INTRODUCTION TO GEOLOGY AND LANDSCAPE
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)的建議而制定。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力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備了一份「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。

土力工程處的「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「斜坡安全組」則負責香港斜坡安全及山泥傾瀉的部份，「斜坡安全組」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致謝。

我相信這教材套對各位負責新高中地理科目的老師在編製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

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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、生物圈及岩石圈四大主要部分組成的動力體系。這四個部份在漫長的地球歷史中，持續互相影響。地質學為一種研究岩石圈的科學，並且包含岩石圈與其他三個部份相互作用的研究。

地形學是指對地表的性質及成因的研究，特別是在大氣圈及水文圈中的風化及侵蝕過程。這些過程不斷改變地表表面形狀（地質與地景之一），並且產生岩石循環中的沉積物。地形是岩石圈、大氣圈及水文圈互動產生的結果（地質與地景之二）。香港的天然地景是基於地質及地貌作用而形成，並多見於香港的郊野公園（地質與地景之三）。人為活動例如填海及築建水壩等，都改變了天然的地貌。

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風化與侵蝕

風化作用是指岩石礦物及岩體暴露在大氣圈下的變質及分解作用。

風化作用發生於原地，亦即同一地點，並沒有涉及主要的岩石物料邊移。

風化作用主要由重力推動，並由流動媒介輔助，例如水（例如河流）和冰（例如冰川），又或是單靠重力推動（例如落石），風也可以移走風化物質（例如風蝕）。

風化作用

風化是一項全球性的基本作用。

風化作用將岩石從堅硬的狀態變為軟弱及較模弱，令它們更容易受到侵蝕。例如它們更可能形成山泥傾瀉。

風化作用主要分為兩類別，而第三類別則為次要：

▶ 物理風化：指岩石經過機械性干擾（例如乾燥風乾、風蝕作用、節理破碎、崩解，或因溫度及壓力改變而成的碎裂）而產生的風化作用。例子有冰楔及礦物體積的改變。

▶ 化學風化：指岩石中的礦物受水、氣溫、氧化、氣態及溶質的作用（例如溶解，水合、氧化及碳化），而導致的分解。

▶ 生物風化：指由植物的出現、或較小程度上動物的介入，而造成或協助的風化作用，當中包括樹根造成的楔裂及動物遺留的窩洞。

在任何特定地點發生的風化作用，其類別主要取決於氣候：

▶ 物理風化：機械性作用，多出現於較寒冷及乾燥的氣候。

▶ 化學風化：礦物分解作用，多出現於較溫暖及溼潤的氣候。

▶ 生物風化：植物及動物普遍傾向出現於溫暖及溼潤的氣候。

控制風化

風化的類別、速度與涉及程度受多個控制因素影響：

▶ 氣候：主導風化作用的類別，大都根據風化作用時所存在的水量及溫度來決定（化學反應在溫度較高的環境，有較快的反應，冰楔作用則發生於較寒冷的氣候）。

▶ 岩石種類：決定岩石在特定環境中對抗風化的能力。

Weathering and Erosion

Weathering is the alteration and breakdown of rock minerals and rock masses when they are exposed to the atmosphere.

Weathering processes occur in situ, that is in the same place, with no major movement of rock materials involved.

Erosion is the removal (transport) of weathered rock materials downslope, and away, from their original site of weathering.

Erosion processes are driven primarily by the force of gravity, which may be aided by a flowing medium such as water (e.g. rivers), and ice (e.g. glaciers), or gravity may act alone (e.g. rockfalls). Wind can also remove weathered materials (e.g. deflation).

Weathering Processes

Weathering is a fundamental Earth process.

Weathering changes rocks from a hard state, to become much softer and weaker, making them more easily eroded. For example, they become more susceptible to landsliding.

Two main groups of weathering processes are identified, with a third supporting group:

▶ Physical weathering: the group of processes, such as frost wedging and volume changes of minerals, that result in the mechanical disruption of rocks (e.g. granular disintegration, exfoliation, joint block separation, shattering by changes in temperature or pressure).

▶ Chemical weathering: the decay of rock forming minerals caused by water, temperature, oxygen, hydrogen and mild acids (e.g. solution, hydration, oxidation, carbonation).

▶ Biological weathering: the group of processes that are caused by, or assisted by, the presence of vegetation, or to a lesser extent animals, including root wedging and the production of organic acids.

The type of weathering processes that occur at any particular location depend predominantly upon the climate.

▶ Physical weathering: mechanical processes dominate in colder and drier climates.

▶ Chemical weathering: processes of mineral decay dominate in warmer and wetter climates.

▶ Biological weathering: vegetation, and animals, tend to be more active in warmer and wetter climates.

Weathering Controls

The type, rate and extent of weathering depends upon several controlling factors:

▶ Climate: dictates the type of weathering processes that operate, largely by determining the amount of water available and the temperature at which the processes occur (chemical reactions are faster at higher temperatures; frost wedging occurs in colder climates).

▶ Rock Type: determines the resistance of the rock to the weathering processes that operate in that particular environment.
Rocks are: rocks that are naturally occurring and are not modified by human activity. They are formed from minerals that are part of the Earth's crust.

In this section, we will discuss the different types of rocks: igneous, sedimentary, and metamorphic.

**Igneous Rocks:** Formed from molten magma that cools and solidifies. They can be classified as intrusive (formed deep below the surface) or extrusive (formed on the surface). Examples include granite and basalt.

**Sedimentary Rocks:** Formed by the deposition of sediment over time. Sediments are typically deposited in layers, and over time, these layers can compact and cement to form sedimentary rocks. Examples include sandstone and limestone.

**Metamorphic Rocks:** Formed when existing rocks are subjected to high pressure and temperature, causing changes in their mineral composition and texture. Examples include marble and gneiss.

Geological processes, such as plate tectonics, can also play a role in the formation of rocks. These processes can create new rocks through the movement of tectonic plates, which can cause the melting of rocks and the formation of new minerals.

The formation of rocks is a complex process that involves the interaction of various factors, including temperature, pressure, and the presence of water. Understanding these processes is essential for geologists and other scientists who study the Earth's crust.
風化的產物

風化作用逐漸使岩石變弱，最終形成於新環境更穩定的大地質質（岩石碎屑、沙粒、粉砂及黏土）。

一般來說，風化作用產生較幼細及疏鬆的岩石物質，以及較弱和多孔懸漂的岩體。

在熱帶及亞熱帶地區，由於受熱及潮濕氣候影響，劇烈的風化作用形成厚厚的風化層，其厚度可達100米或以上。

風化作用導致岩體的不規則面（側面），例如岩石的斷面及節理，並攻擊岩石面，滲入岩體（圖3）。

在岩石風化層中，風化岩石含有的碎石物質（圖4）。

某些岩石（例如花崗岩及粗粒凝灰岩）經過風化後，會形成厚厚的風化層。其特點是在含有粉砂、黏土及沙粒物質結集成的風化土中，出現風化的巨礫（岩石塊）。這些含有岩石塊的風化層是香港島及九龍市區多個削坡的顯著特徵（圖5）。

風化的下限界線可能呈不規則及分散。但在多個個案中，風化的下限均終止於一個細明的水平界線上（圖6）。地形學家稱這條界線為風化基面，而工程師則稱之為基岩（圖7）。

Weathering Products

Weathering gradually weakens rocks, and eventually produces new geological materials (rock fragments, sands, silts and clays) that are more stable in the new environment.

Weathering generally produces finer and less dense rock materials, and weaker, more porous and permeable rock masses.

In the tropics and subtropics, intense weathering in the hot and humid conditions produces thick weathered profiles, which may be up to 100 metres, or more, thick.

Weathering processes penetrate down discontinuities (planes of weakness), such as faults and joints, in the rock mass and then attack the faces of the joint-bounded blocks, penetrating the solid blocks (Figure 3).

Weathering preferentially attacks the corners and edges of the joint blocks, causing them to become rounded. This action is assisted by stress release, which causes the rock to flake into curved shells in a process termed exfoliation (Figure 4).

Weathering of some rock types, such as the granitic rocks and the coarse ash tuffs, results in the development of thick weathered profiles that are characterised by rounded boulders (corestones) set in a matrix of weak, silty, clayey, sandy material. These corestone-bearing profiles are a distinctive feature of many cut-slopes in the urban areas of Hong Kong Island and Kowloon (Figure 5).
侵蝕作用

在運送過程中，流動的粒子會摩擦（磨擦或沖刷）地球的表面，並磨蝕岩石。

因此，山巖的表層可能會受到下方的斜坡或河床，及河流的沉積物會磨蝕河床的岩石部分，而冰川中的岩石碎屑會磨蝕山谷底部。

侵蝕作用通常分為下列四大類別：

▶ 風化：指當地氣候環境改變時移動的侵蝕作用。地點可以是寒冷或炎熱的沙漠，風蝕侵蝕在香港影響不大。

▶ 冰川：指涉及冰的侵蝕作用，冰雪存在於冰川中（例如冰川運輸），或作爲運輸媒體（例如冰川）。冰川作用並沒有直接影響香港。

▶ 控制侵蝕

侵蝕的類別及程度決定於多個因素，包括：

▶ 氣候：氣候基本上控制地區內的侵蝕類別及程度。因為氣候決定水量（雨量）及其季節性分配、溫度（熱帶、寒帶及兩極）以及日照時數。風力及風向等。

▶ 地形：高山地區的地勢較高，潛在力量較低地為高。結合陡峭的斜坡，高速侵蝕作用的動力較周邊平原大。

▶ Erosion Processes

During transportation of the weathered rock materials, the angular particles commonly abrade (rub or scour) the surfaces over which they pass, wearing away and lowering the rocks.

Thus, landslide debris may erode the slope or channel along its course, the sediments in rivers erode the rocky sections of their beds, and the rock fragments in glaciers erode the valley floor.

Erosion processes are usually considered under four distinct categories:

▶ Mass Wasting: the processes that occur on slopes, under the influence of gravity, in which water may play a part, although water is not the main transporting medium. Mass wasting, or landsliding (see below), processes are very important in Hong Kong (Figure 8).

▶ Fluvial: the processes that involve flowing water, which can occur within the soil mass (e.g. soil piping), over the land surface (e.g. rills and gullies) or in seasonal or permanent channels (e.g. seasonal streams and rivers). Fluvial processes are very important in the upland areas around the surrounding plains.

▶ Glacial: the processes that involve the presence of ice, either in the soil (e.g. solifluction), as the transporting medium (e.g. glaciers). Glacial processes do not directly affect Hong Kong.

▶ Rock Structure: highly jointed or faulted rocks are usually more intensely weathered along the lines of weakness in the rock mass. Consequently, these softer weathered materials are more easily eroded out, with the result that river valleys are usually located along the line of a major fault or joint set.
岩石類別：岩石的類別決定地區內受侵蝕影響的程度。在同一氣候環境，每種岩石對風化及侵蝕作用的反應各異。根據當地情況，各種岩石展示其獨特的抵抗力及弱點。抵抗力較強的岩石形成高地，而相對較弱的則形成山谷及低地。

岩石結構：風化作用由內部或由接觸影響的岩石的細紋，通常較嚴重。由於這些風化期的物質較易被侵蝕，河流山谷大多出現在主要斷層或斷層沿線。

侵蝕的產物
經侵蝕作用而剝落的岩石物質，最終將沉積於海底，僅僅在中下可能暫時停留在其他地方，如懸崖之下(例如山石壁)、山澗(例如坡積物(圖10))，河道兩旁(例如沿岸平原)，湖(例如三角洲)，或沙洲(例如沙丘)。

過去千萬年間，一個地區的地形經由侵蝕作用剝落而成。由原來被抬升的岩體，變成浮動的山峰、交錯的山谷及連織的平原。

重力造成山崩、流水侵蝕水溝及溝水河壩(圖11)，細雨沖刷由懸崖剝落形成山石堆。在下游地區，河流勾劃出山谷，沉積物堆積形成沿岸平原。而地面以下，可溶解的岩石(例如石灰岩)經過水的侵蝕，形成洞穴，洞穴及管井。

何謂山崩?
山崩，或稱滑坡崩塌，一般是指由重力機理的過程，影響全球山地。

天然斜坡
在正常情況下，天然斜坡(未受人類活動大量改變的斜坡)達到穩定狀態。即是指，該斜坡的結構、結構、泥土種類及厚度、坡度的範圍及類別，地表及地下水文，以及當時的氣候情況，山崩被侵蝕至一個相對穩定的角度。

風化作用持續在山坡進行，剝落懸崖的岩石。地下水將部分風化物質從岩石剝落或覆蓋的泥土中沖走，而山旁边的溪水將山腳加急。

山坡上的岩石和泥土不斷被剝落及不穩定，導致山坡塌陷，導致山崩後重新剝落山坡(山崩)重新剝落山坡及搖搖欲墜的狀態。

Erosion Products
The rock and soil materials transported by erosion processes are eventually deposited in the sea, although they may be temporarily deposited in other locations such as below cliff faces (e.g., sandstone), on hillsides (e.g., as colluvium (Figure 10)) beside rivers (e.g., as flood plains), in lakes (e.g., as deltas), or on desert plains (e.g., sand dunes).

Over the millennia, the topography of an area is sculpted by the processes of erosion, from an original mass of folded or uplifted rocks into a complex of mountain summits, intervening valleys, and surrounding plains.

Gravity causes landslides on hillsides, flowing water erodes gullies and shallow stream courses (Figure 11), and joint-bounded blocks of rock fall from cliff faces building up scree. On lower ground, rivers carve valleys and deposit floodplain sediments. Below the ground surface, in soluble rocks such as limestone, water erodes passages, caves and shafts.

The ultimate result of erosion is to reduce all mountains, ridges, and high ground to a flat plain (termed a peneplain) that slopes very gently from the centre of a landmass to the sea.

What are Landslides?
Landsliding, or slope failure, is a general term that encompasses the gravity-controlled, mass wasting processes that affects hillslopes throughout the world.

Natural Slopes
Under normal circumstances, natural terrain slopes (i.e. slopes that are largely unmodified by human activities) reach a state of quasi-equilibrium, in which the slope is eroded to an angle that is relatively stable with regard to the underlying rock type and structure, the soil type and thickness, the extent and type of vegetation cover, the surface and subsurface hydrology, and the prevailing climatic conditions and local weather patterns.

Weathering processes continually act upon the slopes, weakening the underlying rocks. Groundwater flushes out some of the weathered materials from the joints in the rocks and from the overlying soils, and hillside streams deepen their channels.

The rocks and soils of the slope progressively become weaker and less stable, so sections of the slope periodically readjust to a more stable profile by failing (landsliding).

Importantly, if one or other of the factors on the slope changes, such as the tree cover is removed by fire or forestry, or an exceptionally heavy rainfall occurs, then large areas of a hillside may be subject to erosion, including failure (landsliding).
重要的是，若其中一個或其它山壁細節因素有所改變，例如追加的樹木被燒毀或伐木所移走，又或遇過反常暴雨，則大規模山崩的可能便會增加，包括塌崩(山崩)。

此外，陡峭的山壁在暴雨期間會帶走大量表層物質，這些水份同同士士是否地透入河道，令溪流岸邊被損，引至斜坡塌崩。

在香港的兩岸，地震可能會引動整個地區，令大量土地顫動，造成山崩。

香港大部分天然斜坡的崩塌，源於兩個主要地點的其中之一。

1. 人造斜坡

許多在香港市區邊緣的山壁，都已變改動為築建楼房的平台以及公路的台階。此過程造成陡峭的人造斜坡，改變了原來斜坡的形態，影響地下水的組織，並使岩石中不利的節理面或其他軟弱面暴露出來。

人造斜坡一般較大多數的天然斜坡陡峭，以及「質地土較年輕」。它們經年累月，失去了原來山坡的自然平衡特質，因此通常需要進行一些穩定工程。

2. 开闢斜坡崩塌：指因開闢而造成的物質，從廣闊的相對平緩斜坡上脫落及移動。

開闢這些傾斜的山坡，會有塵土及維持土地退化的威脅，但也可進入溪道，並沿着溪道流動。

3. 沿著崩塌：於過去期間，發生在溪流源頭的崩塌，泥石被大量雨水直接河頭(圖12)。

部分被削去的崖壁部分的人造斜坡，當發生山崩時，基本上會沿着岩石的節理面塌毀。
在香港，這些節理面常見有黏土填充，形成了在岩石中的弱線，當節理面的拖磁力降低或本身支撐斜坡的物料被移走時，泥石便沿着節理面滑動。

人造斜坡的後果比天然斜坡的傾斜時，因為它們直接影響道路及人口密集的地區。

人造斜坡

許多在香港市區邊緣的山壁，都已變動為築建楼房的平台以及公路的台階。此過程造成陡峭的人造斜坡，改變了原來斜坡的形態，影響地下水的組織，並使岩石中不利的節理面或其他軟弱面暴露出來。

人造斜坡一般較大多數的天然斜坡陡峭，以及「質地土較年輕」。它們經年累月，失去了原來山坡的自然平衡特質，因此通常需要進行一些穩定工程。

4. 支撐斜坡：例如用鋼樑杆、裝設鋼筋及填土攪。

5. 表面保護：例如用石塊包裹及噴射混凝土。

6. 斜坡疏水渠道：例如排水管、排水斜管、U型渠道及梯級渠。

In addition, steep stream courses carry considerable amounts of surface runoff during heavy rainstorms. This water, and the included debris, can severely erode the stream channel, destabilising the stream banks and the adjacent slopes, triggering slope failures.

In extreme circumstances, earthquakes may shake an area and loosen large masses of material, causing landslides or disturbing the previous equilibrium.

Most natural terrain landslides in Hong Kong originate in one of two main locations:

- Open slope failures: occur when a sheet of loose material on a wide, relatively planar slope is detached and displaced. Although, in most cases, the debris does not travel very far from the source, it may enter a stream channel, and become channelised.

- Channelised failures: commonly occur near the head of stream channels during heavy rainfall, the debris travelling down the channel accompanied by large volumes of water (Figure 12).

Man-made Slopes

Many of the hillsides adjacent to urban areas in Hong Kong have been modified to create platforms for buildings and benches for roads. This process creates a very steep cutting (a cut slope), which changes the geometry of the original slope, affects the groundwater regime, and may expose unfavourably oriented joint planes or other lines of weakness within the rock.

Man-made slopes are, by the very nature, steeper than most natural slopes and, being "geologically young", they are not in a natural equilibrium with the profile of the original hillside into which they are excavated. Consequently, some form of engineering stabilisation works are normally required.

Engineers plan and design these cut slopes, or man-made slopes, to make them as safe as possible by using techniques such as:

- Slope support: e.g. rock bolting, soil nailing, and retaining walls.

- Surface protection: e.g. stone pitching and shotcreting.

- Slope drainage: e.g. weepholes, taking drains, U-channels, stepped channels.

Failures of man-made slopes primarily occur along joint planes in fresh rock, and along relict joint planes in weathered rock. These discontinuities, which are commonly clay-filled in Hong Kong, present lines of weakness that allow blocks of material to become detached from the slope when the friction on the plane is overcome, or when the material that originally supported the toe of the slope is removed.

The consequences of failures of man-made slopes are usually more immediately apparent than those on natural terrain, because they directly affect roads and populated areas.