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

Major Findings and Revisions Map Sheet 11 – Hong Kong and Kowloon

GEO Report No. 300

D.L.K. Tang & C.W. Lee

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. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication in print. These include guidance documents and results of comprehensive reviews. They can also be downloaded from the above website.

These publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the second last page of this report.

H.N. Wong
Head, Geotechnical Engineering Office
August 2014

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Foreword

This report describes the major new findings on, and significant revisions to, Hong Kong Geological Survey 1:20,000-scale Geological Map Sheet 11 – Hong Kong and Kowloon, undertaken between 2005 and 2006. The work was carried out by the Hong Kong Geological Survey Section of 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 1987 was first surveyed. The map updating work for Sheet 11 has been implemented on a GIS platform using a standard GIS template, and the map has been made available for promulgation in ArcReader format.

Ms. D L K Tang and Mr. C W Lee jointly managed the update of solid geology and onshore superficial geology of Map Sheet 11, while Dr. R Shaw undertook re-interpretation of the offshore superficial geology. Dr. R J Sewell provided an overall review of the updated map and this report. Technical support was provided by Cartographic and Geological Survey staff.

K.C. Ng
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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 form. This will make these geological maps more easily accessible to the public, and more useful to engineers and planners.

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

The first edition of the Geological Map Sheet 11 – Hong Kong and Kowloon was surveyed between 1984 and 1985, and was published in 1986. Map Sheet 11 is the third map to be updated under the programme. The updating programme gives priority to urban areas. Reliability of the geological maps has been improved after incorporation of the vast amount of new information that has accumulated over the past twenty years, and advances in the understanding Hong Kong's geology since the published maps were first surveyed.

The key findings and revisions to Map Sheet 11 are described in this report. They include: revision of the nomenclature and classification of volcanic stratigraphy and intrusive rocks, re-interpretation of onshore and offshore superficial deposits, an updated reclamation history, and improved accuracy of the locations of concealed major faults and geological boundaries. A 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 (then Geotechnical Control Office until 1991) commenced a geological survey of Hong Kong in 1982, and a series of fifteen 1:20,000-scale, HGM 20 Series, geological maps with six geological memoirs was published between 1986 and 1996 (Figure 1.1). The first edition of the 1:20,000-scale Geological Map Sheet 11 (hereafter, Sheet 11) – Hong Kong and Kowloon, updated by this report, was published in 1986 (GCO, 1986b) with an accompanying geological memoir (Strange & Shaw, 1986). It was based on field surveys carried out in 1984 and 1985. In 1996, five provisional 1:5,000-scale geological maps covering part of Kowloon area (11NW-A to D and 11NE-C) were produced, although they were not formally published (GEO, unpublished, 1996b, 1996c, 1996d, 1996e & 1996f). 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, synthesizing 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 Description of the Project

The map updating project is scheduled to be 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 HKSAR since July 1997, will be incorporated within the update. Priority will also be given to establishing the locations of faults concealed by superficial deposits in both onshore and offshore areas, and to revising areas of complex geology, such as Yuen Long and Ma On Shan. Several inconsistencies between individual map sheets, which resulted from developments in terminology and interpretation that occurred during the preparation of the 1:20,000-scale maps between 1986 and 1996, will also be resolved.

1.3 Scope and Objectives

The scope of the map updating project is comprehensive. Nevertheless, it 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 and including results from recent geophysical surveys), site formation data together with a re-evaluation of the data collected during the original field survey (e.g. original field records, sketches, field photographs, sample descriptions, etc). Other published maps and related publications will also be updated where necessary, including the 1:100,000-scale maps covering the whole of the HKSAR. The objective is to produce up-to-date, on-demand geological reports, including geological maps, cross-sections, legends, and 3D models, for specified areas.

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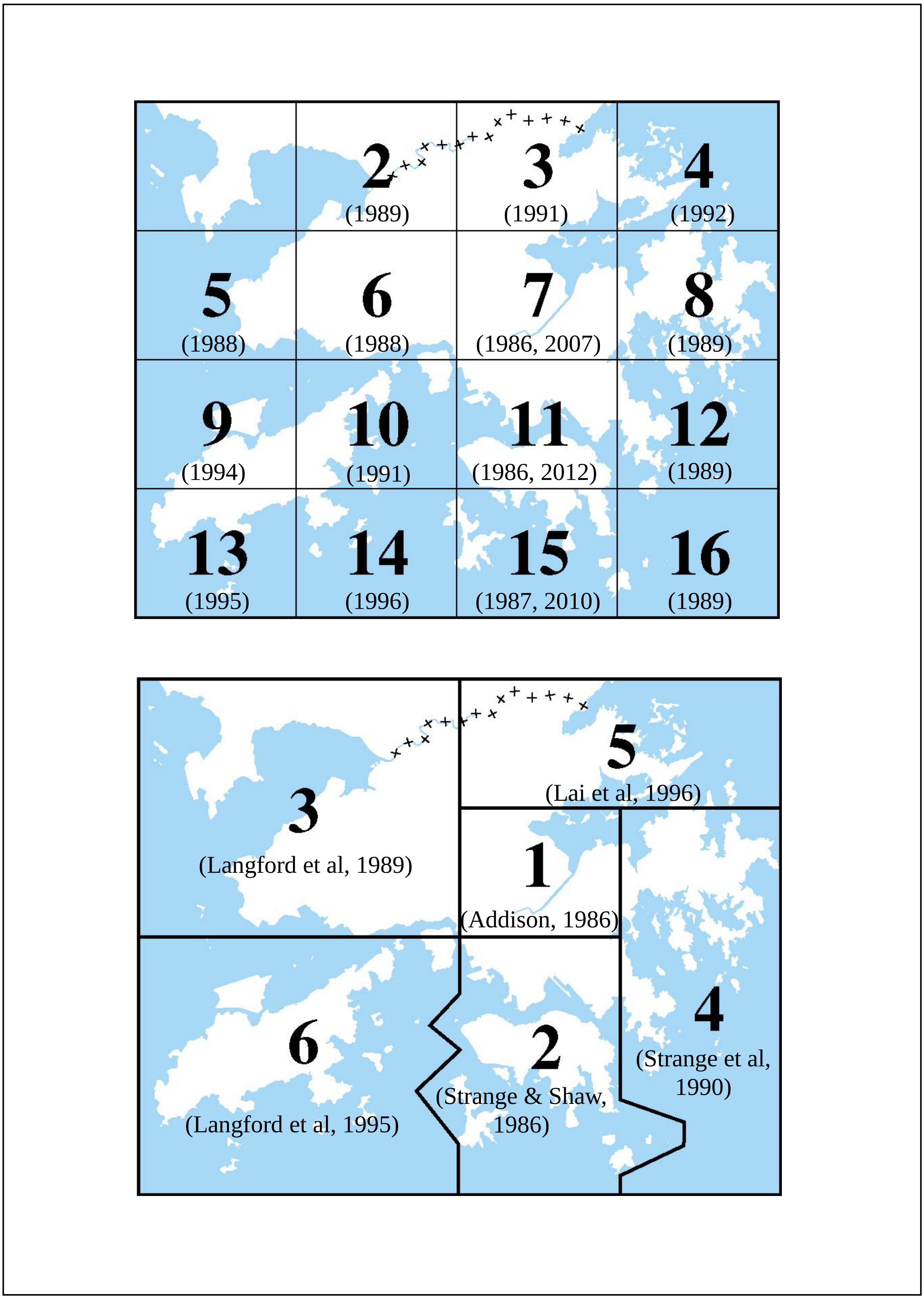

Figure 1.1 Published Hong Kong Geological Survey 1:20,000-scale Solid and Superficial Geological Maps and Geological Memoirs

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

Sheet No.	Name	Survey (Onshore* Offshore#)	Sheet Published	Priority for Map Revision	Completion of Updating
7	Sha Tin	1983-84*#	1986	High	2007
15	Hong Kong South & Lamma Island	1985-86* 1986#	1987	High (north) Low (south)	2009
11	Hong Kong & Kowloon	1984-85* 1985#	1986	High	2012
6	Yuen Long	1984-1987* 1986-1987#	1988	High	(in progress)
5	Tsing Shan (Castle Peak)	1984-1986* 1986-1987#	1988	High (east) Low (west)	(in progress)
2	San Tin	1985-86* 1986-87#	1989	High	(in progress)
3	Sheung Shui	1988-1989* 1989-90#	1991	High (west) Low (east)	
9	Tung Chung	1989-1992* 1991-1992#	1994	High (north) Low (south)	
10	Silver Mine Bay	1985-1989* 1990#	1991	High (north) Low (south)	
12	Clear Water Bay	1986-87* 1988#	1989	High (west) Low (east)	
8	Sai Kung	1986-88* 1988#	1989	Low	
13	Shek Pik	1992*#	1995	Low	
14	Cheung Chau	1985-89* 1990-93#	1995	Low	
16	Waglan Island	1983-1984* 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 cartographical 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 ARC/INFO®. Multiple layers of geological information (Table 2.1) are being developed within a Geodatabase that will form the basis of the data storage and retrieval system.

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Interrogation of geological data within the Geodatabase will be possible using the latest GIS tools and Digital Elevation Models (DEM). The digital 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. Hard copies of the combined solid and superficial map will be printed and made available for purchase.

Geological datasets that have been used for the updating of Sheet 11 are available on request from the Chief Geotechnical Engineer/Planning, Geotechnical Engineering Office, Civil Engineering and Development Department. These datasets represent geological information available up to 2006. The Geodatabase will be updated regularly, and new editions of the digital geological maps will be released from time to time along with revised datasets. The procedures and specifications for the Hong Kong Geological Survey (HKGS) GIS Maps, Data Model and Geodatabase Scheme Diagram will be contained in a separate report.

Table 2.1 Summary of Geological Datasets Stored in the GIS Geodatabase (Sheet 1 of 2)

Dataset	Attribute	Description
Solid Units	Polygon	Areas of Main Solid Mapping Units
Solid Contacts	Line	Contact Types of Solid Mapping Units
Faults	Line	Major Faults
Fold Axes	Line	Major Fold Axes
Structure	Point	Locations of Structural Measurements
Metamorphism	Polygon	Areas of Metamorphism and/or Alteration
Textures	Polygon	Areas of Major Textural Features
Mineral Veins	Line	Major Mineral Veins
Dykes	Polygon	Major Dykes
Rock Samples	Point	Locations of samples in HKGS Collection
Minerals	Point	Economic Mineral Occurrence
Superficial Units	Polygon	Areas of Main Superficial Mapping Units
CLK Contours	Line	Contours on Base of Offshore Superficial Deposit
Hang Hau Isopachs	Line	Thickness of Hang Hau Formation
Buried Channels	Line	Locations of Offshore Channels
Alluvial Terraces	Line	Locations of Alluvial Terraces
NT Landslide Crowns	Point	Location of Landslide Crowns
NT Landslide Trails	Line	Locations of Landslide Debris Trails
Reclamation/Fill Body	Polygon	Areas of Reclamation and Fill Body

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Table 2.1 Summary of Geological Datasets Stored in the GIS Geodatabase (Sheet 2 of 2)

Dataset	Attribute	Description
Marine Magnetic	Polygon	Areas of Offshore Marine Magnetic Anomalies
Airborne Magnetic	Polygon	Areas of Airborne Magnetic Anomalies
Gravity	Polygon	Areas of Gravity Anomalies
Acoustic Turbidity	Polygon	Area of Acoustic Turbidity
Seismic Tracks	Line	Locations of Seismic Tracks
Seismic Profiles	Line	Locations of Seismic Track Plots
Field Notes	Point	Locations of Original Field Notebook Entries
Field Sketches	Point	Scanned Portion of Field Notebook Entries
Field Data Map	Point	Scanned Portions of Field Data Map
Field Photos	Point	Scanned Field Photographs
Boreholes	Point	Locations of Interpreted Boreholes
High Resolution Photos	Point	Scanned High Resolution Photographs
Tunnel Geology	Line	Interpreted Tunnels Geology Profiles
WR-Geochemistry	Point	Locations of Analysed Whole Rock Samples
SS-Geochemistry	Point	Locations of Analysed Stream Sediment Samples
Age Dating	Point	Locations of Dated Rock and Superficial Deposits Samples
Heavy Minerals	Point	Locations of Heavy Minerals Samples
Former Mining Areas	Point	Locations of Former Mining Areas
Former Mine Adits	Point	Locations of Former Mine Adits
Borrow Areas	Polygon	Locations of Borrowed Material
Dumping Grounds	Polygon	Locations of Dumping Grounds

3 Data Sources

The primary data sources for updating Sheet 11 have included records of field notes, rock samples, structural measurements, photographs and analyses compiled during the original field survey and contained in the HKGS archive. In addition, selected drillhole records contained in the Geotechnical Information Unit of Civil Engineering Library, whole-rock geochemical analyses (Sewell & Campbell, 2001b), absolute age data (Sewell & Campbell, 2001a), stream sediment geochemical analyses (Sewell, 1999 & 2007), landslide data (MFJV, 2007), seismic lines and selected scanned traces (Cheung & Shaw, 1993, HKGS archive), and reclamation histories (based on unpublished map from Port Works Division),

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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, 1999 & 2005) and the summary in Sewell et al (2000). As-built tunnel records of various infrastructure project, such as HATS Stage 1 Project, have also been incorporated. These records have been compiled and are accessible within the Geodatabase.

4 Major Findings and Revisions to Sheet 11

4.1 Rock Nomenclature

The first editions of the HKGS 1:20,000-scale geological maps (GCO, 1986a, 1986b, 1987, 1988a, 1988b, 1989a, 1989b, 1989c, 1989d & 1991; GEO, 1991, 1992, 1994, 1995 & 1996b) assigned the volcanic, sedimentary and metamorphic rocks to lithostratigraphic formations, whereas the intrusive rocks were classified primarily on the basis of grain size. Subsequent detailed petrological, geochemical and geochronological analyses of the mapped units enabled a volcanic formation and pluton-based nomenclature to be adopted for the major extrusive and intrusive units depicted on the 1:100,000-scale geological map (Sewell et al, 2000). Similarly, formation or pluton names and rock type descriptors have been assigned to all the geological units depicted on the updated maps. Thus, on the new map, rock type descriptors indicate the dominant lithology of the geological units, so it is possible to depict lithologies alone, or to depict the formation and pluton nomenclature. As a result, several inconsistencies between the original 1:20,000-scale maps have now been rectified, and the nomenclature has been brought into line with the 1:100,000-scale geological map.

4.2 Volcanic Rocks

4.2.1 Nomenclature and Classification

In the first edition of Sheet 11, volcanic rocks in the district were assigned to three formations, comprising the Tai Mo Shan, Ap Lei Chau and Shing Mun formations of the Repulse Bay Volcanic Group. Specific mappable lithological units within these formations were also depicted. The volcanic stratigraphy of Hong Kong was later re-interpreted by Campbell & Sewell (1998) and subsequently incorporated with further refinements in the HKGS 1:100,000-scale geological map (Sewell et al, 2000). During updating of Sheet 11, the stratigraphic nomenclature of volcanic formations has largely been aligned with that on the HKGS 1:100,000-scale geological map. On the updated map, both a formation name and a lithology descriptor, describing the dominant rock type, have been assigned to all the volcanic units.

4.2.2 Repulse Bay Volcanic Group

The Mesozoic volcanic rocks in the district are now divided into four formations. The four formations are the Ap Lei Chau, Long Harbour, Mount Davis and Che Kwu Shan formations (Table 4.1). They belong to the Lower Cretaceous Repulse Bay Volcanic Group that was emplaced at around 143 Ma (Davis et al, 1997; Sewell et al, 2012a). Campbell & Sewell (1998) subdivided the Repulse Bay Volcanic Group into two subgroups, namely the

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Table 4.1 Solid Geology of Updated Sheet 11

Volcanic Rocks				Intrusive Rocks		
Age	Volcanic Group/Formation		Principal Lithology	Granitic Suite/Unit		Principle Lithology
Late Jurassic to Early Cretaceous				Undifferentiated minor dykes		Mafic to intermediate dykes, quartzphyric rhyolite to quartzphyric rhyodacite dykes, feldsparphyric rhyolite to feldsparphyric rhyodacite dykes, and aplite dykes
Early Cretaceous				Lion Rock Suite	Mount Butler Granite	Porphyritic fine- to medium-grained biotite granite
					Kowloon Granite	Equigranular medium-grained biotite granite
					Tei Tong Tsui Quartz Monzonite	Porphyritic medium-grained to fine- to medium-grained quartz monzonite
	Repulse Bay Volcanic Group	Che Kwu Shan Formation	Crystal bearing fine ash vitric tuff, commonly with eutaxitic foliations	Cheung Chau Suite	Shui Chuen O Granite	Inequigranular coarse-grained to porphyritic medium-grained biotite granite
		Ap Lei Chau Formation	Fine ash vitric tuff, commonly with eutaxitic foliations			
		Long Harbour Formation	Coarse ash crystal tuff			
		Mount Davis Formation	Lapilli bearing coarse ash crystal tuff			
Late Jurassic				Kwai Chung Suite	East Lantau Rhyolite	Feldsparphyric rhyolite to rhyodacite and quartzphyric rhyolite to rhyodacite dykes
					Needle Hill Granite	Porphyritic fine-grained biotite granite
					Sha Tin Granite	Inequigranular coarse-grained granite

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"Rhyolitic" and "Trachytic" subgroups based on geochemical evidence. Campbell & Sewell (1998) and Sewell et al (2000) considered that the two subgroups represent products of contemporaneous eruptions from two magmatic sources of different compositions.

Based on recent field evidence, high precision U-Pb zircon geochronology, and whole rock geochemistry (particularly TiO_2 versus Zr plot), Sewell et al (2012b) have established a composite stratigraphy of the Repulse Bay Volcanic Group and Kau Sai Chau Volcanic Group. The earlier eruptions of the Repulse Bay Volcanic Group, represented by the Long Harbour and Mount Davis formations, were dominated by weakly zoned dacite – rhyolite coarse ash crystal tuff. This was followed by the later eruptions of fine ash vitric tuff, represented by the Ap Lei Chau and Che Kwu Shan formations. These are overlain by a volcaniclastic unit represented by the Mang Kung Uk Formation, which is found in the Clear Water Bay area.

4.2.2.1 Long Harbour Formation

Lapilli-bearing coarse ash crystal tuff exposed near Ho Chung in Sai Kung, which was formerly mapped as the Tai Mo Shan Formation (Strange & Shaw, 1986), is now assigned to the Long Harbour Formation. Geochemically, the Long Harbour Formation is rhyodacite to rhyolite in composition (Sewell et al, 2000). The occurrence of pink alkali feldspars in the coarse ash tuff is the distinctive feature, which assists the discrimination of the Long Harbour Formation from other volcanic units in the area. The Long Harbour Formation from Sai Kung has been dated at 142.8±0.2 Ma (Davis et al, 1997).

4.2.2.2 Mount Davis Formation

Blocks of coarse ash crystal tuff, exposed in western Hong Kong Island, and around Chai Wan and Fei Ngo Shan, were originally assigned to the Tai Mo Shan and Shing Mun formations respectively in the first edition of Sheet 11 (Strange & Shaw, 1986). Based on general outcrop relationships and whole-rock geochemical data, these outcrops have been considered as comparable to a coarse ash crystal tuff unit dated at 142.8±0.2 Ma (Campbell et al, 2007) on Lin Fa Shan on central Lantau Island. Accordingly, they have been assigned to the Mount Davis Formation (Langford et al, 1995; Sewell et al, 2000). The age of the Mount Davis Formation at its type locality in northwest Hong Kong Island has been recently confirmed at 143.0±0.2 Ma (Sewell et al, 2012a). The new age data have indicated that the majority of volcanic rocks on Hong Kong Island and Kowloon belong to the 143 Ma Repulse Bay Volcanic Group. The Mount Davis Formation in the district is dominated by dacitic lapilli-bearing coarse ash crystal tuff with minor eutaxitic fine ash tuff, tuff breccia, and tuffaceous siltstone and sandstone. Recent ground investigations and the excavation for cavern development at the University of Hong Kong have revealed the presence of thick metamorphosed tuffaceous sedimentary intercalations within the formation in the western Hong Kong Island.

On the first edition of Sheet 11, an outcrop of porphyritic medium-grained granodiorite was mapped near Ho Chung Valley in Sai Kung. Based on a re-examination of rock samples and thin sections from the HKGS Rock Archive (HK809 and HK811), the lithology is now considered to be lapilli-bearing coarse ash crystal tuff rather than granodiorite. The outcrop has been re-assigned to the Mount Davis Formation based on its lithological characteristics.

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4.2.2.3 Ap Lei Chau Formation

The Ap Lei Chau Formation comprises dominantly fine ash vitric tuff with eutaxitic foliations and some coarse ash crystal tuff and tuffaceous sedimentary units. The formation crops out in the western and southwestern part of Hong Kong Island. The Ap Lei Chau Formation has been dated at 142.7±0.2 Ma (Davis et al, 1997). Previously, volcanic rocks in eastern Kowloon were assigned to the Ap Lei Chau Formation (Strange & Shaw, 1986). However, based on comparison of rock relationships and whole rock geochemistry (Sewell et al, 2000), these rocks have been reassigned to either the Mount Davis Formation (Section 4.2.2.2) or the Che Kwu Shan Formation (Section 4.2.2.4).

4.2.2.4 Che Kwu Shan Formation

Volcanic rocks exposed in Chai Wan (around Pottinger Peak) and around Razor Hill were assigned to the Shing Mun and Ap Lei Chau formations respectively on the first edition of Sheet 11. The rocks are now re-classified as the Che Kwu Shan Formation based on lithological characteristics and geochemical data. Sewell et al (2000) pointed out that although the Che Kwu Shan and Ap Lei Chau formations are lithologically comparable, the whole rock geochemical data revealed a generally lower SiO_2 content for the Che Kwu Shan Formation. The Che Kwu Shan Formation comprises thick sequences of eutaxitic/crystal-bearing fine ash vitric tuff with minor tuff breccia. In Chai Wan, the contact between the Che Kwu Shan and the Ap Lei Chau formations has been further verified by field observations. The Che Kwu Shan Formation has been dated at 142.5±0.3 Ma (Davis et al, 1997). In the eastern Kowloon, the contact between the Che Kwu Shan and Mount Davis formations has been inferred based on the change in dominant lithologies from lapilli-bearing coarse ash crystal tuff of the Mount Davis Formation to the crystal-bearing vitric tuff of the Che Kwu Shan Formation.

4.3 Major Intrusive Rocks

4.3.1 Nomenclature and Classification

The earliest attempt to classify granitic rocks according to various intrusive phases was by Allen & Stephens (1971). However, on the first edition of the 1:20,000-scale geological maps, the classification of major intrusive rocks was primarily based on grain size 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 intrusive bodies of the territory to four suites. The updated Sheet 11 has incorporated the plutonic nomenclature with further revisions. In common with the volcanic rocks, both a unit name and lithological descriptor have been assigned to all the major intrusive igneous rock units in the district.

4.3.2 Kwai Chung Suite

In the district, the Late Jurassic Kwai Chung Suite comprises two granite units, the Sha

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Tin and the Needle Hill granites, and two units of dyke swarms, the East Lantau Rhyolite and the East Lantau Rhyodacite. The Sha Tin Granite is dominantly inequigranular coarse-grained granite exposed in Kwai Chung and near Kowloon Reservoir, with a medium-grained variety identified near Kwai Chung Terminal 5. A coarse-grained granite sample (HK13278) from Beacon Hill has yielded an age of 146.4±0.1 Ma (Sewell et al, 2012a). The finding has confirmed the extent of Sha Tin Granite on the southern side of the Tolo Channel Fault. Consequently, coarse-grained granite exposed near Kowloon Reservoir, which was inferred to be part of the Shui Chuen O Granite in the updated Sheet 7 (Sewell et al, 2010), has now been reassigned to the Sha Tin Granite.

The Needle Hill Granite is composed of porphyritic fine-grained monzogranite with some equigranular medium-grained granite exposed in Kwai Chung and in Shing Mun Valley. High-precision U-Pb zircon dating of the Needle Hill Granite has yielded an age of 146.4±0.2 Ma (Davis et al, 1997). Field observations indicate that the Needle Hill Granite intrudes the Sha Tin Granite, although both units have a comparable U-Pb age of around 146 Ma (Strange & Shaw, 1986; Sewell et al, 2000).

NE-trending quartzphyric rhyolite and feldsparphyric rhyolite dykes in Kwai Chung area, which were previously undifferentiated on the first edition of Sheet 11, have now been assigned to the East Lantau Rhyolite and East Lantau Rhyodacite respectively, following the nomenclature of Campbell & Sewell (1998). The extent of the dyke swarms in the offshore area and beneath reclaimed land of the Kwai Chung Container Terminal has been inferred based on available drillhole data and as-built tunnel records. The East Lantau Rhyolite, East Lantau Rhyodacite, Sha Tin Granite and Needle Hill Granite have yielded comparable U-Pb zircon ages of around 146 Ma (Davis et al, 1997; Sewell et al, 2012a). However, field relationships have suggested that the dyke swarms intrude both the Sha Tin and Needle Hill granites (Strange & Shaw, 1986), and that the East Lantau Rhyolite is slightly younger than the East Lantau Rhyodacite (Li et al, 2000; Sewell et al, 2000).

4.3.3 Cheung Chau Suite

The Early Cretaceous Cheung Chau Suite is represented in the district by the Shui Chuen O Granite. Sewell et al (2000) originally defined the Shui Chuen O Granite, as a NE-oriented ellipsoidal, porphyritic fine- to medium-grained biotite monzogranite pluton centered at Shui Chuen O, in Shatin District. High-precision U-Pb zircon dating of the Shui Cheun O Granite has yielded an age of 144.0±0.3 Ma (Sewell et al, 2012a). In the current update, the outcrop of the Shui Chui O Granite has been redefined based on re-examination of field descriptions, rock samples from the HKGS Rock Archive and extensive drillhole data. The Shui Chuen O Granite is situated between Sha Tin and Kowloon granites, and bounded to the northwest by the NE-trending Tolo Channel Fault. The granite exhibits a wide range of textural variation from porphyritic fine-grained to medium-grained and locally coarse-grained. Field relationships (Addison, 1986) show that this granite intrudes coarse-grained granite (of the Sha Tin Granite, c. 146 Ma), and in turn, is cut by a series of dyke-like intrusions of quartz monzonite and fine-grained granite (now the Tei Tong Tsai Quartz Monzonite, see Section 4.3.4.2 below). Part of the pluton may also have been assimilated by later intrusion of the Lion Rock Suite.

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4.3.4 Lion Rock Suite

4.3.4.1 Granitic Subsuite

The Kowloon Granite and Mount Butler Granite belong to the Granitic Subsuite of the Early Cretaceous Lion Rock Suite (Sewell et al, 2000). The Kowloon Granite (U-Pb zircon age 140.4±0.2 Ma, Davis et al, 1997) is dominantly equigranular medium-gained and is exposed in west and central Kowloon and the northern coastal area of Hong Kong Island. The textural variants of Kowloon Granite, which range from porphyritic fine-grained to porphyritic fine- to medium-grained, are found in the vicinity of King's Park (3510 1910) and Shek Kip Mei (3500 2200).

The Mount Butler Granite is typically porphyritic fine-grained and fine- to medium-grained (Strange & Shaw, 1986; Sewell et al, 1992). It is exposed in central part of Hong Kong Island and eastern Kowloon. The pluton has been dated using Rb-Sr whole rock method at 136±1 Ma (Sewell et al, 1992). However, based on field relationships, the Mount Butler Granite is considered to be coeval with or slightly younger than the Kowloon Granite (Campbell & Sewell, 1998). The intrusive contacts between the Kowloon Granite and Mount Butler Granite have been refined by field observations and extensive drillhole data.

4.3.4.2 Monzonitic Subsuite

On the first edition of Sheet 11, discontinuous but generally NE-trending intrusive bodies of porphyritic quartz syenite and quartz monzonite were mapped near Wong Chung Hang and Mount Butler on Hong Kong Island and in northwestern Kowloon. They are now re-assigned to the Tei Tong Tsui Quartz Monzonite, which was first defined by Campbell & Sewell (1998). The Tei Tong Tsui Quartz Monzonite has not yet been radiometrically dated, although field relationships have suggested that it is possibly older than the Mount Butler Granite (Strange & Shaw, 1986). Sewell et al (2000) suggested that the Tei Tong Tsai Quartz Monzonite is geochemically related to the Clear Water Bay and High Island formations, and was probably emplaced at c. 140 Ma.

Feldsparphyric rhyolite dykes and some dyke-like intrusive bodies of porphyritic fine-grained granite near Tse Wan Shan and Tate's Cairn have been re-interpreted as fractionated equivalents of the Tei Tong Tsui Quartz Monzonite (Sewell et al, 2012b). The interpreted northwesterly trend of these dykes, as shown on the first edition map, has been re-examined (see Section 4.4 below). Based on a review of the original field notes for Sheet 7 and 11 and confirmation by recent field observations, these dykes are now mapped as generally NE-trending.

The offshore extent of the quartz monzonite and related dykes to the west of Stonecutters Island has been verified based on existing as-built tunnel records for HATS Stage 1 (formerly SSDS) together with the geophysical survey and drillhole data.

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4.4 Minor Intrusive Bodies

On the first edition of Sheet 11, no attempt was made to relate the minor intrusions, including mafic, quartzphyric rhyolite, feldsparphyric rhyolite, quartz trachyte and aplite dykes and pegmatite, to individual plutons or to explain their mode of origin. Among these minor intrusions, only the feldsparphyric and quartzphyric rhyolite dykes in the Kwai Chung area, and the quartz monzonite dykes in the district have been classified, based on whole rock geochemical data and age data (Sewell et al, 2000). These dykes are assigned to the East Lantau Rhyolite dyke swarm (Section 4.3.2) and the Tei Tong Tsui Quartz Monzonite (Section 4.3.4.2) respectively.

Based on petrographic analysis and comparison of whole rock geochemistry, the quartz trachyte dykes along with some of the feldsparphyric rhyolite and quartzphyric rhyolite dykes are considered to be associated with the mapped units in their vicinity and have been grouped accordingly on the updated map, based on the following:

(a) The quartz trachyte dykes exposed in Aberdeen (3250 1265) and Wah Fu (3480 1225 and 3530 1210) are interpreted to represent fine-grained variants of the Tei Tong Tsui Quartz Monzonite quartz monzonite dyke.

(b) The NW-trending feldsparphyric rhyolite and N-S-trending quartzphyric rhyolite in Cheung Shan (4054 2335 and 4055 2285) and at Fei Ngo Shan (4110 2230) in eastern Kowloon are interpreted to be the intrusive equivalents associated with the Mount Davis Formation. Further field observations have revealed that the N-S-trending quartzphyric rhyolite displays a distinctive sub-horizontal, highly contorted, flow banding. At the contact with the volcanic rocks, the flow banding appears to be sub-parallel to the eutaxitic fabric seen in the volcanic rocks, suggesting that the quartzphyric rhyolite is likely to be a sill.

(c) At Fei Ngo Shan, several distinctive feldsparphyric rhyolite dykes have been inferred previously as NW-trending. Further field mapping, however, confirmed that these dykes are less extensive. Based on field observations, the dykes have been re-mapped as ENE-trending dykes, which were probably intrusive equivalents associated with the Mount Davis Formation.

(d) At Lei Yue Mun Park (4220 1552), a NW-trending quartzphyric rhyolite dyke was mapped and interpreted to be cutting across the contact between a medium-grained granite and a quartz monzonite on the first edition of Sheet 11. Based on further field verification and petrographic examination, the exposure has now been re-interpreted as representing a fine-grained variant of the

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medium-grained granite, probably as a chilled margin against the quartz monzonite.

The remaining minor feldsparphyric rhyolite/rhyodacite and quartzphyric rhyolite/rhyodacite dykes in the district are left unassigned to a particular grouping owing to insufficient supporting evidence. These dykes are generally found in the southern and southeastern parts of Hong Kong near Mount Nicholson, Shouson Hill and Mount Cameron. These minor intrusive bodies have not been dated previously, but presumably were emplaced during the Early Cretaceous.

Minor mafic intrusions were previously named "basalt" on the original map. Subsequent geochemical analysis, however, has revealed a range of compositions of these dykes from basaltic andesite to andesite (Sewell et al, 2000). Only a few mafic dykes in Hong Kong have been dated using Ar-Ar method (Campbell & Sewell, 2005), and none of them are from the district. Mafic, aplite and pegmatite dykes have not been assigned to a specific group during the map update.

4.5 Structural Geology

4.5.1 Accurate Location of Major and Minor Faults

Under the HATS Stage 1 Project (formerly SSDS), a total of 29 kilometres of deep tunnels were constructed, most of which are in the offshore area in the district. The tunnel records have enabled interpretation of the subsurface geology and more accurate locations of major and minor faults on the updated Sheet 11.

Detailed interpretation of extensive drillhole data in the district has permitted the accurate location of minor faults and provided structural data in areas concealed by superficial deposits and reclamation. For instance, drillhole records have revealed brecciation zones in Kennedy Town, which coincide with the N-S-trending topographic depression extending from Belcher's Bay to Kong Sin Wan. This topographic depression is now interpreted as an inferred fault on the updated map. Lau (2006) has identified several zones of unusually deep weathering along the northwestern coastal area of Hong Kong Island, which are considered to be possibly structurally controlled and bounded by faults. The inferred faults identified by Shaw (1997) based on rockhead contours in the Kowloon Peninsula have also been taken into consideration in the interpretation of faults on the updated Sheet 11.

Offshore geophysical surveys have also provided important data for interpretation of solid and superficial geology, as well as geological structures in the offshore area. A marine magnetic survey in the Western Harbour (EGS, 1999) identified a NE-trending linear magnetic trough that was interpreted as the offshore extension of the Tolo Channel Fault. Recent seismic profiling for the HATS Stage 2 Project across the western side of the Victoria Harbour from Stonecutters and Sai Ying Pun has also provided evidence for interpreting a series of ENE-trending structures. These structures are now considered to represent the Sulphur Channel Fault.

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4.5.2 General Characteristics of Major Faults

A systematic review of the trends and relative displacement of faults has been carried out in parallel with the re-interpretation of the solid geology in the district. In general, the major faults in the district are trending variably from northeast to east-northeast, and northwest. They are not only controlling the development of modern geomorphology, but were probably tectono-magmatic structures that controlled the Mesozoic magmatism (Campbell & Sewell, 1997; Sewell et al, 2000; Sewell et al, 2012b).

The NE-trending Tolo Channel – Lai Chi Kok Fault Zone and Jordan Valley Fault are probably the most significant tectono-magmatic structures in the district and which probably controlled the intrusions of Cheung Chau and Lion Rock Suites. The Tei Tong Tsui Quartz Monzonite and associated minor dyke bodies were likely emplaced within a set of NE-trending deep-seated structures. Other prominent NE-trending faults include the Sandy Bay Fault, which passes from Sandy Bay to Sheung Wan, and the Wan Chai Gap Fault, which passes from Aberdeen through Wan Chai Gap. The Tai Tam Fault and Wong Nai Chung Fault are major NW-trending faults in the central part of Hong Kong Island.

4.6 Contact Metamorphism at Western Hong Kong Island

Contact metamorphosed volcanic rocks were identified in Mid-levels and the western part of Hong Kong Island (GCO, 1982; Strange & Shaw, 1986). Strange & Shaw (1986) classified the metamorphosed volcanic rocks into four metamorphic grades according to the occurrence of various mineral assemblages, and produced a metamorphic zonation plan around Victoria Peak based on petrographic study (Strange & Shaw, 1986).

Examination of the existing drillholes has revealed that the extent of contact metamorphism is probably more widespread than that shown on the original map. The contact metamorphism is considered to extend into the offshore area within the Sulphur Channel. In addition, based on recent excavations of caverns and tunnels in the western part of Hong Kong Island, the variations in metamorphic effects and mineral assemblages are not only related to the proximity to granite intrusions, but also reflect variations in volcanic lithologies, in particular the presence of tuffaceous sediment (Figure 4.1).

4.7 Superficial Deposits

On the first edition of Sheet 11, onshore superficial deposits were not assigned to a lithostratigraphic unit, but were classified on the basis of depositional process or environment and were broadly grouped as Holocene or Pleistocene 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. Superficial deposits along the coastline have been re-examined and re-classified with reference to the recommendations made by Wong & Shaw (2007).

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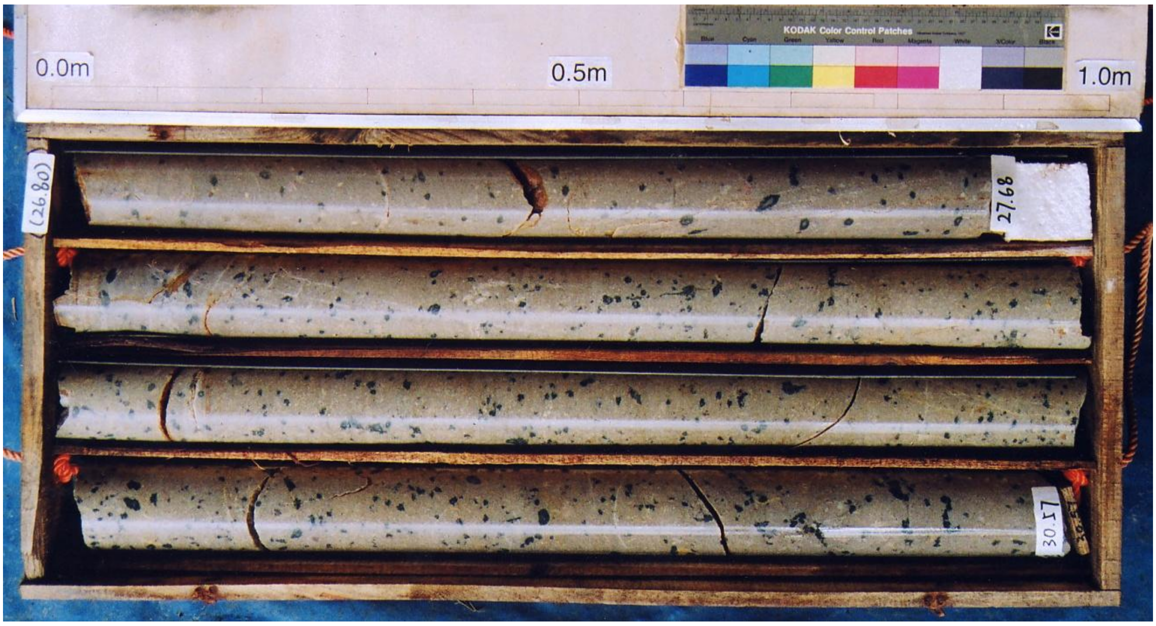

Figure 4.1 Corebox Photograph of Contact Metamorphosed Tuffaceous Rock (Hornfels), Western Hong Kong Island

4.7.1 Onshore Superficial Deposits

The onshore superficial deposits have been re-classified as the Holocene Fanling Formation and the Pleistocene Chek Lap Kok Formation (Fyfe et al, 2000), both being of alluvial and colluvial origin, on the updated Sheet 11. Interpretation has been based on their geomorphological setting, their appearance on aerial photographs, and drillhole records. Landslide debris and alluvial deposits have been mapped as “Undifferentiated” where their age is uncertain.

4.7.2 Offshore Superficial Deposits

The most significant update to the geology of the offshore area on Sheet 11 is the addition of interpreted isopachs of the thickness of the Hang Hau Formation and the total thickness of the Quaternary superficial deposits. The isopachs are based on a re-interpretation of the available seismic profiles for the district, except in the vicinity of Victoria Harbour where major man-induced modifications, including continual dredging of sediments in the harbour, have rendered the interpretation of thickness of superficial deposits meaningless.

In addition to these changes, two offshore superficial units, the Telegraph Bay and East Lamma Channel members, which were previously mapped in the vicinity of the East Lamma Channel, have now been combined into the Hang Hau Formation on the updated map. Strange & Shaw (1986) defined the two members based on the identification of steeply

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inclined erosion surfaces that separate these two units from seismic profiles. However, further studies have found that these units are of limited areal extent and unrelated to major phases of deposition and erosion elsewhere in Hong Kong waters, and therefore, are not distinct lithostratigraphic units (Fyfe et al, 2000).

4.7.3 Reclamation History and Major Fill Bodies

In common with the first edition of Sheet 11, the updated map shows the limits of reclaimed land formed from various generations of reclamation projects around the Victoria Harbour, and in the southwestern part of Hong Kong Island, with the years indicated. The reclamation history has been established based on records and location plans provided by the Port Works Division and on a review of aerial photographs of selected years. A small-scale map showing the extent of reclaimed land and history of reclamations is presented in Figure 4.2. Apart from reclamation fill found along the coast, major onshore fill bodies have also been mapped using aerial photograph interpretation. These fill bodies are either formed by major site formations and construction activities, or are land fill sites. In the database, the reclamation lands, landfill sites and fill bodies associated with construction activities are categorised.

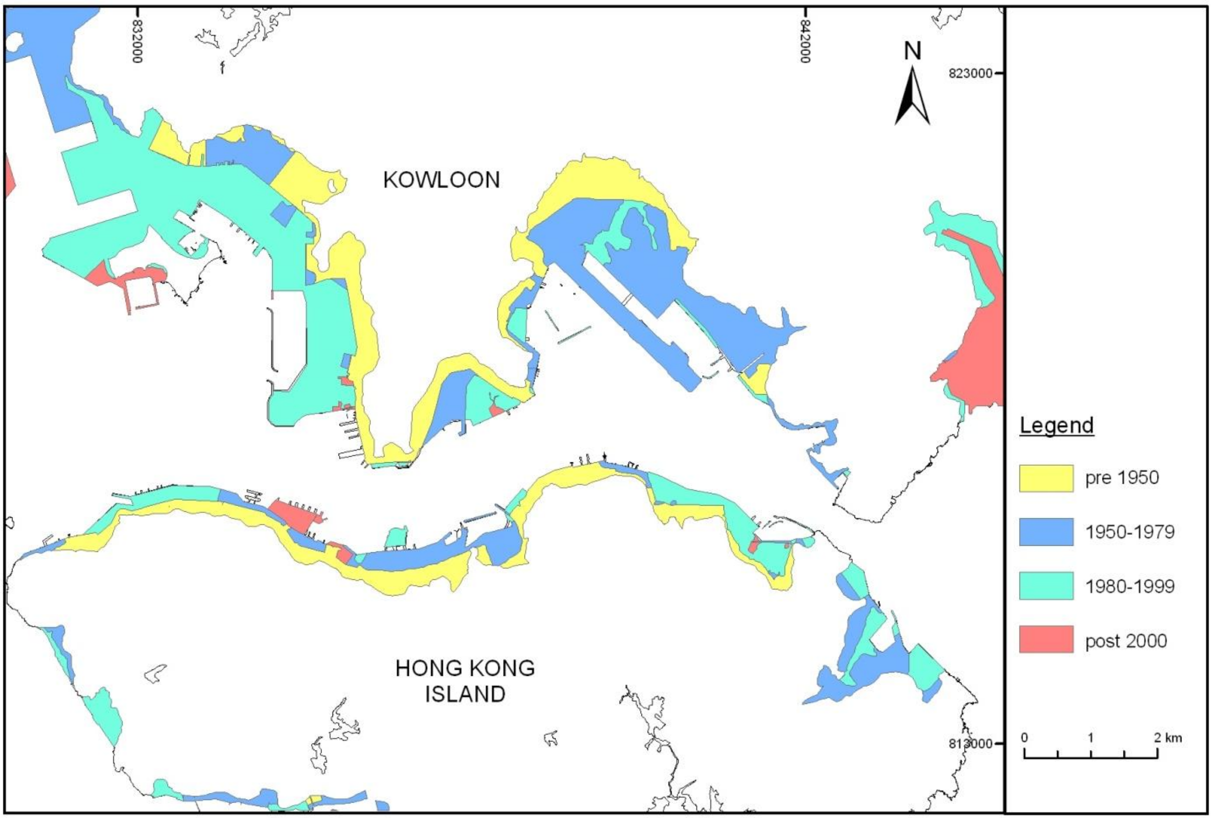

Figure 4.2 Small-scale Map Showing the Extent of Reclaimed Lands in Map Sheet 11

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Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

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TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents