INTRODUCTION TO GEOLOGICAL MAPS
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.

Raymond K S Chan
Head, Geotechnical Engineering Office
Civil Engineering and Development Department
December 2008
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。這四個部份在漫长的地球歷史中，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。

簡單而言，地質圖展示岩石在某地區的分佈形態。然而，要全面了解地質圖，
就必須熟悉一些地質學的基本原則，包括地層學定律、地質年代(地質圖之一)及
地質構造。對於具經驗的人來說，地質圖反映區內岩石三維分佈的情況。同時，
亦能展現該區的岩石發展史(地質圖之二)。香港備有一系列地質及相關地圖
(地質圖之三)，為市民規劃、地質資源分析及地質災害的確認提供有用的資訊。

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.

In simple terms, a geological map shows the surface distribution of rocks in an area. However,
in order to fully understand a geological map, it is necessary to be familiar with several basic
geological principles, including the laws of stratigraphy, geological age (Geological Maps 1),
and geological structures. To the experienced eye, a geological map reflects the three-dimensional
distribution of rocks in an area, and also serves as a visual guide to the geological history of
that area (Geological Maps 2). A range of geological and related maps is available in Hong
Kong (Geological Maps 3). These maps provide useful information for urban planning, locating
resources, and identifying geohazards.
Sediments (mineral grains and fragments of rock) are produced by weathering at the Earth’s surface. They are removed by erosion and deposited elsewhere as layers, which thicken over time and, as the weight and pressure increase, they are eventually compressed and lithified to form sedimentary rock.

The father of modern geology was James Hutton, an eighteenth-century scientist. After observing modern rates of sediment accumulation, Hutton concluded that long periods of time were required to build up the thick layers of sedimentary rock strata seen today. Hutton also concluded that geological processes similar to those today must have operated in the past. This led to the theory of Uniformitarianism, which states that all ancient rocks and geological features can be explained by observing the operation of modern-day processes. Uniformitarianism is usually referred to by the more explanatory phrase “the present is the key to the past.”

The study of rock layers preserved in the geological record is called stratigraphy (Figure 1).

Principles of Stratigraphy

Stratigraphy is based on two underlying principles:

1. The Law of Superposition was introduced by Nicolaus Steno in 1699, after recognizing that successive beds of sediments laid down in horizontal layers have the oldest beds at the base, and the youngest beds at the top, forming a stratigraphical sequence.

2. The Law of Fossil Assemblages was introduced by William Smith, a mining geologist in England. Smith observed that, in any one area, the individual rock layers, or strata, were arranged in a predictable pattern. Importantly, groups of strata containing similar types of fossils (fossil assemblages) always occurred in the same relative stratigraphical (lager) position. This fact enables groups of strata in different areas to be correlated, and allowed Smith to produce the first national geological map in 1815.
相對年齡

相對年齡是地質學中的一個重要概念，它通過化石的出現、岩層的.overlay等方法來確定地層的相對年代。然而，這種方法並非絕對準確，因為化石的種類和年代會受到環境和地質活動的影響。

相對年齡的意義

相對年齡的意義在於：

1. 確定地層的相對年代
2. 確定地層的成層年代
3. 確定地層的層序年代

相對年齡的確定方法

相對年齡的確定方法包括：

1. 化石法
2. 地質層序法
3. 地質年代法

相對年齡的應用

相對年齡的應用在於：

1. 確定地層的年代
2. 確定地層的層序
3. 確定地層的層序年代

相對年齡的限制

相對年齡的限制在於：

1. 化石的種類和年代會受到環境和地質活動的影響
2. 地層的層序年代會受到地質活動的影響
3. 地層的層序年代會受到地質活動的影響

相對年齡的未來

相對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相對年齡的著作

相對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相對年齡的未來

相對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相對年齡的著作

相對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相對年齡的未來

相對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相對年齡的著作

相對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齢的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法

相絕對年齡的未來

相絕對年齡的未來在於：

1. 構建更加準確的地層層序年代
2. 確定地層的年代
3. 確定地層的層序年代

相絕對年齡的著作

相絕對年齡的著作在於：

1. 化石法
2. 地質層序法
3. 地質年代法
In Figure 2, because fragments of mudstone are found within the granite body (the Principle of Included Fragments), the granite intrusion must be younger than (post-date) the formation of limestone and mudstone. Furthermore, the dyke cuts across the layers of sandstone, siltstone, mudstone, limestone and volcanic ash, and also the granite body, but not the conglomerate. This relationship confirms that the intrusion of the dyke post-dated the formation of sandstone, siltstone, mudstone, limestone, volcanic ash and granite, but pre-dated the deposition of conglomerate.

Finally, a normal fault has displaced the rock sequence so that the right hand side has been downthrown.

Therefore, a brief history of the geological events shown in Figure 2 can be summarised below:

1. Deposition of the sandstone
2. Deposition of the siltstone
3. Deposition of the mudstone
4. Deposition of the limestone
5. Deposition of the volcanic ash
6. Intrusion of the granite
7. Intrusion of the dyke
8. Erosion
9. Deposition of the conglomerate
10. Normal faulting
11. Weathering and erosion to form the present day topography

It is very important to be aware that the rock layers observed in a particular stratigraphical sequence may not be a complete record of the history of deposition. Some sediments or rock layers within the sequence may have been weathered and partly removed by erosion. There may have been long periods with no deposition. There may even be other rock layers that have been completely removed by erosion, with the result that an entire period of the geological history of the area is missing. In fact, more geological events are probably missing from the geological record than are recorded by the surviving rock sequences.

Having established the geological history of a particular locality from the stratigraphical relationships, the relative ages of the different sedimentary rock layers can be determined by examining the fossil content. Rock sequences that are separated by long distances can then be correlated by applying the Law of Fossil Assemblages, even though the fossils may not occur in the same rock type due to changes in sedimentary environment across an ancient ocean or landmass. The most useful fossils for long-distance correlation are those that are common, widespread and evolved rapidly over time.
岩石年龄

直至二十世纪初，没有任何科学方法可以推测岩石的精确(绝对)年龄。因此，地质年代单位只代表相对年龄，一直以来有多部有关地球年期的理论面世。以宗教角度估計，地球相当年轻，即使早期的地質學家已認定地球的庞大厚度，需要很长时间形成。英國物理學家凱恩斯數於1848年根據岩石在地球表面的冷卻估計所需的时间为基础，推算出地球的年龄约二至三千萬年。

二十世纪初，岩石具有天然放射性的同位素，被确认可用作岩石年龄的手段。这个发展有助于地质年代单位编排年表，从而使地质年代图(图3)。由于定年法的技巧不断完善，地质年代的框架目前仍在发展。

首部地质年代表于1913年由英国地质学家亚瑟霍尔姆斯(1890-1965)发表。国际地层委员会定期根据新加入的数据，调整地质年代单位的分界线，并由国际地质学会确认，最近的一次修正于2008年完成及发布。

<table>
<thead>
<tr>
<th>代</th>
<th>年代</th>
<th>纪</th>
<th>距今年代的年数</th>
</tr>
</thead>
<tbody>
<tr>
<td>石炭纪</td>
<td>CARBONIFEROUS</td>
<td>299</td>
<td></td>
</tr>
<tr>
<td>泥盆纪</td>
<td>DEVONIAN</td>
<td>359</td>
<td></td>
</tr>
<tr>
<td>二叠纪</td>
<td>PERMIAN</td>
<td>251</td>
<td></td>
</tr>
<tr>
<td>三叠纪</td>
<td>TRIASSIC</td>
<td>195</td>
<td></td>
</tr>
<tr>
<td>侏罗纪</td>
<td>JURASSIC</td>
<td>146</td>
<td></td>
</tr>
<tr>
<td>白垩纪</td>
<td>CRETACEOUS</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>更新世</td>
<td>QUATERNARY</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>前第四纪</td>
<td>PLEISTOCENE</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>中第四纪</td>
<td>MIOCENE</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>新第四纪</td>
<td>PLIO-QUATERNARY</td>
<td>1.8</td>
<td></td>
</tr>
</tbody>
</table>

Geological Time

A geological map shows the surface distribution of different rock types, their structural features, and their age relationships.

The first geological maps simply showed the relative stratigraphical positions of groups of rocks that contained similar fossil assemblages. Over time, as more areas were mapped and knowledge increased, the geological time-scale was developed, based on a wide range of rock and fossil occurrences. Geological Time Units were subsequently devised, which placed particular groups of rocks and fossils into relative age categories. Many of these time units are named after groups of strata that were first described from type localities in the British countryside (e.g. the Devonian).

The last 542 million years to the present is known as the Phanerzoic (meaning "life presence") era. It contains the most subdivisions in the geological time scale because this period in Earth history was teeming with recognisable and evolving plant and animal life. The boundaries between geological time units of the Phanerozoic era are marked by widespread extinctions in the fossil record and by major unconformities in the rock sequence that signify global events, such as major magmatic episodes and meteorite impacts events. Examples include the voluminous global outpourings of magma at the end of the Permain and Cretaceous periods, and a meteorite impact at the end of the Cretaceous.

Rock Ages

Until the beginning of the twentieth century, there were no scientific methods available for determining the true (absolute) age of rocks. Thus, the Geological Time Units represented only relative ages. Over the years, various theories had been proposed for the age of the Earth. Theological estimates suggested that the Earth was very young, but even the early geologists recognised that long periods of time were required to accumulate the vast thicknesses of sedimentary rocks. Based on estimates of the time needed for the exterior of the Earth to cool from a molten state, the British physicist Lord Kelvin calculated, in 1846, that the Earth was about 20 to 30 million years old.

In the early twentieth century, it was recognized that the natural radioactivity inherent in rocks could be used to date rocks in the geological record. This development enabled ages to be assigned to the Geological Time Units, and led to the establishment of the Geological Time Scale (Figure 3), a framework that is still being refined as age-dating techniques are developed and improved.

The first geological time scale was proposed in 1913 by Arthur Holmes (1890 - 1965), a British geologist. Periodically, as new data becomes available, the ages of the boundaries between geological time units are revised by the International Commission on Stratigraphy, and ratified by the International Union of Geological Sciences. The latest revision was completed and promulgated in 2008.
絕對年齡

放射性同位素（「藏於岩石內的時鐘」）用來確定岩石的絕對（或數字）年齡。把岩石的
絕對年齡計算成一個具體的數字年歲（例如
一億四千二百萬年）。

簡單而言，同位素元素的存在，是由於某些
元素的原子核內擁有不同數目的中子，
但具有相同數目的電子和質子。其中有些
同位素（母同位素）不太穩定（指具有放射性），
並經由釋放能量而轉化至另一個較穩定的
同位素（子同位素）。從母同位素轉化至子
同位素的衰減速度是固定的，而個別的
同位素的衰減速度均獨一無二。

許多礦物皆含有放射性同位素。當礦物
形成後，礦物中的母同位素便開始衰減而
轉化至子同位素。理論上，礦物的年齡
（自形成後的時間）可從計算礦物中的母及
子同位素的比率來判斷。礦物的年齡等同
在礦物內，產生出的子同位素數量所需的
時間。根據已知的同位素衰減速度，即可
計算出該所需時間。

地球年歲

地球上已知最古老的岩石約有四十二億八千
萬年歲，然而由於板塊運動的關係，這些
最早的岩石於板塊運動的過程中被循環再生
及破壞，以致未能更準確計算出地球可靠的
年歲。取而代之，估計地球年歲最準確的
方法是利用礦石的放射性定年法。礦石相
是太陽系形成時遺留的物質，最古老而又
進入地球的金屬礦石，所含有的礦物的年齡
是四十五億七千萬年，這年齡被視為目前
地球年歲的最佳估計。

 Absolute Age

Radioactive isotopes ("the clocks in rocks") are used
to determine the absolute (or numerical) age of a
rock. The absolute age of a rock is calculated as a
specific number of years (e.g. 142 million years).

In simple terms, isotopes of an element exist
when the same element has a different number
of neutrons in the nucleus, but the same number
of electrons and protons. Some of these isotopes
(the parent isotope) are unstable (i.e. radioactive),
and decay to a more stable isotope (the daughter
isotope) by releasing energy. The rate of decay
from parent to daughter isotope is constant, and is
unique for each particular isotope.

Many minerals contain radioactive isotopes. Once
a mineral is formed, the parent isotope in the
mineral begins to decay to produce a daughter
isotope. In theory, the age (time since formation)
of these minerals, and thus the age of the rock
bearing them, can be determined by counting the
ratio of parent to daughter isotopes in the mineral.
The age of the mineral is the length of time that
is required to produce the quantity of daughter
isotope that has accumulated in the mineral. This
length of time required can be calculated using
the known decay rate for the isotope.
繪畫地質圖的工具

傳統上，地質圖是根據地質學家在調查範圍內盤查行經的地方，記錄所見的岩石（露頭）、岩石堆積（風化）、地貌、風化程度，以及其他有用的特徵。全部觀察所得的資料均記錄在地質圖上，並且利用磁極磁盤和傾斜儀等工具進行量度。航空照片亦協助地質學家識出目標地質特徵。

地形圖利用等高線顯示區內的地形，包括河流、湖泊、水塘、道路、建築物、步道等。地形圖以不同的比例繪製，香港最常用的地形比例包括：1:50,000，1:20,000，1:10,000，1:5,000及1:1,000。比例1:10,000比例的地形圖地圖上每1公尺代表實地的100公尺（即100米）。選用的比例視乎勘察目的，即地圖上所需記錄的地質資料的多寡而定。

航空照片是從飛機或空中遙測地圖固定的高度拍攝。一份相片的航空照片，若有6%的重疊範圍，則可用於繪製地形的三維視圖。對地質性勘察亦有用。如能掌握拍攝航空照片的飛行高度及鏡頭焦點距離的資料，即可確定航空照片的比例。香港備有少量攝於1924至1963年間，有限地區的航空照片。自1963年開始，每年均有系統地於全港進行黑白航空照片的拍攝。於1985年起，每年進行兩次黑白照片拍攝工作，而到了1993年則定期每年拍攝兩次彩色照片。

磁極磁盤是用來判斷北磁極方向的工具，它的原理是基於地球深處的地磁形成有一個巨型磁石，兩端代表正負極的磁極。地圖上的磁極顯示的是地磁的指向。磁極磁盤具有一支可自由360°旋轉的磁針，讓觀察者能確定其位置與磁極間的方位。然而，磁極與地圖上的磁極顯示的磁極差異不下於1,167千米的偏差，而此偏差按年變動。在香港，北磁極與地圖上的磁極均指向同一方位。然而在世界的其他地方，出現的差異，可能須從磁盤讀數作出的約30°的加減調整。

傾斜儀是用來量度地形的傾斜度，例如岩石的傾斜度。它採用水平尺（高密度注入密封玻璃管內）或鐵板分別來測量水平或垂直的傾斜度。傾斜儀上刻有半圓形數度表，指示一平面的傾角。

Geological Mapping Tools

Traditionally, geological maps are made by geologists who walk over as much of the map area as possible, noting where rocks can be seen (outcrops), the rock types (lithology), their structure, degree of weathering, and any other features that might be useful. All observations are marked upon a topographical base map, and measurements are taken using a magnetic compass and clinometer. Aerial photographs may help the geologist to identify target features in the field.

Topographical base maps show the landscape of an area in the form of contours (lines of equal height), rivers, lakes, reservoirs, roads, buildings, footpaths, etc. Topographical maps are drawn at various scales, the most common scales in Hong Kong being 1:50,000, 1:20,000, 1:10,000, and 1:5,000, with 1:1,000 scale maps also available. This means, for example, that a 1:10,000 scale map, 1 centimetre on the map represents 10,000 centimetres (100 metres) on the ground. The scale of the topographical base map selected depends upon the survey objectives, i.e. the amount of geological detail required on the finished map.

Aerial photographs are taken from aircraft flying at fixed heights above the ground. Adjacent pairs of aerial photographs with 66% overlap can be used under a stereoscope to provide a three-dimensional image of the landscape, which is useful for reconnaissance surveys. The scale of the aerial photograph can be determined if the flying height and the focal length of the camera lens are known. Aerial photographs of limited areas of Hong Kong are available for some years between 1924 and 1963. Systematic, annual, territory-wide black and white aerial photographic coverage began in 1963, twice-annual black and white photography began in 1965, and routine, twice-annual colour photography began in 1993.

Magnetic compasses are instruments used to determine the direction of the magnetic north pole. They work on the principle that the molten core of the earth causes the earth to act like a giant magnet, with the ends (positive and negative poles) of the magnet located in the vicinity of the north and south geographical poles. A magnetic compass, which has a magnetised needle that pivots freely over a 360° graduated dial, is used to determine the direction of the north pole from the position of the observer. However, the magnetic north pole migrates up to about 1,167 kilometres from the geographical north pole, a value that varies annually. In Hong Kong, the magnetic north pole and the geographical north pole are in the same relative direction. In other parts of the world, this difference must be compensated for by adding, or subtracting, an angle of up to about 30° (the magnetic declination) from the compass reading.

Clinometers are used to measure the angle of inclination of a surface, such as the angle of dip of rock strata. They employ a spirit level (a bubble of air in a liquid enclosed in a glass tube) or a pendulum to determine the horizontal and vertical respectively. Clinometers are equipped with graduated half circles from which the angle of dip of a surface from the horizontal can be read.