upper Tai Shek Mo Member, comprising metasandstone, with metaconglomerate and phyllite (Langford et al, 1989). Only the Mai Po Member is exposed in Sheet 6 area. Previously, the Mai Po Member was thought to rest conformably on the Ma Tin Member of the Yuen Long Formation (Frost, 1992). However, Frost (1992) also reported that at Long Ping Estate (8204 8345), and at borehole nos. BGS4 (8201 8232) and BGS17 (8205 8355), metasiltstones of the Mai Po Member rest on dark grey marbles of the Long Ping Member.

Since publication of the 1:5,000-scale solid geology maps (GCO, 1988c, 1989e, 1989f, 1989g, 1989h, 1989i & 1989j), abundant borehole data has revealed evidence supporting a revised stratigraphy of the San Tin Group in Sheet 6 area (Figure 4.3). The revised stratigraphy indicates a succession from white marble, grey and dark grey marbles, calcareous metasiltstone to non-carbonate metasiltstone. Details of the update are given below.

4.3.2.1 Yuen Long Formation (Csy)

The revised extent of the Yuen Long Formation subcrops in Sheet 6 area is based mainly on (a) the marble occurrence in borehole records in the Yuen Long - Long Ping areas, and (b) an interpretation of (i) major geological structures in these areas, (ii) the revised stratigraphy and (iii) limited borehole records of anomalously thick alluvial deposits over flat land at Tai Tong.

Over the course of the review, it became apparent that in eastern areas of the subcrop, for example near Yuen Long MTR Station (8218 8340) and to the east of Ma Tin Pok (8211 8330), the stratigraphic sequence from borehole records (Table B1) shows the Ma Tin Member conformably overlying the Long Ping Member, which was the main reason for the original stratigraphy defined by Frost (1989, 1992). On the other hand, in western areas including Yuen Long Industrial Estate (8209 8359), Long Ping (8206 8342) and Hong Lok Road LRT Station (8207 8339), the Long Ping Member has an interbedded and gradational contact with the underlying Ma Tin Member (Table B1; Figure 4.4). Light bluish grey, massive, dolomitic marble can be found near the gradational contact between the two members. The upper boundary of the Ma Tin Member is defined by the change from dominantly grey and dark grey marbles to white marble. Furthermore, the Long Ping Member has the similar interbedded and gradational contact with the overlying Mai Po Member at Shui Pin Wai Estate (8201 8340), southeast of Yuen Long Park (8200 8334) and Lam Hau Tsuen (8198 8327; Table B1). The upper boundary of the Long Ping Member is defined by the first occurrence of grey or dark grey marble within the interbeds.

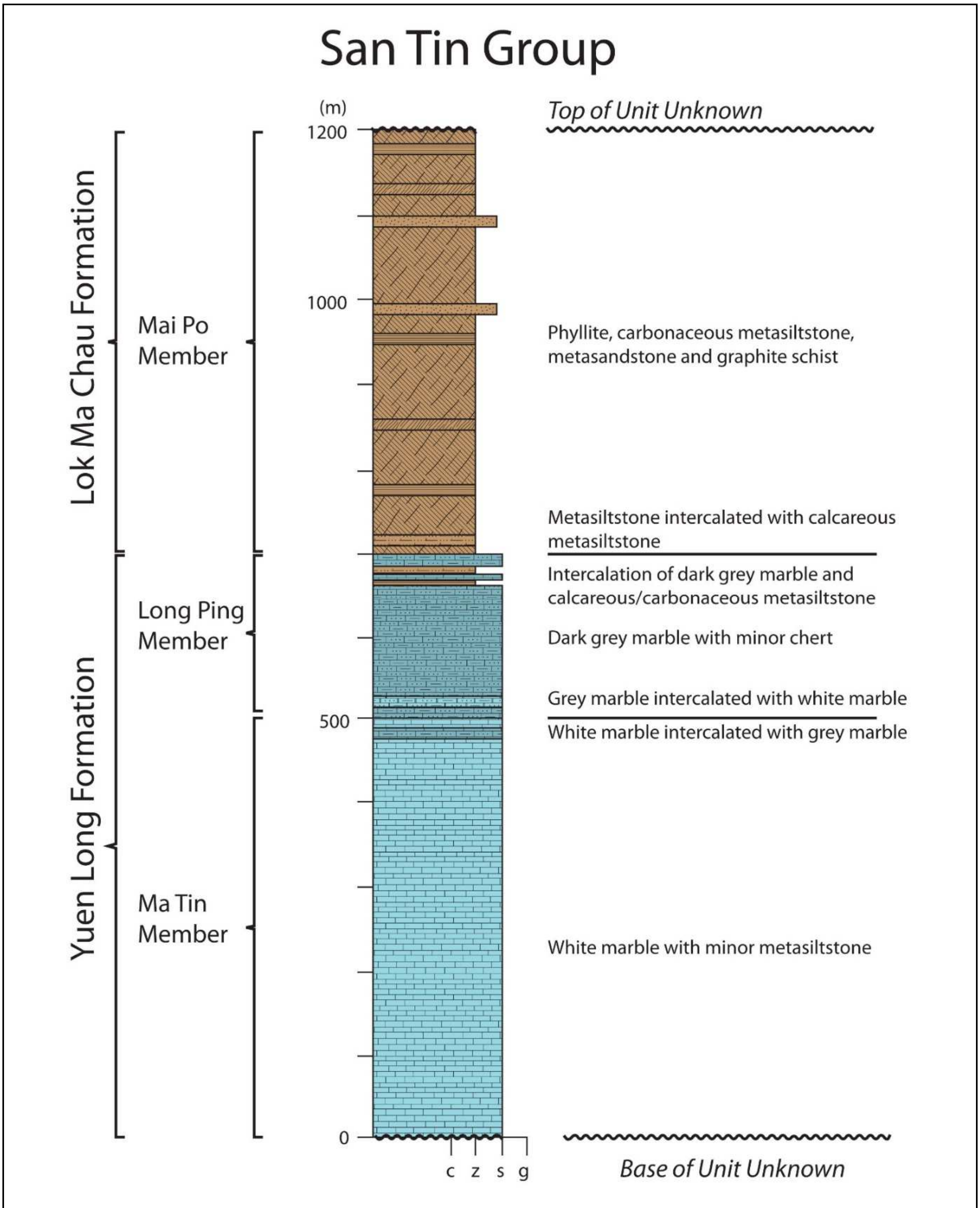


Figure 4.3 Updated Stratigraphic Column of the Carboniferous San Tin Group for Sheet 6. Grain Size: c, Clay; z, Silt; s, Sand; g, Gravel

Figure 4.4 Gradational Contact between Long Ping and Ma Tin Members (Long Ping, GIU No. 35413/DH/647, Left: 0 - 63.15 m, Right: 63.15 - 94.14 m Depth)

The overall structure of the Carboniferous rocks in the north of Sheet 6 area is now interpreted to comprise asymmetrical folds to overfolds (see also Section 4.6.4). The stratigraphy is upright on the western limbs, whereas the strata are overturned on the eastern limbs of most anticlines. In eastern Tin Shui Wai, some domino-like, fault-bounded blocks of the Ma Tin Member subcrops are the combined results of NE- and NW-trending fault movements (see Sections 4.6.2.4 and 4.6.3.2).

4.3.2.2 Lok Ma Chau Formation (Csl)

A sample of metasiltstone (HK13797; Mai Po Member) interbedded with impure marble (Long Ping Member) from a borehole in Tung Tau Industrial Estate (8209 8346) has been constrained temporally using detrital zircon dating (Sewell et al, 2016). The maximum depositional age deduced from the dating results is around 440 Ma, and the sample shares the same provenance as several other samples collected from the Lok Ma Chau Formation to the north of Sheet 6 area (Figure 4.5a). The gradational contact between the Lok Ma Chau and Yuen Long formations suggests that the two formations were part of a vertical facies succession formed during a major marine regression during the Carboniferous.

A sample of metasandstone (HK13915) from an outcrop of the Lok Ma Chau Formation at Shan Pui (8219 8347) has yielded a maximum depositional age of around 415 Ma (Figure 4.5a). The zircon age spectra for this sample are almost identical to other samples from the Lok Ma Chau Formation, suggesting that they share the same provenance.

4.3.3 Tai O Formation (Jo)

On the first edition of Sheet 6, all the sedimentary rocks lying stratigraphically below the Jurassic volcanic units were assigned to the Carboniferous Lok Ma Chau Formation of the

San Tin Group (Table 4.1). However, an ammonite fossil was later discovered in sedimentary rocks at Tai Tong (8211 8303; Yuen, 1989). Subsequently, on the 100,000-scale map published in 2000, and in the accompanying memoir, these rocks were reassigned to the Lower to Middle Jurassic Tolo Channel Formation. In the meantime, the discovery of Middle Jurassic plant fossils in rocks previously assigned to the Lok Ma Chau Formation at Tai O, west Lantau (Lee et al, 1997) led to the reassignment of these rocks to the Middle Jurassic Tai O Formation (Sewell et al, 2000). The Tai O Formation was first introduced for sedimentary rocks at Tai O, west Lantau by Allen & Stephens (1971), but was subsequently abandoned following reassignment of these rocks to the Lok Ma Chau Formation (Langford et al, 1995).

Sewell et al (2016) carried out a detrital zircon U-Pb dating and Hf isotope study of the metasedimentary rocks in western and northern New Territories including west Lantau. The study showed that many of the rocks, which were previously assigned to the Lok Ma Chau Formation in Sheet 6 area, have zircon age population spectra matching the Tai O Formation from west Lantau. Moreover, the researchers showed there were considerable differences in the zircon age population spectra between the Tolo Channel Formation in the northeastern New Territories, and the Tai O Formation in the western and northern New Territories. During the updating of Sheet 6, two further metasedimentary rock samples were collected and dated using detrital zircon U-Pb radiometric methods. One sample came from an isolated outcrop exposed on Mouse Island (8155 8270) and the other sample came from the same outcrop that yielded the ammonite fossil at Tai Tong. The spectra of these two samples are presented in Figure 4.5b, and compared with the spectra for other metasedimentary rock samples from the Tai O Formation in western and northern New Territories. All dated samples show a strong population peak at about 230 Ma, with subordinate peaks at 440 Ma, 790 Ma, 970 Ma, 1860 Ma and 2490 Ma. These rocks cannot belong to the Lok Ma Chau Formation (maximum depositional age of c. 415 Ma), or the Tolo Channel Formation (maximum depositional age of c. 580 Ma; Sewell et al, 2016), and are therefore reassigned to the Lower to Middle Jurassic Tai O Formation on the updated Sheet 6.

In the Tai Tong area, the contacts among carbonaceous sedimentary rocks and coarse ash tuff of the Shing Mun Formation are concealed without reliable structural data. These sedimentary rocks, which were previously assigned to the Lok Ma Chau Formation (Langford et al, 1989), have now been reassigned to the Tai O Formation based on the discovery of an ammonite fossil (Yuen, 1989) and interpretation of sedimentary provenance from detrital zircon age data (Figure 4.5b).

Sedimentary rocks exposed in Fu Tei and on Mouse Island have now been reassigned to the Tai O Formation based on interpretation of sedimentary provenance from detrital zircon age data (Figure 4.5b; Sewell et al, 2016). At Tuen Mun Water Treatment Works (8162 8297), the occurrence of tuffaceous sandstone in several boreholes further suggests that these Jurassic sedimentary rocks lie in close proximity to the contact with overlying Jurassic volcanic rocks.

The contact between the Tai O and Tuen Mun formations in eastern Tuen Mun is interpreted to be a fault (East Tuen Mun Fault, see Section 4.6.2.3), while the contact between the Tai O Formation and the Tai Lam Granite is interpreted to be intrusive (see Section 4.4.3.3). The contact between the Tai O and Lok Ma Chau formations has been overprinted by Tai Lam Granite. However, as there is no known volcanic or sedimentary unit between the Lok Ma Chau and Tai O formations within or in the vicinity of Sheet 6 area, their contact is inferred to be an unconformity.

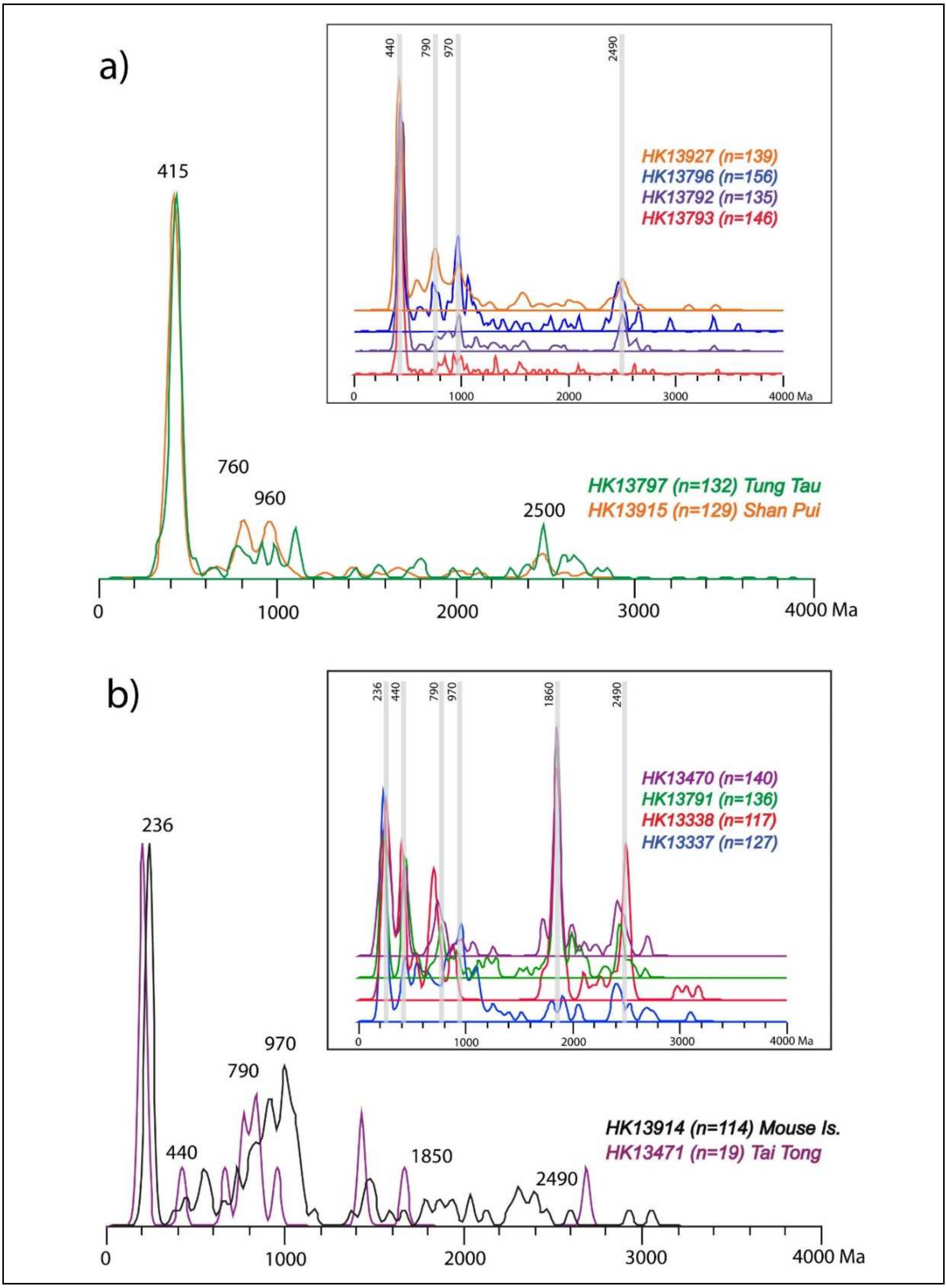


Figure 4.5 Detrital Zircon Age Spectra for Rocks of the (a) Lok Ma Chau and (b) Tai O Formations in Sheet 6 Area, Compared with Published Data (insets) for Similar Rocks Outside Sheet 6 Area. Inset Age Data are Quoted from Sewell et al (2016)

Table 4.1 Major Updates of Geological Units on Sheet 6

<table>
<tr><th rowspan="2">Locality</th><th colspan="3">Geological Unit</th></tr>
<tr><th>First Edition of Sheet 6
(GCO, 1988a)</th><th>1:100,000-scale Map
(Sewell et al, 2000)</th><th>Updated Sheet 6</th></tr>
<tr><td>Shan Pui (8219 8347)</td><td>Upper Jurassic
Tai Mo Shan Formation</td><td>-</td><td>Middle Jurassic
Tai Po Granodiorite</td></tr>
<tr><td>Tsuen Kam Au (8287 8295)</td><td>Upper Jurassic
Ap Lei Chau Formation</td><td>-</td><td>Middle Jurassic
Tai Mo Shan Formation</td></tr>
<tr><td>Ngau Liu (8283 8295),
Tsing Tam Village (8268 8309),
Pat Heung (8240 8316),
Shap Pat Heung (8224 8324),
Yuen Shan (8254 8347)</td><td>Ngau Liu Member of
Upper Jurassic
Shing Mun Formation</td><td>Middle Jurassic
Shing Mun Formation</td><td>Middle Jurassic Shing Mun
Formation (Undifferentiated)
or Tai Mo Shan Formation</td></tr>
<tr><td>Sung Shan New Village (8224 8316),
South of Nam Hang Tsuen (8219 8312)</td><td rowspan="4">Carboniferous
Lok Ma Chau Formation</td><td rowspan="2">Lower Jurassic
Tolo Channel Formation</td><td>Middle Jurassic
Shing Mun Formation</td></tr>
<tr><td>Tai Tong (8211 8305),
Nam Hang Pai (8213 8310)</td><td rowspan="3">Lower to Middle Jurassic
Tai O Formation</td></tr>
<tr><td>Fu Tei (8162 8298)</td><td>Carboniferous
Lok Ma Chau Formation</td></tr>
<tr><td>Mouse Island (8155 8271)</td><td>-</td></tr>
</table>

4.3.4 Tuen Mun Formation (Ju)

The Middle Jurassic Tuen Mun Formation occupies the main north-northeasterly axis of the Tuen Mun Valley in the west of Sheet 6 area. On the first edition of Sheet 6, the formation was described as a dominantly andesitic unit, comprising mainly andesite lava and tuffite, but including intercalated block-bearing tuff and tuffite, and local sedimentary layers. Following the discovery of a narrow belt of marble clast-bearing breccia from boreholes along the eastern faulted margin of the formation in the central Tuen Mun valley (Darigo, 1990), a member unit (Tin Shui Wai Member) of the formation was proposed. So & Sewell (2017) carried out a comprehensive review of all known lithologies of the formation, and proposed some guidelines on their description and classification. Subsequently, Sewell et al (2017) subdivided the formation into three members, namely the Tin Shui Wai (lowest), Siu Hang Tsuen and Tuen Mun Andesite members, and carried out detrital zircon U-Pb dating on samples of the Tin Shui Wai and Siu Hang Tsuen members. The dating results yielded a youngest coherent age group at c. 170 Ma, thereby constraining the maximum depositional age of the formation. The nomenclature of three member units is adopted on the updated Sheet 6. Conformable contacts between the three members were encountered in boreholes which indicate that within Sheet 6 area, the formation dips gently to moderately to the west. Detailed stratigraphic descriptions of the three members from key boreholes within the Tuen Mun Valley are given in Sewell et al (2017). The Tuen Mun Formation has a completely different provenance from other volcanic rocks exposed in Hong Kong (Sewell et al, 2017) and is interpreted to be an allochthonous block that was tectonically emplaced during the Middle to Late Jurassic.

4.3.4.1 Tin Shui Wai Member (Jut)

The Tin Shui Wai Member comprises dominantly monomictic, tuffaceous/epiclastic, marble clast-bearing breccia, sandstone and siltstone with minor andesite peperite. The member is largely restricted to an elongated zone along the eastern faulted margin of the Tuen Mun Formation (see Section 4.6.2.3), which is generally less than 1 km wide in the centre of the valley but narrows to c. 200 m in the north and south. Rocks adjacent to the East Tuen Mun Fault are strongly dynamically metamorphosed to mylonite and ultramylonite featuring attenuated marble clasts (e.g. at GIU no. 29625/TH1). However, less deformed sequences are recorded in boreholes westwards from this boundary fault, particularly in the central part of the valley, and reveal that the matrix to these breccia-conglomerate layers is tuffaceous.

4.3.4.2 Siu Hang Tsuen Member (Jus)

The Siu Hang Tsuen Member comprises dominantly polymictic (including marble clasts), tuffaceous/epiclastic conglomerate, sandstone and siltstone with minor andesite peperite (e.g. at GIU no. 54157/BH3). This member crops out largely in the western central portion of Sheet 6 area. A gradational contact with the underlying Tin Shui Wai Member is inferred based on the first occurrence of monomictic, marble clast-bearing tuffites or epiclastic rocks at boreholes. At Tuen Mun Typhoon Shelter, the narrow subcrop of the member is interpreted based on an unaltered, polymictic, marble clast-bearing tuffaceous breccia recorded at Tuen Mun Town Hall (8155 8279; Table B1).

4.3.4.3 Tuen Mun Andesite Member (Jua)

The Tuen Mun Andesite Member comprises mainly andesite lava, autobreccia, lapilli-bearing ash-flow crystal tuff, and tuffaceous sandstone and siltstone. The member crops out chiefly in the southwest of Sheet 6 area. A gradational contact between the Tuen Mun Andesite Member and Siu Hang Tsuen Member is inferred from the first occurrence of marble clast-bearing tuffaceous conglomerate (e.g. at Tuen Mun Area 54 and Castle Peak Hospital). Andesitic lavas are interpreted to intrude the Siu Hang Tsuen Member and extrude as a dome around southwestern Hung Shui Kiu (8165 8323), with possible hyaloclastite (Figure 4.6). Another minor andesitic lava injection into tuffaceous sediments of the Tin Shui Wai Member is interpreted at Fu Tai Estate (8165 8304; Table B1).

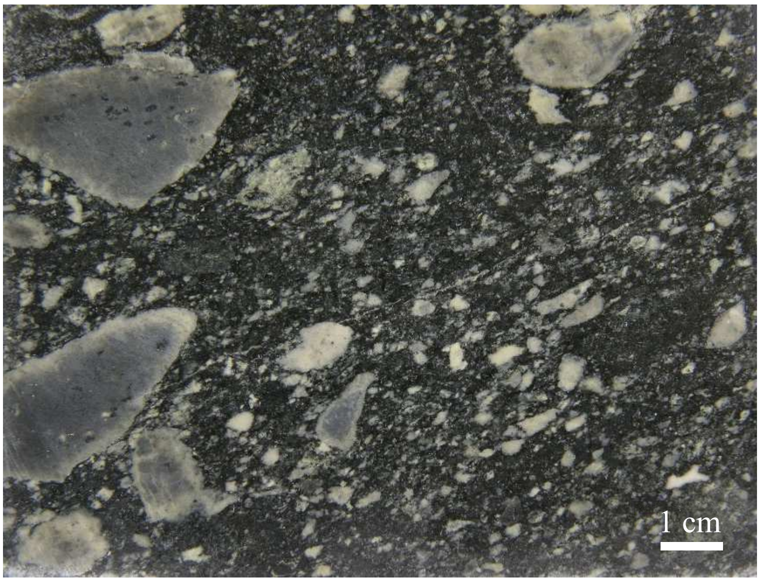


Figure 4.6 Altered Andesite Hyaloclastite (Southwestern Hung Shui Kiu, Sample No. HK12780, GIU No. 40758/NDH48, 27 m Depth)

4.3.5 Tsuen Wan Volcanic Group

The Middle Jurassic Tsuen Wan Volcanic Group conformably overlies the Tai O Formation and represents the first phase of widespread volcanic activity which affected the Hong Kong region in the Middle Jurassic (Campbell & Sewell, 1998; Sewell et al, 2000). On Sheet 6, it comprises the Yim Tin Tsai (lowest), Shing Mun and Tai Mo Shan formations. These three formations have been precisely radiometrically dated at c. 164 Ma (Davis et al, 1997). The Yim Tin Tsai Formation is exposed only in the southeastern corner of Sheet 6. The updated Sheet 6 shows the offshore subcrop of the Yim Tin Tsai Formation, the inferred contact with the Shing Mun Formation, and intrusive contacts with the Tai Po Granodiorite, Tai Lam Granite, and Needle Hill Granite based on borehole data. By contrast, in the central and northern portions of Sheet 6 area, the basal unit of the Tsuen Wan Volcanic Group is represented only by the Shing Mun Formation. The updated Sheet 6 shows large areas of newly-interpreted subcrops of the Shing Mun and Tai Mo Shan formations.

4.3.5.1 Shing Mun Formation (Jts)

On the first edition of Sheet 6, Langford et al (1989) described two member units of the Shing Mun Formation: the Shek Lung Kung and Ngau Liu members. These were considered to be key mappable units within the largely undifferentiated Shing Mun Formation comprising lapilli lithic-bearing coarse ash crystal tuff, tuffaceous sandstone, tuffaceous siltstone and tuffite. The Shek Lung Kung Member was defined as a local tuff breccia unit within the formation.

Langford et al (1989) originally defined the Ngau Liu Member as a crystal-vitric tuff, in which the crystal and vitric components are roughly equal, in contact with the overlying Tai Mo Shan Formation. Langford et al (1989) also described that the Ngau Liu Member has a granite-like appearance, crops out as a lapilli-ash to coarse ash crystal tuff at Ngau Liu (8283 8295) and a lapilli lithic-bearing coarse ash crystal tuff at Yuen Shan (8250 8342), and is exposed as a lapilli-ash crystal tuff within the Western Aqueducts (8236 8322). In a review of available samples from the HKGS rock archive, all rock samples originally assigned to the Ngau Liu Member have similar characteristics (e.g. granite-like texture) to either the undifferentiated Shing Mun Formation or the Tai Mo Shan Formation. These samples do not have sufficiently distinctive lithological characteristics to warrant assignment as a separate member of the Shing Mun Formation. On the updated Sheet 6, outcrops of the original Ngau Liu Member are therefore reassigned to either the Shing Mun Formation or the Tai Mo Shan Formation based on the stratigraphic position and the similarity of lithological characteristics (e.g. the proportion of lithic fragments and mafic minerals; Table 4.1).

A small outcrop of sandstone at the boundary between the Yim Tin Tsai and Shing Mun formations at Tsing Yi (8279 8242) on the first edition of Sheet 6 is now reassigned as a tuffaceous sedimentary intercalation within the Shing Mun Formation based on detailed review of borehole data associated with highway development.

4.3.5.2 Tai Mo Shan Formation (Jtm)

On the first edition of Sheet 6, a fine ash vitric unit at the contact between the Tai Mo Shan and Shing Mun formations was assigned to the Ap Lei Chau Formation. This assignment was largely an artefact from matching units with the first edition of neighbouring Sheet 7 (GCO, 1986a). The Ap Lei Chau Formation defined on the 1:100,000-scale map belongs to the Lower Cretaceous Repulse Bay Volcanic Group (Sewell et al, 2000), so its stratigraphic position between the Tai Mo Shan and Shing Mun formations on Sheets 6 and 7 is incompatible. All outcrops of the Ap Lei Chau Formation on the first edition of Sheet 7 have been reassigned to the Tai Mo Shan Formation on the second edition (GEO, 2008). Therefore, the same practice is implemented on the updated Sheet 6.

In Sheet 6 area, occasional marble fragments were first reported within coarse ash tuffs of the Tai Mo Shan Formation at a cut slope at Au Tau Fresh Water Service Reservoir (8238 8325) by Wong (1991). Subsequent ground investigations in western Kam Tin (8238 8339) and at Long Shin Estate (8227 8336) have also encountered marble fragments occasionally in the tuffs, which concur with the observation by Langford (1991a).

4.3.6 Kat O Formation (Kk)

The Cretaceous Kat O Formation is not exposed but inferred as a subcrop in the northwestern corner of Sheet 6, based on offshore borehole records from the Kong Sham Western Highway (formerly Shenzhen Western Corridor) project. The sedimentary sequence was first described by Langford et al (1989) from outcrops at Lau Fau Shan on Sheet 2. It comprises a succession of thickly-bedded, poorly- to semi-sorted, breccia with some conglomerate, sandstone and siltstone. The borehole records indicate that the breccia and sandstone are dominantly granite clast-bearing and that the succession rests non-conformably on top of an undifferentiated granite. Langford et al (1989) suggested that the sequence dips gently at 20° to southwest. Although the sequence has been correlated with the Cretaceous Kat O Formation in the northeastern New Territories (Langford et al, 1989), compositionally it is not identical. Breccia/conglomerate of the Kat O Formation in the northeastern New Territories is dominated by volcanic clasts, while that in the northwestern New Territories is dominated by both volcanic and some granitic clasts.

4.4 Major Intrusive Rocks

4.4.1 Nomenclature

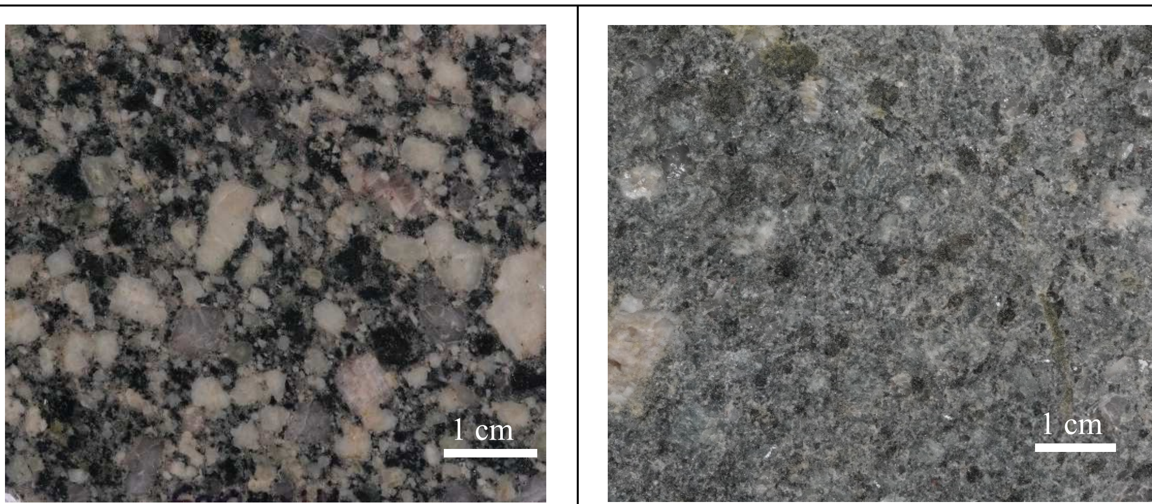
The earliest classification of granitic rocks according to various intrusive phases was attempted by Allen & Stephens (1971). However, on the first edition of the 1:20,000-scale geological maps (Series HGM20), the classification of major intrusive rocks was primarily based on grain size and composition without delineation of individual plutons (Strange, 1985). Subsequently, Campbell & Sewell (1998) proposed a classification for plutonic rocks on the basis of petrographic, geochemical and age criteria. Sewell et al (2000) assigned the major intrusive bodies of the territory to four suites. During updating of Sheet 6, the pluton nomenclature has largely been aligned with that on the 1:100,000-scale geological map with further revisions.

4.4.2 Tai Po Granodiorite (Jp)

The Tai Po Granodiorite was previously assigned to the ‘I-type’ subgroup of the Lamma Suite (Campbell & Sewell, 1998). Based on the age and isotopic composition (Darbyshire & Sewell, 1997; Davis et al, 1997), the unit is now considered to be the sole member representing the plutonic equivalent of the Tsuen Wan Volcanic Group. The age of c. 164 Ma for the Tai Po Granodiorite is identical within error of all members of the Tsuen Wan Volcanic Group. It is therefore now excluded from the Lamma Suite.

The Tai Po Granodiorite in the southeastern corner of Sheet 6 dominantly comprises porphyritic fine- to medium-grained granodiorite (Figure 4.7a). Dacite depicted on the first edition of Sheet 6 is typically dark greenish grey to black, mottled pink and white, and commonly medium (2 - 6 mm) to coarsely (> 6 mm) porphyritic (Figure 4.7b). The best example showing a transition from porphyritic medium-grained granodiorite, fine-grained granodiorite to dacite (which was logged as rhyolite) has been found at GIU no. 43494/BH28 near Yau Kom Tau Village (8281 8260). On the second edition of Sheet 7 (GEO, 2008), some feldsparphyric rhyolite outcrops were inferred as margins to the intrusion of the Tai Po

Granodiorite (Sewell et al, 2010). By combining the field and borehole evidence from Sheets 6 and 7, these intrusions are now considered to be textural and compositional variants, i.e. porphyritic dacite to rhyodacite, of the Tai Po Granodiorite near the intrusive contacts with the three formations of the Tsuen Wan Volcanic Group (Table 4.2). A minor fault at western Tsuen Wan (8280 8255) on the first edition of Sheet 6 is reinterpreted to be a zone of minor hydrothermal alteration of the coarse ash tuff and sandstone of the Yim Tin Tsai Formation in association with an intrusion of the Tai Po Granodiorite.



(a) (b)

Figure 4.7 (a) Porphyritic, Fine- to Medium-grained Granodiorite (Tsing Yi, Sample No. HK11025) and (b) Porphyritic Dacite (Tsuen Wan, Sample No. HK10269)

In Yuen Long, most outcrops and subcrops of the granodiorite have been extensively chloritised and silicified and these are depicted on the updated Sheet 6 by the screen showing low-grade metamorphism. Although the original igneous texture in these rocks has largely been overprinted by the metamorphism, occasional fresh, least-altered, medium-grained granodiorite recovered from boreholes at Yuen Long Industrial Estate (8213 8354) is typically dark grey, mottled white and light grey, and massive. Due to variable degrees of metamorphism, textural variants of the granodiorite may sometimes resemble layers of volcanic and volcaniclastic deposits (e.g. at Shan Pui; Table 4.1).

4.4.3 Lamma Suite

Based on the age and isotopic composition (Darbyshire & Sewell, 1997; Davis et al, 1997), the Lamma Suite (Campbell & Sewell, 1998; Sewell et al, 2000) is here redefined as comprising the Lantau, Chek Lap Kok (not exposed on Sheet 6), Tai Lam and Tsing Shan granites. The 'subgroup' designation is abandoned. By contrast with the Tai Po Granodiorite, granites of the Lamma Suite have no recognised volcanic equivalents within and in the vicinity of the HKSAR. The ages of the granites lie between 162 Ma and 159 Ma (Davis et al, 1997).

Table 4.2 Correlation of Textural Variants of Major Intrusions in the East of Sheet 6 Area (Modified from Li et al, 2000; Sewell et al, 2000)

Nomenclature of Intrusion	Tai Po Granodiorite (*Jp*)	Sha Tin Granite (*Jkt*) and East Lantau Rhyodacite (*Jkd*)	Needle Hill Granite (*Jkn*) and East Lantau Rhyolite (*Jko*)
Granitoid	I-type	I-type	A-type
Coarsest Variant	Porphyritic medium-grained granodiorite (*Jp_gd*)	Equigranular medium-grained biotite granite (*Jkt_gm*)	Porphyritic fine-grained granite (*Jkn_gf*)
Medium Variant	Porphyritic fine-grained granodiorite (*Jp_gd*)	Feldsparphyric microgranite (1) (*Jkd_rf*)	Quartzphyric microgranite (1) (*Jko_rq*)
Finest Variant	Porphyritic dacite /rhyodacite (2) (*Jp_d*)	Feldsparphyric rhyodacite /rhyolite (2) (*Jkd_rf*)	Quartzphyric/ massive rhyolite (3) (*Jko_rq*)
Locality	Kam Tin, Tsuen Wan, North Tsing Yi	North and East Tsing Yi	Tsuen Wan, North Tsing Yi, North Ma Wan

Notes:
(1) "Microgranite" is equivalent to "fine-grained granite" for subvolcanic rocks.
(2) These names are equivalent to "feldspar porphyry" for subvolcanic rocks.
(3) "Quartzphyric rhyolite" is equivalent to "quartz porphyry" for subvolcanic rocks.

4.4.3.1 Lantau Granite (Jml)

An area of medium- and coarse-grained granites near Tuen Mun on the first edition of Sheet 6 is now assigned to the Lantau Granite, in line with the nomenclature of Campbell & Sewell (1998) and the 1:100,000-scale map (Sewell et al, 2000). The offshore extension of the granite to the south of Tuen Mun and Tai Lam Chung is based on borehole data and examination of available samples held in the HKGS rock archive.

4.4.3.2 Tsing Shan Granite (Jms)

On the first edition of Sheet 6, the contact between the inequigranular fine- to medium-grained granite (assigned to the Tsing Shan Granite on the 1:100,000-scale map; Sewell et al, 2000) and the Tuen Mun Formation is shown as a fault, with local development of foliations in the Tuen Mun Formation and mylonite in the Tsing Shan Granite along the fault. However, an intrusive contact between these two units is evident from (a) one field measurement (dipping at 48° to northwest) of the contact on the northeastern flank of Tsing Shan on Sheet 5 (GCO, 1988b), (b) borehole records (e.g. GIU no. 12699/BH310 in Sheet 5 area) as well as (c) rock samples of andesite and tuffaceous sandstone of the Tuen Mun Formation underlying the granite along the Tsing Shan Sewage Tunnel beneath the Yuen Tau Shan area (8157 8336). Elsewhere, field notes and some borehole records in Sheet 6 area show evidence of a shear zone overprinting hydrothermally altered rocks at the contact. However, overall the Tsing Shan Granite is generally undeformed close to the contact. The original interpretation of a fault contact is retained on the updated Sheet 6, although the extent of mylonite in the Tsing Shan Granite is much reduced.

4.4.3.3 Tai Lam Granite (Jma)

A large outcrop of inequigranular fine-grained and fine- to medium-grained granites, and equigranular medium-grained granite, around the Tai Lam Chung Reservoir area is assigned to the Tai Lam Granite, in line with the nomenclature of Campbell & Sewell (1998) and the 1:100,000-scale map (Sewell et al, 2000). The Tai Lam Granite is texturally highly variable (Langford, 1991b) and reinterpretation of the boundaries, particularly between adjacent plutons, has relied on detailed examination of available rock hand specimens in HKGS rock archive.

On the first edition of Sheet 6, the contact between Carboniferous rocks and the northwestern part of the Tai Lam Granite was interpreted to be a fault. However, most borehole records and field notes reveal that the granite near the contact with the Lok Ma Chau, Tai O and Tuen Mun formations has not been deformed or brecciated. A few records further indicate intrusive contacts with metasiltstone of the Lok Ma Chau Formation at eastern Hung Shui Kiu (8179 8322) and with the Tuen Mun Formation at Tuen Mun San Hui (8157 8290; Table B1). In addition, a minor subcrop of pinkish grey, fine- to medium-grained granite showing an intrusive contact with the Tuen Mun Formation was reported to the north of Fu Tai Estate (8163 8306; Table B1). Therefore, the intrusion of the Tai Lam Granite must postdate the East Tuen Mun Fault (see Section 4.6.2.3), which marks the boundary between the Tuen Mun Formation and the Palaeozoic and Mesozoic sedimentary rocks.

In southern Tai Lam Chung, Tsing Lung Tau and Sham Tseng, some outcrops previously assigned to the Lantau Granite on the 1:100,000-scale map (Sewell et al, 2000) are now reassigned to the Tai Lam Granite. The intrusive contact between the Lantau and Tai Lam granites is proved at a borehole along Tuen Mun Road (8203 8241; Table B1). At Ping Shan (8192 8337), subcrops of fine-grained granite proving an intrusive contact with the overlying Carboniferous metasiltstone at boreholes are assigned to the Tai Lam Granite. In southeastern Tin Shui Wai (8185 8341), a small subcrop of chloritised and silicified porphyritic granite proving an intrusive contact with white marble at boreholes is also assigned to the Tai Lam Granite.

4.4.4 Kwai Chung Suite

4.4.4.1 Sha Tin Granite (Jkt)

A medium-grained granite shown in the southeastern corner on the first edition of

Sheet 6 is now assigned to the Sha Tin Granite, in line with the nomenclature of Campbell & Sewell (1998) and the 1:100,000-scale map (Sewell et al, 2000). Interpretation of the offshore subcrop of the Sha Tin Granite between Tsing Yi and Tsuen Wan is based on borehole data, and examination of available samples held in the HKGS rock archive.

4.4.4.2 Needle Hill Granite (Jkn)

An area of fine-grained granite outcrop, and offshore subcrop, in the southeastern corner on the first edition of Sheet 6 is now assigned to the Needle Hill Granite, in line with the nomenclature of Campbell & Sewell (1998) and the 1:100,000-scale map (Sewell et al, 2000). The updated outcrop pattern and subcrop boundaries with the adjacent Tai Po Granodiorite and San Tin Granite are based on extensive borehole data on top of the 1:5,000-scale map interpretation (GEO, 1995c, 1995d). The Needle Hill Granite in this area shows a textural variation from quartzphyric to feldsparphyric. Some small fine-grained granite stocks and dykes on Tsing Yi on the first edition of Sheet 6 are now assigned to the East Lantau Rhyolite, which is likely to be the subvolcanic equivalent of the Needle Hill Granite (Table 4.2; Sewell et al, 2000).

4.4.4.3 East Lantau Rhyodacite (Jkd) and East Lantau Rhyolite (Jko)

Feldsparphyric rhyolite and quartzphyric rhyolite dykes shown at Tsing Yi and Ma Wan in the southeastern corner on the first edition of Sheet 6 are now assigned to the East Lantau Rhyodacite and East Lantau Rhyolite respectively, in line with the nomenclature of Campbell & Sewell (1998) and the 1:100,000-scale map (Sewell et al, 2000). The East Lantau Rhyodacite comprises (a) finely (< 2 mm) to coarsely (> 6 mm) feldsparphyric rhyodacite/rhyolite and (b) coarsely feldsparphyric to equigranular microgranite dykes, while the East Lantau Rhyolite comprises (a) massive or finely to medium (2-6 mm) quartzphyric rhyolite and (b) medium quartzphyric to equigranular microgranite dykes (Table 4.2; Figure 4.8; Li et al, 2000; Sewell et al, 2000). Most of these dykes are E- or ENE-trending and subvertical in this area. Since many dykes of less than 5 m wide were depicted as over-thickened bodies on some of the first edition geological maps (Sewell et al, 2012b), the extent of the East Lantau Rhyodacite and East Lantau Rhyolite dykes in the Tsing Yi area is now reinterpreted to be thinner rectangular shapes on the updated Sheet 6 based on the recent extensive reviews.

Several 'basalt' dykes shown on the margins of these dykes on the first edition map are now incorporated within the felsic dyke assignment as they have been shown to constitute mafic margins to large, composite, dominantly felsic dykes (Li et al, 2000). Similarly, some feldsparphyric rhyolite dykes previously shown in the Tsuen Wan area are reassigned to the East Lantau Rhyodacite. The interpretation of felsic dykes in the offshore area between Tsing Yi and Tsuen Wan is based on borehole data.

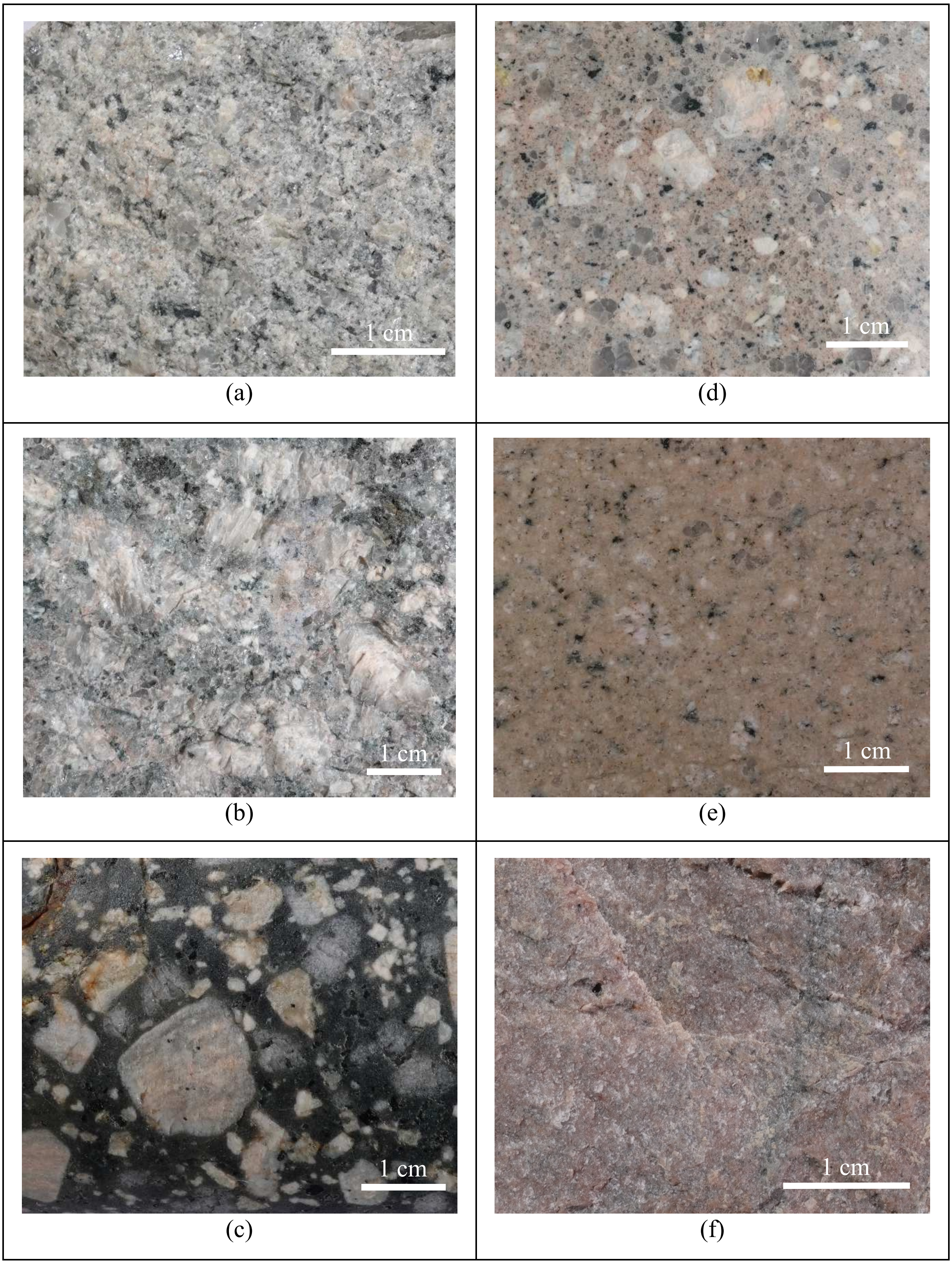


Figure 4.8 Textural Variants of East Lantau Rhyodacite ([a] Equigranular Microgranite, HK2298; [b] Coarsely Feldsparphyric Microgranite, HK5637; [c] Coarsely Feldsparphyric Rhyodacite/Rhyolite, HK3691) and East Lantau Rhyolite ([d] Medium Quartzphyric Microgranite, HK10867; [e] Finely Quartzphyric Rhyolite, HK10868; [f] Massive Rhyolite, HK10592) at Tsing Yi

4.5 Minor Intrusive Rocks

On the first edition of Sheet 6, there was no attempt to relate minor intrusions, including mafic to intermediate, dacite, quartzphyric rhyolite, feldsparphyric rhyolite, aplite, pegmatite, and fine-grained granodiorite and granite dykes, to individual plutons or to explain their mode of origin. Among these minor intrusions, only the 'basalt' dykes in the Tsing Yi area have been incorporated within the composite dykes of the East Lantau Rhyodacite and East Lantau Rhyolite (see Section 4.4.4.3). Other minor mafic to intermediate dyke intrusions, which were previously named 'basalt' on most of the first edition of 1:20,000-scale maps, have been found to be basaltic andesite to andesite in composition by geochemical analysis (Sewell et al, 2000). Only a few mafic to intermediate dykes in Hong Kong have been dated using Ar-Ar method (Campbell & Sewell, 2007), and none of them are from Sheet 6 area. In the Yuen Long area, some dark greenish grey veins (less than 1 m wide) cross-cutting marble were recorded as 'basalt' in existing borehole records. These veins have been found to have a chlorite-talc-pyrite assemblage, likely associated with metasomatism or hydrothermal alteration. Thus, these veins are not classified as true mafic to intermediate dykes.

A few quartzphyric rhyolite dykes to the northeast of Lam Tei Quarry (8175 8305) were previously assigned to the Chek Mun Rhyolite (c. 161 Ma; Sewell et al, 2012a) of the Lamma Suite on the 1:100,000-scale map (Sewell et al, 2000). However, these dykes intrude the Tai Lam Granite (c. 159 Ma; Davis et al, 1997) and therefore must be younger than 159 Ma. Accordingly, they are now shown as undifferentiated on the updated Sheet 6. All other minor intrusions which cannot easily be related to individual plutons or dyke swarms are shown as undifferentiated on the updated Sheet 6.

4.6 Structural Geology

4.6.1 Accurate Location and Nomenclature of Major Faults

In the Yuen Long and Tin Shui Wai areas, where the geology is dominated by Palaeozoic metasedimentary rocks (including marble) and Mesozoic marble clast-bearing rocks, over 9,000 borehole data has become available from the completion of development projects. These extremely dense and deep borehole records in these areas of complex geology have enabled a thorough subsurface mapping of abrupt changes in lithologies and degree of metamorphism, which support a more accurate interpretation of the alignment of concealed major faults beneath extensive flat areas of superficial deposits.

On the first edition of Sheet 6, major faults were not named in the geological explanatory notes although they were named and described in the accompanying memoir (Langford et al, 1989). Following the practice of Sheet 2 (Series HGM20S; GEO, 1994b), major faults are named in the geological explanatory notes for the updated Sheet 6. During previous geological surveys, more than one name had been used for a few individual faults because these faults had been mapped and described on a local basis before their lateral extent was fully realised. Following the practice by Sewell et al (2000), newly-identified faults on the updated Sheet 6 are named using one representative geographic location only to avoid cumbersome names (Appendix C). The known relative age of solid geological units and major faults since Jurassic, along with the radiometric ages of igneous rocks on the updated Sheet 6, is summarised in Table 4.3.

Table 4.3 Summary of Known Relative Ages of Solid Geological Units and Major Faults since the Jurassic

Relative Age Order	Name (with Age)	Type of Fault	Evidence [3]
12	Deep Bay Fault Sha Tau Kok Fault	NE-trending strike-slip	D, F D
11	*Nam Sang Wai Fault*	NW-trending strike-slip	D
10	Tai Lam Fault	NE-trending strike-slip	D, F
9	*Tai Tong Fault* *Yuen Long Faults* *Au Tau Faults*	NW-trending strike-slip	D
8	Yuen Tau Shan Fault *Tin Shui Wai Fault*	NE-trending NE-trending strike-slip	D, F
7	Tai Lam Granite (159.3 ± 0.3 Ma) [2a] Tsing Shan Granite (< 159.6 ± 0.5 Ma) [2a]		
6	Lantau Granite (161.5 ± 0.2 Ma) [2a]		
5	East Tuen Mun Fault *Wang Chau Fault*	NE-trending strike-slip	D, F
4	San Tin Fault	NE-trending thrust	D, F
3	Tai Po Granodiorite (< 164.6 ± 0.2 Ma) [2a]		
2	Tai Mo Shan Formation (< 164.5 ± 0.7 Ma) [2a] Shing Mun Formation (164.7 ± 0.3 Ma) [2b] Yim Tin Tsai Formation (164.5 ± 0.2 Ma) [2a]		
1	Tai O Formation (Lower to Middle Jurassic) [2c]		

Notes:
(1) Newly-interpreted faults are named in italic.
(2) Age data of igneous rocks are quoted from (a) Davis et al (1997) and (b) Campbell et al (2007). (c) Detrital zircon age data of sedimentary rocks is quoted from Sewell et al (2016) and discussed in Section 4.3.3.
(3) Evidence of fault interpretation. D: displacements of geological boundaries on map; F: fault evidence, e.g. mylonite, slickenside, fault breccia or gouge.
(4) The Tuen Mun Formation (169.5 ± 0.3 Ma) is an allochthonous tectonic block (Sewell et al, 2017). The timing of the Mai Po Fault is uncertain.

4.6.2 Major Northeast-trending Faults

4.6.2.1 Deep Bay Fault

The Deep Bay Fault (Sewell et al, 2000), formerly Lau Fau Shan Fault (Langford et al, 1989; GEO, 1994b), is located in the northwestern corner of Sheet 6. Its inferred alignment is based on evidence of mylonitic granites in boreholes from the Kong Sham Western Highway (formerly Shenzhen Western Corridor) on Sheet 5, and outcrops of fault materials at Lau Fau Shan to the north on Sheet 2. This major fault is associated with a broad (up to c. 300 m wide) zone of mylonite in the Tsing Shan Granite and Kat O Formation.

4.6.2.2 Yuen Tau Shan Fault

The Yuen Tau Shan Fault (Langford et al, 1989), formerly Tsing Shan Fault (GEO, 1994b) and Tuen Mun Fault (Sewell et al, 2000), extends from Sheet 5, passing Chung Shan (8152 8317) and Sha Kong Wai Tsai (8170 8360) to Sheet 2 in the northwest of Sheet 6 area, where it marks the boundary between the Tsing Shan Granite and Tuen Mun Formation. The boundary is partly faulted and partly intrusive as described in Section 4.4.3.2.

4.6.2.3 East Tuen Mun Fault

The East Tuen Mun Fault (Sewell et al, 2017), formerly Tuen Mun Fault (GEO, 1994b), is located from Tuen Mun Typhoon Shelter (8155 8270), passing Tin Ching Estate (8186 8360) to Sheet 2, where it marks the eastern boundary of the Tuen Mun Formation against Carboniferous and Middle Jurassic metasedimentary rocks. The western side of this fault is marked by a broad zone of mylonitised rocks as described in Section 4.3.4.1.

4.6.2.4 Tin Shui Wai Fault

A fault-bounded, narrow strip of shallow white marble subcrop is mapped beneath western Ping Shan in the south and eastern Tin Shui Wai in the north within the northern Tuen Mun Valley. Brittle contacts (e.g. fault gouge) between white marble and metasiltstone are identified along both the western (8184 8344) and eastern (8187 8354) fault boundaries (Table B1). This fault-bounded strip is interpreted to be an east- to southeast-dipping, compressional strike-slip duplex, which is collectively named the Tin Shui Wai Fault.

4.6.2.5 Wang Chau Fault

The Wang Chau Fault is a newly-interpreted strike-slip fault, which lies across the central outcrop of Carboniferous rocks from southern Yuen Long (8200 8316), passing Yuen Long Industrial Estate (8208 8360) to Sheet 2, and has caused vertical and significant left-lateral displacements of the strata. Near Long Ping, Wang Chau, southwestern and northern Yuen Long Industrial Estate, the shallow subcrop of marble is most likely associated with a compressional strike-slip duplex of this fault. Brittle evidence including fault breccia (Figure 4.9) and gouge is common along the fault planes of this strike-slip duplex (e.g. near Long Ching Estate; 8209 8342), leading to an anomalously deep weathering profile around the fault zone.

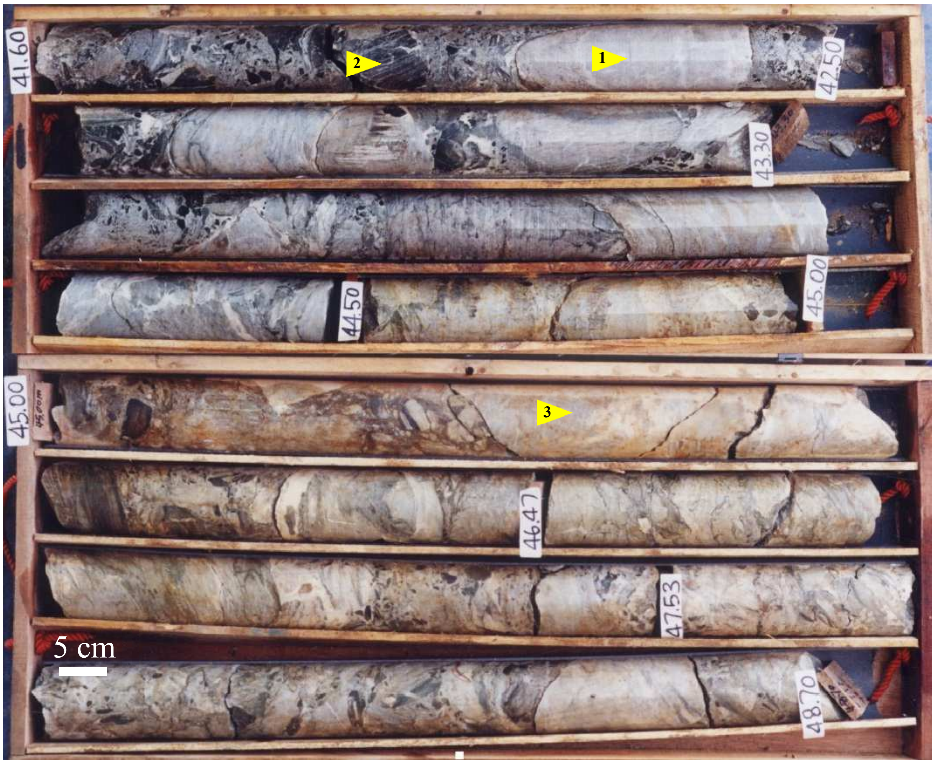


Figure 4.9 Cohesive Fault Breccia (Near Long Ping, GIU No. 35413/DHPZ/624, 41.6 - 48.7 m Depth) Comprising up to Boulder-sized Quartzite (Arrow 1), Mudstone (Arrow 2) and Impure Marble (Arrow 3) Fragments Cemented by Hydrothermal Fluid

4.6.2.6 Mai Po Fault

The Mai Po Fault, formerly Ma Tso Lung Fault (Langford et al, 1989; Sewell et al, 2000) and Lo Wu Fault (GEO, 1994b), is a newly-interpreted, NW- to WNW-dipping normal fault, which separates the Mai Po Member of the Lok Ma Chau Formation to the northwest and the Ma Tin Member of the Yuen Long Formation to the southeast, extending from the southwest of Yuen Long MTR Station (8213 8338) to Sheet 2. Parts of this fault appear to have been overprinted by granodiorite intrusion mapped at Yuen Long Industrial Estate (8207 8357) and Tung Tau Wai San Tsuen (8210 8350), and subsequently offset by major NW-trending faults. However, the precise timing of fault movement is uncertain.

4.6.2.7 San Tin Fault

The NE-trending thrust fault, namely San Tin Fault (Langford et al, 1989;

Sewell et al, 2000), runs from southwest of Tai Tong Tsuen (8202 8305), passing Nam Sang Wai (8222 8358) to Sheet 2. This fault separates Carboniferous metasedimentary rocks to the northwest and Jurassic volcanic and sedimentary rocks to the southeast. In places, this fault appears to have split into at least two imbricate thrust slices. Although there is no reliable structural data along the deformation zone of the thrust, the concealed Jurassic rocks within the zone are inferred to be overturned. Locally intense silicification and folding identified at Ma Tso Lung (on Sheet 2) and Sandy Ridge (on Sheet 3) may be associated with an extension of this thrust fault.

4.6.2.8 Tai Lam Fault

The Tai Lam Fault (Sewell et al, 2000), formerly Siu Lam Fault (Langford et al, 1989), extends from offshore of So Kwun Wat (8189 8251), passing Tai Lam Chung Reservoir, Pat Heung and Ta Shek Wu (8289 8360), to Sheet 2. Two ENE-trending faults extending from Tuen Mun Typhoon Shelter (8151 8265) and Golden Beach (8169 8257) respectively are thought to be branches intersecting the main Tai Lam Fault at the reservoir. This fault is marked by strong topographic lineaments and major dextral offsets of intrusive and volcanic rocks. At Butterfly Beach on Sheet 5, the Tuen Mun Formation is locally mylonitised. The inferred offshore continuation of this fault towards Sheets 9 and 10 is based on geophysical and borehole data from new highway and infrastructure developments between Tuen Mun and the Hong Kong International Airport.

4.6.2.9 Sha Tau Kok Fault

The Sha Tau Kok Fault (Sewell et al, 2000), formerly Sham Tseng Fault (Langford et al, 1989), extends from offshore in the south, passing Sham Tseng (8243 8252) and The Kadoorie Institute (8297 8322) to Sheet 7. It is defined by a strong NE-trending topographic lineament coupled with major sinistral offsets of intrusive and volcanic rocks.

4.6.2.10 Tsing Yi Channel Fault

A major ENE-trending fault, namely Tsing Yi Channel Fault (Sewell & Fyfe, 1995), is interpreted to extend from an intersection with the Sha Tau Kok Fault, passing Tsuen Wan to Sheet 7, and has resulted in forming the channel between Tsuen Wan and Tsing Yi. This fault is also interpreted to truncate two minor NW- and N-trending faults on Tsing Yi Island based on GEO (1995c, 1995d). Although the inferred alignment within Sheet 6 area is entirely offshore and the sense of displacement is unknown, the existence of this fault was proved by highly fractured and altered rocks at boreholes of the Ting Kau Bridge project (8263 8248) between Tsing Yi and Sham Tseng (Table B1).

4.6.3 Major Northwest-trending Faults

Several major NW-trending faults concealed beneath Yuen Long floodplain in the northwest of Sheet 6 area have led to systematic offset of the NE-trending faults and more complex distribution of geological units in the Yuen Long - Tin Shui Wai area. Elsewhere, the only other major NW-trending fault occurring in the southeast of Sheet 6 area is extended from Sheet 15 (GEO, 2010).

4.6.3.1 Tai Tong Fault

The Tai Tong Fault is a newly-interpreted strike-slip fault which extends from an intersection with the Tai Lam Fault at Tai Lam Chung Reservoir, passing Tai Tong (8200 8308) and Ha Tsuen to Ngau Hom Shek (8158 8348) in the northwest. This fault is inferred to have offset all the sedimentary, volcanic and intrusive rocks, along with major NE-trending faults, in the west of Sheet 6 area.

4.6.3.2 Yuen Long Faults and Au Tau Faults

Newly-interpreted, NW- and WNW-trending strike-slip duplexes, namely the Yuen Long Faults and the Au Tau Faults, run parallel to and immediately north of the Tai Tong Fault and have the same offset relationships. The Yuen Long Faults extend from Tai Tong (8220 8300) or Shap Pat Heung (8227 8307; 8236 8328), passing Yuen Long floodplain, southern Tin Shui Wai and Lau Fau Shan Road (8167 8359) to Sheet 2, while the Au Tau Faults extend from Au Tau Service Reservoir (8228 8336), passing Wang Chau and central Tin Shui Wai to Sheet 2. Dense borehole data has revealed considerable vertical and left-lateral displacements of the Yuen Long, Lok Ma Chau and Tuen Mun formations in the Yuen Long - Tin Shui Wai area, suggesting the Yuen Long and Au Tau faults cross-cut all these strata.

4.6.3.3 Nam Sang Wai Fault

The Nam Sang Wai Fault is the collective name for a newly-interpreted strike-slip duplex which extends from Shek Kong in the southeast, passing Nam Sang Wai (8218 8353) or Wing Kei Tsuen (8230 8360) to Sheet 2. Evidence for this fault is given by a major sinistral offset of the San Tin Fault, both vertical and horizontal displacements of the Wang Chau Fault, and subordinate offsets of isolated blocks of the Lok Ma Chau Formation and the Tai Po Granodiorite around Yuen Long Industrial Estate (8212 8356) where the fault bifurcates.

At the intersection between the Tai Lam and Nam Sang Wai faults in Shek Kong (8269 8333), a major brittle zone was identified in many boreholes from the Express Rail Link project. This brittle zone appears to have been displaced left-laterally across the Nam Sang Wai Fault, and thus this fault is inferred to continue along the NW-trending Shek Kong valley.

4.6.3.4 East Lamma Channel Fault

A NNW-trending fault is inferred to lie between the islands of Tsing Yi and Ma Wan in the southeastern corner of Sheet 6. This fault is considered to be an extension of the major NW-trending dextral fault, namely the East Lamma Channel Fault (Strange & Shaw, 1986), shown on the updated Sheet 15 (GEO, 2010) and the first edition of Sheet 10 (GEO, 1991). The fault is thought to be truncated in the north by the Tsing Yi Channel Fault. Although there is no obvious magnetic anomaly or lineament in the Tsing Yi - Ma Wan Channel, fault breccias were encountered at two marine boreholes (GIU nos. 13464/5DW9A&B in Sheet 10 area and 13464/5DW6; Table B1) in the centre of the channel.

4.6.4 Folds

Langford et al (1989) previously recognised two phases of folding: Palaeozoic and Mesozoic. The Palaeozoic folds were described as occurring within the Lo Wu - Tuen Mun Fault zone, and to comprise a series of asymmetric anticlines, with NE- to NNE-trending fold axes and moderately NW-inclined axial planes. Some SE limbs of the folds were thought to be cut out by thrust faulting. Several anticlines were named within Sheet 6 area, including the Yuen Long, Shan Ha Tsuen, Tin Shui Wai and Lam Tei anticlines. On the other hand, Mesozoic folds were considered to affect the volcanic and sedimentary rocks of Late Jurassic to Cretaceous age, and to be broad and gentle with fold axes plunging toward the southwest.

By resolving both NE- and NW-oriented movements of the fault-bounded blocks of Carboniferous strata in the Yuen Long - Tin Shui Wai area, a few gently NE- to NNE-plunging, WNW-inclined, asymmetrical folds to overfolds are now reinterpreted beneath Sheets 2 and 6 area. Generally, strata on the eastern flank of the folds are steep and overturned whereas that on the western flank are gently WNW-dipping. In the Yuen Long - Nam Sang Wai area, a persistent NNE-plunging anticline has been divided into many small parts by the NE-trending Wang Chau and Mai Po faults and the NW-trending Tai Tong, Yuen Long, Au Tau and Nam Sang Wai faults, forming apparently a number of anticlines.

There is insufficient evidence in Sheet 6 area to confirm the existence of other previously identified folds. The timing of this reinterpreted folding is not well constrained, as the folded Carboniferous strata are apparently displaced by the Mai Po Fault, which is inferred to have been overprinted by the Tai Po Granodiorite that predates the San Tin Fault. If the folding is associated with the San Tin Fault, then the folding must be either of Middle Jurassic or younger age. A possible younger constraint on the timing of folding is provided by the Tai Lam Granite, which intrudes the folded Carboniferous strata and was dated at 159.3±0.2 Ma (Davis et al, 1997). Elsewhere in the northern New Territories, the Carboniferous rocks appear to be folded in harmony with Middle Jurassic sedimentary and volcanic rocks.

4.7 Metamorphism

4.7.1 Regional and Hydrothermal Metamorphism

Regional metamorphism on the first edition of Sheet 6 was represented by dynamic and hydrothermal metamorphism associated with SE-directed thrusting of Carboniferous sedimentary rocks over Jurassic volcanic rocks along the San Tin Fault (Ho & Langford, 1987; Langford et al, 1989). The thrust zone was thought to be up to 2 km wide and to extend from Tuen Mun in the southwest to Lo Wu in the northeast (on Sheet 3) and was termed the Lo Wu - Tuen Mun Fault Zone by Burnett & Lai (1985). ‘Mylonitic schist and schist’ were reported to form narrow bands close to the footwall of the main thrust, and to grade southeastward into slightly schistose to non-schistose tuff. Shear belts similar to the San Tin Fault, although of smaller scale, were also considered to be responsible for schistose volcanic and sedimentary rocks, including ‘phyllite and sericite schist’, within the Lok Ma Chau and

Tuen Mun formations of the Tuen Mun valley (Langford et al, 1989). In the adjacent Sheet 2, all strongly-foliated volcanic and intrusive rocks along major faults were subsequently reclassified as mylonites (GCO, 1989a; GEO, 1994b).

During updating of Sheet 6, re-examination of archival rock samples and thin sections has revealed that all the Carboniferous sedimentary rocks, as well as many of the Jurassic volcanic, intrusive and sedimentary rocks in the vicinity of the East Tuen Mun and San Tin faults, have been subjected to low-grade, up to greenschist facies, metamorphism. Although the schistose volcanic rocks on the footwall of the San Tin Fault display slaty cleavages, earlier workers considered these fabrics to be shear bands resulted from ductile faulting (GEO, 1994b), rather than axial planar cleavages related to folding. Crenulation cleavages are also present in both the Carboniferous and Jurassic rocks along the previously recognised Lo Wu - Tuen Mun Fault Zone (Tang, 2005; Lo, 2019). The intensity of metamorphism decreases gradually away from the San Tin Fault such that in the southeast of Sheet 6, most rocks are non-foliated.

The foliated or regionally hydrothermally altered Jurassic volcanic, intrusive and sedimentary rocks close to the East Tuen Mun and San Tin faults, and in the northeast of Sheet 6 area, are now indicated by the screen depicting low-grade metamorphism on the updated Sheet 6.

4.7.2 Dynamic Metamorphism

Dynamic metamorphism in Sheet 6 area is most strongly developed along the East Tuen Mun Fault bounding the Tuen Mun Formation. A zone of strongly-mylonitised rocks of the Tuen Mun Formation of up to c. 400 m wide is depicted on the western side of the fault. Mylonite and ultramylonite can be clearly identified in the Tin Shui Wai Member of the formation, while they are not readily apparent in the foliated and commonly highly-fractured metasedimentary rocks. On the western side of the Tuen Mun valley, the Yuen Tau Shan Fault shows local development of mylonite in both the Tuen Mun Formation and Tsing Shan Granite. In the northwestern corner of Sheet 6, a zone of mylonitic granite of c. 300 m wide is associated with the inferred Deep Bay Fault. On the eastern side of the San Tin Fault, a narrow zone of mylonite is still inferred along parts of the deformation zone of the thrust, where an intensely-silicified mylonite was recovered from boreholes (Figure 4.10).

4.8 Superficial Geology

On the first edition of Sheet 6, onshore superficial deposits were not assigned to a lithostratigraphic unit. However, these deposits were classified on the basis of depositional process or environment and broadly grouped as Pleistocene or Holocene in age. Offshore superficial deposits, on the other hand, were divided into two formations: the Pleistocene Chek Lap Kok Formation of alluvial origin and the Holocene Hang Hau Formation of marine origin (Strange & Shaw, 1986). Subsequently, Fyfe et al (2000) undertook a comprehensive review of the Quaternary superficial stratigraphy in Hong Kong and proposed a revised classification, which has been largely adopted in this revision (Figure 4.11).

Figure 4.10 Intensely-silicified Mylonite (Near Tung Shing Lei, [8223 8344], Borehole No. DH56, 60.95 [Top Left] - 64.28 m [Bottom Right] Depth)

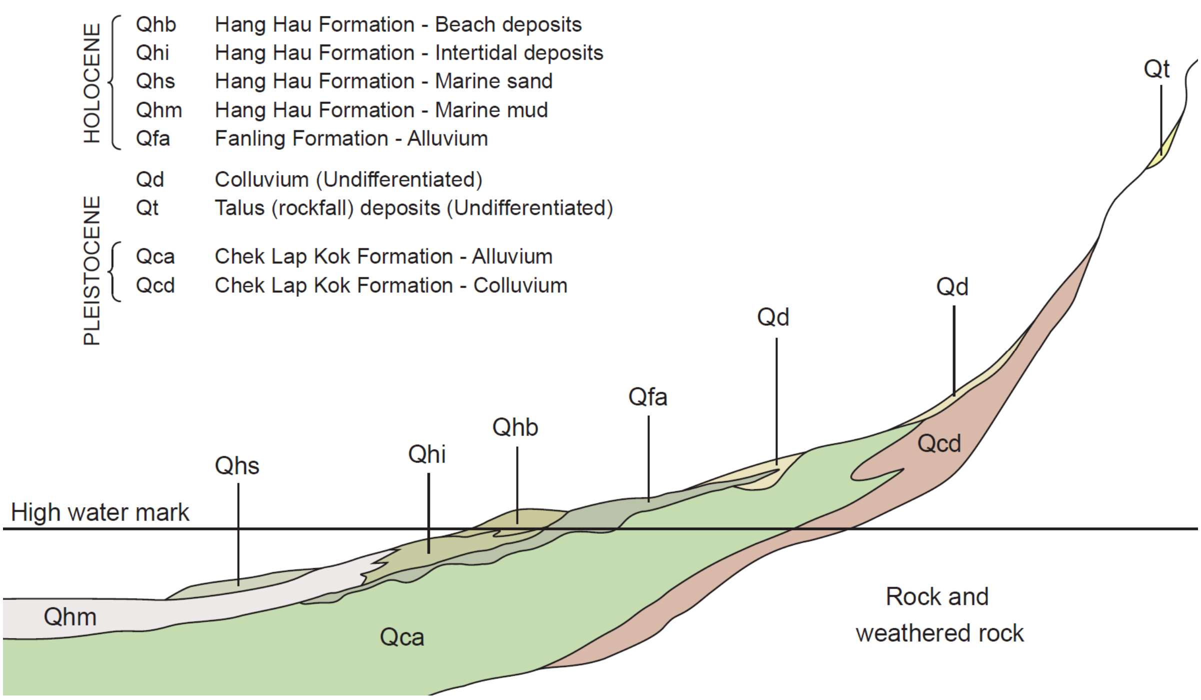


Figure 4.11 Schematic Diagram Showing the Quaternary Stratigraphy of Updated Sheet 6 (Modified from Fyfe et al, 2000)

4.8.1 Onshore Superficial Deposits

Onshore superficial deposits on the updated Sheet 6 have been reclassified as the Pleistocene Chek Lap Kok Formation and the Holocene Fanling Formation (Fyfe et al, 2000), both being of alluvial and colluvial origin. The alluvial facies of the Fanling Formation is contemporaneous with the coastal and marine facies of the Hang Hau Formation (Fyfe et al, 2000). Reinterpretation of the extent of onshore superficial deposits has been based on their geomorphological setting, their appearance on aerial photographs and available borehole records. Colluvium and talus (rockfall) deposits have been mapped as "Undifferentiated" where their age is uncertain.

4.8.2 Intertidal Units and Beaches

With reference to the recommendations made by Wong & Shaw (2009), coastal deposits on the updated Sheet 6 have been re-examined and reclassified as intertidal, beach and backshore deposits. Prior to urban developments, the intertidal areas of Tuen Mun, Yuen Long and Tin Shui Wai were mapped as marine mud of the Hang Hau Formation, as shown on the first edition of Sheet 6. Reinterpretation by Fyfe et al (2000) suggests that these deposits were located within a tide-dominated estuary comprising intertidal mudflats and brackish swamps. Dark brownish grey, plant remains- or shell-bearing, organic mud, which is commonly inferred to be "pond deposit" in existing borehole logs, probably reflects lagoon deposits in shallow, brackish water. The marine mud is now reclassified as the intertidal deposits of the Hang Hau Formation on the updated Sheet 6.

4.8.3 Offshore Superficial Deposits

The major update to the offshore superficial geology on Sheet 6 is the addition of interpreted contours on the thickness of the Hang Hau Formation and the total thickness of the Quaternary superficial deposits. These two sets of isopachs are based on a reinterpretation of available marine seismic survey profiles as well as offshore borehole data for Sheet 6 area, except for reclaimed areas where superficial deposits may have been largely modified.

4.8.4 Reclamation History and Major Fill Bodies

In common with the first edition of Sheet 6, the updated Sheet 6 shows the limits of reclaimed land formed around Tsuen Wan, north and east Tsing Yi, Sham Tseng, Tai Lam Chung and Castle Peak Bay. The reclamation history (i.e. years indicated beside the limits of reclaimed land) has been established based on a review of available aerial photographs of selected years. In addition, the artificial Golden Beach, major site formation fill bodies in the Tuen Mun, Yuen Long and Tin Shui Wai areas, and large-scale fill slopes have also been mapped using aerial photograph interpretation, borehole and slope information. All these types of fill are categorised in the geodatabase.

5 Conclusion

The 1:20,000-scale geological map Sheet 6 - Yuen Long is the fourth map updated under the map updating project carried out by the Hong Kong Geological Survey. Both the updated solid and superficial geology map (Series HGM20 Edition II) and the new solid geology map (Series HGM20S Edition I) will be available in both printed and digital versions. The key findings and revisions of Sheet 6 include (a) new interpretation of the solid geology covered by superficial deposits, (b) revision of the stratigraphy of the Carboniferous San Tin Group, (c) reassignment of sedimentary units to Jurassic formations, (d) revision of the nomenclature and classification of volcanic stratigraphy and intrusive rocks, (e) improved accuracy of the alignment of concealed major faults and geological boundaries, (f) revision of a fold model, (g) revision of the type and extent of metamorphism, (h) reinterpretation of onshore and offshore superficial deposits, and (i) updating of the reclamation history. A whole-territory geodatabase has been developed, within which geological data of various aspects are arranged in multiple GIS data layers.

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Appendix A

Summary of Geological Datasets

Content

List of Tables

Table A1 Summary of Geological Datasets on Updated Geological Maps (Sheet 1 of 2)

Dataset	Attribute	Description	Series HGM20	Series HGM20S
Solid Geology	Polygon	Areas of Main Solid Geological Mapping Units	✓	✓
Subcrop	Polygon	Areas of Marble Subcrop Units		✓
Textures	Polygon	Areas of Major Textural Features	✓	✓
Metamorphism	Polygon	Areas of Metamorphism and/or Alteration	✓	✓
Dykes	Line	Major Dykes	✓	✓
Mineral Veins	Line	Major Mineral Veins	✓	✓
Solid Contacts	Line	Contact Types of Solid Geological Mapping Units	✓	✓
Faults	Line	Major Faults	✓	✓
Fold Axes	Line	Major Fold Axes	✓	✓
Structures	Point	Locations of Major Structural Measurements	✓	✓
Minerals	Point	Economic Mineral Occurrence	✓	✓
Fossils	Point	Fossil Locality	✓	✓
Former Mine Adits	Point	Locations of Former Mine Adits and Shafts	✓	✓
Key Boreholes	Point	Locations of Interpreted Key Boreholes		✓
Superficial Deposits	Polygon	Areas of Main Superficial Geological Mapping Units	✓	
Alluvial Terraces	Line	Locations of Alluvial Terraces	✓	
Hang Hau Isopachs	Line	Contours on Thickness of Hang Hau Formation	✓	
Superficial Isopachs	Line	Contours on Thickness of Offshore Superficial Deposits	✓	
Buried Channels	Line	Locations of Offshore Channels	✓	
Fill	Polygon	Areas of Reclamation and Fill Bodies	✓	

Table A1 Summary of Geological Datasets on Updated Geological Maps (Sheet 2 of 2)

Dataset	Attribute	Description	Series HGM20	Series HGM20S
Acoustic Turbidity	Polygon	Areas of Acoustic Turbidity	✓	
Borrow Areas	Polygon	Areas of Borrowed Materials	✓	
Dumping Grounds	Polygon	Areas of Dumping Grounds	✓	

Table A2   Summary of Geological Datasets in the GIS Geodatabase

Dataset	Attribute	Description
Boreholes	Point	Locations of Interpreted Boreholes
Rock Samples	Point	Locations of Samples in HKGS Collection
Field Notes	Point	Locations of Original Field Notebook Entries
Fields Sketches	Point	Scanned Portions of Field Notebook Sketches
Field Data Maps	Polygon	Scanned Portions of Field Data Maps
Field Photos	Point	Scanned Field Photographs
High Resolution Photos	Point	Scanned High Resolution Photographs
Tunnel Geology	Line	Interpreted Tunnel Geology Profiles
Seismic Tracks	Line	Scanned Seismic Track Plots
Seismic Running Points	Point	Locations of Seismic Running Points
Marine Magnetic	Point	Locations of Measured Marine Magnetic Anomalies
Airborne Magnetic	Point	Locations of Measured Airborne Magnetic Anomalies
Gravity	Point	Locations of Measured Gravity Anomalies
WR-Geochemistry	Point	Locations of Analysed Whole Rock Samples
SS-Geochemistry	Point	Locations of Analysed Stream Sediment Samples
Heavy Minerals	Point	Locations of Analysed Heavy Mineral Samples
Age Dating	Point	Locations of Dated Rock and Superficial Deposit Samples
Scheduled Areas	Polygon	Outline of Scheduled and Designated Areas

Appendix B

Summary of Key Borehole Records

Content

List of Table

Table B1 Summary of Key Borehole Records in Sheet 6 Area (Sheet 1 of 2)

GIU Reference No.	Location	Easting	Northing	Feature
03602/D3	Tuen Mun Town Hall	815537	827900	Polymictic Tuffaceous Breccia
11187/BGS2	Fraser Village	821044	832933	Type Section of Long Ping Member (Frost, 1992)
11188/BGS3	Lung Tin Tsuen	820744	833279	Type Section of Ma Tin Member (Frost, 1992)
12076/BD13A	North of Fu Tai Estate	816326	830663	Intrusive Contact between Fine- to Medium-grained Granite and Tuen Mun Formation
12505/DH10	South of Tin Yiu Estate	818490	834468	Fault Contact between Ma Tin Member and Mai Po Member
13074/D-10	Yuen Long Industrial Estate	820914	835968	Long Ping Member Conformably Overlying Ma Tin Member
13464/5DW6	Tsing Yi - Ma Wan Channel	825518	824049	Fault Breccia
16014/D182	Eastern Tin Shui Wai	818754	835441	Fault Contact between Mai Po Member and Ma Tin Member
17657/BH8 17657/BH9	Ting Kau Bridge	826320 826346	824852 824865	Highly Fractured and Altered Rocks
21216/SP34	Shui Pin Wai Estate	820109	834019	Mai Po Member Conformably Overlying Long Ping Member
26748/TMA98	Fu Tai Estate	816555	830416	Andesite-sandstone Peperite
26984/DH1	Southeast of Yuen Long Park	820086	833435	Mai Po Member Conformably Overlying Long Ping Member
29625/TH1	Hung Tin Road	818012	833994	Type Section of Tin Shui Wai Member (Sewell et al, 2017)
35413/DHPZ/624	Long Ping	820419	834276	Cohesive Fault Breccia of Impure Marble

Table B1 Summary of Key Borehole Records in Sheet 6 Area (Sheet 2 of 2)

GIU Reference No.	Location	Easting	Northing	Feature
35413/DH/647	Long Ping	820619	834281	Long Ping Member Conformably Overlying Ma Tin Member
35413/DHCH/925 35413/DH/926	Yuen Long MTR Station	821861 821885	834064 834064	Ma Tin Member Conformably Overlying Long Ping Member
35748/DH1	Lam Hau Tsuen	819880	832780	Mai Po Member Conformably Overlying Long Ping Member
36610/MBH3 36610/MBH4	Hong Lok Road LRT Station	820731 820736	833931 833873	Long Ping Member Conformably Overlying Ma Tin Member
40104/BH12	Tuen Mun San Hui	815720	829003	Intrusive Contact between Tai Lam Granite and Tuen Mun Formation
40758/NDH48	Southwestern Hung Shui Kiu	816507	832946	Altered Andesite Hyaloclastite
43494/BH28	Yau Kom Tau Village	828132	826071	Transition from Porphyritic Medium-grained Granodiorite, Fine-grained Granodiorite to Dacite
44514/BH62	Eastern Hung Shui Kiu	817929	832286	Intrusive Contact between Tai Lam Granite and Lok Ma Chau Formation
45223/LB6	Tuen Mun Road	820330	824146	Intrusive Contact between Tai Lam Granite and Lantau Granite
54157/BH3	Southeast of Siu Hang Tsuen	815362	830445	Type Section of Siu Hang Tsuen Member (Sewell et al, 2017)
60093/AH5	East of Ma Tin Pok	821121	833061	Ma Tin Member Conformably Overlying Long Ping Member
60324/BH12	Long Ching Estate	820974	834201	Fault Gouge

Appendix C

Nomenclature of Major Faults

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List of Figures

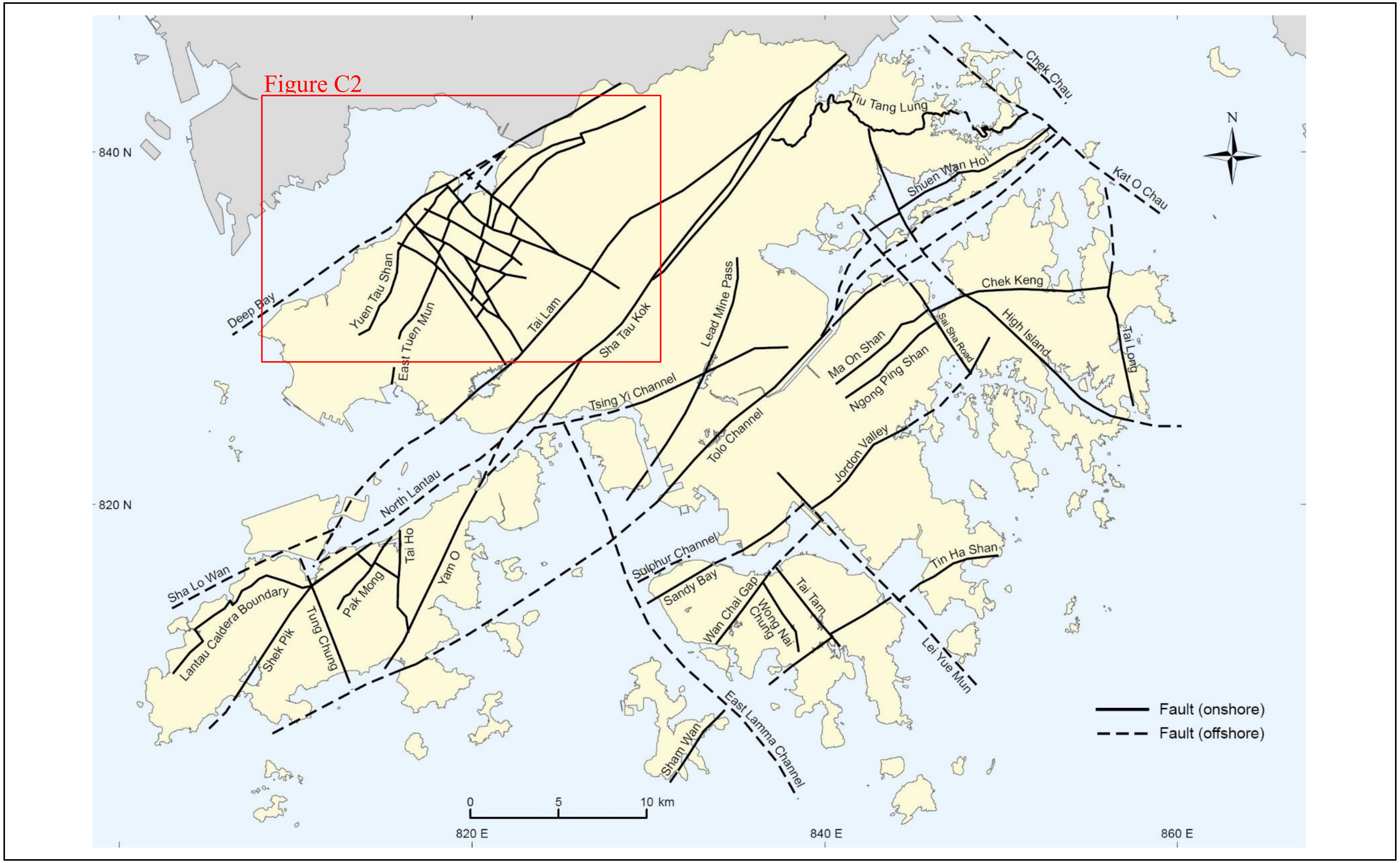

Figure C1 Distribution of Named Major Faults in Hong Kong (Modified from Sewell et al, 2000). Anonymous Major Faults and Named Minor Faults are Not Shown.

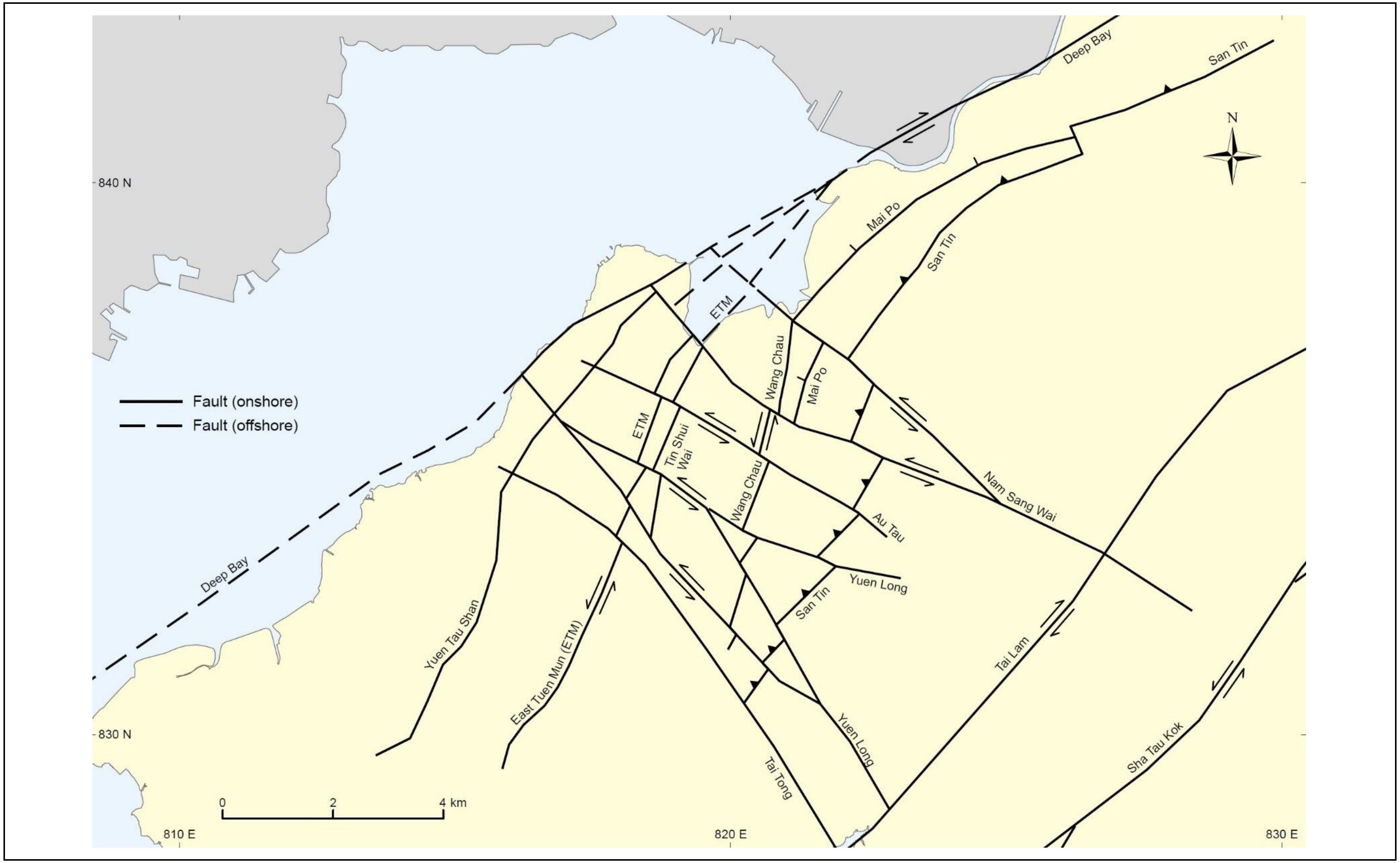

Figure C2 Distribution of Named Major Faults in the Northwestern New Territories (Modified from Sewell et al, 2000). Anonymous Major Faults and Named Minor Faults are Not Shown.

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