APPENDIX A

NATURE AND OCCURRENCE OF HONG KONG ROCKS AND SUPERFICIAL DEPOSITS

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CONTENTS

A.1 INTRODUCTION

Rocks and soils may be described for engineering purposes by the methods given in Chapters 2 and 3 respectively. The purpose of this Appendix is to explain the nature and occurrence of Hong Kong rocks and superficial deposits from the geological viewpoint.

Geological classifications of natural earth materials are based on characteristics such as lithology, chemistry, mode of formation and occurrence, and age. On the geological maps of the Hong Kong Geological Survey, a distinction is made between the solid lithified rocks, which include their insitu weathered mantles, and the transported superficial deposits. To most geologists, soil is the natural material which occurs above the lower limit of biological activity, and it is not included on the geological maps; an engineer tends to refer to this material as 'topsoil'. The differences between the engineering and geological uses of the terms 'rock', 'soil' and 'superficial deposits' are discussed in Section 1.2.1.

Solid rocks are classified into the following four broad types, based on their mode of formation :

(a) Igneous, which are crystalline or glassy rocks that are formed by the solidification of molten material known as 'magma'. They are either intrusive, solidifying beneath the earth's surface, or extrusive, erupting at the surface before cooling.

(b) Sedimentary, which are formed either from fragmented rock or material particles that have been transported by gravity, water, wind or ice, or from chemical precipitates from solutions or secretions by organisms. Sediments are often well stratified or have structures which indicate their mode of deposition.

(c) Pyroclastic, which are formed of fragments and particles of magma and pre-existing rocks that are ejected explosively from a volcano and which settle at the surface by sedimentation through air or water. These rocks share some features of both sedimentary rocks (i.e. they are fragmental and may be stratified) and igneous rocks (i.e. they are erupted at the surface).

(d) Metamorphic, which are derived from pre-existing rocks by mineralogical, chemical and structural changes. Metamorphism is caused by the effects of changing temperature, pressure, shearing stress and chemical environment acting on solid rocks.

Superficial deposits commonly mantle and obscure the underlying, older solid rocks. Most superficial deposits are sediments which, because they are geologically very young, have not yet been lithified to form solid sedimentary rocks. Both solid rocks and superficial deposits can be modified by weathering.

The following sections give a brief account of each of the four broad rock types and of the superficial deposits, plus some general information on structural geology and weathering. More detailed information of specific relevance to Hong Kong can be obtained from Bennett (1984a, 1984b, 1984c) and from numerous other references given by Brand (1988). The most detailed accounts of the distribution and nature of geological materials in Hong Kong are given in the series of maps and memoirs produced by the Hong Kong Geological Survey. The geological classification of rocks and superficial deposits used in the maps and memoirs is given in Table A1. All the rock types found in Hong Kong are illustrated in Plate A1.

Additional information on geological processes, and on the geological and engineering classifications of rocks and soils, can be found in the sources listed in Sections A.9 and A.10. In particular, the importance of geological processes in engineering has been well reviewed by Blyth & de Freitas (1984) and Leggett & Karrow (1983).

As with the remainder of this Geoguide, the meanings of all the specialised geological terms used in the following sections are given in the Glossary. Most of the entries in the Glossary are based on the definitions given by Bates & Jackson (1980).

A.2 IGNEOUS ROCKS

A.2.1 Nature

Igneous rocks are formed by the solidification of magma. They may be extrusive or intrusive, and these two types are distinguished by the large-scale form of the rock mass and its relationship to adjacent rocks. As this form may not always be readily apparent, the rock names used are not dependent on mode of occurrence (e.g. it is possible to have a basalt intrusion or a basalt extrusion). The normal methods of classifying igneous rocks are based on the relative abundance of selected minerals and the chemical composition. This is often supplemented by studies of the texture, as seen in the field and under a microscope.

A.2.2 Occurrence

Intrusive igneous rocks, which are very common in Hong Kong, are usually markedly crystalline. The grain size can vary from very fine (< 0.06 mm) to coarse (> 6 mm), and may be pegmatitic (> 20 mm). The intrusions of granite found in Hong Kong usually display a wide range of grain sizes, indicating a complex cooling history. In the simplest cases, the cooling of an intrusion results in a finer-grained margin near the contacts with other rocks. Minor intrusions, which are usually very fine-grained, may occur as dykes, which are near vertical, or as sills, which are roughly flat-lying. These small intrusions cut the older rocks in which they are found.

Extrusive igneous rocks, more generally described as 'lavas', have flowed from a volcanic vent or fissure. Lavas may occur as a single flow or a succession of flows, and may be interbedded with sediments.

A.2.3 Composition

The composition of igneous rocks, which is the basis for their classification, can be described in terms of the minerals present or the chemical composition. Most igneous rocks are derived from magma rich in silica, so nearly all the minerals are silicates. The commonest are quartz and feldspar (felsic), which are light in colour, but distinctive dark minerals (mafic), such as biotite, can alter the appearance of a rock when present in small amounts. Thus, a simple division of the igneous rocks based on mineral content can be made in terms of colour : leucocratic (light), mesocratic (medium) and melanocratic (dark).

The most widely-used classification of the crystalline igneous rocks (Streckeisen, 1974) is based on the relative proportions of quartz (Q), alkali feldspar (A) and plagioclase feldspar (P), from which such common names as granite, granodiorite and gabbro are defined. The proportions of these minerals are obtained by modal analysis, i.e. by measuring the actual percentage mineral composition, and the results are plotted on a QAP triangular diagram (Figure A1). The very fine or glassy igneous rocks, whose individual crystals cannot be distinguished, are classified on the basis of chemical composition (Cox et al, 1979). The rock types defined, such as rhyolite, dacite and basalt, have their equivalents in the QAP classification (Streckeisen, 1980). These equivalents are given in Figure A1, but, because different methods of classification are used, the correspondence with the chemical classification is not exact.

A.2.4 Chemical Types

Igneous rocks can be grouped together in related families based on their chemical composition. If the composition is not known in detail, the following simple system of classification can be used for Hong Kong rocks :

(a) Basic rocks, which are melanocratic, with usually more than about 30% dark minerals, and 44 to 54% silica (e.g. gabbro).

(b) Intermediate rocks, which are usually mesocratic, with less than 50% dark minerals, and 54 to 62% silica (e.g. andesite and syenite).

(c) Acid rocks, which are often leucocratic, with less than 20% dark minerals and more than 62% silica (e.g. granite and granodiorite).

A.2.5 Textures

The texture of an igneous rock is concerned with the size, shape and disposition of the constituent minerals. Intrusive rocks are predominantly crystalline, with grain boundaries interlocked, while extrusive rocks, which have cooled rapidly at the surface, are partly or dominantly glassy.

The textural feature of most importance in igneous rock classification is the dominant grain size of the groundmass. The very fine-grained rocks, (aphanitic), with a grain size of less than 0.06 mm, have crystals that cannot be distinguished with the naked eye. For larger grain sizes, there is a division into fine-, medium-, and coarse-grained rock (Table A1). The very coarse-grained (pegmatitic) rocks have grains larger than 20 mm.

Within the groundmass, there are often significantly larger crystals, termed 'megacrysts'. There is a wide variety of megacrystic textures, each indicating a different mode of occurrence of the megacryst, for example porphyritic and xenocrystic. Megacrysts may be aligned parallel to the flow direction in a rock; this is commonly seen in the syenites and monzonites, and also in lavas and narrow dykes. Where these textural differences result in a visible layering or banding, an igneous rock is said to have a 'flow-banded' structure.

A.2.6 Alteration

At a late stage in the crystallization of an igneous rock, the release of accumulated hot liquids and gases may alter the rock extensively. A typical example is kaolinization of granite, in which the feldspar is altered to kaolinite. Alteration is usually controlled by existing discontinuities in the rock mass, and there may be a gradation from, for example, completely altered granite adjacent to a discontinuity outwards into fresh granite.

A.2.7 Named Varieties

The varieties of igneous rocks found in Hong Kong are listed below. These notes are intended to highlight the differences between varieties.

(a) Granite, which is the most widespread igneous rock type, is a leucocratic, silica-rich (acid), crystalline rock composed of quartz, feldspar and dark biotite mica. The dominant feldspar is usually alkali. Granite forms major and minor intrusions, including very narrow dykes. Aplite dykes are generally granitic in composition, and are characterised by an equigranular fine-grained texture. Pegmatite is also usually granitic in composition, but is characteristically very coarse-grained.

(b) Granodiorite is a mesocratic, silica-rich (acid), crystalline rock composed of quartz, feldspar and abundant biotite (which results in a darker colour than granite). The dominant feldspar is plagioclase. Granodiorite forms major intrusions, typically seen at Tai Po, and sometimes forms dykes.

(c) Quartz syenite is a leucocratic to mesocratic crystalline rock with intermediate silica content, in which there is less than 20% quartz. The rock is mostly feldspar, with alkali feldspar dominant. The rock occurs as intrusions, for example at D'Aguilar Peak, and as large dykes, for example at Wong Chuk Hang. Quartz monzonite is related to quartz syenite, but plagioclase and alkali feldspar are present in roughly equal amounts. Examples can be found at Tai Wai, Sha Tin.

(d) Rhyolite is the very fine-grained equivalent of granite. The megacrysts of quartz (quartzphyric) or feldspar (felsparphyric) give the different rhyolites their character. Rhyolite is found as narrow dykes, for example at Kwai Shing and the Lower Shing Mun Reservoir, and as lava flows in the Clear Water Bay Peninsula and the Sai Kung Country Park.

(e) Dacite is the mesocratic, very fine-grained equivalent of granodiorite. There are usually megacrysts of quartz and feldspar, and biotite is often clearly seen. Dacite is either associated with the rhyolite as narrow dykes, as on Tsing Yi, or forms the margin to the granodiorite. Rocks which cannot be distinguished as either rhyolite or dacite are called 'rhyodacite', and can be seen on Mt. Stenhouse, Lamma Island.

(f) Quartz trachyte is the mesocratic, very fine-grained equivalent of quartz syenite. The rock is characterised by alkali feldspar megacrysts. It occurs as dykes, for example at Aberdeen, and on the margins of quartz syenite intrusions, as at Cape D'Aguilar. Quartz latite, the very fine-grained equivalent of quartz monzonite, is a related rock.

(g) Trachyandesite is intermediate, usually melanocratic and is very fine-grained. Megacrysts of alkali feldspar are common. It is found as lava flows in the Clear Water Bay area.

(h) Andesite is intermediate, usually melanocratic or mesocratic, and is very fine-grained. Megacrysts of feldspar and mafic minerals are common. Andesite is found as lava flows within the tuffs, as at Ma Wo (Tai Po) and Tuen Mun, and as dykes, as at Tsing Lung Tau.

(i) Gabbro and its very fine-grained equivalent, basalt, are basic, melanocratic rocks composed of an intergrowth of plagioclase feldspar and mafic minerals. These rocks are commonly found as narrow dykes; for example, gabbro at Diamond Hill and basalt at Siu Lam.

(j) Lamprophyre is a basic, melanocratic rock characterised by the abundance of mafic minerals, with feldspar only present in the groundmass. It is occasionally found as narrow dykes, for example at Rennies Mill.

A.3 PYROCLASTIC ROCKS

A.3.1 Nature

Pyroclastic rocks are formed by the lithification of material which has been ejected explosively from a volcanic vent. Materials from non-explosive volcanic eruptions are lavas, which are classified as igneous rocks (see Section A.2.2). Pyroclastic rock material is composed of glass and pumice, broken crystals and rock fragments. The rock fragments may be solidified magma from the vent, or material which formed the sides of or choked the vent. The majority of the material in a pyroclastic rock is of igneous origin, but since the rock is composed of fragmental material and is sedimented, it is classified in a manner similar to that used for sedimentary rocks.

A.3.2 Composition

The normal method of classifying pyroclastic rocks is on the basis of composition and size range of the individual components or pyroclasts (Figures A2 and A3). Pyroclastic rocks may contain sedimentary material. Rocks with roughly equal amounts of pyroclastic and primary sedimentary material are 'tuffites', and are usually given the sedimentary rock name with 'tuffaceous' as a prefix (e.g. tuffaceous sandstone).

The largest pyroclasts are blocks and bombs, and, when lithified, become 'pyroclastic breccia' and 'agglomerate' respectively (Figure A3). Lapilli, equivalent in sediment grain size to gravel, are lithified to a 'lapilli tuff', less commonly called 'lapillistone'. Ash, which is equivalent in grain size to sand and mud, is lithified to 'coarse ash tuff' and 'fine ash tuff' respectively. It is very common to find poorly-sorted rocks containing a mixture of different-sized pyroclasts, and these are covered by the names 'tuff-breccia', 'lapilli-ash tuff' and 'ash-lapilli tuff'. When the composition is known in greater detail, it is possible to refine this nomenclature to give such rocks as 'lapilli-coarse ash tuff' and 'coarse ash-fine ash tuff'.

Pyroclastic rock names are qualified by a term which reflects the composition of the dominant variety of pyroclast. This is either 'vitric' (glass), 'crystal' or 'lithic', but in rocks older than Tertiary (c. 60 million years) it is very unlikely that glass will survive, as it rapidly becomes stable and microcrystalline. Therefore, in the pyroclastic rocks of Hong Kong, which are Jurassic in age (much older than the Tertiary), the term 'vitric' is used to describe fragments that are recognized from their shape and texture to have been glass when the rock was first deposited. An example of such a rock is eutaxite, a variety of vitric tuff, which is found, for example, on Mt Kellett and Razor Hill. The terms 'crystal' and 'lithic' refer to pyroclasts composed of crystals (or crystal fragments) and rock fragments respectively.

A.3.3 Types

Pyroclastic fragments are created by the explosive expansion of gases in a magma, by fragmentation of adjacent magmatic rocks from previous volcanic eruptions, or by the break-up of the basement rocks under the volcanic vent or fissure. On ejection from the vent or fissure, the fragments become either 'fallout deposits' or 'pyroclastic flow deposits', as follows :

(a) Fallout deposits have many structures that resemble those of sedimentary rocks. They are generally well-sorted when deposited in water, with well-defined, rapidly alternating beds. Such deposits are found in Hong Kong, but they are rare, only being seen at Lai Chi Chong, Sham Chung and Clear Water Bay.

(b) Pyroclastic flow deposits are formed of hot, gaseous, dense masses of material that move rapidly away from a volcanic vent. The material is usually a highly concentrated mixture of gases and solids. The resultant deposit may be stratified, but in Hong Kong it more usually forms massive, poorly-sorted units of great thickness. Most of the thick sequences of poorly-sorted tuffs in Hong Kong originated as pyroclastic flow deposits. However, the process of welding, in which there is viscous deformation of vitric fragments, can result in marked planar fabrics, which is a characteristic of eutaxite. When water has de-stabilised an existing unlithified pyroclastic deposit, the resulting water-transported, poorly-sorted material is known as a 'laharic' deposit. Both pyroclastic flows and, to a lesser extent, lahars are found in Hong Kong; the latter, for example, at Hong Lok Yuen.

A.4 SEDIMENTARY ROCKS

A.4.1 Nature

Sediment is produced by the weathering and erosion of pre-existing rocks, or by chemical or biochemical precipitation. Sedimentary rocks produced by the lithification of the transported products of weathering are termed 'detrital' sedimentary rocks. Those produced by chemical precipitation or biochemical action are 'chemical' and 'biochemical' sedimentary rocks; for example, salt deposits and limestone. Generally, when a sediment has been deposited but not lithified, it is called a 'superficial deposit' (see Section A.6).

Sediments, and the rocks produced from them, are classified on the basis of the size of the constituent particles, mineralogical composition and origin. The system adopted by the Hong Kong Geological Survey is based on the 2-6 grain size divisions which are commonly used for the engineering description of soils (Table A1).

A.4.2 Detrital Sedimentary Rocks

A.4.2.1 Types

Detrital sedimentary rocks are divided on the basis of grain size into 'rudaceous' (gravelly), 'arenaceous' (sandy) and 'argillaceous' (clayey and silty).

A.4.2.2 Rudaceous Rocks

Lithified deposits of gravel, which may include cobbles and boulders, are called 'conglomerate' when the particles are rounded, and 'sedimentary breccia' when they are angular. The coarse particles may all be one type of rock, or they may be derived from more than one source rock. The matrix, which is subordinate, is either sand or silt and may be cemented. Conglomerates can be found at Harbour Island and at Brides Pool, and sedimentary breccias on Yim Tin Tsai in Tolo Harbour. Sedimentary breccia is so-called to distinguish it from fault breccia, pyroclastic breccia and other genetic types.

A.4.2.3 Arenaceous Rocks

Lithified deposits of material in which sand is the dominant grain size are sandstones. There is commonly fine material (silt or clay) between the sand grains, and when the amount of this finer matrix is less than 15%, the sandstone is called an 'arenite'. When the matrix exceeds 15%, the rock is a 'wacke'. The cement which binds the sand particles together to form a rock is either silica, iron oxides, clay or carbonates.

Arenaceous rocks in Hong Kong can be split into the following four main types :

(a) Quartzose sandstone is nearly all quartz, cemented by silica. It is generally well-sorted, well-rounded and clay-free, probably being composed of material that has travelled a long way from the source rock. Examples can be seen on Bluff Head.

(b) Feldspathic sandstone contains many feldspar grains, indicating relatively rapid erosion and deposition close to the source. Examples can be seen at The Chinese University and Tai Po Kau.

(c) Lithic sandstone is very variable, containing recognizable fragments of other rocks. Although usually associated with rivers, it can be deposited in any environment. Examples can be seen at Sham Chung and on Yim Tin Tsai.

(d) Calcareous sandstone is a sandstone cemented by calcareous material in which the clasts are not themselves calcareous. An example is the beach rock containing tuff clasts and calcareous cement found at Tau Chau, Repulse Bay.

A.4.2.4 Argillaceous Rocks

Both siltstone and claystone can be recognized in Hong Kong, but, because of the difficulty in distinguishing grain sizes of lithified material, it is usual to restrict the term 'siltstone' to rocks composed of the coarser silt grains, and to use 'mudstone' or 'shale' for all finer mixes. Mudstones are non-fissile, while shale is fissile; shale should not be confused with slate, which has a metamorphic fissility (cleavage). Apart from fissility, the important characteristics of the argillaceous rocks are colour, sedimentary structures and non-clay material (e.g. sand grains, organic matter, fossils). Good examples of siltstones are found on Ping Chau. Mudstones can be seen at Fei Ngo Shan, and graphite-bearing mudstones can be found on Mo To Chau.

A.4.3 Chemical and Biochemical Sedimentary Rocks

A.4.3.1 Types

The dominant types of chemical and biochemical rocks are limestones (calcium carbonate) and dolomites (calcium magnesium carbonate). There are also siliceous rocks and evaporites in this group.

A.4.3.2 Limestone and Dolomite

Although essentially chemical or biochemical in origin, these rocks may contain fragmented material, e.g. broken calcareous fossils. Non-carbonate material, such as sand grains and chert, may also be present in small amounts. Limestone occurs in Hong Kong beneath the alluvium in the Yuen Long area.

Most of the limestone has been metamorphosed to marble. Dolomite is found offshore from Ma Shi Chau and possibly in the Ma On Shan mine.

A.4.3.3 Chert

Chert is an organic or inorganic precipitate of silica; the silica is mostly cryptocrystalline quartz, but may be amorphous in part (opal). Impurities in chert give it different colours, and flint is synonymous with one of the darker varieties. Chert is either bedded or nodular; nodular chert is common in limestone, and bedded chert can be found on Ping Chau. Chert lenses associated with pyroclastic rocks are found on the western shores of Junk Bay.

A.4.3.4 Evaporites

Evaporites include gypsum, anhydrite and halite. They are often associated with mudstones and siltstones, forming in shallow basins which are periodically flooded and dried out; this association can be seen on Ping Chau, although only evaporite mineral pseudomorphs can be seen.

A.5 METAMORPHIC ROCKS

A.5.1 Nature

Metamorphism describes the process of production of new minerals, structures and textures in pre-existing rocks, excluding the processes of weathering. There are three types of metamorphism, based on the variables of pressure due to depth of burial, temperature, strain resulting from stress applied during deformation, and fluid pressure :

(a) thermal or contact metamorphism, characterised by high temperature, low pressure and low strain,

(b) dynamic metamorphism, characterised by high strain and high fluid pressure, and

(c) regional metamorphism, characterised by high temperature and high pressure.

These three types overlap considerably, but thermal and dynamic metamorphism are restricted to localised areas, respectively, along the edges of large intrusions and on narrow thrusts and faults.

A.5.2 Contact Metamorphism

Both heat and hot fluids from a large intrusion of igneous rock affect a narrow belt of country rock surrounding the intrusion. Thermal metamorphism takes place within this contact aureole, affecting different country rocks in different ways. Mudstones and impure carbonates show the greatest mineralogical changes, e.g. the mudstones at The Chinese University which have been affected by the major granite intrusion in the Sha Tin area. The least affected are those possessing mineral assemblages which are stable at temperatures as high as those of the intruding granite, e.g. sandstones and vitric tuffs on Victoria Peak.

In mudstones, these changes start as spotting of the rock, often caused by new mineral growth, while close to the intrusion complete recrystallisation gives a hornfels, a hard glassy rock with no fabric. Thermally metamorphosed limestones become marbles, as at Yuen Long, and skarns (calcium-bearing silicate minerals), as reported in the Ma On Shan mine. Sandstones become quartzite, e.g. at Sandy Bay, but impurities in the sediment can give small quantities of new minerals such as sillimanite, andalusite and muscovite, e.g. behind Belcher's Street, Kennedy Town.

A.5.3 Dynamic Metamorphism

The high shear stress in fault zones results in crushing of the wall rocks, allowing mobile fluids to develop high fluid pressures. Temperatures can be raised locally, but there is no regional heating. The processes and rock types associated with faulting can be split into three types :

(a) Brittle faults, which give cataclasites such as fault breccia and fault gouge. These rocks are non-foliated, and can be seen in places such as Lai Chi Kok and northwest Tai Lam Country Park.

(b) Ductile faults, which give mylonites, i.e. finely crystalline rocks containing survivor megacrysts. These rocks are generally foliated, and can be seen throughout the granite of the Castle Peak area. When green (chlorite-rich) and shiny, they are called 'phyllites', e.g. in the Lok Ma Chau Formation sediments of Mouse Island, Tuen Mun.

(c) Ductile flow, which gives metamorphic rocks characterised by a penetrative foliation such as schist. Examples of schist can be seen within the metatuffs of the northern New Territories.

Although thrusts and faults are limited in width, often a large number of them can be found in belts several kilometres wide. Shear stresses and fluid pressures in these belts can lead to the formation of such minerals as sericite (fine muscovite), pyrite and calcite. All these features can be found in the northern New Territories.

A.5.4 Regional Metamorphism

Regional metamorphism is achieved by ductile flow under high temperature and pressure in broad belts of folded or sheared rocks. A broad belt of metamorphic rocks, which includes schists, metatuffs and phyllites, occurs in the southern part of Guangdong Province and extends into the northern New Territories.

A.6 SUPERFICIAL DEPOSITS

A.6.1 Types

Superficial deposits are those sediments that have not been lithified to form rocks. The classification of superficial deposits and sedimentary rocks is essentially the same. The most important types of superficial deposits in Hong Kong are mass wasting deposits or colluvium (see below), fluvial deposits, and marine deposits. Some small quantities of organic deposits are also found.

A.6.2 Mass Wasting Deposits

In Hong Kong, mass wasting deposits (commonly called 'colluvium') are predominantly debris flow deposits and comprise heterogeneous mixtures of sediment and rock. They are formed by the rapid downslope movement of saturated masses of material, predominantly by flow (i.e. the moving mass does not contain discrete shear or slide surfaces and has the general appearance of a body that has behaved as a fluid). Other types of slope movement (e.g. rock slides, debris slides) and slow soil creep also contribute to the formation of mass wasting deposits. These deposits usually collect in valleys and at the bases of slopes, for example in the Mid-levels area. The deposits frequently grade into river deposits (alluvium) or marine deposits at the foot of a slope.

Some other, less common, types of mass wasting deposit are boulder fields and screes. Boulder fields are accumulations of boulders on a slope, which result from large pieces of rock being weathered and eroded from outcrops higher upslope, or by the eluviation of fines from a weathered mantle or from sheets of boulder-rich debris flow deposits. Boulder fields commonly grade downslope into boulder streams along valleys and depressions. Examples can be seen at Cape D'Aguilar and Lin Fa Shan. 'Talus' or 'scree' is coarse material which has weathered and fallen from a rock face and accumulated on or at the base of a slope; good examples can be seen below Lion Rock.

A.6.3 Fluvial Deposits

These deposits are collectively known as 'alluvium'. In Hong Kong two ages of fluvial deposition are recognized; Holocene alluvium, found next to existing rivers and stream courses, and older alluvium, found in higher terraces and offshore beneath the Holocene marine deposits. Both are composed of similar materials, dominantly silt, but with significant amounts of sand, gravel and clay. The older alluvium is evidence of a more extensive floodplain. Examples can be seen around Yuen Long and Shek Kong. A widespread development of this older alluvium occurs offshore, beneath marine deposits, which indicates a much lower sea-level at the time of its deposition. Small patches of alluvium can also be found on high ground, where a natural constriction in an upland valley has resulted in the valley being infilled by locally reworked colluvial debris.

A.6.4 Marine Deposits

Marine superficial deposits in Hong Kong have accumulated on older alluvial deposits and the pre-Holocene eroded rock surface. The commonest material is a light or dark grey, or greenish grey, mud. Deposits of sand are also found on the floors of contemporary deep-water channels and in other areas of strong currents. Older sand deposits can also be found buried beneath mud. Close to the present coastline, the most distinctive marine deposits are sand beaches, which are accumulations of fluvially-derived sand washed onto the shore by waves and currents. Storm beaches and raised beaches are two other beach types, but these are much less common. The former are the result of unusually high waves (e.g. due to typhoons) and the latter are remnants of older beaches associated with periods of higher sea-level. Estuarine fans and deltas of sand and silt are other types of distinctive marine deposit. Examples of beach deposits, estuarine fans and a delta can be found at Lung Kwu Tan, Tai Po and Nim Wan respectively.

A.6.5 Organic Deposits

The main type of organic deposit in Hong Kong is peat, which is a dark accumulation of organic material that has not fully decayed because of its very high moisture content. Peat is derived from organic debris which has accumulated in poorly-drained level sites. There is usually some sediment within the peat, and the depositional environment is often similar to that of river deposits. Peat can be found interbedded with sediments south-west of Yuen Long.

A.7 STRUCTURAL GEOLOGY

A.7.1 General Aspects

Geological structures in rocks and superficial deposits can be divided into faults and other fractures, and folds. Associated with folds are minor structures such as foliations, lineations and mineral fabrics.

A.7.2 Faults and Other Fractures

Rock fractures (discontinuities) are the commonest of geological structures, and can be defined as surfaces in a rock mass across which the cohesion of the rock material is lost. The two most important types of fracture are faults and joints. Where there has been visible movement along the surface, the fracture is a 'fault', otherwise it is a 'joint'. This distinction is somewhat arbitrary, since nearly all fractures involve some movement, however slight.

At or near the surface, faults can be classified into three types, depending on the orientations of the principal stresses :

(a) normal faults, with the maximum compressive stress vertical,

(b) low-angle reverse faults or thrusts, with the maximum compressive stress horizontal, and the minimum vertical, and

(c) strike-slip or wrench faults, with the maximum and minimum compressive stresses both horizontal.

Faults are often found arranged in sets (i.e. in groups with similar orientation). Major faults may have associated minor faults. Fault planes vary from single shear planes, which may be polished and smoothed, to fault zones in which the associated rocks are broken to fault breccia or fault gouge, or converted to a mylonite (see Section A.5.3).

Another feature associated with faulting is 'slickensiding'. Slickensides are polished and finely striated surfaces that result from friction along a fault plane. Although slickensides are used as movement direction indicators, they are not reliable. At best they only indicate the direction of movement during their formation, which may not be the main movement phase.

Joints commonly develop in regularly-spaced sets, which may be geometrically related to tectonic stress and the form of the rock body. However, it is virtually impossible to establish the relative ages of joints of different orientations, which makes systematic analysis difficult. The following three main types of jointing can be recognized :

(a) Tectonic joints, which are regular sets produced by regional compression or extension. Their orientation can give an indication of the stress field. They are related in origin to faults or folds, and there is often a symmetrical arrangement of these three features. In Hong Kong, such joints are well displayed in the granites, particularly at Castle Peak.

(b) Cooling joints, which result from the contraction of an igneous, pyroclastic or other heated rock body. These joints may form polygonal columns which have their axes perpendicular to the surface of the hot rock mass, but they may also be parallel to the surface of the body. A well-known example is the marked columnar jointing in the trachyandesites and welded tuffs in the High Island area of the Sai Kung peninsula.

(c) Unloading or sheeting joints, which result from expansion of the rock mass as the confining pressure is reduced, usually by erosion. These joints are usually parallel or near-parallel to the erosional surface, and are well displayed on Po Toi Island, at Cape D'Aguilar and at Siu Lam.

The surfaces of joints can vary widely in texture and may have been altered, weathered, or coated with minerals. Individual joints are usually reasonably straight, but may be curved or show sharp changes in direction. Joints close to the surface may be opened by weathering and infilled by superficial deposits or the products of insitu weathering.

A.7.3 Folds

A fold is a curve or bend in the rock structure, and its recognition requires the presence of a planar feature such as rock stratification, foliation or cleavage. Although a relatively homogeneous rock mass, such as a granite intrusion, may be folded, if there are no planar markers within the rock mass the fold cannot be seen. Fold structures may be complex when the rocks have been affected by more than one period of folding.

Folds are classified by attitude into three main types :

(a) synclines, which are folds that close downwards, with the beds younging towards the centre,

(b) anticlines, which are folds that close upwards, with the beds younging away from the centre, and

(c) neutral folds, which are folds that close sideways.

The geometry of folds can be described further by the angle of dip of the axial plane from vertical to horizontal (using the terms 'upright', 'inclined', 'overfolded' and 'recumbent'), and by the angle between the opposing fold limbs from 0° to over 120° (using the terms 'gentle', 'open', 'close', 'tight' and 'isoclinal'). These terms are defined in the Glossary.

Major folds may be many kilometres across, as is the Tolo Channel Anticline, or hundreds of metres across, as are those found on Victoria Peak. Minor folds, visible in small exposures, often mirror the form of the major folds and are then called 'parasitic' folds. Good examples of these folds can be seen on Ma Shi Chau.

A.8 WEATHERING

A.8.1 General Aspects

Weathering is the process responsible for the breakdown and alteration of materials near the earth's surface. In igneous, pycroclastic and metamorphic rocks, it is the response of rocks to lower temperatures and stresses than those that prevailed at the time they were formed. In most sedimentary rocks, whose constituent minerals have previously been weathered to some extent, it is chiefly the response of the cementing agent in the rock to atmospheric conditions (i.e. the presence of oxygen and weak acids). In superficial deposits, the weathering of individual minerals may still be continuing at the present. The weathering process can be divided into the two main categories :

(a) mechanical weathering (or disintegration), which is caused by stresses, from both within the rock and as applied externally, that disrupt the rock fabric, and

(b) chemical weathering (or decomposition), which involves chemical reactions that transform minerals to more stable forms in the new environment.

The susceptibility of different rock types to disintegration and decomposition may differ markedly. Where two or more rock types are present together, e.g. where there is an igneous intrusion into another rock, relatively more weathered rock may occur beneath or adjacent to less weathered rock, and such a sequence may be repeated.

Weathering profiles may be of considerable age on a geological time scale. Consequently, they do not necessarily reflect the response of the rocks to the present climate. Also, they may have been partly removed by subsequent erosion. Rock exposed in a recent excavation may be affected by subsequent mechanical or chemical weathering effects, or both, under prevailing climatic conditions.

A.8.2 Mechanical Weathering

Mechanical weathering is brought about chiefly by changes of stress and temperature at or near the exposed rock surface. The important physical processes involved are expansion of water on freezing in rock pores or cracks, reduction in confining stress by erosion of overlying material, and differential expansion of the rock or rock minerals when strongly heated by insolation. The expansion of certain minerals in joints is also caused by chemical reactions such as hydration and oxidation, so that in some respects mechanical and chemical weathering are not easily separated and produce similar effects. A common form of mechanical weathering is exfoliation, which is the scaling or peeling-off of flakes and curved shells of rock blocks, as can be seen at To Kwa Wan. The biological components of mechanical weathering include breakdown of rocks by plant roots and animals.

A.8.3 Chemical Weathering

Chemical weathering is brought about mainly by the action of substances dissolved in rainwater and circulating groundwater. The intensity of chemical weathering is controlled by the rates of decomposition of individual minerals and the removal of decomposed minerals from the rock. Silicate minerals, the most important rock-forming group, are broken down by hydrogen ion introduction, oxidation of ferrous to ferric ions, and hydration. Clay minerals are the chief residual products of feldspar decomposition, while clay, chlorite and limonite are produced from the decomposition of mafic minerals such as biotite. These products are commonly removed by eluviation and erosion, which allows the process of chemical weathering to progress. The biological components of chemical weathering include changes in soil pH and the formation of complex organic-mineral substances.

In limestone or marble, solution is the dominant aspect of chemical weathering. Distinctive landforms are produced, notably 'karst' topography. This is characterised by sinkholes, caves and underground drainage, and has been found buried beneath superficial deposits at Yuen Long.

A.8.4 Weathering Features

The following examples of weathering features are found in Hong Kong :

(a) Weathered mantle, which is the entire depth of the weathering profile, excluding any transported material at the top.

(b) Weathering front, which is an essentially planar surface at the downward limit of active weathering within the rock mass. A sharp well-defined weathering front is a relatively rare feature, but good examples can be seen on Tai Tam Reservoir Road.

(c) Colour banding, and the more structured spheroidal weathering, which are caused by alternating enrichment and depletion of iron oxides. Colour banding can be seen in sediments on the west side of Three Fathoms Cove.

(d) Joint hardening, caused by the migration and deposition of ferromagnesian minerals, which makes the joints stand out on erosional surfaces. Examples can be seen at Ma Shi Chau and on the east side of Deep Bay.

(e) Weathering pits, caused by the preferential weathering of different lithologies, e.g. mudstone lapilli in tuff, or of different crystals in homogeneous rocks such as granite. Examples can be seen in the tuffs north of Tsuen Wan and in granite on Hammer Hill.

(f) Mineral boxwork, which is similar to joint hardening, but in this case the hard substance is an unaltered iron mineral deposit. This can be seen in the granodiorite of Cape D'Aguilar.

(g) Tors and corestones, which are piles of jointed rocks (tors), for example as at To Kwa Wan, or single blocks (corestones). However, the term 'corestone' should be applied only to blocks within the weathered mantle which are not in contact with solid rock.

(h) Solution grooves and basins, which are normally associated with soluble rocks such as limestone, but may also develop on siliceous rocks. Examples can be seen in granite on Hammer Hill and in tuff in the Tai Po Kau Nature Reserve.

(i) Karst topography, described under chemical weathering in Section A.8.3.

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Table A1 - Classification of Solid Rocks and Superficial Deposits in Hong Kong

Superficial Deposits		Grain Size (mm)	Solid Rocks: Sedimentary Rocks – Detrital Rocks	Sedimentary Rocks – Chemical & Biochemical Rocks	Pyroclastic Rocks	Igneous Rocks	Igneous – Acid	Igneous – Intermediate	Igneous – Basic	Metamorphic Rocks – Foliated	Metamorphic Rocks – Non-Foliated
Boulders			Conglomerate / Sedimentary Breccia	Limestone and Dolomite, Evaporites	Pyroclastic Breccia		Pegmatite				Fault Breccia Quartzite Marble
		200									
Cobbles											
		60									
Gravel	Coarse				Lapilli Tuff	Coarse-grained	Granite, Granodiorite	Quartz Monzonite Quartz Syenite	* Gabbro		
		20									
	Medium					Medium-grained					
		6									
	Fine										
		2									
Sand	Coarse		Sandstone		Coarse Ash Tuff	Fine-grained	Aplite		*	Schist	
		0.6									
	Medium										
		0.2									
	Fine										
		0.06							Lamprophyre		
Silt (Mud)			Siltstone (Mudstone)		Fine Ash Tuff		Rhyolite Rhyodacite Dacite	Quartz Latite Quartz Trachyte Trachyandesite Andesite	* Basalt	Phyllite / Mylonite	
		0.002									
Clay (Mud)			Claystone (Mudstone)	Chert							

Legend :

* Equivalent to Dolerite in Allen & Stephens (1971)

Note : This table is based on the classification scheme used by the Hong Kong Geological Survey.

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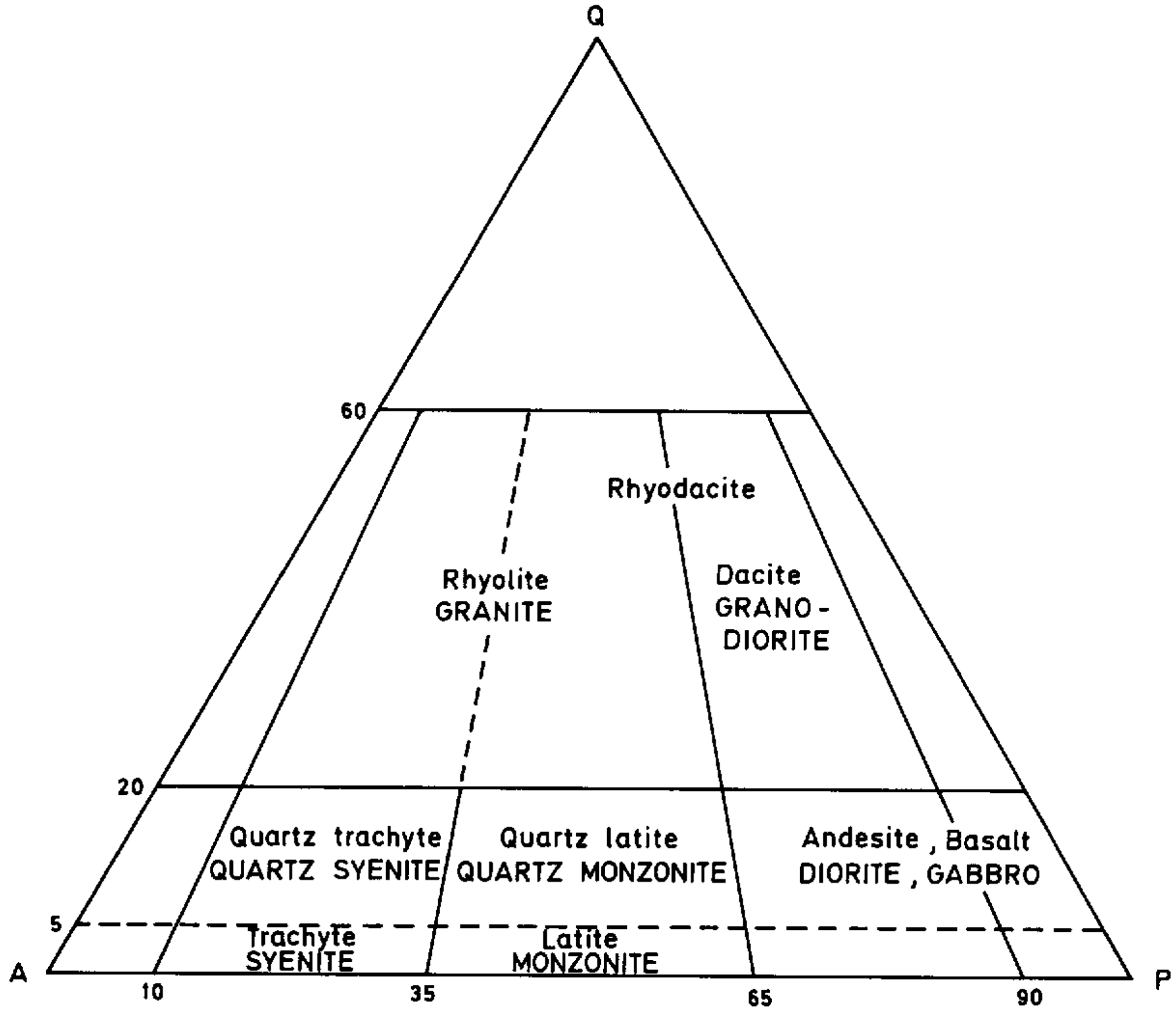


Legend :

Q	Silica minerals
A	Alkali feldspar
P	Plagioclase feldspar

Notes : (1) Plutonic in capitals; volcanic in lower case.
(2) Classification after Streckeisen (1974, 1980).

Figure A1 - Classification of Hong Kong Igneous Rocks

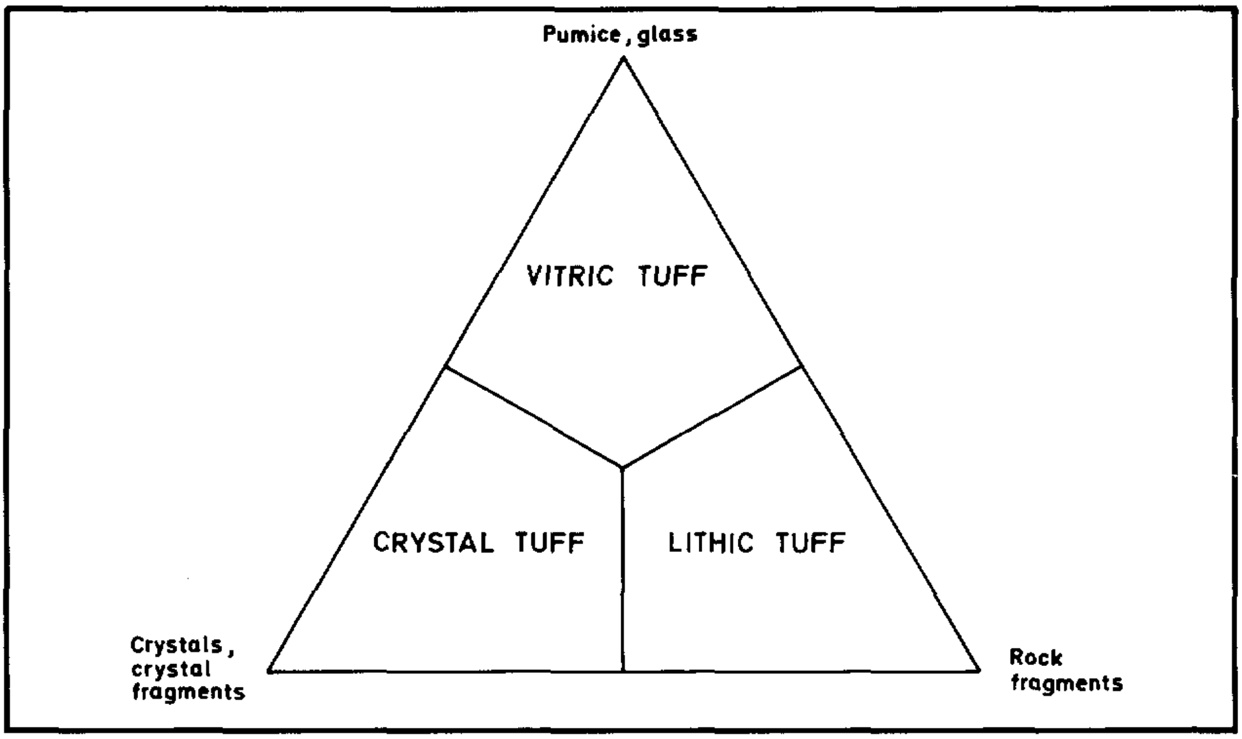
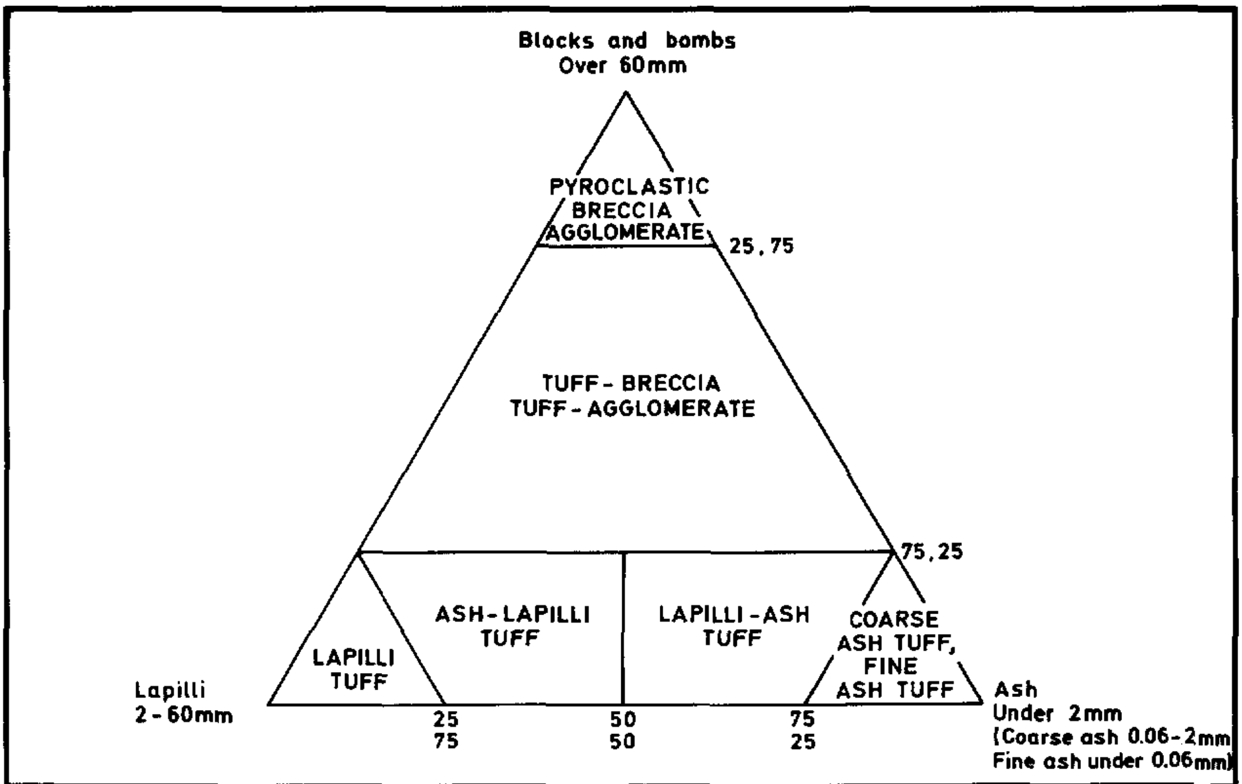


Figure A2 - Pyroclastic Rock Composition



Note : Figure adapted from Fisher and Schmincke (1984).

Figure A3 - Pyroclastic Rock Names

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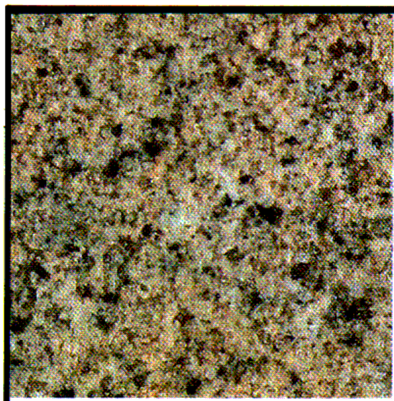
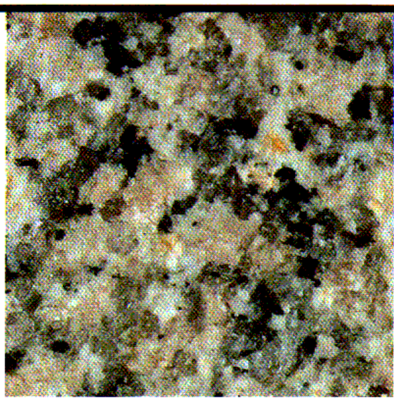
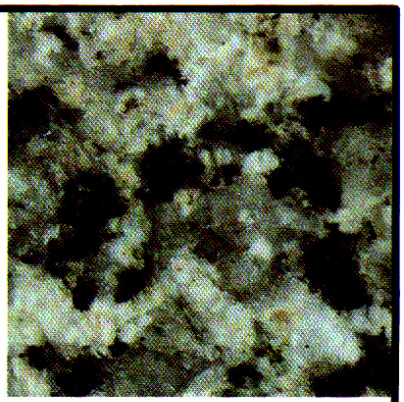


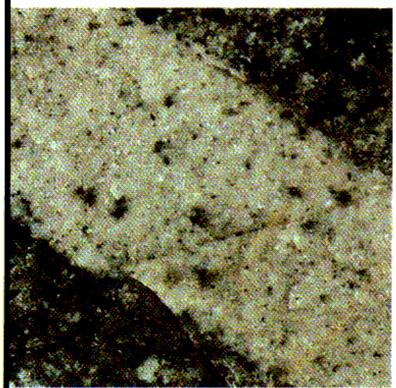
A: Fine-grained Granite



B: Medium-grained Granite

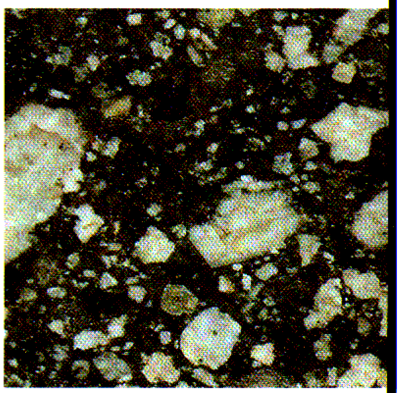


C: Coarse-grained Granite



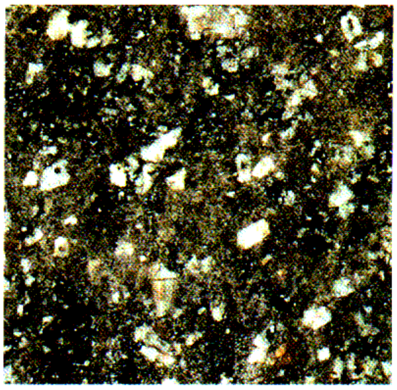
D: Aplite
(intruding granodiorite)

E: Pegmatite

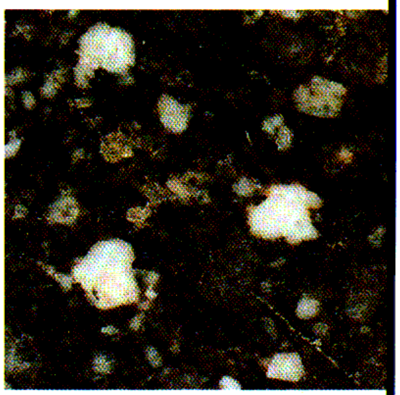


F: Granodiorite

G: Rhyolite



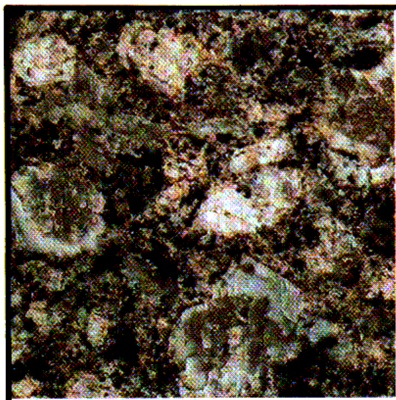
H: Rhyodacite

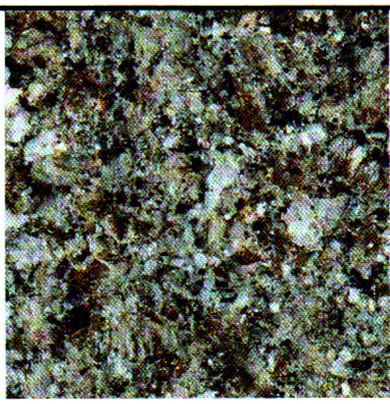


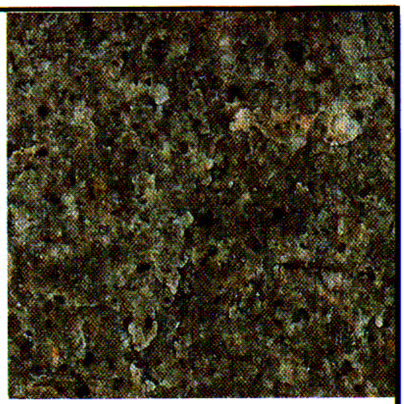
I: Dacite

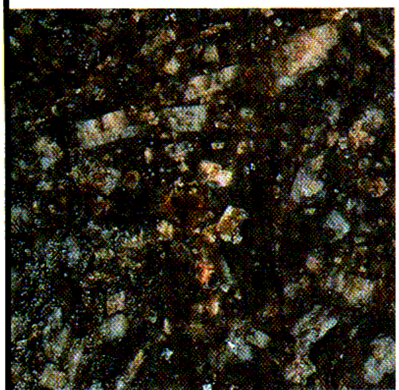
Natural scale

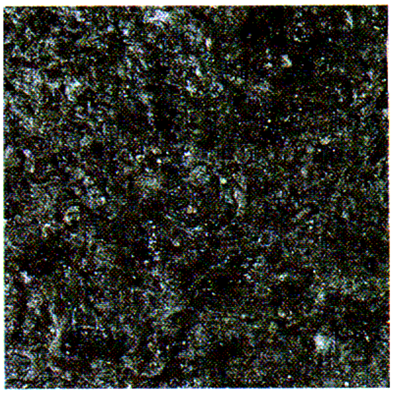
Plate A1 - Hong Kong Rock Types (Sheet 1 of 4)

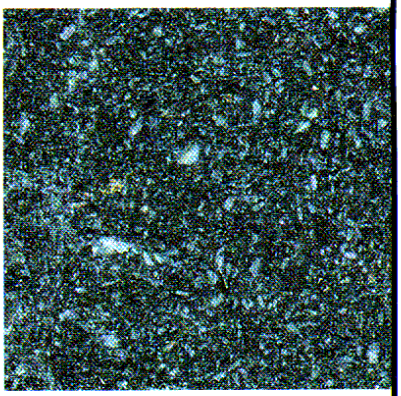

J : Quartz Monzonite

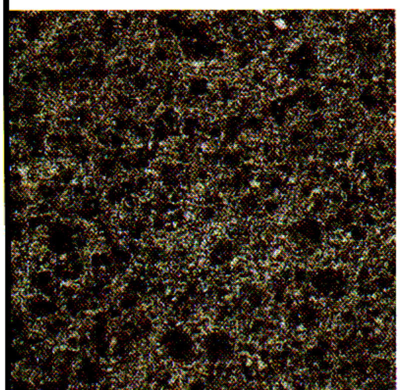

K: Quartz Syenite

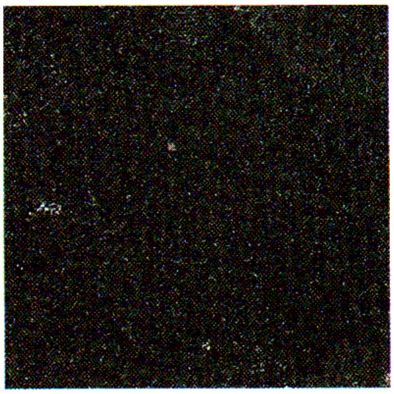

L: Quartz Latite

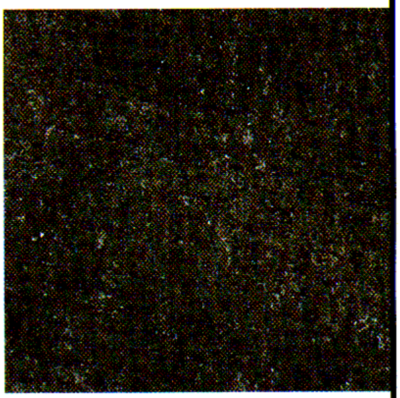

M: Quartz Trachyte


N: Trachyandesite


O: Andesite

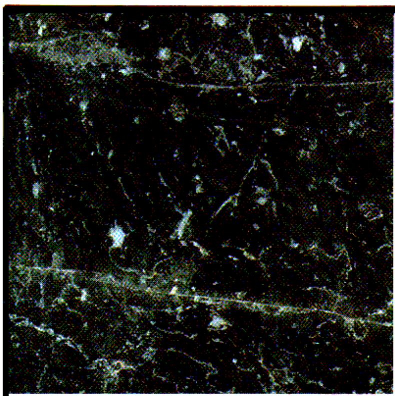

P: Gabbro


Q: Basalt

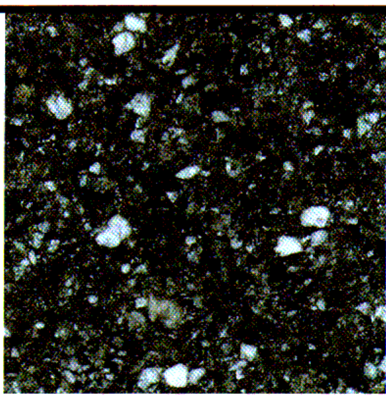

R: Lamprophyre

Natural scale

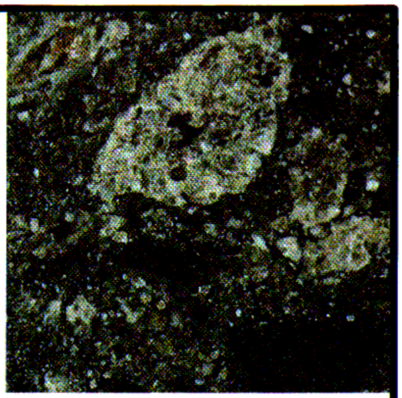
Plate A1 - Hong Kong Rock Types (Sheet 2 of 4)



S: Fine Ash Tuff

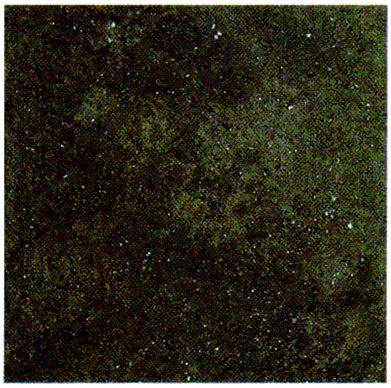


T: Coarse Ash Tuff

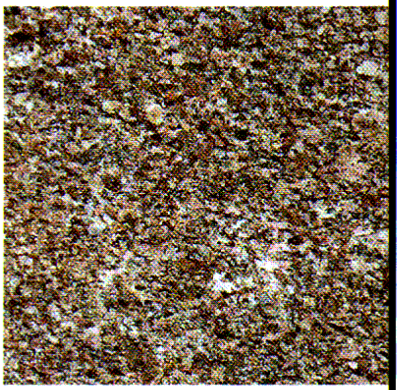


U: Lapilli Tuff

V: Pyroclastic Breccia
(× 1/2)



W: Mudstone



X: Sandstone

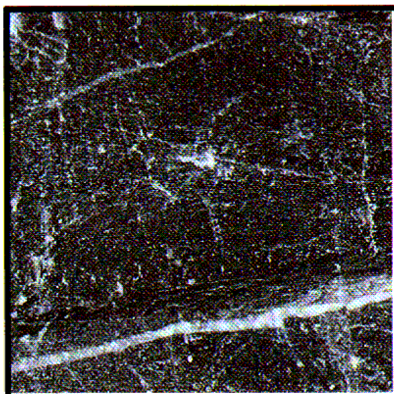
Y: Conglomerate

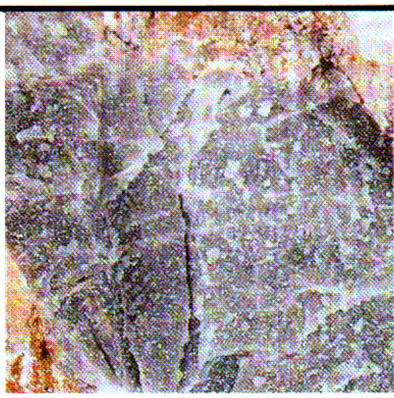
Z: Sedimentary Breccia

AA: Chert

Natural scale

Plate A1 - Hong Kong Rock Types (Sheet 3 of 4)

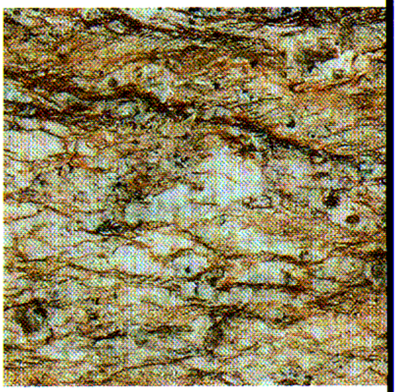

AB: Limestone

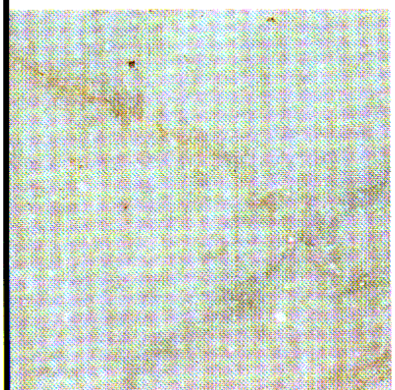

AC: Dolomite

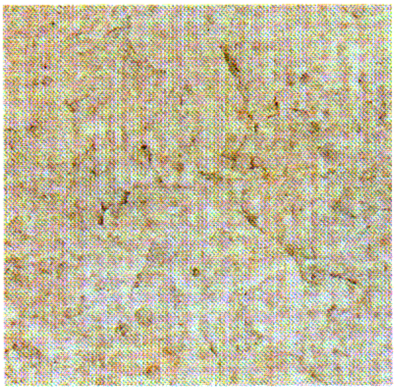

AD: Evaporite

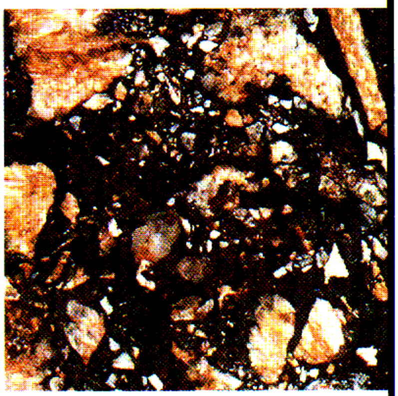

AE: Mylonite


AF: Phyllite


AG: Schist


AH: Marble


AI: Quartzite


AJ: Fault Breccia

Natural scale

Plate A1 - Hong Kong Rock Types (Sheet 4 of 4)