INTRODUCTION TO ROCKS AND MINERALS
Foreword

In 2005, the Education Bureau (EDB) announced that a three-year New Senior Secondary (NSS) curriculum would be implemented at Secondary 4 in September 2009. Geography is one of the elective subjects under the NSS curriculum.

The NSS curriculum has been developed on the basis of the recommendations made by an EDB document in 2005 and a Senior Secondary Curriculum Guide of 2007. Within the curriculum, geography is seen as a key educational discipline that provides students with a spatial understanding of the Earth on which we live and work.

At the request of the EDB, the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department have prepared support teaching materials for the NSS Geography curriculum under the topics of Natural Hazards and Earth Science. The materials written on rocks, minerals and ores in Hong Kong are also suitable for part of the Chemistry curriculum.

The "Teaching Support Materials Kit" consists of 14 booklets, 4 posters, 3 CDs and other supplementary information sheets. This teaching kit contains pertinent and up-to-date information on slope safety, landslides, geology and geomorphology in Hong Kong, written at a level that is suitable for the NSS Geography curriculum.

Hong Kong Geological Survey of GEO have compiled the teaching materials that describe the geology and geomorphology of Hong Kong. The Slope Safety Division of GEO have prepared the teaching materials on Hong Kong slope safety and landslides. Colleagues in the Slope Safety Division are also responsible for the overall planning and coordination of this project. Their contributions are gratefully acknowledged.

I am confident that, for years to come, secondary school geography teachers will find the kit invaluable for preparing their classroom teaching materials. The contents will also be of interest to the more general readers who may wish to learn more about these topics.

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引言
Introduction

我們的地球是一個由大氣圈、水文圈、生物圈及岩石圈四個主要部份組成的動力體系。這四個部份在長遠的地球歷史中，持續互相影響。地質學為一門研究岩石圈的科學，並且包含岩石圈與其他三個部份相互作用的研究。

礦物和岩石是岩石圈的重要成分。雖然礦物種類超過三千種，但只有少數為常見組成岩石的礦物，例如石英、長石、雲母、角閃石、輝石、橄欖石及方解石（岩石與礦物之一）。岩石可視乎其形成的模式，劃分為火成、沉積及變質岩三大類（岩石與礦物之一）。過去地質年代期間，岩石逐漸從一種類變成另一類，這過程稱為什麼岩石循環（岩石與礦物之二）。從常見岩石的岩理、成分及內部結構等特徵，可推斷該岩石的來源，這就是識別岩石的基礎（岩石與礦物之二）。在香港出現的岩石種類繁多，顯示區內複雜的地質情況（岩石與礦物之三）。

Our Earth is a dynamic system that comprises four main components: the atmosphere, the hydrosphere, the biosphere and the geosphere. These four components have been continuously interacting throughout the Earth’s long history. Geology is the science that studies the geosphere, and encompasses the interactions between the geosphere and the other three components.

Minerals and rocks are essential components of the geosphere. Although there are over 3,000 species of minerals, only a few of them, such as quartz, feldspar, mica, amphibole, pyroxene, olivine and calcite, occur commonly as rock-forming minerals (Rocks and Minerals 1). Rocks are classified into three main types, igneous, sedimentary and metamorphic, depending upon their mode of formation (Rocks and Minerals 1). Over geological time, rocks are gradually transformed from one type to another in what is termed the Rock Cycle (Rocks and Minerals 2). The origin of any particular rock can be determined by careful examination of its texture, composition, and internal structure, features that form the basis of rock identification and classification (Rocks and Minerals 2). The large variety of rock types present in Hong Kong reflects the complexity of the geology of the region (Rocks and Minerals 3).
礦物

礦物是岩石的基本成分，是天然形成的無機物質。它們由特定化學元素組成，原子按照規律地重複構成晶體結構。

砂礫礦物是地球表面的岩石中所含最豐富的成分，佔地殼物質的33%。砂礫礦物的基本成分是二氧化硅（SiO₂）（圖1）。

礦物的分類及鑑定

礦物是以其化學成分分類。

礦物按照其物理性質，如堅硬度、光澤、顏色、解理、斷口及相對密度來鑑別。這些特性主要由礦物的原子結構（晶體結構）決定。

構成岩石的常見礦物

- **石英（圖2）**
  - 石英，常稱鈣。是地殼中最常見的礦物之一。
  - 石英由化合物二氧化硅形成。
  - 石英的晶體多呈六角及棱柱形狀。
  - 純石英是無色的。但它含有雜質時，則會呈現各種不同的顏色，如紫、粉色或橙色。
  - 石英是製造玻璃的原料。

礦物

- **矿物**

  - **What are Minerals?**

    Minerals are the fundamental components of rocks. Minerals are naturally occurring inorganic substances with a specific chemical composition and an orderly repeating atomic structure that defines a crystal structure.

    Silicate minerals are the most abundant components of rocks on the Earth's surface, making up over 90% by mass of the Earth's crust. The fundamental chemical building block of silicate minerals is the chemical compound silicon dioxide, SiO₂ (Figure 1).

    The common non-silicate minerals, which constitute less than 10% of the Earth's crust, include carbonates, oxides, sulphides, phosphates and salts. A few elements may occur in pure form. These include gold, silver, copper, bismuth, arsenic, lead, tellurium and carbon.

    Although 92 naturally occurring elements exist in nature, only eight of these are common in the rocks of the Earth's crust. Together, these eight elements make up more than 98% of the crust.

    The eight most common elements in the Earth's crust (by mass) are:

    | Mineral | Mass (%) |
    |---------|----------|
    | Oxygen (O) | 46.6% |
    | Silicon (Si) | 27.7% |
    | Aluminium (Al) | 8.1% |
    | Iron (Fe) | 5.0% |
    | Calcium (Ca) | 3.6% |
    | Sodium (Na) | 2.8% |
    | Potassium (K) | 2.6% |
    | Magnesium (Mg) | 2.1% |

Common Rock-forming Minerals

- Quartz (Figure 2)
  - Quartz, which is usually called silica, is one of the most common minerals in the Earth's crust.
  - Quartz is made up of silicon dioxide (SiO₂).
  - Quartz crystals are usually hexagonal and prismatic in shape.
  - Pure quartz is colourless, although the presence of impurities may give a range of colours, such as violet, pink and orange.
  - Quartz is the raw material for making glass.
斜長石（圖3）
- 斜長石是含有豐富鈣質或鈣質的長石。
- 其化學成分組合範圍從鈉鋁硅酸鹽（NaAlSi_3O_8）至鈣鋁硅酸鹽（CaAl_2Si_2O_8）。
- 斜長石的晶體多呈短而粗的橢柱狀。
- 斜長石通常呈白至灰白色，並顯出玻璃光澤。
- 斜長石是製造搪瓷的重要工業礦物原料。

雲母（圖6）
- 雲母屬砂漿質礦物。
- 雲母由鈣、鈣及鉀，以及鎂、鈣和水份這些不同成分組成。
- 雲母的晶體多呈片狀，可沿其解理面分裂為平滑片狀，形如書本的薄頁。
- 雲母是侵入性火成岩中常見的礦物，亦見於沉積岩及變質岩。
- 黑雲母（圖5）色澤深，帶黑或黑色，而淺色或透明的雲母則稱為白雲母（圖6）。

Plagioclase feldspar（圖3）
- Plagioclase feldspar is a sodium- or calcium-rich feldspar. The chemical composition ranges from sodium aluminium silicate, NaAlSi_3O_8, to calcium aluminium silicate, CaAl_2Si_2O_8.
- Plagioclase feldspar crystals usually occur as stubby prisms.
- Plagioclase feldspar is generally white to grey and has a vitreous lustre.
- Plagioclase feldspar is an important industrial mineral used in ceramics.

爾性長石（圖4）
- 烈性長石是斜長石礦物類中另一種礦石。
- 烈性長石（鈉鈣鋁硅酸鹽（K_{Na}AlSi_3O_8）含有豐富鈣金屬原子。
- 烈性長石的晶體多呈短而粗的橢柱狀。
- 烈性長石色澤以粉紅色為主。
- 烈性長石一般用作製造瓷磚的原料。

閃石類（圖7）
- 閃石類礦物屬砂漿質礦物。
- 閃石類礦物含有鈣、鎂、鈣、鈣及水份。
- 閃石類礦物形成橢柱狀或針狀晶體。
- 閃石類礦物中多種變質岩及變質岩中的礦物成分。
- 角閃石（圖7）是岩石礦物中閃石類礦物的常見成員。

Amphiboles（圖7）
- Amphiboles are a family of silicate minerals.
- Amphibole minerals generally contain iron, magnesium, calcium and aluminium as well as silicon, oxygen, and water.
- Amphiboles form prismatic or needle-like crystals.
- Amphibole is a component of many igneous and metamorphic rocks.

hornblende（圖7）is a common member of the amphibole group of rock-forming minerals.

Micas（圖7）
- Micas are a family of silicate minerals.
- Micas are made up of varying amounts of potassium, magnesium, iron, as well as aluminium, silicon and water.
- Micas form flat, book-like crystals that split into individual sheets, separating into smooth flakes along the cleavage planes.
- They are common minerals in intrusive igneous rocks, and can also be found in sedimentary and metamorphic rocks.
- Biotite (figure 5) is a dark, black or brown mica, muscovite (figure 6) is a light-coloured or clear mica.
Pyroxene (Figure 8)
- Pyroxenes are a family of silicate minerals.
- Pyroxene minerals generally contain magnesium, iron, calcium and aluminium as well as silicon and oxygen.
- Pyroxenes form short or columnar prismatic crystals.
- Pyroxene is a component in many igneous and metamorphic rocks.
- Pyroxene crystals are commonly faceted as gemstones. For instance, precious jade (jadeite) is a pyroxene.

Olivine (Figure 9)
- Olivine is a silicate mineral.
- Olivine ([Mg,Fe]_{2}SiO_{4}) contains iron and magnesium.
- Olivine is a green, glassy mineral.
- Olivine is common in mafic and ultramafic rocks, but has not been found in Hong Kong.
- Clear and transparent olivine crystals are commonly faceted as gemstones.

Calcite (Figure 10)
- Calcite is a carbonate mineral.
- Calcite is made up of calcium carbonate (CaCO_{3}).
- Calcite is generally white to clear, and is easily scratched with a knife.
- Calcite is a common sedimentary mineral that is the major component of calcareous sedimentary rocks such as limestone. Metamorphism of limestone produces marble.
岩石

岩石是什麼？

岩石是礦物、岩石碎塊或有機物質的天然集合體。岩石的成分、外貌、形狀，以及岩石內顆粒和晶體的排列（即岩石結晶）皆顯示其形成過程。根據岩石的形成模式，岩石可分成三種類別：火成岩、沉積岩及變質岩。

火成岩

火熱的岩漿冷卻凝固後形成火成岩。岩漿來自地球深處，鄰近液態的板塊邊緣或熱點，並在地球表面上上升。火成岩根據岩漿在不同地點凝固而劃分為兩大類：侵入岩及噴出岩。

沉積岩

沉積岩是由已存在的岩石被風化後剝落的碎屑或死物的植物或生物的骨骼碎屑結合而成。沉積岩通常集中於地球表面的不同環境，一般呈現平緩的層次或層理。沉積岩可細分為三類，包括碎屑沉積岩、生物沉積岩及化學沉積岩。

侵入岩，或稱深成岩，是當岩漿上升期間因受到地球重力，導致冷卻過程非常緩慢，往往歷時數千或數萬年才能以完全冷卻。緩緩的冷卻過程給予個別礦物足夠的時間結晶，結晶體積相對較大的晶體。侵入性火成岩一般擁有較粗糙的岩質及互連的礦物。花崗岩(圖11)是香港常見的侵入性火成岩。

Rocks

What are Rocks?

Rocks are naturally occurring aggregates of minerals, rock fragments or organic matter. The composition of a rock, as well as the appearance, shape, and arrangement of the grains or crystals within the rock(e.g. its texture), are the characteristics that reveal its process of formation. Based on their mode of formation, rocks are classified into three main types: igneous, sedimentary and metamorphic.

Igneous Rocks

Igneous rocks form when hot, molten rock (magma) cools and solidifies. The magma originates deep within the Earth near active plate boundaries or hot spots, then rises toward the surface. Igneous rocks are subdivided into either, intrusive or extrusive rocks, depending upon where in the earth the magma solidifies.

- Intrusive, or plutonic, igneous rocks are formed when rising magma is trapped deep within the Earth, where it cools very slowly over many thousands or millions of years until it finally solidifies. Slow cooling allows the individual mineral grains sufficient time to grow and form relatively large crystals. Intrusive rocks have a coarse-grained texture with interlocking minerals. Granite (figure 11) is a commonly occurring intrusive rock in Hong Kong.

- Extrusive, or volcanic, igneous rocks are produced when magma is erupted at or very near the Earth’s surface. The erupted magma cools and solidifies relatively quickly when it is exposed to the cooler temperatures of the atmosphere. Lava and tuff (figure 12) are two common volcanic rocks.

Sedimentary Rocks

Sedimentary rocks are formed from the eroded fragments of pre-existing rocks, or from the skeletal fragments of once-living plants or organisms. They accumulate in various environments on the Earth’s surface. Sedimentary rocks commonly have distinctive layering or bedding. Sedimentary rocks are subdivided into three groups, including clastic, biological and chemical.

Clastic sedimentary rocks are made up of fragments (clasts) of pre-existing rocks. Crystals or fragments of the pre-existing rocks are loosened by weathering, and subsequently transported to a site where they are deposited. Clastic sedimentary rock is formed when the sediment is buried, then compacted and cemented.

The table below shows the classification of clastic sedimentary rocks based on their grain size:

<table>
<thead>
<tr>
<th>Grain Size (mm)</th>
<th>Sediment</th>
<th>Sedimentary Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 200</td>
<td>Boulder</td>
<td>Conglomerate / Breccia</td>
</tr>
<tr>
<td>200 - 60</td>
<td>Cobble</td>
<td>Conglomerate / Breccia</td>
</tr>
<tr>
<td>60 - 2</td>
<td>Gravel</td>
<td>Sandstone</td>
</tr>
<tr>
<td>2 - 0.06</td>
<td>Sand</td>
<td>Sandstone</td>
</tr>
<tr>
<td>0.06 - 0.002</td>
<td>Silt</td>
<td>Siltstone / Mudstone</td>
</tr>
<tr>
<td>&lt; 0.002</td>
<td>Clay</td>
<td>Siltstone / Mudstone</td>
</tr>
</tbody>
</table>

Figure 11: Granite — an example of intrusive igneous rock.

Figure 12: Tuff — an example of extrusive igneous rock.

Figure 13: Siltstone — an example of clastic sedimentary rock.
**Metamorphic Rocks**

Metamorphic rocks are formed when a pre-existing rock is subject to high temperature, high pressure, hot and mineral-rich fluid, or a combination of these conditions. The original rocks could be igneous, sedimentary, or earlier metamorphic rocks. In the case of metamorphic rocks, some or all of the original minerals are replaced by new minerals, and the original textures are commonly masked due to the deformation (such as shearing and folding) that may accompany metamorphism. Metamorphic rocks are generally formed deep within the Earth, or where tectonic plates meet.

**Foliated metamorphic rocks** exhibit a platy or sheet-like structure. Foliation develops when platy or prismatic minerals within the rock are compressed and aligned under extreme pressure. The foliation pattern reflects the direction in which pressure was applied. Slate, schist (Figure 15), and gneiss are examples of foliated metamorphic rocks.

**Non-foliated metamorphic rocks** display a massive structure. Non-foliated metamorphic rocks can be formed by contact metamorphism that occurs around intrusive igneous rocks. The pre-existing rocks that come into contact with the intruding igneous rocks are essentially baked by the heat. In this case, the mineral structures of the pre-existing rocks are changed without being subjected to intense pressure. Quartzite and marble (Figure 14) are examples of non-foliated metamorphic rocks.
### 表土沉積

#### 表土沉積是什麼？

岩石經過風化後，被分解成細散的岩石碎屑及礦物顆粒，並經風吹過程轉移至另一地點。這些沉積物可能由水力、風力或地心吸力推動，最終堆積至不同的沉積環境。表土沉積是指未被整合在地表上的沉積物。

### 表土沉積的分類

表土沉積物一般按其沉積環境分為三大類：陸上(土地)、海岸及海洋沉積環境(表2)。沉積環境受各不同因素相互影響，包括該地點的棲地構造環境、地理位置、沉積物輸送媒體、可影響沉積物的生物、以及氣候系統等。沉積環境可能隨著時間，因海平面變化或河道變更等因素，而作出相應改變。

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**表2. 陸上及海岸沉積環境的例子**

<table>
<thead>
<tr>
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<th>海岸沉積環境例子包括：</th>
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<td>Examples of terrestrial (land) sedimentary environments are:</td>
<td>Examples of marine sedimentary environments are:</td>
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<tr>
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**Superficial Deposits**

### What are Superficial Deposits?

Superficial deposits are generally classified into three broad categories according to environments of deposition: terrestrial (land), shoreline and marine environments (Table 2). A sedimentary environment results from the interaction of various factors, including the plate tectonic setting, geographical location of the site, transporting agents, organisms that may modify the sediments, and the climatic system. The sedimentary environment of a site may change over time in response to factors such as shifting river channels and relative sea level changes.

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**Classification of Superficial Deposits**

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