Guidelines on the Description and Classification of Rocks of the Tuen Mun Formation in the Tuen Mun Valley, Northwestern New Territories

GEO Report No. 327

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

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

Guidelines on the Description and Classification of Rocks of the Tuen Mun Formation in the Tuen Mun Valley, Northwestern New Territories

GEO Report No. 327

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

This report was originally produced in June 2016 as GEO Geological Report No. GR 2/2016

Table of Contents
Table of Contents
Table of Contents
Table of Contents

First published, March 2017

Prepared by:

Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

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.

W.K. Pun
Head, Geotechnical Engineering Office
March 2017

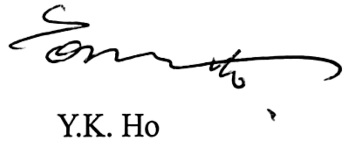
Table of Contents
Table of Contents
Table of Contents
Table of Contents

Foreword

Since the completion of earlier regional geological surveys in the northwestern New Territories, there have been difficulties among Hong Kong's geotechnical practitioners concerning the description and classification of rocks of the Tuen Mun Formation. Therefore, this report aims to provide guidelines on the description and classification of the rocks based on a comprehensive review of all known lithologies in the Tuen Mun Formation. A lexicon is also introduced to facilitate the proposed lithological classification scheme among practitioners.

This study was carried out by Mr K.W.F. So and Prof R.J. Sewell, based on an earlier research study completed by Dr D.L.K. Tang in 2007. Dr D.L.K. Tang and Mr K.W. Lai contributed significantly to collection of rock samples and preparation of thin sections in the Tuen Mun Valley area. Further contributions have been made by members of the Hong Kong Geological Survey, including Messrs C.W. Lee, P.C.S. Ho, S.S.C. Wong, E.Y.H. Ng, S.H.S. Leung, K.S.C. Mok and Ms P.N.Y. Lau at different stages, to the review of geology of the Tuen Mun Valley and the lithological classification scheme.

Helpful advice and review comments on the earlier draft were given by Dr D.L.K. Tang of the Planning Division and Dr K.C. Ng. All contributions are gratefully acknowledged.



Y.K. Ho
Chief Geotechnical Engineer/Planning

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Contents

Page No.

Table of Contents
Table of Contents
Table of Contents

List of Tables

List of Figures

Table of Contents
Table of Contents
Table of Contents
Table of Contents

1 Introduction

1.1 Background and Objectives of this Study

Since the publication of Hong Kong Geological Survey (HKGS) Memoir No. 3 (Geology of Western New Territories) by Langford et al (1989), and HKGS Sheet Report No. 1 (Geology of Yuen Long) by Frost (1992), there has been a continual debate among Hong Kong's geotechnical practitioners on how best to describe and interpret the rocks of the Tuen Mun Formation. The formation underlies much of the Tuen Mun Valley in the northwestern New Territories. It is lithologically highly variable and has been locally subjected to metasomatism, hydrothermal alteration and dynamic metamorphism.

Recently, a comprehensive study of the Tuen Mun Formation has been carried out as part of the HKGS's 1:20,000-scale geological map updating programme. The objectives of this study are:

(a) to propose a classification scheme and to recommend geological terms that enables the rocks of the Tuen Mun Formation to be described accurately and consistently according to published guidelines on rock description in Geoguide 3 (GCO, 1988a) and in alignment with international practice,

(b) to review and classify all known key lithologies of the Tuen Mun Formation based on (i) literature review, (ii) field mapping, (iii) drill core logging, and (iv) examination of rock samples and thin sections, and

(c) to introduce a lexicon which facilitates drill core logging and surface mapping in the Tuen Mun Valley to aid practitioners in the description and characterisation of rocks of the Tuen Mun Formation (Appendix A).

1.2 Methodology and Limitations

A detailed review of all available geological and geotechnical information was carried out to gain a thorough understanding of the complexity of the Tuen Mun Formation. The information reviewed under this study includes:

(a) published geological maps, memoirs, sheet reports, study reports, research theses and technical papers,

(b) newly available ground investigation records from recent developments, and existing records from the Geotechnical Information Unit (GIU), and

(c) available GEO in-house records and archival materials (e.g. photograph records, field description notes, core

Table of Contents
Table of Contents
Table of Contents
Table of Contents

logging notes and thin section petrography reports).

Despite having reviewed over 10,700 high-quality drillhole records, 400 rock samples and 100 thin sections, it should be emphasised that this study is not an exhaustive survey of all lithologies in the Tuen Mun Valley. The main purpose is to introduce a method to describe drill cores, rock samples and thin sections accurately and consistently so that experienced logging geologists can easily follow. This study does not attempt to interpret rock-forming processes, environments of deposition and the geological history of the Tuen Mun Valley. Inevitably, there will be lithologies that will not fit with the characteristics described in Section 4 of this report.

Whole rock geochemistry cannot be reliably applied to the classification of most lithic- or clast-bearing lithologies in the Tuen Mun Formation because these lithologies have been subjected to different types of metamorphism, which hinder the identification of original rock composition and textures.

2 Overview of Geology of the Tuen Mun Valley

2.1 Previous Geological Surveys

Allen & Stephens (1971) first divided the rocks of Tuen Mun and Tin Shui Wai areas into two formations, namely the Repulse Bay Formation (comprising mainly sedimentary and water-lain volcanic rocks) and the Lok Ma Chau Formation (comprising metasedimentary and volcanic rocks). Subsequently, Langford et al (1989) grouped the solid geology of the Tuen Mun Valley into three formations as shown on the 1:20,000-scale HKGS Solid and Superficial Geology Map Sheets 2 (San Tin), 5 (Tsing Shan) and 6 (Yuen Long) (GCO, 1988b, 1988c & 1989d):

(a) Lok Ma Chau Formation - comprising mainly metasiltstone or phyllite, with subordinate metasandstone and quartzite between Tin Shui Wai and Ha Tsuen to the south.

(b) Tsing Shan Formation - comprising a sequence of quartzitic sandstone, metasiltstone and phyllite, with subordinate tuff, tuffite and conglomerate in Tsing Shan (Castle Peak) area.

(c) Tuen Mun Formation - comprising andesite lava and lapilli-bearing ash crystal tuff in the broad valley between Tsing Shan Wan (Castle Peak Bay) and Ha Tsuen to the north.

During the latter period of this survey, the discovery of extensive marble subcrops led to a number of detailed geological studies in Yuen Long and Tin Shui Wai areas (Darigo, 1989, 1990). Six 1:5,000-scale HKGS Solid Geology Maps (GCO, 1989a, 1989b, 1989c, 1989e, 1989f & 1989g) together with a report on the geology of Yuen Long and Tin Shui Wai area were also published (Frost, 1992). A new stratigraphic member of the Tuen Mun Formation, represented by a distinctive interbedded sequence of volcaniclastic rocks, was proposed by Darigo (1989 & 1990) and Frost (1992), and termed the Tin Shui Wai Member.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

The 1:20,000-scale HKGS Solid Geology Map Sheet 2 was later published for the northernmost area of the Tuen Mun Valley (GEO, 1994).

During the late 1990s, a revision of the volcanic stratigraphy and plutonic rock classification of Hong Kong was proposed by Campbell & Sewell (1998) based on whole rock geochemical data (Campbell & Sewell, 1997) and U-Pb zircon ages (Davis et al, 1997). The Tuen Mun Formation, however, was excluded from this proposed classification system because of its distinctive geochemical composition in comparison with other volcanic formations in Hong Kong (Campbell & Sewell, 1998).

Based on a comprehensive review of all the previous surveys and available data, Sewell et al (2000) and Fyfe et al (2000) subsequently produced two geological reports and ten accompanying territory-wide maps, which together presented an up-to-date synthesis of the geology of Hong Kong. Sewell et al (2000) suggested that the Tsing Shan Formation should be incorporated within the Tuen Mun Formation, and that the Tuen Mun Formation should be divided into an upper dominantly volcanic unit, and a lower dominantly volcanogenic sedimentary unit.

2.2 Previous Geological Models of the Tuen Mun Valley

Since the 2000s, there have been two models proposed for the origin of the lower unit of the Tuen Mun Formation. One interpretation (e.g. Lai, 2004 & 2013; Lai et al, 2004; Lai & Chan, 2011; Li et al, 2014) suggested a magmatic origin for clast-bearing rocks, including the existence of palaeovolcanic vent-shaped plugs preserved in the Tuen Mun and Tsing Shan areas. Clast-bearing rocks were considered to be andesite lavas, tuff-breccias and vent breccias, in which rising magma had incorporated country rock lithologies.

An alternative interpretation (e.g. Campbell & Sewell, 2004; GEO, 2007a & 2007b; Tang, 2007) proposed that the lower unit was dominantly a volcaniclastic and epiclastic sequence of breccias, conglomerates, sandstones, siltstones and mudstones in the Tuen Mun Valley. The large variety of clast fragments was entrained and deposited by sedimentary processes, despite the fact that a major source of sediment originates from volcanic materials.

3 Proposed Lithological Classification Scheme of the Tuen Mun Formation

At present, a number of high-quality core samples and drillhole records are available from recent developments in the Tuen Mun, Hung Shui Kiu and Tin Shui Wai areas where a large variety of lithologies, including intrusive, volcanic and metasedimentary rocks, has been identified. Since the classification schemes related to sedimentary and metamorphic rocks stipulated in GCO (1988a) are of limited use for a detailed description of the rocks of the Tuen Mun Formation, the following scheme is proposed in line with the guidelines in GCO (1988a) and also the recommendations given by the British Geological Survey (BGS) and the International Union of Geological Sciences (IUGS) (Figure 3.1; Gillespie & Styles, 1999; Hallsworth & Knox, 1999; Robertson, 1999; Le Maitre et al, 2002; Brodie et al, 2007; Rosen et al, 2007; Schmid et al, 2007; Zharikov et al, 2007).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

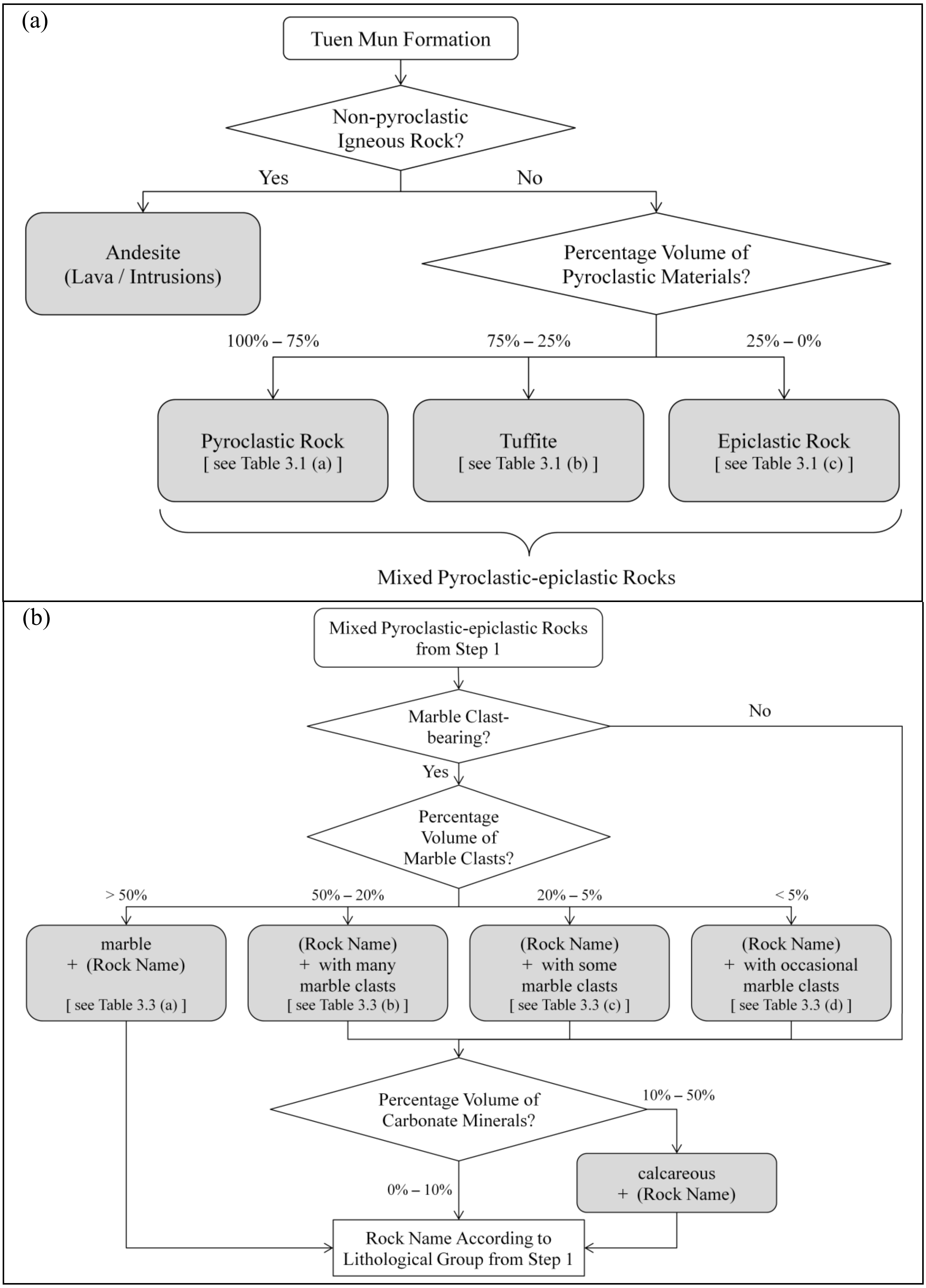


Figure 3.1 Workflow on the Lithological Classification of the Tuen Mun Formation. (a) Classification of Lithological Group (Step 1); (b) Classification of Carbonate- and Marble Clast-bearing Rocks (Step 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

3.1 Lithological Groups

In this lithological classification scheme, rocks of the Tuen Mun Formation can be assigned to four lithological groups, namely ‘andesite’, ‘pyroclastic rock’, ‘tuffite’ and ‘epiclastic rock’, based on, but not limited to, the following key criteria:

(a) the rock colour and matrix composition,

(b) the size, roundness, sorting, composition and percentage volume of clasts or rock fragments (> 2 mm),

(c) igneous textures or sedimentary structures, and

(d) evidence of magma intrusion, magma-sediment mixing and/or metamorphism.

Compared with the other three lithological groups, ‘andesite’ is the group of non-pyroclastic igneous rocks of intermediate composition (57% – 63% SiO_2), including both extrusive (i.e. lavas and autobrecciated lavas) and intrusive variants (e.g. dykes and sills). The andesitic composition has been confirmed by geochemical analysis (Langford et al, 1989).

Based on Schmid (1981), Gillespie & Styles (1999) and Le Maitre et al (2002), rocks comprising both pyroclastic and epiclastic materials (i.e. mixed pyroclastic-epiclastic rocks) are classified according to the percentage volume of pyroclastic materials and the grain size (Table 3.1). Pyroclastic materials refer to fragments that have formed as a direct result of volcanic activities and have not been reworked by sedimentary processes (Gillespie & Styles, 1999). These materials include, but are not limited to, juvenile (i.e. crystals, crystal fragments, glass fragments and/or rock fragments formed directly from cooling magma during transport prior to primary deposition), accidental and cognate fragments (i.e. rock fragments that are derived from either country rocks or volcanic rocks formed during earlier volcanic activities, and that are incidentally incorporated during a later eruption (McPhie et al, 1993; Gillespie & Styles, 1999)). On the other hand, epiclastic materials are fragments produced by weathering and erosion of pre-existing consolidated rocks as a direct result of surface sedimentary processes (GCO, 1988a; Gillespie & Styles, 1999).

GCO (1988a) defines ‘tuff’ as a general rock name for all lithified pyroclastic deposits composed of rock fragments of gravel or finer size (< 60 mm). In this study, the term ‘tuff’ can be used for pyroclastic rocks only when the rocks are composed of at least 75% by volume of pyroclastic materials (Schmid, 1981; Gillespie & Styles, 1999; Le Maitre et al, 2002). According to dominant grain sizes, tuffs are subdivided into lapilli tuff (2 to 60 mm), coarse ash tuff (0.06 to 2 mm) and fine ash tuff (< 0.06 mm) (GCO, 1988a).

GCO (1988a) defines ‘tuffite’ as a rock with roughly equal proportions of pyroclastic and sedimentary materials, and ‘tuffaceous’ as a prefix given before the name of sedimentary rocks containing up to 50% tuff material. In this study, the term ‘tuffite’ is defined as the group of some mixed pyroclastic-epiclastic rocks containing between 25% and 75% by volume of pyroclastic materials (Schmid, 1981; Gillespie & Styles, 1999; Le Maitre et al, 2002). The term ‘tuffaceous’ is incorporated in the rock names for the tuffite group.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 3.1 Classification of Mixed Pyroclastic-epiclastic Rocks (modified from Schmid, 1981; GCO, 1988a; Gillespie & Styles, 1999; Le Maitre et al, 2002)

<table>
<tr><th>Grain Size (in mm)</th><th>(a)
Pyroclastic Rocks (1)(2)</th><th>(b)
Tuffites (1)(3)</th><th>(c)
Epiclastic Rocks (1)(3)</th></tr>
<tr><td></td><td>Pyroclastic Breccia, Agglomerate</td><td rowspan="2">Tuffaceous Breccia, Tuffaceous Conglomerate</td><td rowspan="2">Sedimentary Breccia, Conglomerate</td></tr>
<tr><td>60</td><td>lapilli Tuff</td></tr>
<tr><td>2</td><td>coarse ash Tuff</td><td>Tuffaceous Sandstone</td><td>Sandstone</td></tr>
<tr><td>0.06</td><td rowspan="2">fine ash Tuff</td><td>Tuffaceous Siltstone</td><td>Siltstone</td></tr>
<tr><td>0.002</td><td>Tuffaceous Claystone, Tuffaceous Shale</td><td>Claystone, Shale</td></tr>
<tr><td>Percentage Volume of Pyroclastic Materials</td><td>100% – 75%</td><td>75% – 25%</td><td>25% – 0%</td></tr>
</table>

Notes:
(1) Rock names under each lithological group are capitalised.
(2) 'Tuff-breccia', 'ash-lapilli Tuff' and 'lapilli-ash Tuff' can be used for poorly-sorted pyroclastic rocks given in Section A.3.2 and Figure A3 of Geoguide 3 (GCO, 1988a).
(3) 'Tuffaceous Mudstone' and 'Mudstone', both of which are composed mainly of both silt and clay, can be used for classification of tuffites and epiclastic rocks, respectively.

Epiclastic rocks in this study refer to volcanic and non-volcanic sedimentary rocks comprising less than 25% by volume of pyroclastic materials (Schmid, 1981; Gillespie & Styles, 1999; Le Maitre et al, 2002). When an epiclastic rock is classified as a breccia, the term 'sedimentary breccia' can be used to distinguish it from other genetic types (GCO, 1988a), such as pyroclastic breccia, tuff-breccia, tuffaceous breccia and fault breccia.

3.2 Carbonate- and Marble Clast-bearing Rocks

Marbles and calcareous (meta-)sedimentary rocks are the dominant carbonate and carbonate-bearing rocks in Hong Kong. In this study, these rocks are classified using the percentage volume of carbonate minerals (Table 3.2). Since no known continuous marble layers have been identified or are anticipated in the Tuen Mun Formation, pure and impure marbles are not included in the workflow on the lithological classification (Figure 3.1).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 3.2 Classification of Marbles and Calcareous (Meta-)Sedimentary Rocks (after Hallsworth & Knox, 1999; Rosen et al, 2007)

Percentage Volume of Carbonate Minerals (in Sand or Finer Grain Size)	Rock Name (1)	
100% – 95%	pure Marble (2)	(a)
95% – 50%	impure Marble (2)	(b)
50% – 10%	calcareous + (Rock Name) (3)	(c)

Notes: (1) Rock names are capitalised.
(2) Pure and impure marbles are not anticipated in the Tuen Mun Formation.
(3) Refer to Tables 3.1(c) and 3.4 for the classification of epiclastic and partially metamorphosed rocks, respectively.

The term 'marble clast-bearing' is adopted in this study to describe mixed pyroclastic-epiclastic rocks containing angular to rounded marble clasts, as large as boulder size, set in a finer matrix. To indicate the percentage volume of marble clasts (less than 50% of the total rock volume) in the rocks, the description 'with occasional/some/many marble clasts' using the most suitable qualifier is added following the rock name (GCO, 1988a). If the percentage volume of marble clasts is over 50%, the qualifier 'marble' should be added before the rock name instead of adding the above description (e.g. marble agglomerate, marble tuffaceous conglomerate and marble conglomerate; Table 3.3; Hallsworth & Knox, 1999). Should any marble fragments be present in rocks of the andesite group as xenoliths (less than 50% of the total rock volume), the description 'with occasional/some/many marble fragments' using the most suitable qualifier can be added following the rock name.

Table 3.3 Classification and Description of Marble Clast-bearing, Mixed Pyroclastic-epiclastic Rocks (modified from GCO, 1988a; Hallsworth & Knox, 1999)

Percentage Volume of Marble Clasts (in Gravel or Larger Grain Size)	Rock Name and Description		
> 50%	marble + (Rock Name) (Note)		(a)
50% – 20%	(Rock Name) (Note)	with many marble clasts	(b)
20% – 5%		with some marble clasts	(c)
< 5%		with occasional marble clasts	(d)

Note: Refer to Table 3.1 for the classification of mixed pyroclastic-epiclastic rocks.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

When some mixed pyroclastic-epiclastic rocks are composed of various types of clasts (e.g. marble, quartzite, andesite, tuff, rhyolite, sandstone and/or mudstone), each of which occupies less than 50% of the total rock volume, similar descriptions can be added following the rock name if found necessary (e.g. tuffaceous conglomerate with many marble clasts, some quartzite clasts and occasional mudstone clasts).

3.3 Metamorphism

As described in Section 1.1, most rocks of the Tuen Mun Formation have been partially metamorphosed. The types of metamorphism include, but are not limited to, metasomatism, hydrothermal alteration and dynamic metamorphism. Therefore, in addition to the lithological classification, some descriptive terms based on GCO (1988a), Brodie et al (2007) and Schmid et al (2007) are also adopted for metamorphic features commonly identified in the lithologies in the Tuen Mun Valley (Table 3.4).

Table 3.4 Proposed Descriptive Terms Used for Metamorphic Features (modified from GCO, 1988a; Brodie et al, 2007; Schmid et al, 2007)

Type of Metamorphism	Term	Description
All Types	Meta-	A prefix used with an intrusive, volcanic or sedimentary rock name (e.g. metagranite, metatuff and metasiltstone) to indicate that the rock has been partially metamorphosed, without specifying the type of metamorphism. The prefix should only be applied when the original rock can be identified.
Metasomatism or Hydrothermal Alteration	Altered	A qualifier used with an intrusive, volcanic or sedimentary rock name (e.g. altered granite/tuff/siltstone) to indicate that the rock has undergone metasomatism or hydrothermal alteration (see Table 3.5 for details).
Dynamic Metamorphism	Mylonitic	A qualifier used with an intrusive, volcanic or sedimentary rock name (e.g. mylonitic granite/tuff/siltstone) to indicate a cohesive fault rock, characterised by a well developed foliation resulting from tectonic reduction of grain size during faulting.

3.3.1 Metasomatism and Hydrothermal Alteration

Metasomatism and hydrothermal alteration (or hydrothermal metamorphism) are metamorphic processes which involve mineralogical, chemical and textural changes resulting from the interaction of the rock with hot mineralised aqueous fluids, and during which the rock remains in a solid state (Smulikowski et al, 2007; Zharikov et al, 2007; Pirajno, 2009).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

The fluids may be heated up as a result of igneous intrusion in the vicinity, penetrate along weakness planes (e.g. bedding, joints, foliations and microfractures) within country rocks or previously solidified intrusions, and alter the surrounding rocks.

Most rocks of the Tuen Mun Formation, in particular those in the vicinity of igneous intrusions and within fault zones, have undergone metasomatism and/or hydrothermal alteration to variable degrees. Known types of metasomatism and hydrothermal alteration identified in the Tuen Mun Formation in this study are given in Table 3.5. In addition, garnet, which is one of the major alteration minerals of calc-silicate rocks (i.e. skarn) formed by contact metasomatism, is commonly identified in marble clast-bearing (tuffaceous) metasedimentary rocks.

Table 3.5 Known Types of Metasomatism and Hydrothermal Alteration in the Tuen Mun Formation (modified from Fletcher, 2004; Pirajno, 2009)

Type of Metasomatism/ Hydrothermal Alteration	Original Mineral	New Main Mineral Assemblage	Example of Colour of Altered Rock
Propylitic Alteration (Figure A38 in Appendix A)	hornblende, biotite, pyroxene	epidote, chlorite, albite, K-feldspar, calcite, pyrite	greyish green to dark greenish grey
Sericitic Alteration	feldspar	sericite, quartz, pyrite, clay minerals	dark grey
Greisenisation (Figure A39 in Appendix A)	feldspar, biotite	muscovite, quartz	dark brownish grey
Chloritisation	hornblende, biotite	chlorite	light green to dark green
Silicification (by replacement)	-	quartz	light grey to white

3.3.2 Dynamic Metamorphism

Dynamic metamorphism used in this study is also known as dislocation metamorphism of local extent which is associated with fault zones or shear zones (Smulikowski et al, 2007). Mylonite, fault breccia and/or fault gouge are fault rocks commonly formed by dynamic metamorphism (GCO, 1988a; Brodie et al, 2007; Schmid et al, 2007).

Intense dynamic metamorphism has occurred mainly in the northern Tuen Mun Valley area close to contacts between the Tuen Mun Formation and other rock formations (Tang, 2005). Strained crystals (e.g. quartz) and sedimentary clasts (e.g. marble), recrystallisation (e.g. quartz and calcite), subgrain development (e.g. quartz), and preferably orientated

Table of Contents
Table of Contents
Table of Contents
Table of Contents

alteration minerals (e.g. sericite) are the typical features of dynamically metamorphosed rocks of the Tuen Mun Formation.

3.3.3 Partially Metamorphosed Rocks

For a rock, e.g. granite, which has undergone dynamic metamorphism only, it can be termed either 'mylonitic granite' (specifying the type of metamorphism) or 'metagranite' (without specifying the type of metamorphism), but not 'mylonitic metagranite' as the latter term implies the rock has undergone at least two phases of metamorphism. The similar case can be applied to a rock which has undergone metasomatism or hydrothermal alteration only.

4 Distribution and Detailed Description of Key Lithologies

A summary of known key lithologies of the Tuen Mun Formation assigned to the four lithological groups is shown in Table 4.1. Typical characteristics and diagnostic features of the key lithologies are discussed in this section.

4.1 Andesites

4.1.1 Andesite Lava

Andesite lava mainly crops out in the southern Tuen Mun Valley and is closely associated with coarse ash tuff. Fresh andesite lava is typically strong to very strong, dark grey spotted white and black, massive but locally flow-banded, aphanitic with plagioclase, hornblende and/or pyroxene phenocrysts, and with very few quartz xenocrysts if present. However, andesitic lava may sometimes be autobrecciated comprising subangular to subrounded andesite lithic blocks (Figure A1 in Appendix A). In places, andesite lava has been pervasively altered, and usually displays dark greenish grey spotted black and white colour, with secondary biotite, epidote, chlorite and pyrite mineralisation (Figures A2 and A3 in Appendix A). Secondary calcite veins are sometimes present. Upon complete weathering, meta-andesite lava typically becomes reddish brown or yellowish brown, clayey silt (Figure A4 in Appendix A).

4.1.2 Andesitic Intrusions

Andesitic intrusions, commonly in the form of dykes and sills (up to a few metres in apparent thickness in vertical drillholes) are generally restricted to the southern and central Tuen Mun Valley. Fresh andesitic intrusions are usually strong to very strong, dark grey, massive, aphanitic with sharp intrusive contacts and chilled margins with country rocks (e.g. tuffaceous sandstone and breccia; Figures A5 & A6 in Appendix A). In some cases, andesitic magma has intruded into semi-consolidated or unconsolidated pyroclastic and epiclastic sediments, resulting in a chaotic mixture of magma and altered tuffaceous sediments with fused intrusive contacts (Figure A7 in Appendix A). Pervasive propylitic alteration is common in these mixed assemblages.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 4.1 Distribution of Known Key Lithologies of the Tuen Mun Formation

Lithological Group	Rock Name and Description	Typical Locality [(3)]
Andesites	Andesite Lava	Southern Tuen Mun Valley
	Andesitic Intrusions	*Tuen Mun Area 52*
Pyroclastic Rocks	Coarse Ash Tuff	Southwestern Tuen Mun Valley *Castle Peak Hospital*
	Tuff-breccia	*Tuen Mun Area 54 Sites 1 and 1A*
Tuffites	Tuffaceous B/C/S with marble clasts [(1)(2)]	*Tuen Mun Area 52* *Central Hung Shui Kiu*
	Tuffaceous B/C/S with various clasts [(1)(2)]	*Tuen Mun Area 54 Site 2* *Western Hung Shui Kiu*
Epiclastic Rocks	Sandstone and Siltstone	*Northern Tuen Mun Valley*
	B/C/S with marble clasts [(1)(2)]	*Eastern Hung Shui Kiu* *Southwestern Tin Shui Wai*
	B/C/S with various clasts [(1)(2)]	*Northwestern Tin Shui Wai* *Mai Po*
	marble Breccia/Conglomerate	*Northeastern Hung Shui Kiu* *Tin Shui Wai Areas 3, 8 and 27*

Notes:
(1) B/C/S = (Sedimentary) Breccia, Conglomerate, Sandstone.
(2) 'With marble clasts' and 'with various clasts' refer to the rocks comprising marble clasts and various types of clasts respectively. Each type of the clasts occupies less than 50% of the total rock volume (see also Section 3.2).
(3) Typical localities in italic represent subcrop identified from drillholes (Figure A40 in Appendix A).

4.2 Pyroclastic Rocks

4.2.1 Coarse Ash Tuff

Coarse ash tuff dominantly crops out in the southwestern Tuen Mun Valley. Fresh coarse ash tuff is typically very strong, dark grey to dark greenish grey, massive with variable proportion of quartz and feldspar crystals, crystal fragments, devitrified glass fragments and lithic fragments (Figures A8 and A9 in Appendix A). The whole rock geochemical composition of coarse ash tuff probably varies from andesite to dacite (Lai & Chan, 2011).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Secondary biotite, epidote, chlorite and pyrite may be present in coarse ash metatuff. Upon complete weathering, coarse ash tuff usually turns into light red to light brownish yellow, slightly clayey silt (Figure A10 in Appendix A).

4.2.2 Tuff-breccia

Tuff-breccia appears to be generally restricted to the southwestern portion of Tuen Mun Area 54, where it is associated with andesite lava and coarse ash tuff. In this area, the tuff-breccia contains many angular, lapilli- and block-sized fragments of light grey coarse ash tuff set in a dark grey, fine ash matrix (Figures A11 and A12 in Appendix A).

4.3 Tuffites

Due to considerable degrees of recrystallisation, the tuffaceous nature of some partially metamorphosed, mixed pyroclastic-epiclastic rocks in the Tuen Mun Valley may be difficult to confirm in hand specimen and even thin section. A relatively feldspar-depleted but quartz-rich microcrystalline matrix in some of these rocks may suggest an epiclastic protolith (e.g. siltstone) instead of a pyroclastic protolith (e.g. fine ash tuff). However, it is possible that feldspar crystals and crystal fragments in such rocks have been replaced by micaceous minerals (e.g. sericite) during metamorphism.

Nevertheless, where mixed pyroclastic-epiclastic rocks have undergone compaction and/or alteration to an extent that the nature of the original constituent fragments cannot be determined with confidence, these rocks should be classified as either tuffites or epiclastic rocks (Gillespie & Styles, 1999; Le Maitre et al, 2002). The following criteria can be used to differentiate tuffites from epiclastic rocks in the Tuen Mun Valley:

(a) Evidence of possible pyroclastic materials of andesitic or dacitic composition in the matrix, e.g. an abundance of feldspar crystals and crystal fragments, an abundance of epidote and chlorite, and a relatively minor amount of quartz.

(b) Evidence of andesite lava clasts or coarse ash tuff clasts (i.e. intraclasts), which likely indicate reworking and redeposition of consolidated or semi-consolidated pyroclastic materials of the Tuen Mun Formation.

4.3.1 Tuffaceous Sedimentary Rocks with Marble Clasts

In the Tuen Mun Valley, tuffaceous sedimentary rocks (predominantly breccias, conglomerates and sandstones) with marble clasts were first identified as 'marble clast-bearing volcanic rocks' by Darigo (1989 & 1990), and subsequently assigned to the Tin Shui Wai Member of the Tuen Mun Formation by Frost (1992).

In this study, these rocks dominantly occur as subcrops beneath the east-central Tuen

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Mun Valley area. Fresh marble clast-bearing tuffaceous breccia is usually strong, dark grey mottled white, matrix supported, massive but occasionally normally graded, calcareous, locally foliated and altered (Figures A13 to A15 in Appendix A). The breccias, conglomerates and sandstones may also contain a minor proportion of other clast varieties, including quartzite and andesite. Occasionally, a normally-graded tuffaceous sedimentary sequence is revealed by decreasing grain size and proportion of marble clasts with decreasing depth (Table 4.2 and Figure 4.1).

Table 4.2 Description of a Normally-graded Tuffaceous Sedimentary Sequence in a Drillhole No. 35413/DD200/DH/007, Central Hung Shui Kiu

Depth	Description
37.34 m	calcareous, tuffaceous sandstone
	calcareous, tuffaceous sandstone with occasional gravel-sized marble clasts
	calcareous, tuffaceous sandstone with some gravel-sized marble clasts
c. 43.20 m (Base)	calcareous, tuffaceous breccia with many gravel- to cobble-sized marble clasts and occasional gravel-sized possible andesite clasts

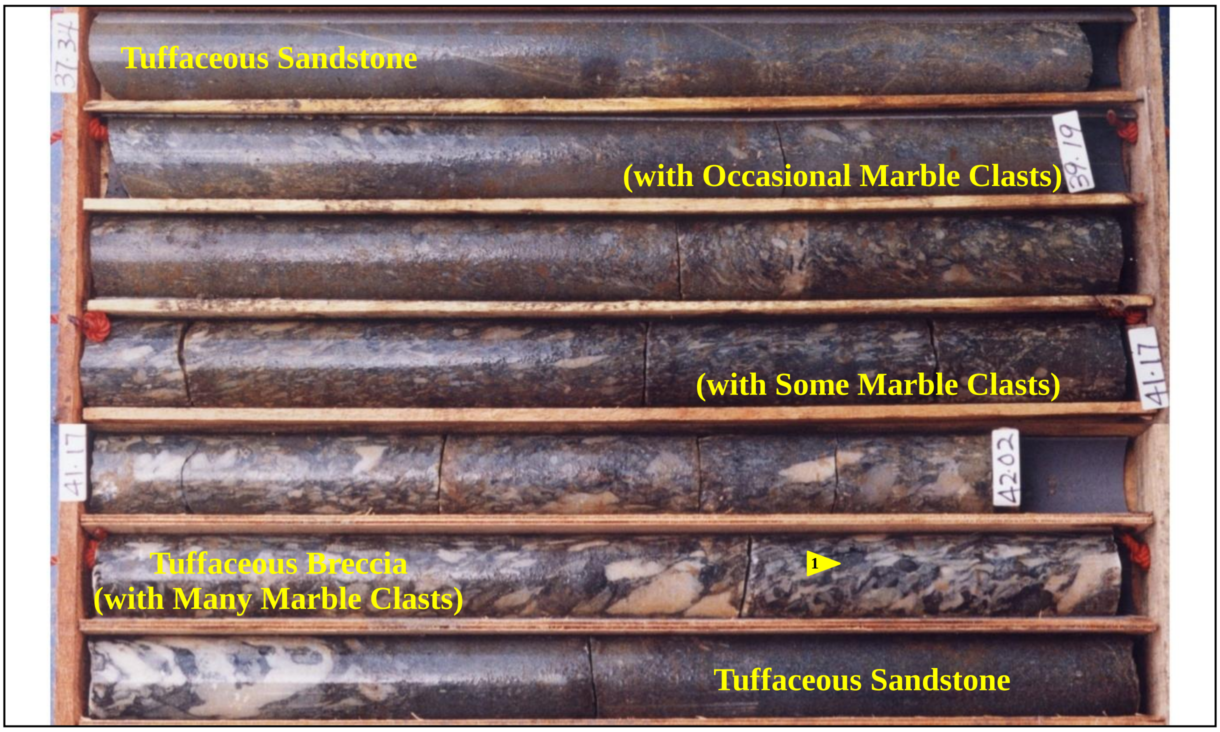


Figure 4.1 Normally-graded, Slightly Foliated, Calcareous, Tuffaceous Breccia-Sandstone Sequence with an Apparent Thickness of at least 5.8 m. (Occasional possible andesite clasts (arrow 1) are evident) (Central Hung Shui Kiu, Drillhole No. 35413/DD200/DH/007, Boxes 4 and 5)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

In general, marble clasts in tuffaceous sedimentary rocks are not interconnected. Dissolution of these clasts is localised and typically leads to honeycomb structures of the rocks only, but not to the development of karst features (Figure A16 in Appendix A; GEO, 2005).

4.3.2 Tuffaceous Sedimentary Rocks with Various Clasts

In these tuffaceous lithologies (predominantly breccias, conglomerates and sandstones), the proportion of various types of clasts can be highly variable. Some of these rocks were also originally identified as ‘marble clast-bearing volcanic rocks’ by Darigo (1989 & 1990), and assigned to the Tin Shui Wai Member of the Tuen Mun Formation by Frost (1992).

In this study, outcrops and subcrops of these rocks have been identified mainly in the west-central Tuen Mun Valley area (Figures 4.2 and 4.3). The material characteristics and the degree of metamorphism of these rocks can be locally highly variable. Fresh tuffaceous breccia and conglomerate may have the following characteristics:

(a) strong to very strong,

(b) (i) dark grey dappled light grey, or

(ii) greyish green and dark grey, mottled pink and white, spotted brown and grey,

(c) matrix supported but occasionally clast supported,

(d) massive but occasionally normally graded, and

(e) pervasively altered (e.g. propylitic alteration and skarn mineralisation; Figures A18 to A23 in Appendix A).

The abundance of rounded cobbles and boulders of coarse ash tuff in a tuffaceous conglomerate suggests a mature degree of abrasion of these clasts, by means of surface transport processes, prior to lithification (Figure A17 in Appendix A). Metamorphic minerals, such as epidote, garnet, chlorite and andalusite, are common in some tuffaceous metabreccias and metaconglomerates with various clasts (Figure A18 in Appendix A; Tang, 2007). As described in Section 4.3.1, dissolution of marble clasts in tuffaceous metabreccias and metaconglomerates is localised and typically leads to honeycomb structures of the rocks only (Figure A23 in Appendix A).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

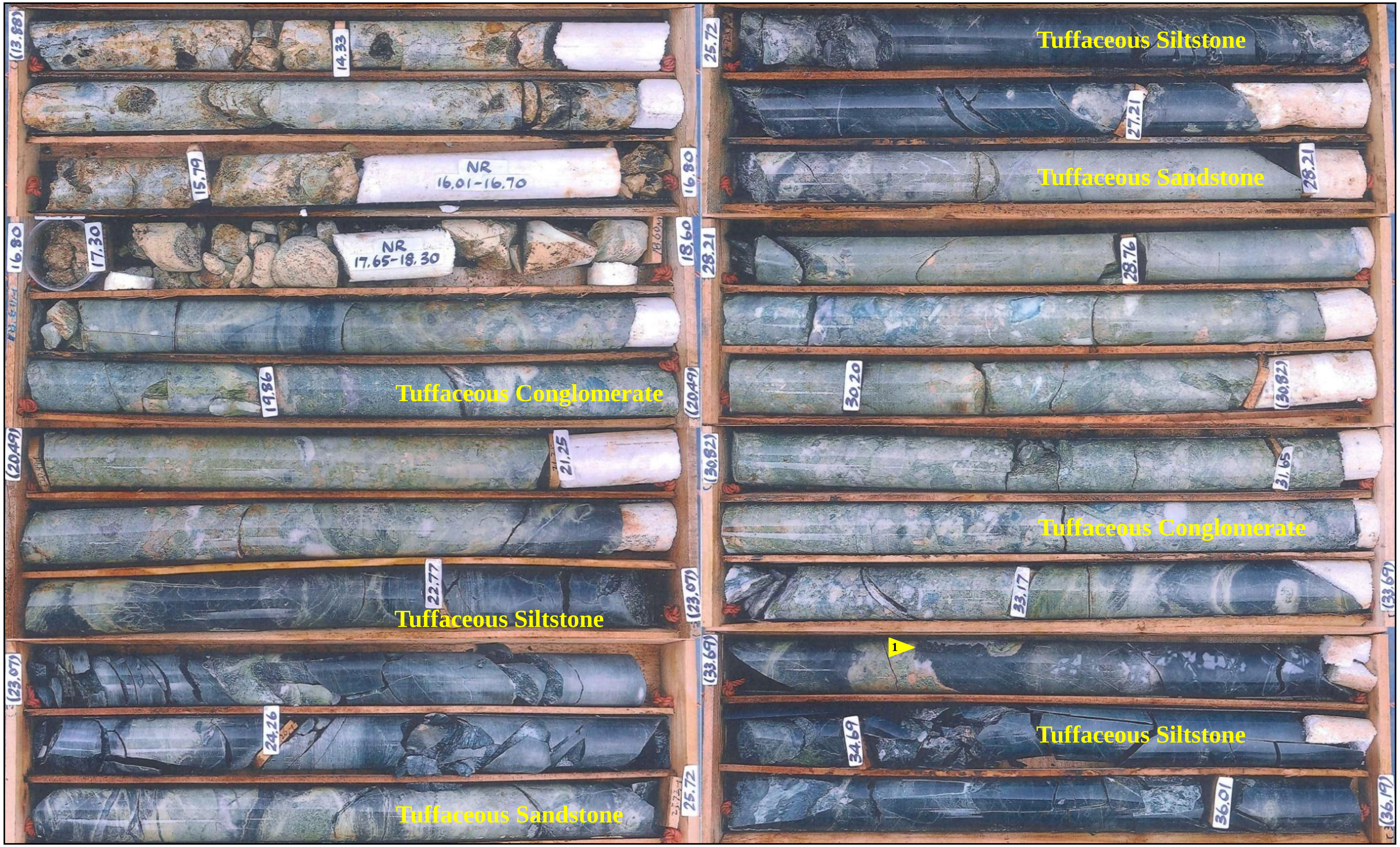


Figure 4.2 Graded and Repeated Sequences of Altered Tuffaceous Conglomerate-Sandstone-Siltstone. (Highly contorted sedimentary contacts (arrow 1) between the underlying siltstone and the overlying conglomerate likely indicate high-energy transport processes) (Siu Hang Tsuen, Drillhole No. 54157/BH3, Left: Boxes 2 to 5, Right: Boxes 6 to 9)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Figure 4.3 Tuffaceous Conglomerate with Occasional Sandstone (arrow 1) and Feldsparphyric Rhyolite (arrow 2) Clasts. (Both the sandstone and feldsparphyric rhyolite are older than the tuffaceous conglomerate) (Southwest of Por Lo Shan, E813690 N828804)

4.4 Epiclastic Rocks

In this study, all epiclastic rocks including sedimentary breccias, conglomerates, sandstones and siltstones have been partially metamorphosed. As described in Section 4.3, the epiclastic nature of these rocks is revealed by the feldspar-depleted but quartz-rich composition of the microcrystalline matrix. Outcrops and subcrops of epiclastic rocks beneath the northernmost Tuen Mun Valley area were previously assigned to the Carboniferous Lok Ma Chau Formation by Langford et al (1989) and Frost (1992), and subsequently incorporated within the Tuen Mun Formation by GEO (1994) and Sewell et al (2000).

4.4.1 Sandstone and Siltstone

Metamorphosed sandstone and siltstone are widespread beneath the northern Tuen Mun Valley area. Fresh metasandstone and metasiltstone are typically strong, dark greenish grey, foliated, altered and sometimes calcareous. In some cases, metasandstone and metasiltstone display a number of planar discontinuities including cleavages, mylonitic foliations and tectonic joints, suggestive of at least two phases of metamorphism (Figure A24 in Appendix A). Upon weathering, these rocks disintegrate along the discontinuities and may be recovered during drilling as highly fractured and non-intact cores (Figure A25 in Appendix A).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

4.4.2 Sedimentary Rocks with Marble Clasts

Similar to the lithologies described in Sections 4.3.1 and 4.3.2, metamorphosed sedimentary rocks (predominantly breccias, conglomerates and sandstones) with marble clasts in the Tuen Mun Valley were first identified as ‘marble clast-bearing volcanic rocks’ by Darigo (1989 & 1990), and subsequently assigned to the Tin Shui Wai Member of the Tuen Mun Formation by Frost (1992). In this study, these rocks occur as subcrops beneath the northeastern Tuen Mun Valley area.

Fresh marble clast-bearing metasedimentary breccia and metasandstone are typically strong, grey to dark grey mottled white and green, matrix supported, calcareous, foliated and altered (Figures A26 to A29 in Appendix A). Weathering characteristics of these rocks are comparable with those lithologies described in Section 4.3.1.

4.4.3 Sedimentary Rocks with Various Clasts

Metamorphosed sedimentary rocks (predominantly breccias, conglomerates and sandstones) with various clasts occur mainly as subcrops but also isolated outcrops in the northwestern Tuen Mun Valley area. Similar to the tuffaceous metabreccia and metaconglomerate described in Section 4.3.2, fresh metasedimentary breccia and metaconglomerate may have the following characteristics:

(a) strong to very strong,

(b) (i) dark greyish green, mottled white and light yellow, spotted pink, or

(ii) light greenish grey, mottled white and pink, spotted brown and light grey,

(c) matrix supported but occasionally clast supported,

(d) massive but occasionally normally graded (Figure 4.4), and

(e) intensely altered (e.g. silicification and chloritisation; Figures A30 to A33 in Appendix A).

4.4.4 Marble Breccia/Conglomerate

‘Marble breccia/conglomerate’ is the term used for ‘marble breccia or marble conglomerate’ (see Section 3.2 for lithological classification) because the original angularity of marble clasts in this lithology in the Tuen Mun Valley is almost always obscured by extreme flattening and elongation due to intense dynamic metamorphism. Since the discovery of marble clast-bearing rocks in the 1980s, various terms including ‘tuff-breccia’, ‘tuffaceous breccia’ and ‘impure marble’ have been used to describe marble breccia/conglomerate.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Figure 4.4 Normally-graded Metasedimentary Breccia-Metasandstone-Metasiltstone Sequence with an Apparent Thickness of c. 5 m (from 38.45 m to 33.40 m). (The metasedimentary breccia comprises many intensely altered clasts (arrow 1) with garnet mineralisation. The strata were previously assigned to Carboniferous Lok Ma Chau Formation by Langford et al (1989) and Frost (1992)) (Tin Shui Wai Area 115, Drillhole No. DH14, Box 3)

Marble breccia/conglomerate is known to occur only as subcrops within restricted areas beneath the northeastern Tuen Mun Valley area. Fresh marble breccia/conglomerate is typically very strong, white streaked greenish grey and bluish grey, dappled light grey, unsorted, clast supported, very thickly bedded and mylonitised, with some quartzite clasts (Figures A34 and A35 in Appendix A). Mylonitic marble breccia/conglomerate strata are commonly intercalated with marble clast-bearing calcareous metasedimentary rocks (refer to Section 4.4.2), from which the foliation orientation and the vertical thickness of bedding can be determined from the contacts. Occasionally, for example in drillhole no. 29625/TH1, the vertical thickness of interbedded strata of mylonitic marble breccia/conglomerate and marble clast-bearing calcareous metasedimentary rocks can exceed 75 m. The unsorted and very thickly-bedded characteristics of marble breccia/conglomerate suggest a high-energy, gravity-induced depositional process (e.g. mass wasting event).

Both mylonitic marble breccia/conglomerate and impure marble contain over 50% by volume of carbonate components. However, mylonitic marble breccia/conglomerate strata usually interdigitate with metasedimentary rocks and, as a result, the weathering susceptibility of these strata is less severe compared with that of continuous marble layers. It is reiterated that dissolution of these interbedded strata rarely results in the formation of sizeable cavities and related infill deposits. However, skeletal residuum and/or ‘residual soil’ is commonly developed and defined as follows:

Table of Contents
Table of Contents
Table of Contents
Table of Contents

(a) Skeletal residuum refers to an intact skeleton of residual soil/rock material derived from dissolution of a significant proportion of carbonate components (e.g. marble clasts) within the rock (Figure A36 in Appendix A).

(b) 'Residual soil' represents in-situ weathered, residual soil/rock material that may be recovered as:

(i) intact, soft or stiff, silty or clayey soil, or

(ii) non-intact, angular, gravel- to cobble-sized rock fragments, from drilling (Figure A37 in Appendix A).

5 Summary

As part of the Hong Kong Geological Survey's 1:20,000-scale geological map updating programme, this study has:

(a) proposed a lithological classification scheme for rocks of the Tuen Mun Formation and recommended geological terms for accurate and consistent descriptions according to Geoguide 3 (GCO, 1988a) and in alignment with international practice,

(b) reviewed and classified all known key lithologies of the Tuen Mun Formation based on all available information, and

(c) introduced a lexicon to help practitioners in the description and characterisation of rocks of the Tuen Mun Formation during drill core logging and surface mapping.

6 References

Allen, P.M. & Stephens, E.A. (1971). *Report on the Geological Survey of Hong Kong*. Government Printer, Hong Kong, 107 p.

Brodie, K., Fettes, D. & Harte, B. (2007). Structural terms including fault rock terms. In: Fettes, D. & Desmons, J. (editors). *Metamorphic Rocks: A Classification and Glossary of Terms.* Recommendations of the International Union of Geological Sciences (IUGS), Subcommission of the Systematics of Metamorphic Rocks, Cambridge University Press, Cambridge, pp 24-31.

Campbell, S.D.G. & Sewell, R.J. (1997). Structural control and tectonic setting of Mesozoic volcanism in Hong Kong. *Journal of the Geological Society, London*, vol. 154, pp 1039-1052.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Campbell, S.D.G. & Sewell, R.J. (1998). A proposed revision of the volcanic stratigraphy and related plutonic classification of Hong Kong. *Hong Kong Geologist*, vol. 4, pp 1-11.

Campbell, S.D.G. & Sewell, R.J. (2004). The controls of distribution and geological characteristics of marble and marble-bearing rocks in Hong Kong. In: Yeung, A.T. (editor). *Proceedings of Conference on Foundation Practice in Hong Kong*, Centre for Research and Professional Development, Hong Kong, pp A1-A4.

Darigo, N.J. (1989). A volcanic breccia in the buried karst of Hong Kong. *Proceedings of the Third Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst*, St Petersburg, Florida, pp 225-232.

Darigo, N.J. (1990). Marble-bearing Jurassic volcanics of the western New Territories, In: Langford, R.L., Hansen, A. & Shaw, R. (editors). Karst Geology in Hong Kong. *Geological Society of Hong Kong, Bulletin No. 4*, pp 61-72.

Davis, D.W., Sewell, R.J. & Campbell, S.D.G. (1997). U-Pb dating of Mesozoic igneous rocks from Hong Kong. *Journal of the Geological Society, London*, vol. 154, pp 1067-1076.

Fletcher, C.J.N. (2004). *Geology of Site Investigation Boreholes from Hong Kong*. Applied Geoscience Centre, Department of Earth Sciences, The University of Hong Kong, 132 p.

Frost, D.V. (1992). *Geology of Yuen Long*. Hong Kong Geological Survey Sheet Report No. 1. Geotechnical Engineering Office, Hong Kong, 69 p.

Fyfe, J.A., Shaw, R., Campbell, S.D.G., Lai, K.W. & Kirk, P.A. (2000). *The Quaternary Geology of Hong Kong*. Geotechnical Engineering Office, Hong Kong, 208 p. plus 6 maps.

GCO (1988a). *Guide to Rock and Soil Descriptions (Geoguide 3)*. Geotechnical Control Office, Hong Kong, 186 p. (Reprinted in 2000).

GCO (1988b). *Tsing Shan (Castle Peak)*. Hong Kong Geological Survey Sheet 5, Solid and Superficial Geology, 1:20,000 Series HGM20. Geotechnical Control Office, Hong Kong.

GCO (1988c). *Yuen Long*. Hong Kong Geological Survey Sheet 6, Solid and Superficial Geology, 1:20,000 Series HGM20. Geotechnical Control Office, Hong Kong.

GCO (1989a). *Deep Bay*. Hong Kong Geological Survey Sheet 2-SW-C, Solid Geology, 1:5,000 Series HGP5B. Geotechnical Control Office, Hong Kong.

GCO (1989b). *Hung Shui Kiu*. Hong Kong Geological Survey Sheet 6-NW-C, Solid Geology, 1:5,000 Series HGP5B. Geotechnical Control Office, Hong Kong.

GCO (1989c). *Muk Kiu Tau*. Hong Kong Geological Survey Sheet 6-NW-D, Solid Geology, 1:5,000 Series HGP5B. Geotechnical Control Office, Hong Kong.

GCO (1989d). *San Tin*. Hong Kong Geological Survey Sheet 2, Solid and Superficial Geology, 1:20,000 Series HGM20. Geotechnical Control Office, Hong Kong.

GCO (1989e). *Shan Pui*. Hong Kong Geological Survey Sheet 2-SW-D, Solid Geology, 1:5,000 Series HGP5B. Geotechnical Control Office, Hong Kong.

GCO (1989f). *Tin Shui Wai*. Hong Kong Geological Survey Sheet 6-NW-A, Solid Geology, 1:5,000 Series HGP5B. Geotechnical Control Office, Hong Kong.

GCO (1989g). *Yuen Long*. Hong Kong Geological Survey Sheet 6-NW-B, Solid Geology, 1:5,000 Series HGP5B. Geotechnical Control Office, Hong Kong.

GEO (1994). *San Tin*. Hong Kong Geological Survey Sheet 2, Solid Geology, 1:20,000 Series HGM20S. Geotechnical Engineering Office, Hong Kong.

GEO (2005). *Supplementary Guidelines for Foundation Design in Areas Underlain by Marble and Marble-bearing Rocks (GEO Technical Guidance Note No. 26 (TGN 26)).* Geotechnical Engineering Office, Hong Kong, 4 p.

GEO (2007a). *Engineering Geological Practice in Hong Kong (GEO Publication No. 1/2007).* Geotechnical Engineering Office, Hong Kong, 278 p.

GEO (2007b). *Hong Kong Geology Guide Book*. Geotechnical Engineering Office, Hong Kong, 177 p. (English Edition Published in 2008).

Gillespie, M.R. & Styles, M.T. (1999). *BGS Rock Classification Scheme, Volume 1, Classification of Igneous Rocks*. British Geological Survey Research Report (2nd edition), RR 99-06, 52 p.

Hallsworth, C.R. & Knox, R.W.O'B. (1999). *BGS Rock Classification Scheme, Volume 3, Classification of Sediments and Sedimentary Rocks*. British Geological Survey Research Report, RR 99-03, 44 p.

Lai, K.W. (2004). The influence factors of buried karst upon the foundation design of Hong Kong. In: Yeung, A.T. (editor). *Proceedings of Conference on Foundation Practice in Hong Kong*, Centre for Research and Professional Development, Hong Kong, pp I1-I11.

Lai, K.W. (2013). The characteristics of cavernous marble and their influence on foundation design in Hong Kong. *Proceedings of the HKIE Geotechnical Division Annual Seminar on Geotechnical Aspects of Housing Supply and Development*, The Hong Kong Institution of Engineers, pp I1-I11.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Lai, K.W., Chan, H.H.K., Choy, C.S.M. & Tsang, A.L.Y. (2004). The characteristics of marble clast-bearing volcanic rock and its influence on foundation in Hong Kong. In: Yeung, A.T. (editor). *Proceedings of Conference on Foundation Practice in Hong Kong*, Centre for Research and Professional Development, Hong Kong, pp E1-E10.

Lai, K.W. & Chan, H.M.S. (2011). An accurate geological model is an essential requirement for geotechnical engineering – a case study on the geology of Tuen Mun to Tin Shui Wai area, Hong Kong. *Proceedings of the 5th Cross-strait Conference on Structural and Geotechnical Engineering (SGE-5)*, pp 327-336.

Langford, R.L., Lai, K.W., Arthurton, R.S. & Shaw, R. (1989). *Geology of the Western New Territories*. Hong Kong Geological Survey Memoir No. 3. Geotechnical Control Office, Hong Kong, 140 p.

Le Maitre, R.W. (editor), Streckeisen, A., Zanettin, B., Le Bas, M.J., Bonin, B., Bateman, P., Bellieni, G., Dudek, A., Efremova, S., Keller, J., Lamere, J., Sabine, P.A., Schmid, R., Sorensen, H. & Woolley, A.R. (2002). *Igneous Rocks: A Classification and Glossary of Terms (2nd Edition).* Recommendations of the International Union of Geological Sciences (IUGS), Subcommission of the Systematics of Igneous Rocks, Cambridge University Press, Cambridge, 236 p.

Li, Y.H.M., Zhou, M.F., Lai, K.W., Chan, L.S. & Chen, W.T. (2014). Geochemical and geochronological constraints on Late Jurassic volcanic rocks at Tuen Mun, Hong Kong, with implications for the Palaeo-Pacific subduction. *International Geology Review*, vol. 56, pp 408-429.

McPhie, J., Doyle, M. & Allen, R. (1993). *Volcanic Textures: A Guide to the Interpretation of Textures in Volcanic Rocks*. Tasmania Government Printing Office, Tasmania, 198 p.

Pirajno, F. (2009). *Hydrothermal Processes and Mineral Systems*. Springer Science and Business Media, 1250 p.

Robertson, S. (1999). *BGS Rock Classification Scheme, Volume 2, Classification of Metamorphic Rocks*. British Geological Survey Research Report, RR 99-02, 24 p.

Rosen, O.M., Desmons, J. & Fettes, D. (2007). Metacarbonate and related rocks. In: Fettes, D. & Desmons, J. (editors). *Metamorphic Rocks: A Classification and Glossary of Terms.* Recommendations of the International Union of Geological Sciences (IUGS), Subcommission of the Systematics of Metamorphic Rocks, Cambridge University Press, Cambridge, pp 46-50.

Schmid, R. (1981). Descriptive nomenclature and classification of pyroclastic deposits and fragments: Recommendations by the International Union of Geological Sciences (IUGS) Subcommission on the Systematics of Igneous Rocks. *Geology*, vol. 9, pp 41-43.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Schmid, R., Fettes, D., Harte, B., Davis, E. & Desmons, J. (2007). How to name a metamorphic rock? In: Fettes, D. & Desmons, J. (editors). *Metamorphic Rocks: A Classification and Glossary of Terms.* Recommendations of the International Union of Geological Sciences (IUGS), Subcommission of the Systematics of Metamorphic Rocks, Cambridge University Press, Cambridge, pp 3-15.

Sewell, R.J., Campbell, S.D.G., Fletcher, C.J.N., Lai, K.W. & Kirk, P.A. (2000). The *Pre-quaternary Geology of Hong Kong*. Geotechnical Engineering Office, Hong Kong, 181 p. plus 4 maps.

Smulikowski, W., Desmons, J., Fettes, D., Harte, B., Sassi, F. & Schmid, R. (2007). Types, grade and facies of metamorphism. In: Fettes, D. & Desmons, J. (editors). *Metamorphic Rocks: A Classification and Glossary of Terms.* Recommendations of the International Union of Geological Sciences (IUGS), Subcommission of the Systematics of Metamorphic Rocks, Cambridge University Press, Cambridge, pp 16-23.

Tang, D.L.K. (2005). *Petrological Study of Dynamically Metamorphosed Rocks in the NW New Territories, Hong Kong SAR (Part I: Hand Specimens and Thin Sections) (Geological Report No. 1/2005).* Geotechnical Engineering Office, Hong Kong, 41 p.

Tang, D.L.K. (2007). *Geology of Tuen Mun Area, NW Hong Kong*. MPhil Thesis, The University of Hong Kong, 208 p. plus 1 map.

Zharikov, V., Pertsev, N., Rusinov, V., Callegari, E. & Fettes, D. (2007). Metasomatism and Metasomatic Rocks. In: Fettes, D. & Desmons, J. (editors). *Metamorphic Rocks: A Classification and Glossary of Terms.* Recommendations of the International Union of Geological Sciences (IUGS), Subcommission of the Systematics of Metamorphic Rocks, Cambridge University Press, Cambridge, pp 58-68.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Appendix A

Lexicon of Terms Used for Drill Core Logging and Surface Mapping in the Tuen Mun Valley

Contents

Table of Contents
Table of Contents
Table of Contents

List of Figures

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents
Table of Contents
Table of Contents

A.1 Andesite (Lava)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

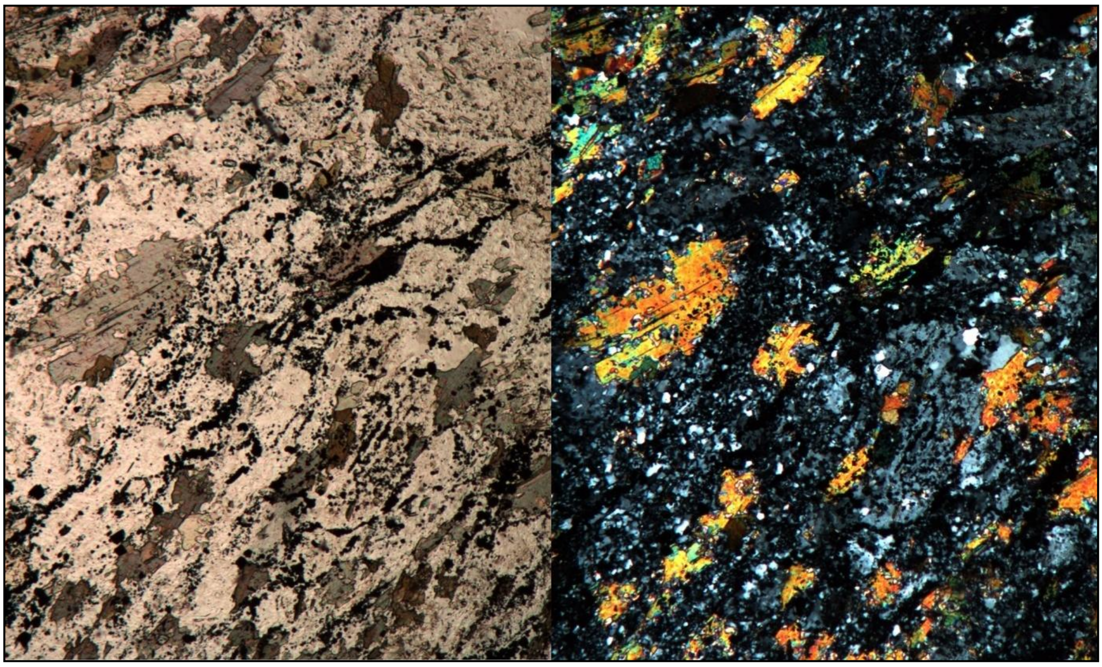
Note: The autobrecciated andesite lava is aphanitic with evenly distributed plagioclase phenocrysts, and comprises some dark grey, subangular to subrounded, lapilli- to block-sized, andesite fragments. (Castle Peak Hospital, Drillhole No. 17204/BH10, Boxes 1 and 2)

Figure A1 Andesite

Note: Fresh meta-andesite lava is typically dark greenish grey spotted black and white, massive, aphanitic, along with plagioclase phenocrysts and secondary biotite. (Tin King Light Rail Station, Drillhole No. 34859/DH4, Boxes 3 and 4)

Figure A2 Meta-andesite

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: Plagioclase phenocrysts and biotite crystals set in a granular matrix of plagioclase and opaque minerals. (Ho Tin Tsuen, Sample No. HK2105) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A3 Photomicrograph of Meta-andesite

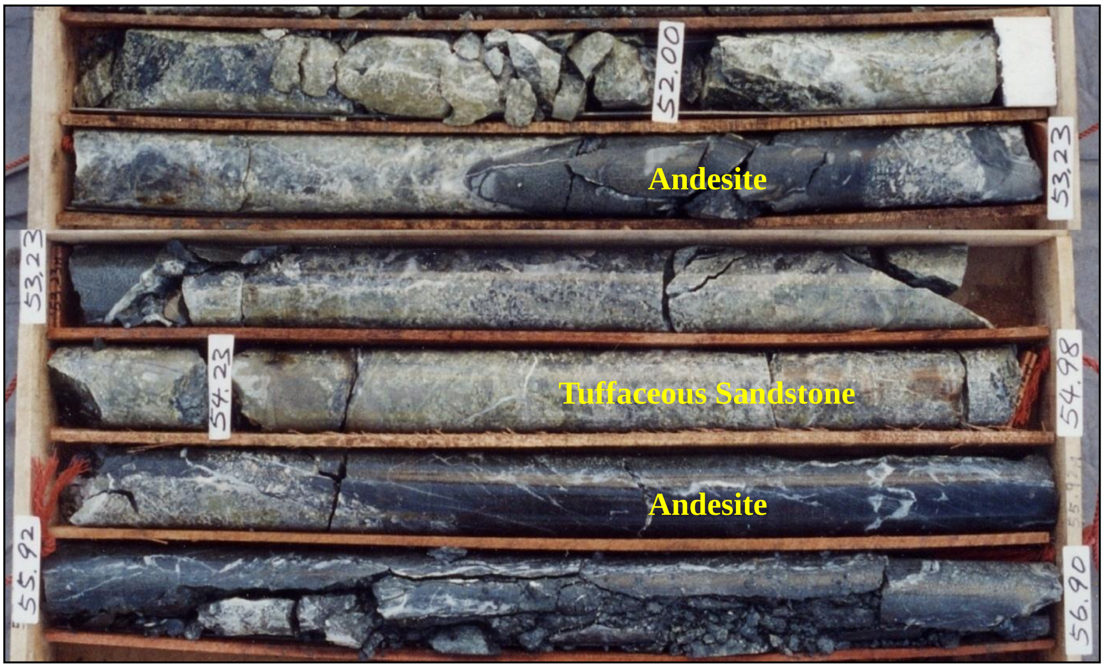
Note: The dark greenish grey mottled dark green, meta-andesite lava becomes reddish brown to yellowish brown, clayey silt upon complete weathering. (West of Tuen Mun MTR Station, Drillhole No. 35305/DD220/DH/004, Boxes 2 and 3)

Figure A4 Meta-andesite

Table of Contents
Table of Contents
Table of Contents
Table of Contents

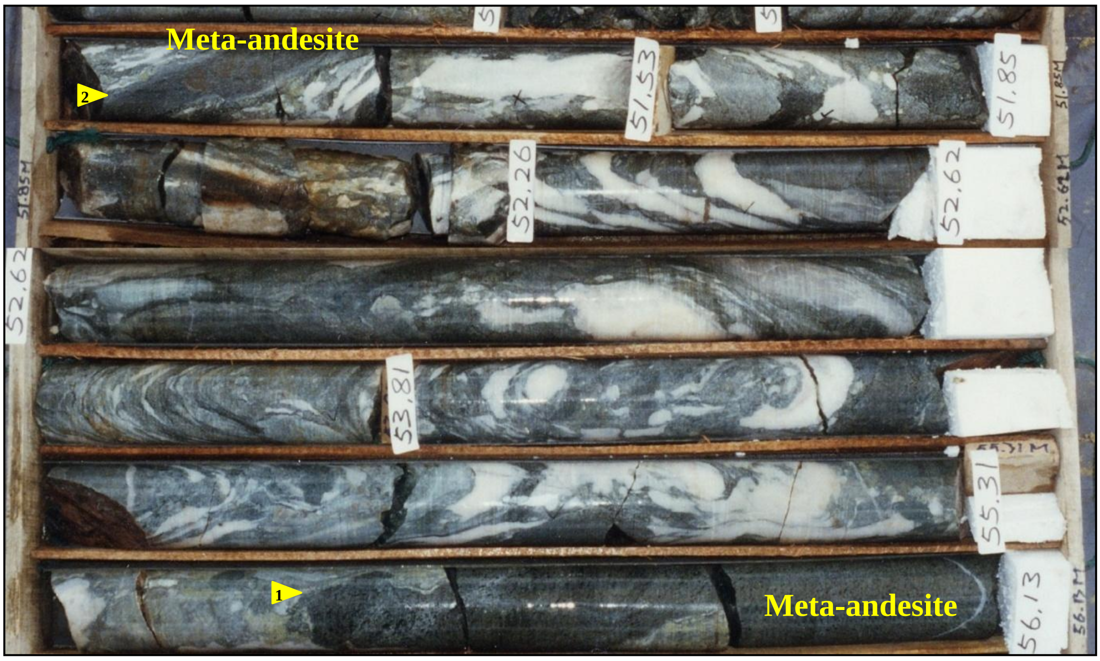
A.2 Andesite (Dyke and Sill)

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: Sharp and subvertical intrusive contacts between tuffaceous sandstone and andesite are evident. Calcite veins are common in the andesitic intrusions. (Tuen Mun Area 52, Drillhole No. 24295/TMA82, Boxes 3 and 4)

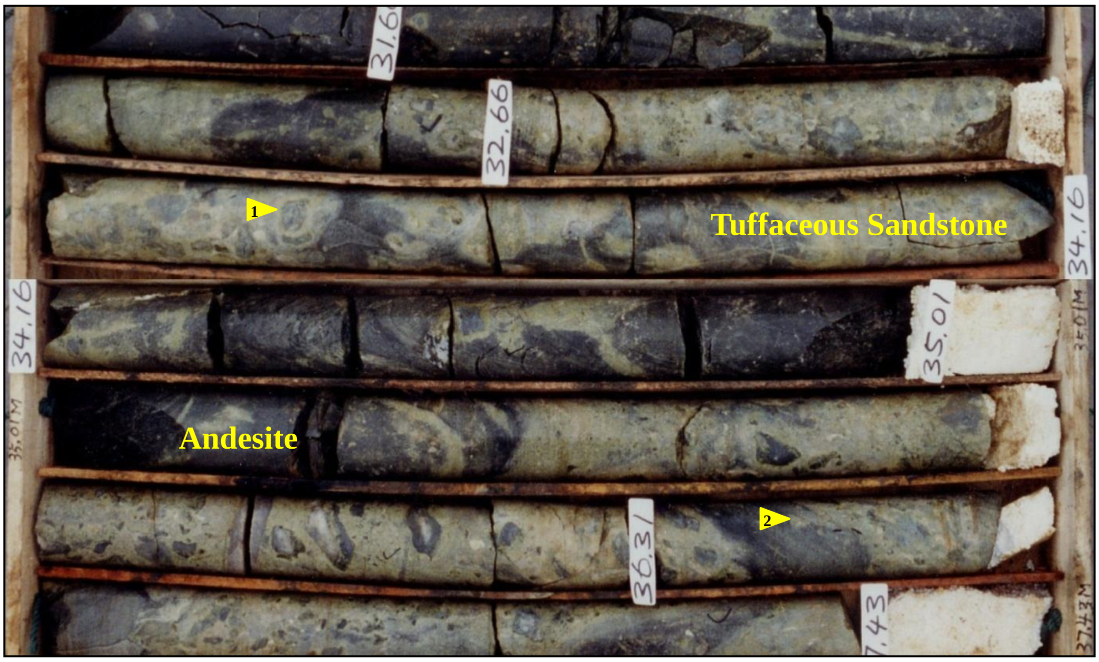
Figure A5 Altered Tuffaceous Sandstone, and Andesite



Note: Curvy intrusive contacts (arrow 1) and chilled margins (arrow 2) are evident on both sides of the andesitic intrusion. Mylonitisation postdates both the breccia and the intrusions. (Tuen Mun Area 52, Drillhole No. 24296/TMA50, Boxes 5 and 6)

Figure A6 Mylonitic Tuffaceous Breccia with Many Marble Clasts, and Meta-andesite

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: The reaction rim (arrow 1) around light grey clasts and fused intrusive contacts (arrow 2) are likely the result of andesitic magma injection into unconsolidated tuffaceous sediments. (Tuen Mun Area 52, Drillhole No. 24293/TMA59, Boxes 3 and 4)

Figure A7 Altered Tuffaceous Sandstone, and Andesite

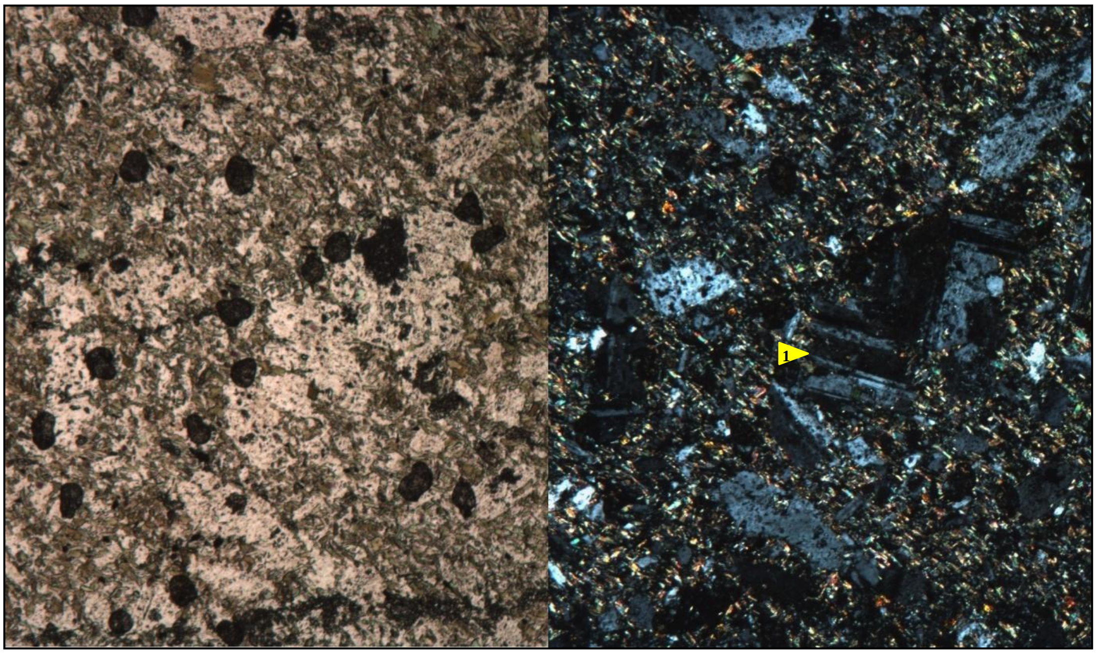
Table of Contents
Table of Contents
Table of Contents
Table of Contents

A.3 Coarse Ash Tuff

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Note: Fresh coarse ash tuff is typically dark grey to dark greenish grey, massive, and contains a variable content of crystals and crystal fragments (mainly quartz and feldspar), along with some lithic fragments. (Tuen Mun North Service Reservoir, Drillhole No. 55674/S13, Boxes 1 to 3)

Figure A8 Coarse Ash Tuff



Note: Angular, broken phenocrysts of plagioclase (arrow 1) set in a chlorite-feldspar-quartz matrix. (Tuen Mun Golf Centre, Sample No. HK4920) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A9 Photomicrograph of Coarse Ash Tuff

Table of Contents Table of Contents Table of Contents Table of Contents

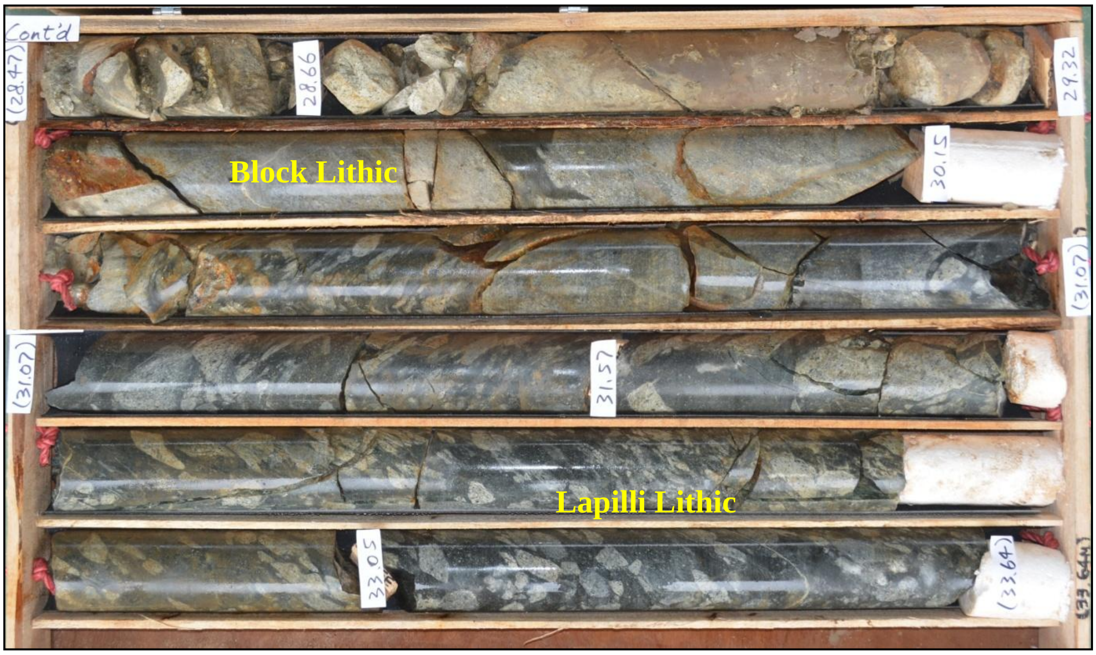
Note: The tuff turns into light red to light brownish yellow, clayey silt upon complete weathering. (Castle Peak Hospital, Drillhole No. 27083/BH1-8, Boxes 1 to 2)

Figure A10 Coarse Ash Tuff

Table of Contents
Table of Contents
Table of Contents
Table of Contents

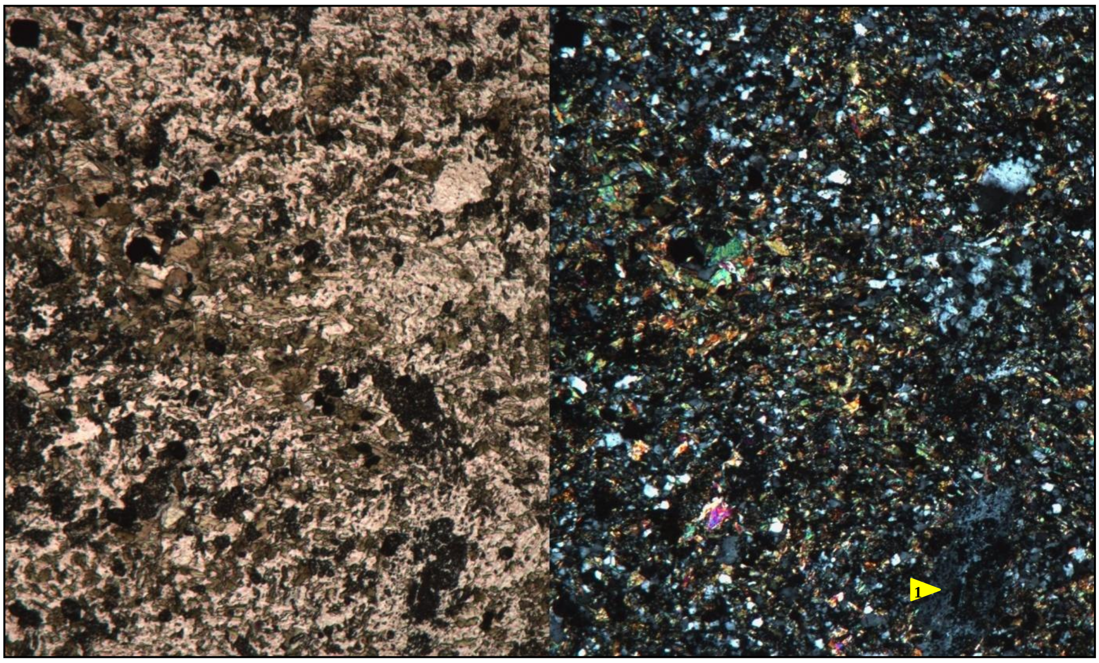
A.4 Tuff-breccia

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: The tuff-breccia comprises light grey, angular, lapilli- to block-sized, coarse ash tuff (lithic) fragments set in a dark grey, fine ash matrix. (Tuen Mun Area 54 Sites 1 and 1A, Drillhole No. 61016/ADH5, Boxes 3 and 4)

Figure A11 Tuff-breccia



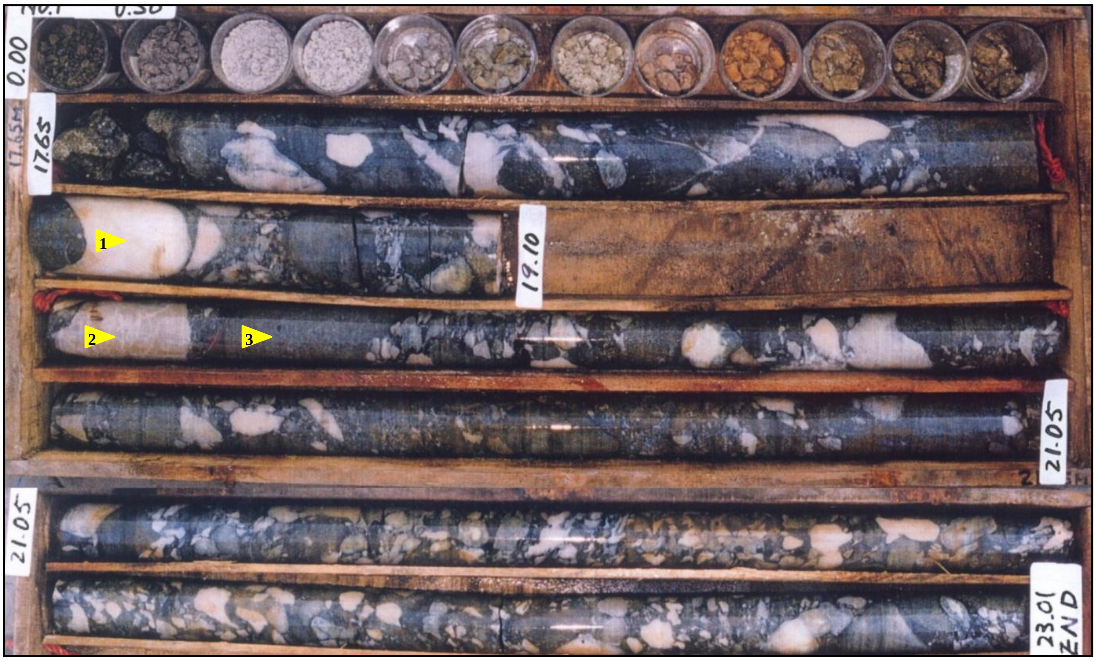
Note: A fragment of a feldspar phenocryst (arrow 1) along with opaque minerals set in a hornblende-feldspar-quartz- chlorite matrix, likely indicating a dacitic composition. (Tuen Mun Area 54 Sites 1 and 1A, Sample No. HK13891) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A12 Photomicrograph of Tuff-breccia

Table of Contents Table of Contents Table of Contents Table of Contents

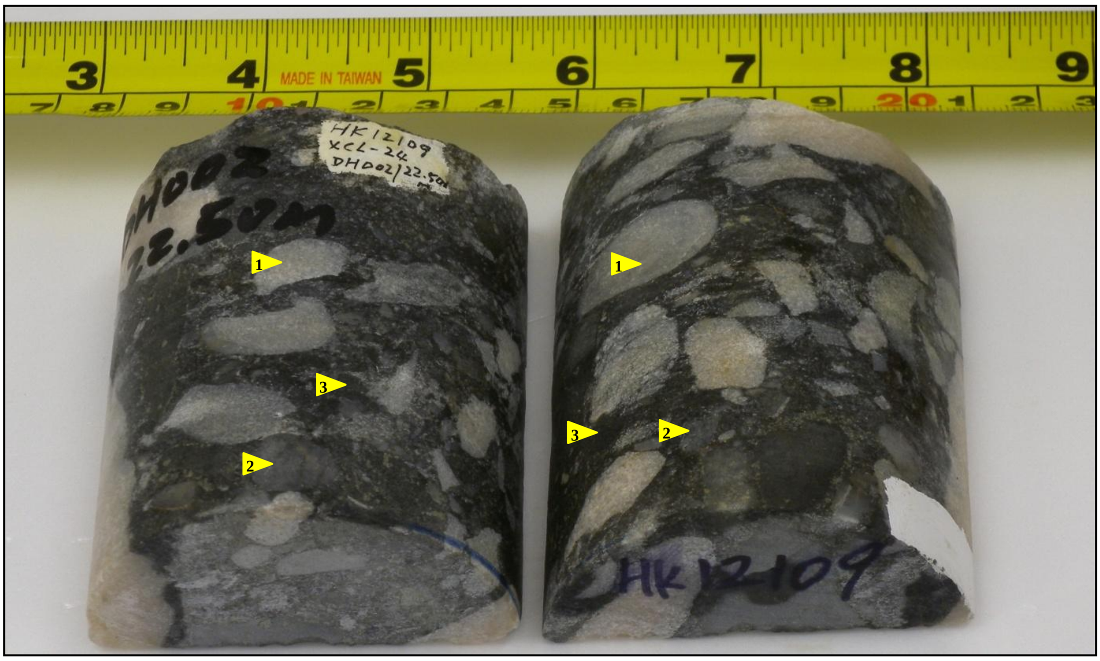
A.5 Tuffaceous Breccia and Conglomerate

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: The breccia is poorly sorted, matrix supported and massive. The size of marble (arrow 1), quartzite (arrow 2) and possible andesite (arrow 3) clasts ranges from gravel to cobble. (Central Hung Shui Kiu, Drillhole No. 35262/DD210/DH/002, Boxes 1 and 2)

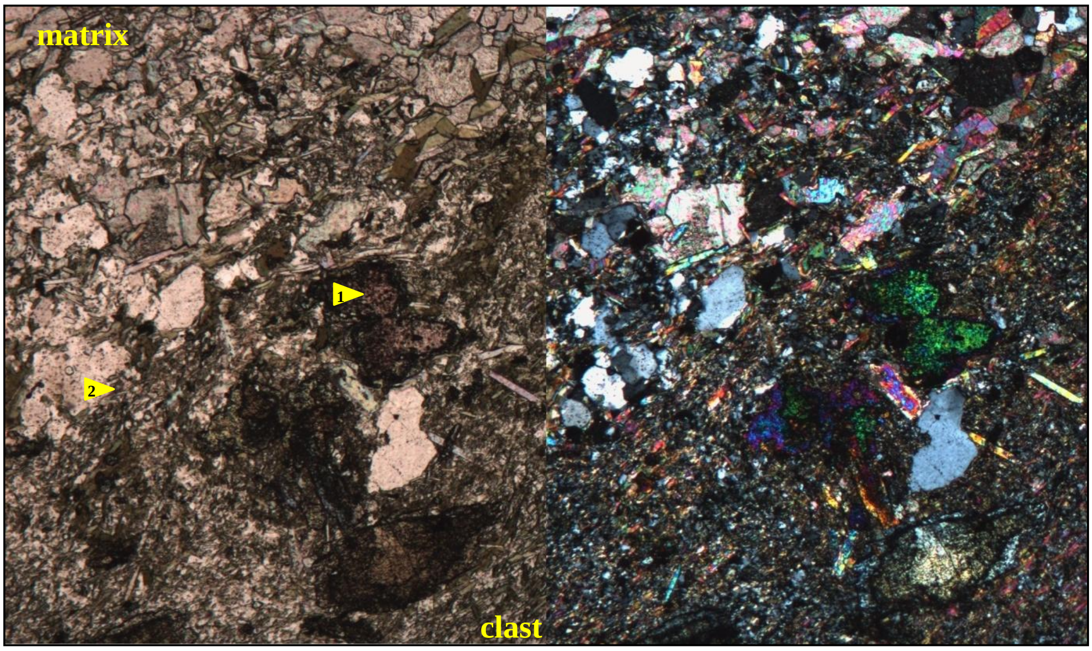
Figure A13 Altered, Calcareous, Tuffaceous Breccia with Many Marble Clasts



Note: The marble (arrow 1), quartzite (arrow 2) and possible andesite (arrow 3) clasts have sharp boundaries with matrix without any reaction or alteration rims. (Central Hung Shui Kiu, Sample No. HK12109, Drillhole No. 35262/DD210/DH/002, 22.50 m Depth)

Figure A14 Altered, Calcareous, Tuffaceous Breccia with Many Marble Clasts

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: A dark greenish grey clast composed of sericite-chlorite-quartz-epidote (arrow 1) has a sharp boundary (arrow 2) with the quartz-calcite matrix. Prior to alteration, the clast may have been andesite. (Central Hung Shui Kiu, Sample No. HK12109) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A15 Photomicrograph of Altered, Calcareous, Tuffaceous Breccia

Note: Dissolution of many marble clasts in the breccia has led to honeycomb structures. Occasional quartzite and mudstone clasts are evident. (Central Hung Shui Kiu, Drillhole No. 35413/DD200/DH/009, Boxes 3 and 4)

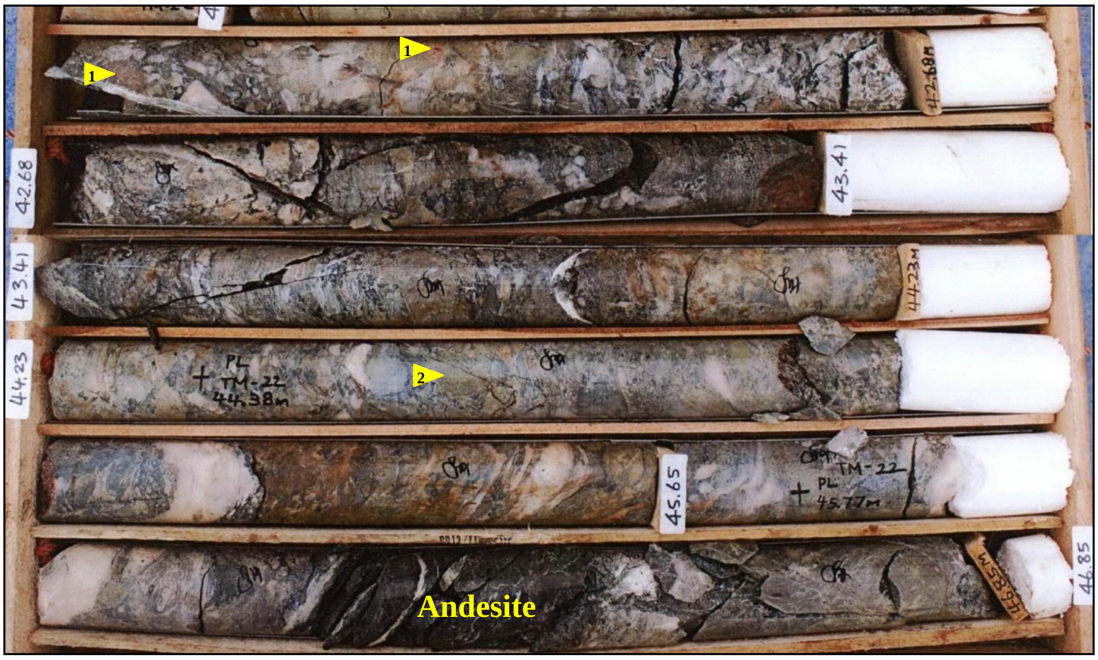
Figure A16 Altered, Calcareous, Tuffaceous Breccia with Honeycomb Structures

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents
Table of Contents
Table of Contents
Table of Contents

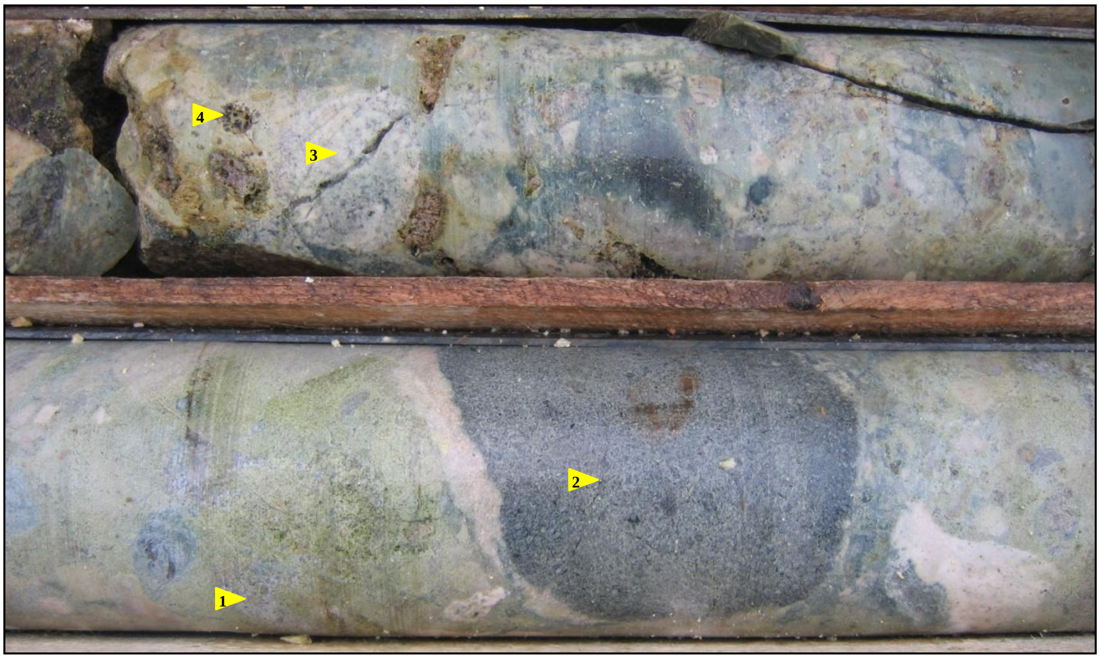
Note: The clast-supported conglomerate contains many rounded, cobble- to boulder-sized, coarse ash tuff (arrow 1) clasts with sharp boundaries against a finer matrix, suggesting a mature degree of abrasion of these clasts due to surface transport processes prior to lithification. (Southwest of Por Lo Shan, E813660 N828640)

Figure A17 Tuffaceous Conglomerate



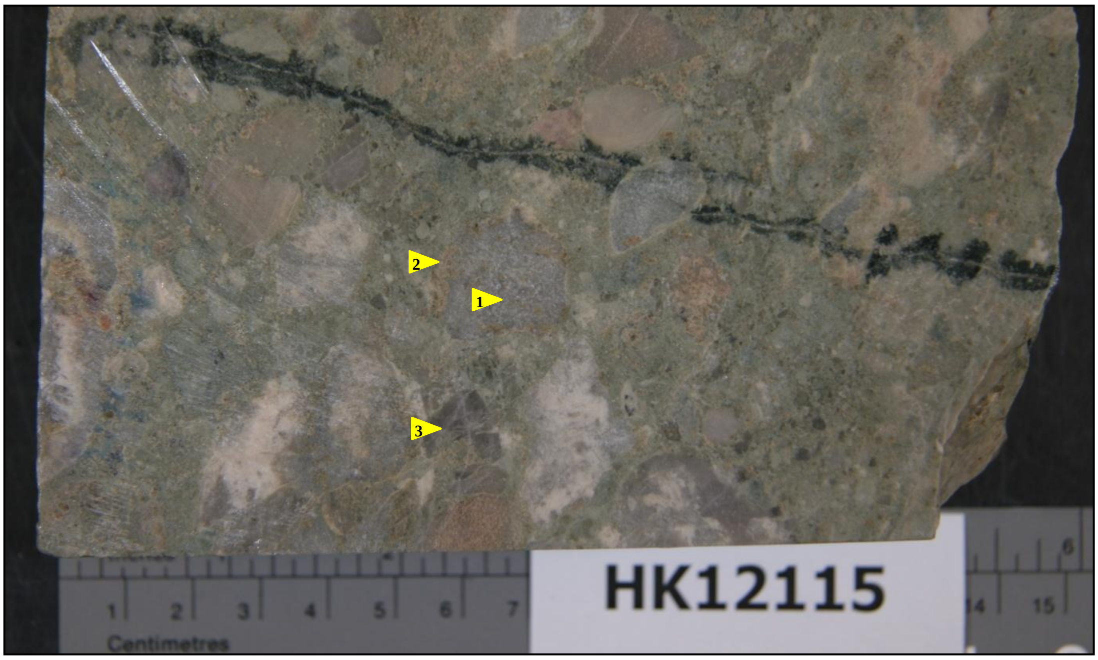
Note: Garnet (arrow 1) and epidote (arrow 2) mineralisation along with an andesitic intrusion are evident, likely indicating intense metasomatism and hydrothermal alteration in the vicinity of hot magma intrusions. (Tuen Mun Area 54 Site 2, Drillhole No. 57101/TM-22, Boxes 4 and 5)

Figure A18 Altered Tuffaceous Conglomerate with Many Marble Clasts, and Andesite



Note: The conglomerate comprises some marble clasts (arrow 1) and andesite intraclasts (arrow 2). Pervasive alteration can be observed in the sand-sized matrix, in light pink clasts (arrow 3) and around the andesite intraclast, which was likely remobilised from a consolidated lava flow or pyroclastic deposit. Preferential weathering has taken place in garnet minerals (arrow 4). (Tuen Mun Area 54 Site 2, Drillhole No. 42914/DHA210, Box 2)

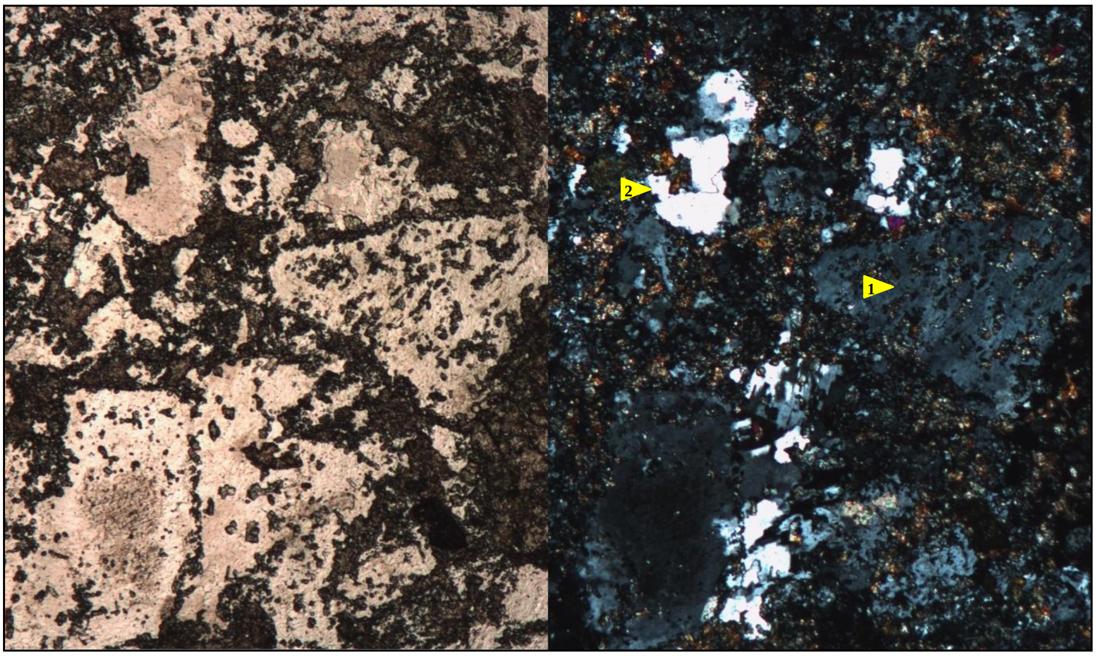
Figure A19 Altered Tuffaceous Conglomerate with Some Marble Clasts



Note: The conglomerate contains some marble clasts (arrow 1) along with garnet mineralisation (arrow 2), and some quartzite (arrow 3) clasts. A dark green chlorite vein penetrates most clasts and the finer matrix. (Siu Hong MTR Station, Sample No. HK12115, Drillhole No. 35262/DD210/DH/065, 18.0 m Depth)

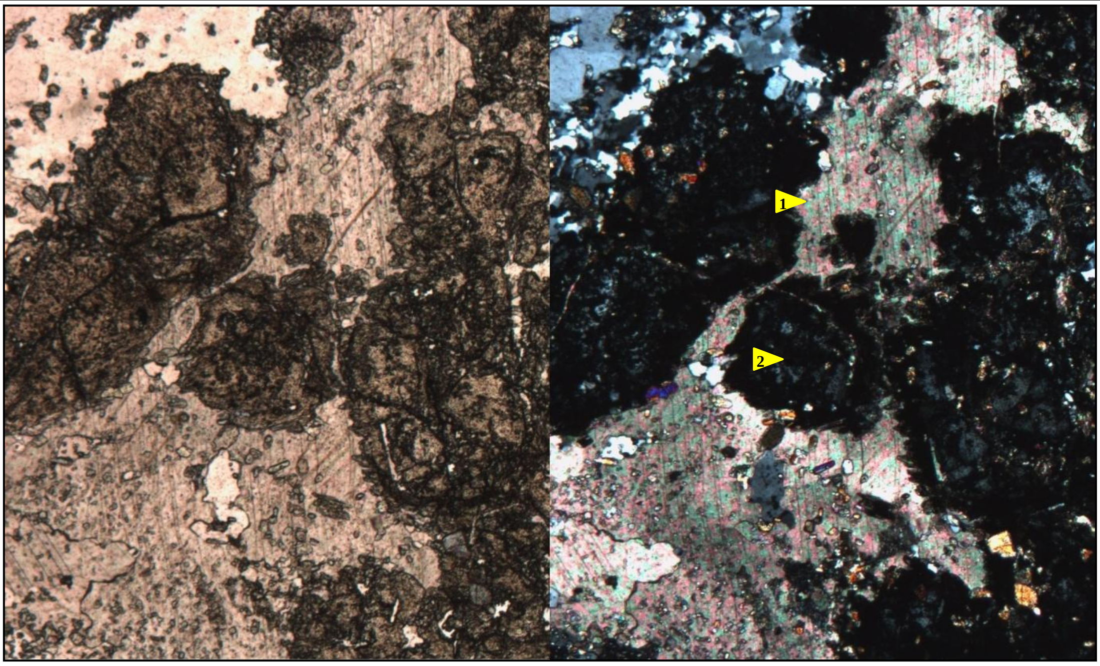
Figure A20 Altered Tuffaceous Conglomerate with Some Marble Clasts

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: Feldspar (arrow 1) and quartz (arrow 2) fragments set in a chlorite-quartz matrix. (Siu Hong MTR Station, Sample No. HK12115) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A21 Photomicrograph of Altered Tuffaceous Conglomerate



Note: Parts of calcite crystals (marble clast, arrow 1) have been replaced by garnet (arrow 2). (Siu Hong MTR Station, Sample No. HK12115) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A22 Photomicrograph of Altered Tuffaceous Conglomerate

Table of Contents
Table of Contents
Table of Contents
Table of Contents

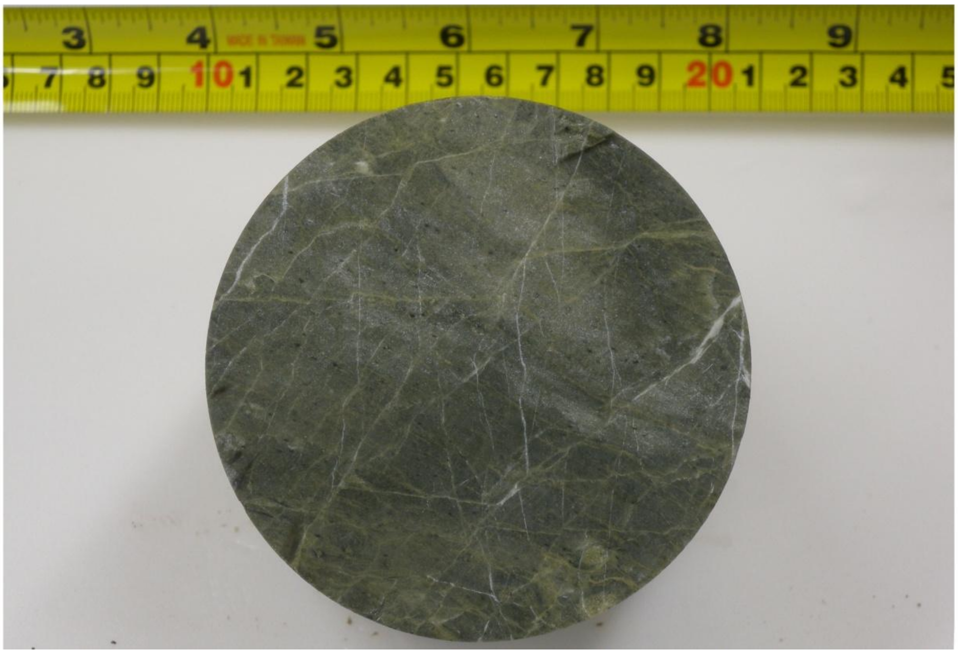
Note: Dissolution of marble clasts has resulted in repeated development of honeycomb structures along the cores of the tuffaceous sequences. (Castle Peak Hospital, Drillhole No. 17204/BH21, Boxes 2 and 3)

Figure A23 Altered Tuffaceous Conglomerate with Honeycomb Structures

Table of Contents
Table of Contents
Table of Contents
Table of Contents

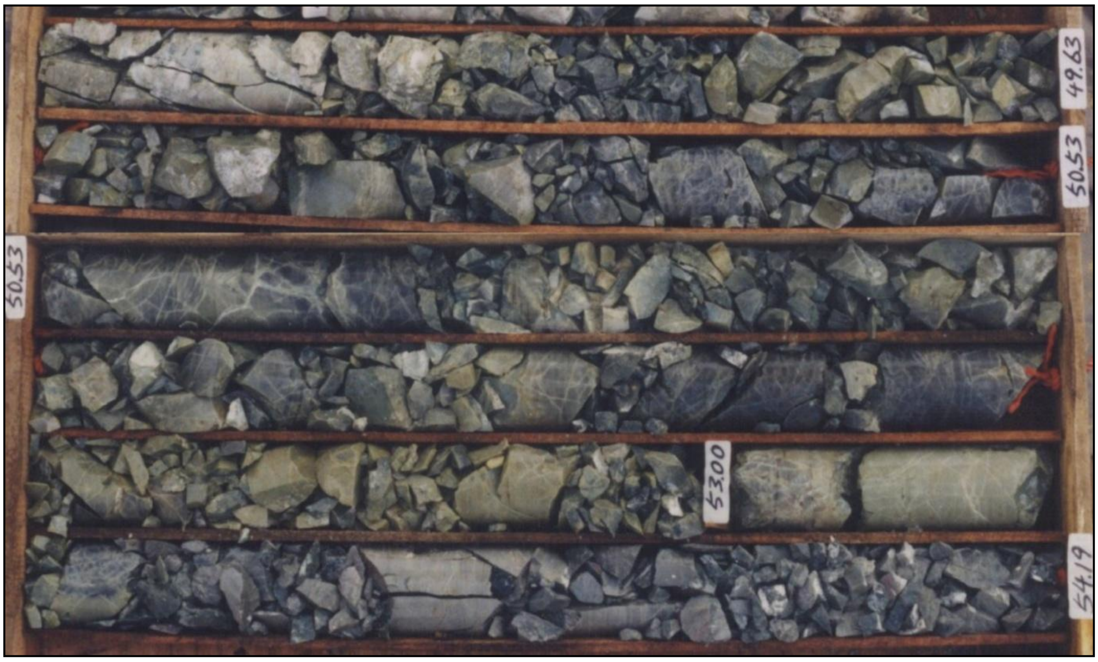
A.6 Sedimentary Breccia, Conglomerate, Sandstone and Siltstone

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note:	A few sets of closely-spaced fractures, likely caused by hydrothermal brecciation, have been infilled by chlorite, calcite or quartz. (Tin Shui Wai Area 103, Sample No. HK13253, Drillhole No. 38822/103/F96, 64.0 m Depth)

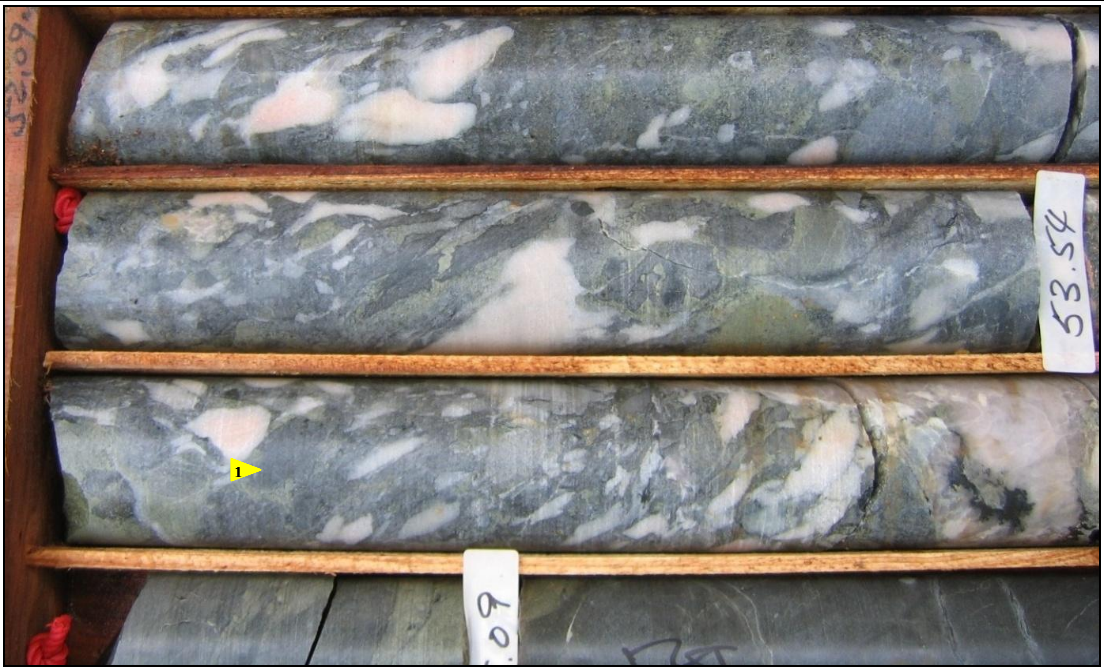
Figure A24 Metasiltstone



Note:	The metasiltstone has undergone some phases of metamorphism and displays a number of planar discontinuities (revealed by dense hydrothermal veins). Large portions of the metasiltstone cores are highly fractured and non-intact. (Tin Shui Wai Area 31, Drillhole No. 24388/TSW-A31-13, Boxes 2 and 3)

Figure A25 Metasiltstone

Table of Contents
Table of Contents
Table of Contents
Table of Contents



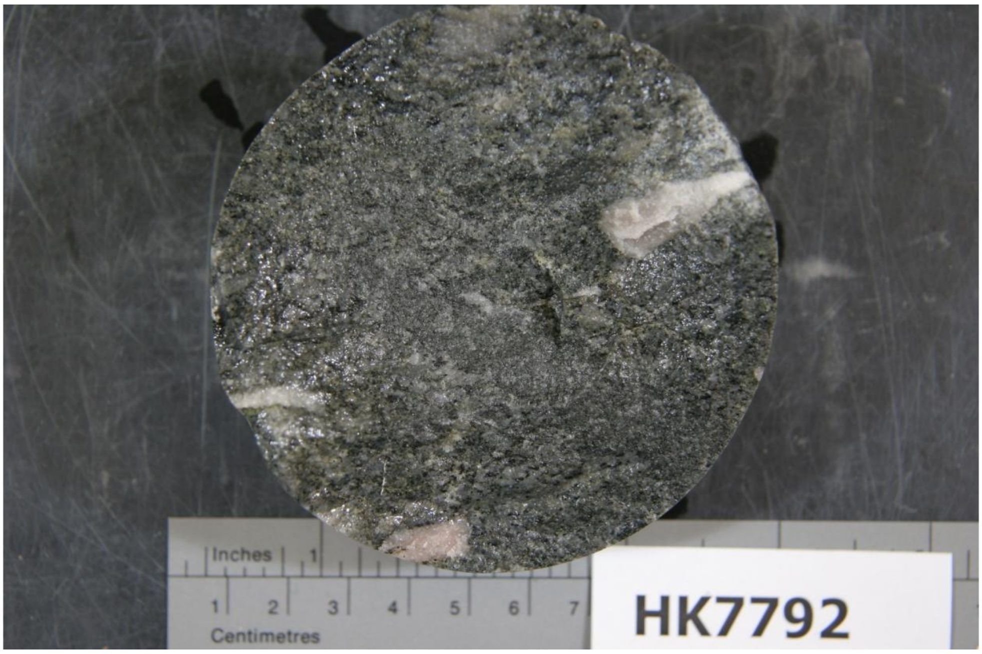
Note: Slightly flattened and elongated marble and quartzite (arrow 1) clasts set in a sand-sized, chlorite-rich matrix. (Hung Shui Kiu Area 13, Drillhole No. 62268/A3, Box 4)

Figure A26 Calcareous Metasedimentary Breccia with Many Marble Clasts

Note: The metasandstone contains occasional, gravel- to cobble-sized, marble and quartzite (arrow 1) clasts, both of which have been slightly flattened and elongated. (Ha Tsuen, Drillhole No. 12416/BGS18, Boxes 3 and 4)

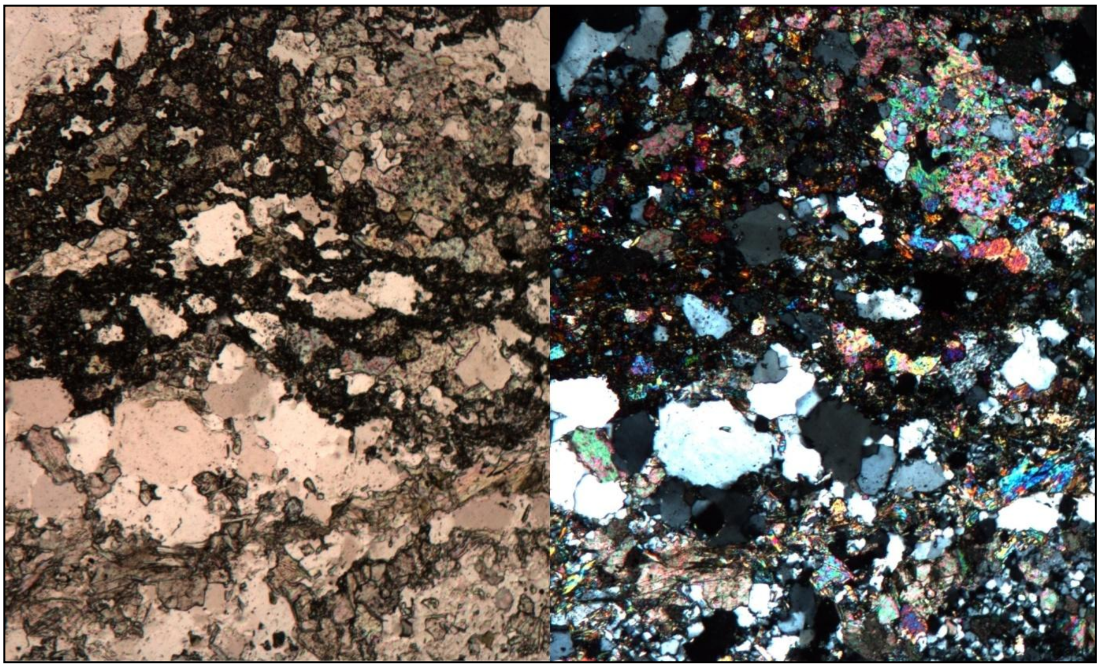
Figure A27 Calcareous Metasandstone with Occasional Marble Clasts

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: The marble clasts have sharp boundaries, without any reaction or alteration rims, against a sand-sized matrix. (Ha Tsuen, Sample No. HK7792, Drillhole No. 12416/BGS18, 32.67 m Depth)

Figure A28 Calcareous Metasandstone with Occasional Marble Clasts



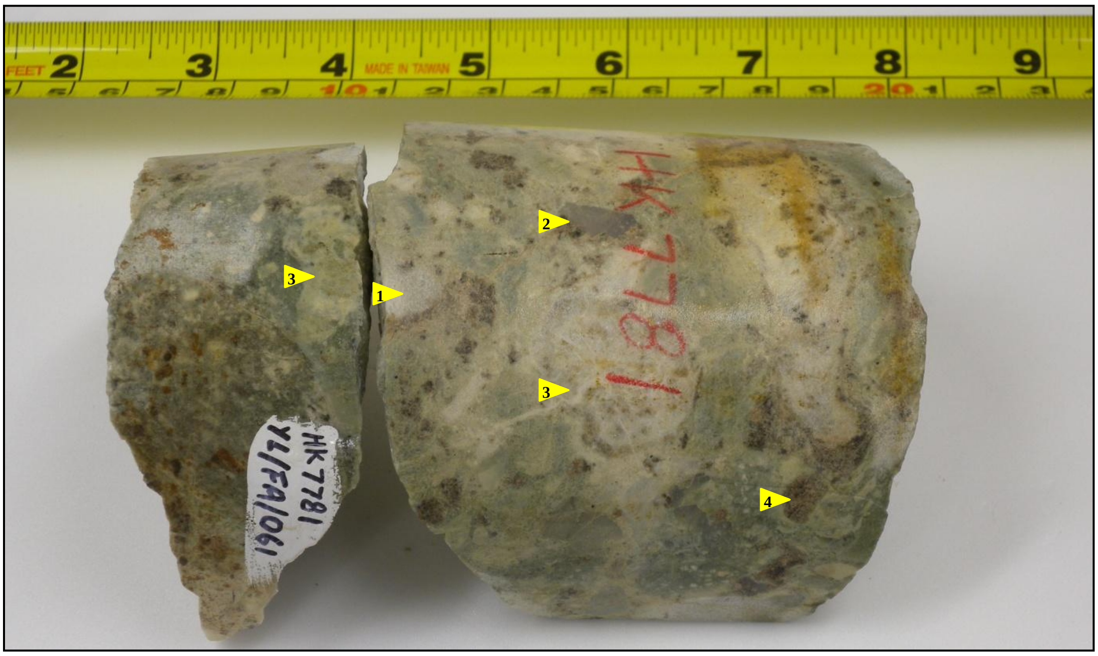
Note: Sand-sized quartz and calcite crystals set in a quartz-chlorite matrix. (Ha Tsuen, Sample No. HK7792) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A29 Photomicrograph of Calcareous Metasandstone

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Note: The original texture and composition of the metaconglomerate is obscured by intense metasomatism and hydrothermal alteration. (Mai Po, Drillhole No. 12443/BGS15, Boxes 6 and 7)

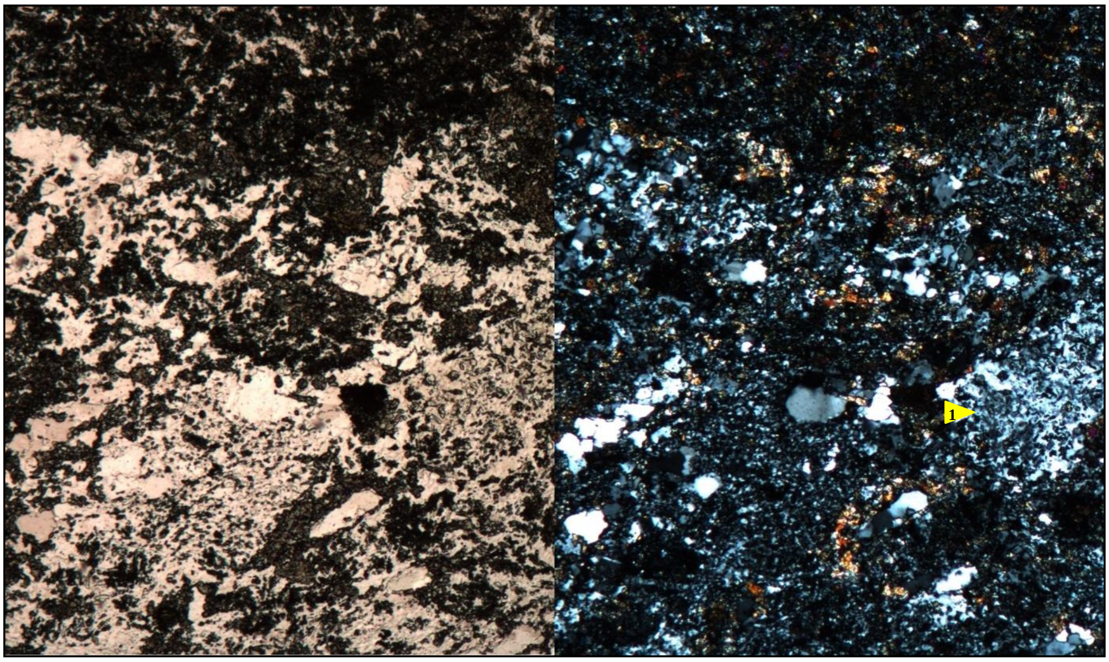
Figure A30 Metaconglomerate with Some Marble Clasts



Note: The metaconglomerate comprises some marble (arrow 1), quartzite (arrow 2) and other intensely altered clasts (arrow 3). Garnet mineralisation (arrow 4) is also evident along the boundary of some clasts, and in the matrix. (Mai Po, Sample No. HK7781, Drillhole No. 12443/BGS15, 50.38 m Depth)

Figure A31 Metaconglomerate with Some Marble Clasts

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: An occasional feldspar fragment (arrow 1) is evident in a chlorite-quartz-rich matrix. (Mai Po, Sample No. HK7781) (Left: PPL, Right: XPL, Field of View on Each Side = 1.34 mm x 1.59 mm)

Figure A32 Photomicrograph of Metaconglomerate

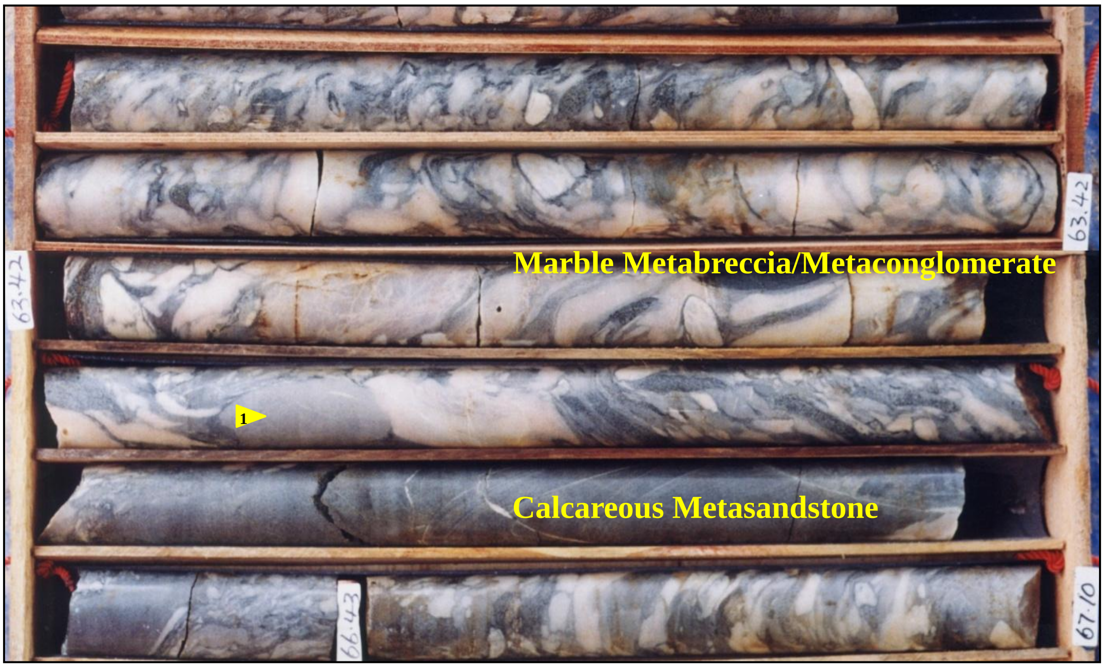
Note: Honeycomb structures are evident from 39.15 m to 42.06 m depth due to partial dissolution of marble clasts in the metaconglomerate. (Tin Shui Wai Area 102, Drillhole No. 24483/RZE-89, Boxes 2 and 3)

Figure A33 Metaconglomerate with Some Marble Clasts and Honeycomb Structures

Table of Contents Table of Contents Table of Contents Table of Contents

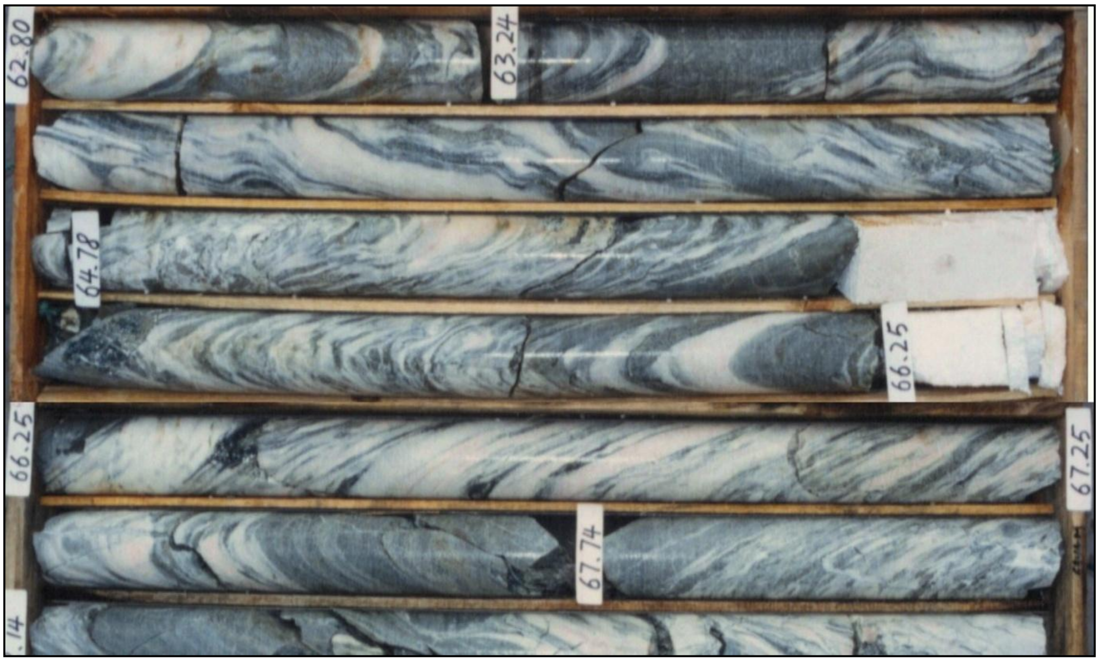
A.7 Marble Breccia/Conglomerate

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: The marble metabreccia/metaconglomerate comprises occasional, gravel- to cobble-sized, quartzite clasts (arrow 1) with sharp boundaries against marble clasts and a finer matrix. The lithology is unsorted, clast supported and very thickly bedded, and conformably overlies calcareous metasandstone. (Southwest of Tin Shui Wai MTR Station, Drillhole No. 35413/DD200/DHCH/025, Boxes 4 and 5)

Figure A34 Marble Metabreccia/Metaconglomerate



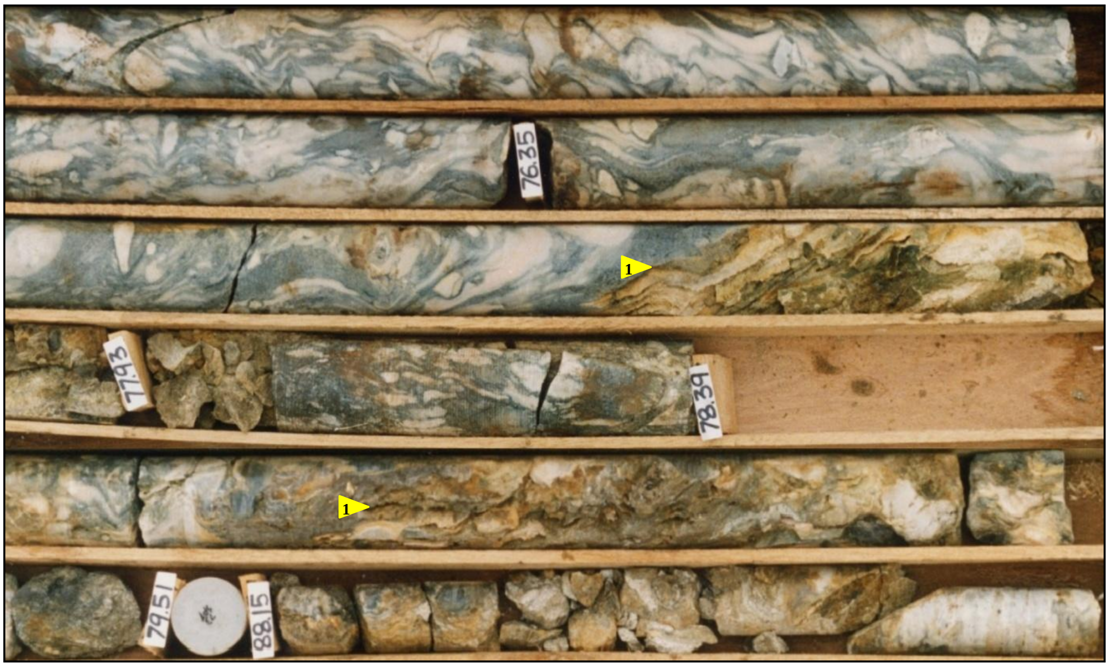
Note: All marble clasts have been extremely flattened and elongated during ductile deformation to form subparallel bands of recrystallised calcite. The breccia/conglomerate resembles dark grey streaked white, foliated, impure marble. (Tin Shui Wai Area 27, Drillhole No. 26722/TSW27-10, Boxes 4 and 5)

Figure A35 Mylonitic Marble Breccia/Conglomerate

Table of Contents
Table of Contents
Table of Contents
Table of Contents

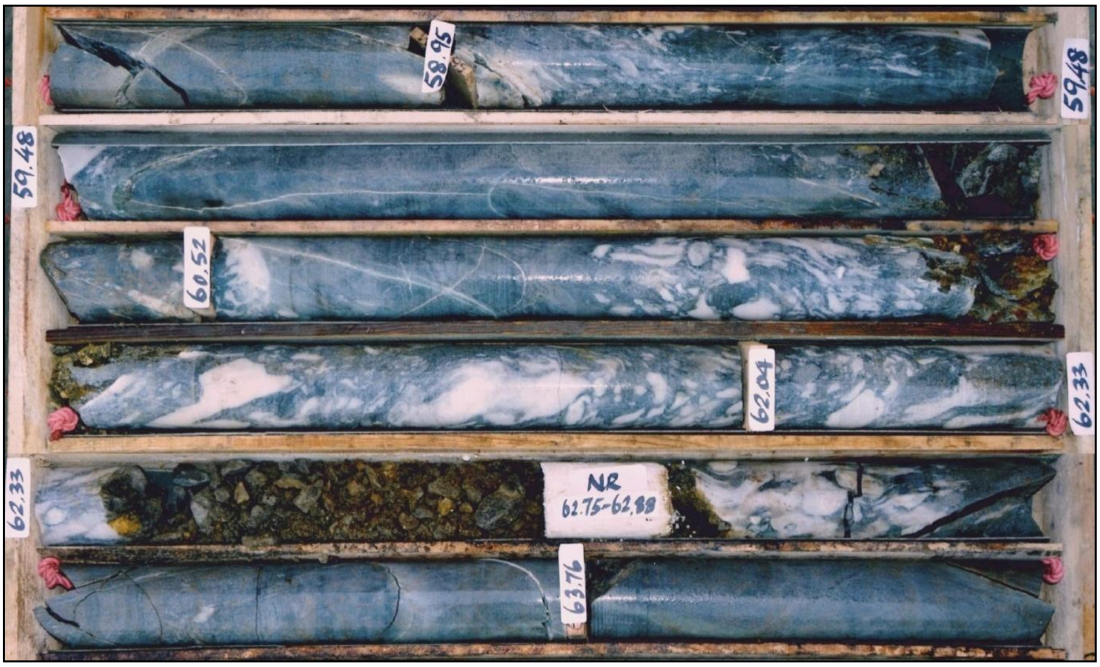
A.8 Skeletal Residuum and 'Residual Soil' derived from Marble Breccia/Conglomerate

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: Preferential weathering, by means of dissolution, has taken place along the subparallel calcite bands, resulting in the formation of skeletal residuum (arrows 1) with heavy iron oxide staining. (Tin Shui Wai Area 8, Drillhole No. 12950/DH2, Boxes 3 and 4)

Figure A36 Mylonitic Marble Breccia/Conglomerate with Skeletal Residuum



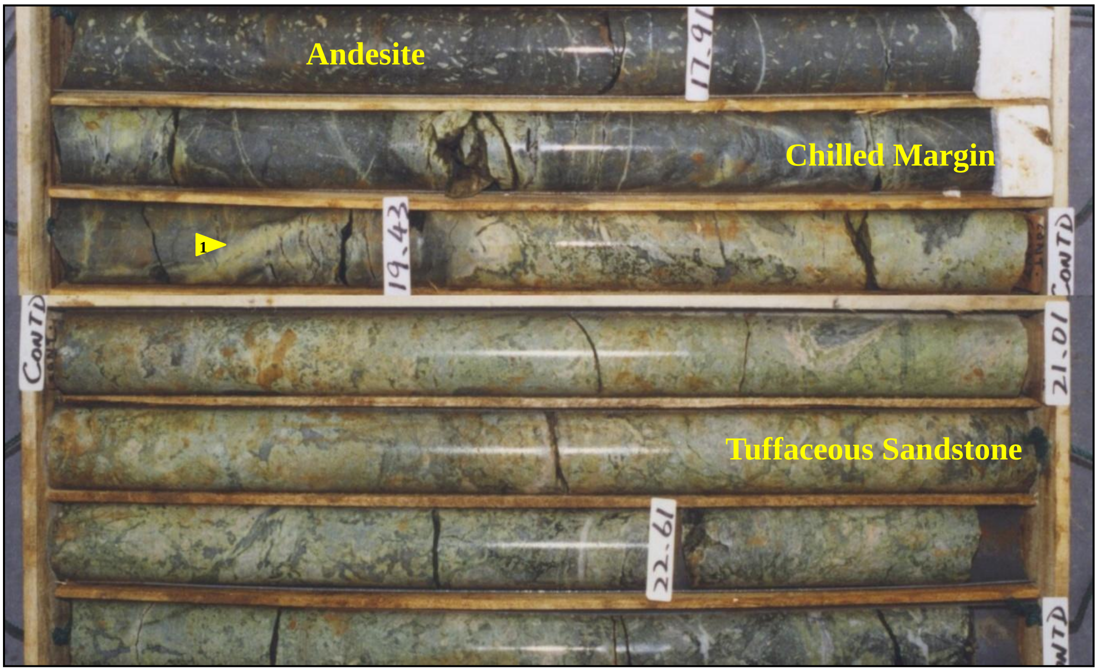
Note: Local and intense weathering zones exist in the breccia/conglomerate from 61.20 m to 61.50 m and from 62.44 m to 62.88 m depth. 'Residual soil' of the breccia/conglomerate, comprising non-intact, angular, gravel-sized rock fragments, was recovered from drilling. (Southwest of Tin Shui Estate, Tin Shui Wai, Drillhole No. 57854/HSK-ABH8, Boxes 9 to 11)

Figure A37 'Residual Soil' of Mylonitic Marble Breccia/Conglomerate

Table of Contents
Table of Contents
Table of Contents
Table of Contents

A.9 Propylitic Alteration and Greisenisation

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note: Propylitic alteration has taken place in the tuffaceous sandstone close to the intrusive contact (arrow 1) with andesite. (Tuen Mun Area 52, Drillhole No. 26748/TMA98, Boxes 2 and 3)

Figure A38 Altered Tuffaceous Sandstone, and Andesite

Note: Greisenisation of the tuffaceous siltstone, most likely associated with a granitic intrusion in the vicinity, is revealed by the dark greyish brown mottled dark grey, muscovite-quartz assemblage. (Tuen Mun Area 54 Sites 1 and 1A, Drillhole No. 61016/ADH17, Box 4)

Figure A39 Altered Tuffaceous Siltstone

Table of Contents
Table of Contents
Table of Contents
Table of Contents

A.10 Distribution of Key Lithologies of the Tuen Mun Formation

Table of Contents
Table of Contents
Table of Contents
Table of Contents

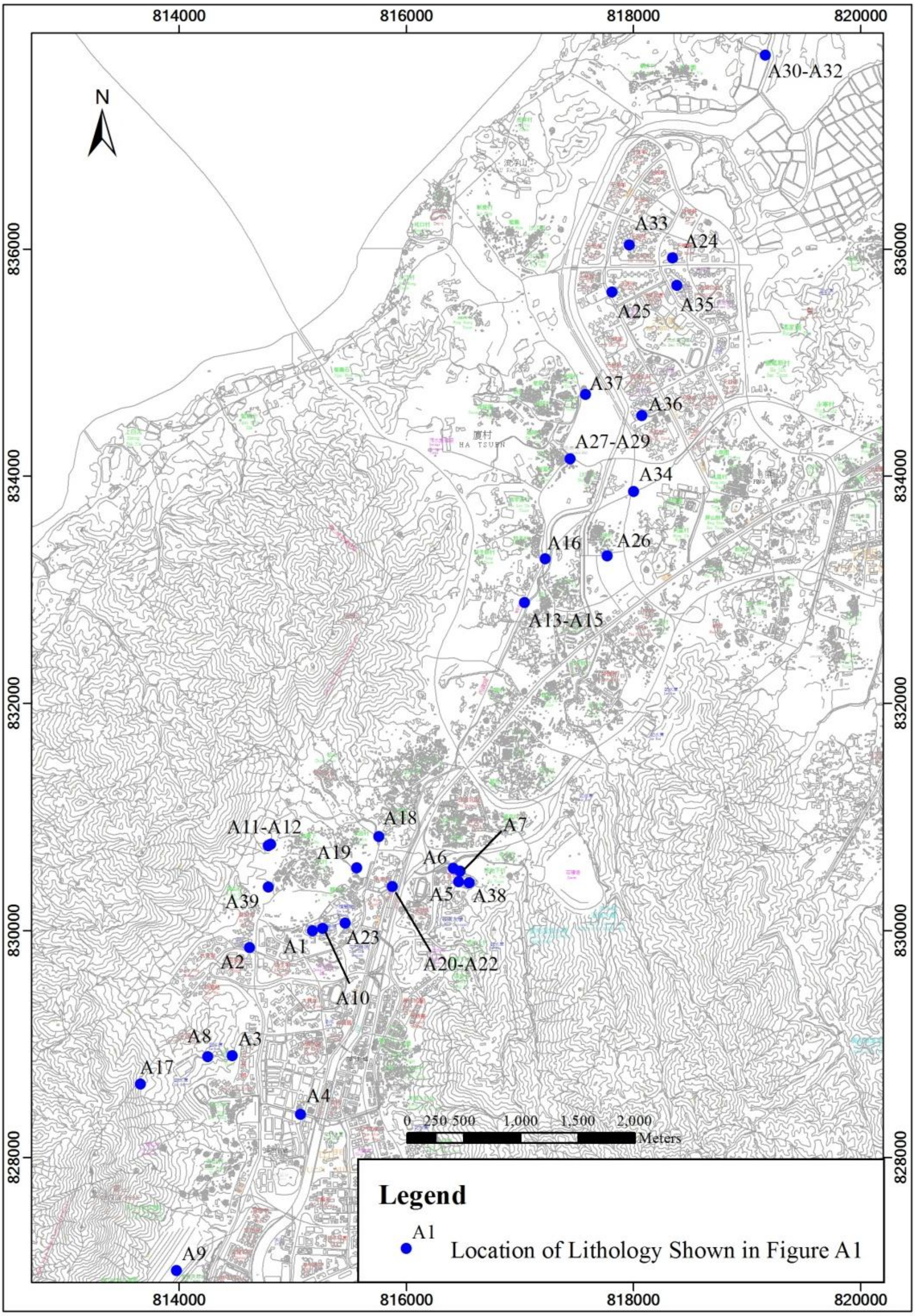


Figure A40 Distribution of Key Lithologies of the Tuen Mun Formation

Table of Contents
Table of Contents
Table of Contents
Table of Contents

GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except geological maps and other publications which are free of charge) can be purchased either by:

Writing to
Publications Sales Unit,
Information Services Department,
Room 626, 6th Floor,
North Point Government Offices,
333 Java Road, North Point, Hong Kong.

or

- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at http:// www.bookstore.gov.hk
- Downloading the order form from the ISD website at http://www.isd.gov.hk and submitting the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

書面訂購
香港北角渣華道333號
北角政府合署6樓626室
政府新聞處
刊物銷售組

或

- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
- 進入網上「政府書店」選購，網址為 http://www.bookstore.gov.hk
- 透過政府新聞處的網站 (http://www.isd.gov.hk) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真：(852) 2523 7195)
- 以電郵方式訂購 (電郵地址：puborder@isd.gov.hk)

1:100 000, 1:20 000 and 1:5 000 geological maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
Tel: (852) 2231 3187
Fax: (852) 2116 0774

讀者可於下列地點購買1:100 000、1:20 000及1:5 000地質圖：

香港北角渣華道333號
北角政府合署23樓
地政總署測繪處
電話: (852) 2231 3187
傳真: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports and other publications which are free of charge should be directed to:

For Geological Survey Sheet Reports which are free of charge:
Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
E-mail: jsewell@cedd.gov.hk

For other publications which are free of charge:
Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5346
Fax: (852) 2714 0275
E-mail: florenceko@cedd.gov.hk

如欲索取地質調查報告及其他免費刊物，請致函：

免費地質調查報告:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: jsewell@cedd.gov.hk

其他免費刊物:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5346
傳真: (852) 2714 0275
電子郵件: florenceko@cedd.gov.hk

Table of Contents
Table of Contents
Table of Contents
Table of Contents

MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 302 p. (English Version), (Reprinted, 2011).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.
Geoguide 7	Guide to Soil Nail Design and Construction (2008), 97 p.

GEOSPECS

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.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.
GEO Publication No. 1/2007	Engineering Geological Practice in Hong Kong (2007), 278 p.
GEO Publication No. 1/2009	Prescriptive Measures for Man-Made Slopes and Retaining Walls (2009), 76 p.
GEO Publication No. 1/2011	Technical Guidelines on Landscape Treatment for Slopes (2011), 217 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents