THE ROCK CYCLE AND ROCK IDENTIFICATION

ROCKS AND MINERALS
前言

教育局於2005年公布，三年新高中學制將於2009年9月在中四級實施。地理科是其中一個重點的選修科目。

新高中地理科課程是根據2005年教育局出版的一份文件和課程發展議會《高中課程指引》(2007)的建議而編訂。在此課程中，地理被視為一門學科讓學生可以從空間的角度了解自身所處的地球。

土木工程拓展署轄下的土木工程處應教育局的請求，在天然災害及地球科學兩個新高中地理科課程內容上編寫了一份『教學支援教材套』。其中有關香港岩石及礦物的資料亦適用於部份化學科的課程。

『教學支援教材套』包括了14本小冊子，4張海報，3片光碟及其他一些補充資料。此教材套在香港的斜坡安全、山泥傾瀉、地質及地貌等課題上提供了合適及最新的資料並同時符合新高中地理科課程的水平。

土木工程處的『香港地質調查組』負責編寫有關香港地質及地貌方面的內容，而『斜坡安全部』則負責香港斜坡安全及山泥傾瀉的部份。「斜坡安全部」的同事亦負責整個項目的策劃與安排。我謹向各位參與這項工作的同事表謝。

我相信這款教材套對各位負責新高中地理科目的老師在編輯教材時能提供合適的參考。此教材套亦給予有興趣於這些課題的廣大讀者一些有用的資料。

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土木工程拓展署
土木工程處處長
2008年12月

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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December 2008
引言
Introduction

我們的地球是一個由大気圈、水文圈、生物圈及岩石圈四個主要部份組成的動力體系。這四個部份在漫長的地球歷史中，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、沉積及變質三類類（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，這過程稱為岩石循環（岩石與礦物之二）。從細胞細胞岩石的岩理、成分及內部結構等特徵，可判斷該岩石的來源，這就是識別岩石的基礎（岩石與礦物之二）。在香港出機的岩石種類繁多，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).
岩石循環

岩石循環是一個概念模型，用以理解岩石的形成、變質和再循環過程。岩石循環的主要過程包括風化、成岩、變質、復原和新生。

要理解岩石循環，首先要明白何為岩質：

岩石循環的三個主要階段：
1. 風化：岩石在地表經受各種物理和化學作用而發生的變化。
2. 成岩：風化的岩石經受物理或化學作用形成新的岩石。
3. 剛性化：剛性化岩石經受溫度和壓力變化形成變質岩。

岩石循環的過程包括：
1. 風化：岩石在地表經受各種物理和化學作用而發生的變化。
2. 成岩：風化的岩石經受物理或化學作用形成新的岩石。
3. 剛性化：剛性化岩石經受溫度和壓力變化形成變質岩。
4. 剛性成岩：剛性成岩岩石經受溫度和壓力變化形成新的岩石。
5. 成岩化：成岩化岩石經受物理或化學作用形成新的岩石。

在岩石循環的過程中，岩石可以經歷多次循環，從風化到成岩，再到剛性化，最後再回到風化，這就是岩石循環的整個過程。

岩石循環的示意圖展示了岩石循環的整個過程，從風化到成岩，再到剛性化，最後再回到風化，這就是岩石循環的整個過程。

The Rock Cycle

The Rock Cycle (Figure 1) is a conceptual model that explains how geological processes acting on any one of the three main rock types - igneous, sedimentary, and metamorphic - can change one rock type into another over geological time. Plate tectonics is the driving force of the Rock Cycle.

In order to understand the Rock Cycle, it is important to understand the rock-forming processes.

When molten rock deep within the Earth is termed magma. When magma cools and crystallizes it forms igneous rock, either deep inside the Earth's crust (intrusive igneous rocks) or at the Earth's surface (extrusive igneous rocks). Igneous rock-forming processes involve melting, cooling and crystallization.

When tectonic activity exposes rocks at the Earth's surface, they are subject to weathering and erosion. The resulting sediments are transported and deposited in a basin, where they are buried, compacted and cemented to form sedimentary rock. The sedimentary rock-forming processes involve weathering, erosion, deposition, burial and lithification.

When rocks are subject to high temperatures and pressures, and to hot, mineral-rich fluids, their textures and/or mineral compositions are changed to form metamorphic rock. The metamorphic rock-forming processes involve changes to rock textures and mineral compositions under different temperature, pressure or hot fluid conditions.

The Rock Cycle can begin with any one of the three rock types. It is important to understand that a rock does not necessarily pass all the way through the Rock Cycle from igneous, to sedimentary, to metamorphic, and back to igneous rock again. For example, an igneous rock can become a metamorphic rock without reaching the Earth's surface, and without first becoming a sedimentary rock. Also, any type of rock can become a new rock of the same type.
岩石鑑定介紹

岩石根據形成的模式分為三大主要類別，即火成岩、沉積岩和變質岩。在大多數情況下，岩石的形成過程不可能直接觀察得到。因此，要判斷岩石的類型，就必須從其獨有的特徵來判別。而岩石的岩理及礦物成分是推斷岩石類型的兩個可靠線索。

香港常見岩石的鑑定

鑑定和識別岩石的類型，許多時是一項需要技巧行的工作，要求擁有廣博的地球科學及豐富經驗。然而，本章將提供一些辨認香港常見岩石的實用指引。

侵入性火成岩的特徵

- 花崗岩
  - 花崗岩主要成分是長石和石英礦物，其次是角閃石及黑雲母。
  - 花崗岩以深成岩體、礦脈或岩床形態出現（圖2）。
  - 偶爾礦物一般可進肉眼觀察（圖3及圖4）。
  - 花崗岩內的礦物呈晶體狀，並顯現出互諧的岩理（圖3及圖4）。
  - 未受風化的花崗岩一般呈棕紅色或淡灰色。

Introduction to Rock Identification

Rocks are classified into three main types, igneous, sedimentary and metamorphic, according to their mode of formation. In most cases, it is not possible to directly observe how rocks are formed. Therefore, it is necessary to rely on the distinctive features of a rock to infer its origin. Texture and mineral composition are two important characteristics that may help to confirm the origin of a rock.

- Texture refers to the sizes and shapes of the component minerals or grains, and to their collective arrangement in a rock.

- Composition refers to the crystals, mineral grains, fragments of other rocks, and/or fossils, that make up a rock. It also refers to the chemical constituents of a rock. The colour of a rock may also provide an important guide to its composition.

Identification of Common Rocks in Hong Kong

In many cases, the identification and classification of rocks is a skilled task that requires a broad understanding of geology and considerable experience. Nevertheless, this section will provide some useful guidelines for identifying the common rock types in Hong Kong.
噴出性火成岩的特徵

熔岩
- 熔岩中的個別礦物顆粒都非常細小，難以憑肉眼辨認。
- 熔岩中的礦物質在巖漿中冷卻後，形成晶體。
- 熔岩可呈現流動構造。

凝灰岩
- 凝灰岩（圖6）成分包括礦物、玻璃、浮石及/或已存在岩石的碎塊。
- 凝灰岩根據不同碎塊的相對成分分類。
- 碎片一般呈棱角狀及破碎。
- 未被風化的凝灰岩通常呈深灰色。
- 岩石可呈棱紋狀斑狀（圖6）、熔結構造等特徵。
- 部分凝灰岩顯現柱狀節理。

沉積岩的特徵

碎屑沉積岩（粉砂岩、砂岩及頁岩）
- 碎屑沉積岩由已經存在的岩塊與風化後逃出的岩石及礦物顆粒結晶而成（圖7及圖8）。
- 個別顆粒由石英或方解石礦物組成的膠結物凝結而成。
- 碎屑沉積岩可能含有化石。
- 沉積層理可能出現，是岩石中詰列有序的顆粒，因其結構及成分改變而劃定。
- 顏色的變化反映了岩石的成份沉積環境，及/或遭受風化的狀況。

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<th>Characteristics of Extrusive Igneous Rocks</th>
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<td>Lava</td>
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<td>Lava contains grains that are generally small and can be identified with the naked eye.</td>
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<tr>
<td>Lava may contain some larger crystals (phenocrysts) within the fine-grained groundmass.</td>
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<td>Lava may display a flow fabric.</td>
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Tuff
- Tuff (Figure 5) contains fragments of minerals, glass, and pre-existing rocks.
- Tuff is classified based on the relative components of the various fragments.
- The fragments are generally angular and broken.
- Tuff is commonly dark grey in colour when the rock is unweathered.
- The rock may show a welding structure (Figure 6).
- Some tuff is columnar-jointed.

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<th>Characteristics of Sedimentary Rocks</th>
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<tr>
<td>Claystone and Sandstone</td>
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<td>Claystone and sandstone rocks are composed of rock and mineral grains eroded from pre-existing rocks (Figures 7 &amp; 8).</td>
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<td>Sedimentary bedding may be present, defined by variations in the texture and composition of the constituent grains that are systematically arranged in layers.</td>
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<td>Colour variations reflect composition, the depositional environment of the sediments and/or the texture and weathering state.</td>
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<td>Figure 5: Course ash-crystal tuff, containing mainly crystal fragments.</td>
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<td>Figure 6: Lutite tuff (unoxidized tuff), containing porphyritic fragments (flame) and glass shards that are feldspar during its formation.</td>
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<td>Figure 7: Conglomerate, containing rounded lithic clasts.</td>
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<td>Figure 8: Siltstone, showing thin sedimentary layers.</td>
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變質岩的特徵

► 片岩及千枚岩
- 岩石原有的礦物可能被新的變質礦物取代，如雲母（片狀礦物）及角閃石（板狀礦物）。
- 呈現葉理，由片狀或板狀的礦物排列而成（圖9）。
- 變質岩一般呈現深色帶交替，層次分明，反映深色和淺色礦物的不同密度度。
- 由於岩石含雲母質，一般呈絲質的光澤。

► 大理岩
- 大理岩（圖10）是由方解石礦物晶體形成。
- 純大理岩是白色或奶白色，但亦可能因為含雜質而變成淺灰或灰藍色。
- 大理岩遇稀鹽酸會有化學反應，產生氣泡（泡騰）。

$$2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$$

- 大理岩很容易被小刀刮花。
- 礦物晶體互鎖。

Charactersitics of Metamorphic Rocks

► Schist and Phyllite
- The minerals of the original rock may be replaced by new metamorphic minerals, such as micas (platy minerals) and amphibole (a prismatic mineral). The rocks show a foliation, which is defined by the alignment of platy or elongate prismatic minerals (Figure 9).
- The rocks commonly display alternating dark and light coloured bands that reflect the concentration of dark and light coloured minerals.
- The rocks generally display a silky or shiny appearance due to the presence of micas.

► Marble
- Marble is composed of crystalline calcite minerals (Figure 10).
- Pure marble is in white or creamy colour, but impure marble may be light grey to bluish grey.
- Marble reacts with dilute hydrochloric acid to produce gas bubbles (effervescence).

$$2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$$

- The rock is easily scratched with a knife.
- The mineral grains are interlocking.