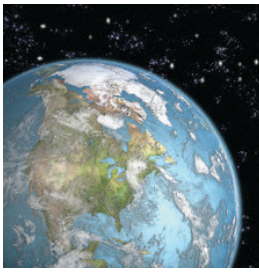
土木工程拓展署
土力工程處
Geotechnical Engineering Office
Civil Engineering and
Development Department

火山、地震與板塊運動
VOLCANOES, EARTHQUAKES AND PLATE TECTONICS

板塊運動 PLATE TECTONICS 2



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製備了一份「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本小書冊、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擬備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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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。

板塊運動是指在岩石圈推動地質作用的基本機制。板塊運動理論是基於對地球內部結構，不同類型板塊和板塊邊緣，以及板塊活動推動力的了解**(板塊運動之一)**。板塊運動理論扼要地闡釋地震及火山的產生、不同種類岩石的分佈、岩石循環、以及山脈的形成、大陸張裂和海洋擴張等地質現象**(板塊運動之二)**。褶皺及斷層是地質構造，是岩石以及板塊受壓而作出的反應**(板塊運動之二)**。詳細研究香港的岩石，有助解釋本港的地質歷史及板塊構造環境的演變**(板塊運動之三)**。

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.

Plate tectonics is the fundamental mechanism that drives geological processes in the geosphere. Plate tectonic theory is based on an understanding of the Earth's internal structure, the different types of tectonic plates and plate boundaries, and the driving forces of plate movements **(Plate Tectonics 1)**. The occurrence of earthquakes and volcanoes, the distribution of different rock types, and the Rock Cycle, as well as the processes of mountain building, continental rifting and seafloor spreading, can be concisely explained by plate tectonic processes **(Plate Tectonics 2)**. Folds and faults are geological structures that result from the response of rocks to tectonic stresses **(Plate Tectonics 2)**. Detailed studies of the rocks enable the geological history and the evolution of the tectonic setting to be deciphered **(Plate Tectonics 3)**.

內容
Contents

岩漿活動

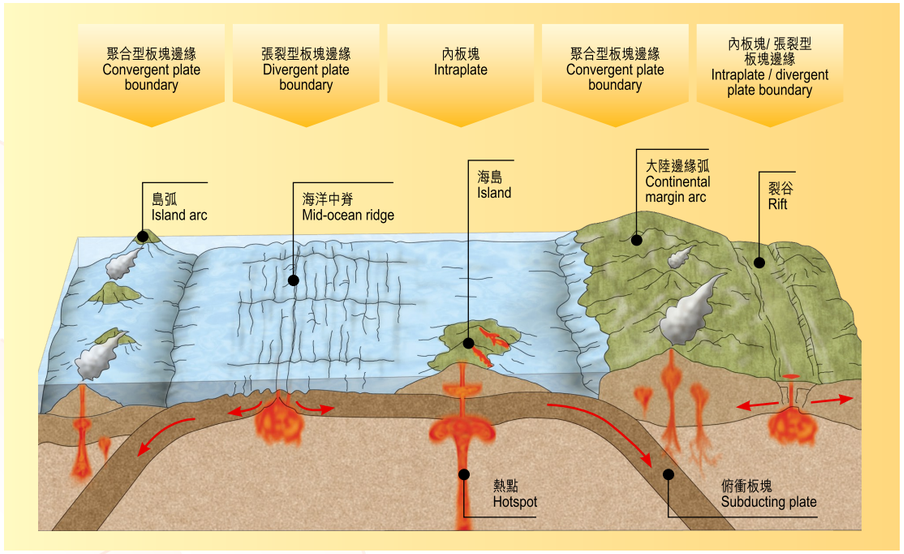


圖1. 板塊構造環境。
Figure 1. Plate tectonic setting.

岩漿來自地球深處的上地幔或下地殼，由局部熔融產生，其成份包括高溫混合的矽酸鹽物質(岩漿)、水和溶解氣體。岩漿內還可能包含岩漿於冷卻時凝結的晶體及岩漿湧上地球表面時夾雜的岩石碎片。

岩漿活動是指岩漿湧上地殼的過程，可能導致以下情形出現：

- 岩漿因冷卻及結晶較緩慢而形成侵入性火成岩(深成岩)，或
- 當火山爆發，岩漿以熔岩及火山灰的形態湧上地球表面，熔岩及火山灰快速冷卻而形成噴出性火成岩(火山岩)。

當堅固的地幔物質上湧至接近地球表面的張裂型板塊邊緣時，地幔的壓力會逐漸減低，地幔物質的熔點亦隨之下降，所以當堅固的地幔上升至某程度時，便會開始局部熔融而形成岩漿(圖1)。浮力會使岩漿向地面上升至遠離熔融區，遺留下未熔化的固態地幔物質。這種由於地幔上升及壓力下降而引起的局部熔融過程，稱為減壓熔融。

熱點是地幔內活躍對流系統的位置，在熱點內發現的岩漿同樣是由減壓熔融形成(圖1)。這裏的固體地幔物質溫度較高及密度較低，並像捲流般向地殼上升。

在聚合型板塊邊緣，當**俯衝板塊**被擠壓下沉時，板塊的溫度會上升，同時釋放出水合液體，這些液體令上覆板塊的地幔物質的熔點下降，使地幔局部熔融成岩漿(圖1)。當岩漿湧上地殼時便會形成島弧及大陸邊緣弧式火山。例如：沿太平洋盆地聚合型板塊邊緣的一列火山便被稱為**「環太平洋火圈」**(圖2)。

Magmatism

Magma is derived from deep within the earth by partial melting of the upper mantle or lower crust. It is composed of a high temperature mixture of silicate material (magmatic liquid), water, and dissolved gases. Magma may also contain crystals that formed during cooling of the magma, and rock fragments incorporated into the magma during its ascent towards the Earth's surface.

Magmatism is the process by which molten rock (magma) rises to the upper crust where it may:

- Either, cool and crystallize relatively slowly to form intrusive igneous rock (plutonic rock);
- Or, be erupted from volcanoes at the Earth's surface in the form of lava and ash that cool relatively quickly to form extrusive igneous rock (volcanic rock).

Solid mantle material rises close to the Earth's surface at divergent plate boundaries (Figure 1). This process is accompanied by a decrease of pressure, which lowers the melting temperature of the mantle material. Thus, when the solid mantle reaches a certain level, it begins to partially melt to form a magmatic liquid. Buoyancy causes the magmatic liquid to rise towards the Earth's surface, away from the zone of melting, leaving behind unmelted solid material. Partial melting, caused by the reduction in pressure associated with the upward movement of mantle, is termed decompression melting.

Decompression melting is also responsible for the production of magma at **hotspots** (Figure 1). A hotspot is a location where an active convection system occurs within the mantle. At these locations, the solid mantle materials are hotter and less dense, and are moving upwards towards the crust in plumes.

At convergent plate boundaries, the **subducting plate** is heated as it descends, releasing hydrous fluids into the plate above (Figure 1). The injection of these fluids into the overlying lithospheric mantle causes a lowering of the melting point of the mantle materials, which partially melt to form magma. These magmas rise to the surface through the crust, feeding the volcanoes that occur in both island arc and continental margin arc settings. For example, the chain of volcanoes along the convergent plate boundaries surrounding the Pacific Ocean basin is known as the **"Ring of Fire"** (Figure 2).

圖2. 活躍火山、板塊運動及「環太平洋火圈」。
Figure 2. Active volcanoes, plate tectonics and the "Ring of Fire".

在不同板塊構造環境下形成的火山

一般來說，火山爆發時噴出的岩漿由三種主要成份組成，包括晶體、岩漿和溶解氣體(主要為水蒸氣)。不同類型的火山在不同的板塊構造環境下，會產生不同的爆炸力，爆炸強度視乎所噴出的岩漿成份而定，尤其是其中溶解氣體的含量。當火山岩漿噴出至地表時，溶解於岩漿中的氣體將以氣泡釋放。岩漿中的氣體含量越高，噴發力越強烈。

目前，世界各地可發現一系列不同組合的岩漿，包括含豐富鎂和鐵的鋁矽酸鹽礦物(**玄武岩**)，以至含豐富鈉、鉀、鈣和鋁的矽酸鹽礦物(**流紋岩**)和介乎兩者之間的岩漿(例如**安山岩**)。

由於玄武岩質的岩漿溫度較高，流動性相對亦較高，導致岩漿中的氣泡得以釋放，因此噴發出岩漿時多數沒有爆炸力。相反，流紋岩質的岩漿溫度相對較低及較黏稠，岩漿內的氣泡較難釋出，當火山爆發時，釋出氣泡產生的爆炸力強烈至可以粉碎岩漿。因此流紋岩火山的爆炸力較玄武岩火山猛烈，並產生較多的火山灰。層狀火山爆發時產生的熔岩及火山灰比例大致相等，環太平洋的火山便是其中例子(圖2及3)。

在各種板塊構造環境中常見的三種火山是**盾狀火山**、**層狀火山**及**破火山口火山**。

圖3. 美國聖海倫火山(相片由美國地質調查局喀斯開火山觀察站提供)。
Figure 3. Mount St. Helens volcano, USA (Photo courtesy of USGS/ Cascades Volcano Observatory).

盾狀火山

大部份在內板塊或大洋中脊擴張中心爆發的玄武岩質火山，其斜坡坡幅較小，形成狀似盾牌的**盾狀火山**。玄武岩火山爆發時，熔岩通常如噴泉般由火山通道噴出，大量低黏稠度的岩漿會以熔岩流的狀態瀉出。夏威夷火山群便是著名的例子(圖4)。

層狀火山

層狀火山與**大陸邊緣弧**或**島弧**結構有關，大部份是安山岩質或流紋岩質。這些火山群形成**層狀火山(混合火山)**，其爆炸力較夏威夷式火山更強。層狀火山特徵為外型呈斜錐體形，由火山灰及熔岩層疊形成(圖5)。

層狀火山的噴發力多變，由最弱的史沖包連式至極具爆炸性的普林尼式噴發類型(圖3)都有，視乎岩漿內可溶解的氣體含量而定，岩漿中溶解氣體含量越多，火山之爆炸力就越強，所形成的火山灰亦越多。

Volcanoes in Different Plate Tectonic Settings

Magma erupted from a volcano is generally a mixture of three main components, crystals, magmatic liquid, and dissolved gases (mostly water vapour). Different types of volcanoes occurring in contrasting plate tectonic settings will exhibit varying degrees of explosivity depending upon the composition of the erupting magma, in particular the dissolved gas content. When a magma is erupted at the surface, any dissolved gas comes out of solution and is released in the form of gas bubbles.

Around the world, a complete spectrum of magma compositions can be found. These range from magmas rich in magnesium and iron aluminium silicate minerals (**basalt**), to those rich in sodium, potassium, and calcium aluminium silicate minerals (**rhyolite**), with a range of intermediate magmas occurring in between (*e.g.* **andesite**).

The magma in basaltic volcanoes is relatively hot, and flows easily. This allows any gas bubbles to escape, resulting in largely non-explosive eruptions. In contrast, the magma in rhyolitic volcanoes is relatively cooler and more viscous. Any gas bubbles in the rhyolitic magma have great difficulty escaping, and are explosively released, shattering the magma. Thus, rhyolitic volcanoes are more explosive than basaltic volcanoes, producing greater quantities of ash. Volcanoes that generate roughly equal proportions of lava and ash produce the characteristic stratovolcanoes that occur around the Pacific "Ring of Fire"(Figures 2 & 3).

Three common types of volcanoes that occur in different tectonic settings are **shield volcanoes, stratovolcanoes,** and **caldera volcanoes**.

Shield Volcanoes

Most basaltic eruptions in intraplate or mid-ocean spreading centre settings form low surface slope **shield volcanoes**. Typically, lava fountains from the vent in these eruptions (Figure 4). Large volumes of low viscosity basaltic magma pour out as rivers of lava. This style of eruption is characteristic of Hawaiian-type volcanoes.

圖4. 夏威夷津勞維亞火山。
Figure 4. Kilauea volcano, Hawaii.

破火山口火山

在聚合型板塊邊緣環境，流紋岩質火山可能形成**破火山口火山**。破火山口火山的形成是由於火山頂部因強烈爆發而崩塌，並陷落於下面的岩漿庫(圖6)所致。

香港發現的火山岩大部份為流紋岩質，主要成份是火山灰，它們大都由破火山口火山爆發時噴出的火山灰形成。破火山口火山的灰雲體積通常很大，會因地心吸力而塌下來， 像火熱的液體般在地面流動。

火山災害

火山爆發帶來的災害主要分為直接引起的主要災害及間接引起的次要災害(圖5)。

主要災害包括：熔岩流、火山碎屑流、橫向爆發、灰降及氣體噴發。

次要災害包括：泥石流、水災、火災及海嘯。

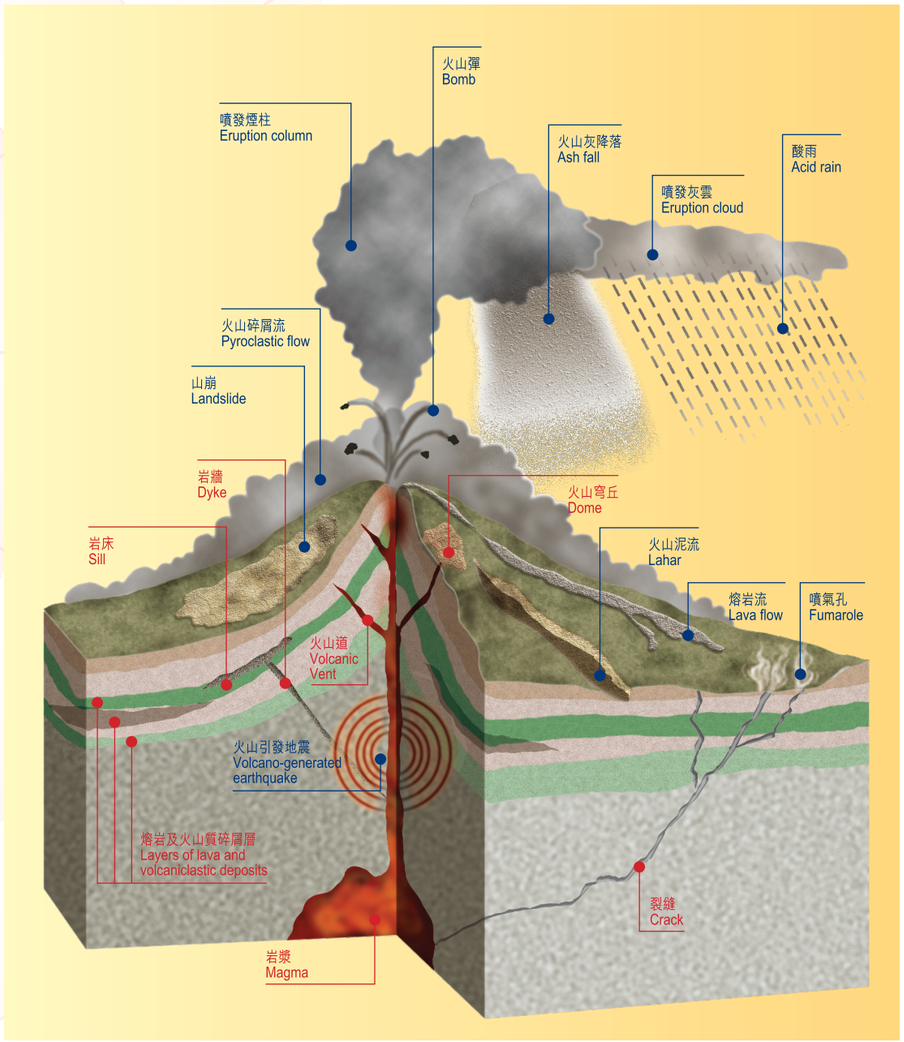
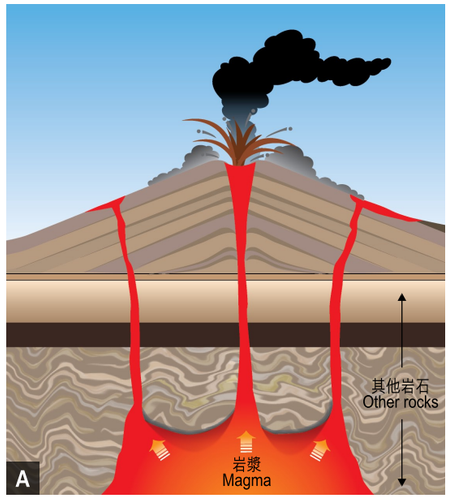


圖5. 層狀火山基本結構及火山災害。
Figure 5. Generalised structure of a stratovolcano and associated volcanic hazards.

Stratovolcanoes

Volcanoes associated with **continental margin arc** or **island arc** tectonic settings are dominantly andesitic or rhyolitic in composition. These volcanoes typically form **stratovolcanoes (composite volcanoes)**, and the eruption style is generally more explosive than Hawaiian-type volcanoes. A typical stratovolcano has a steep cone shape, made up of alternating layers of ash and lava (Figure 5).



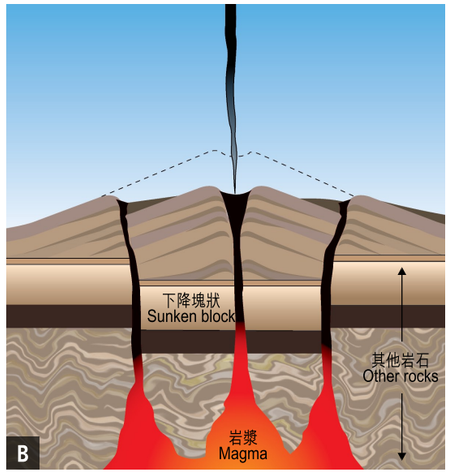


圖6. 破火山口火山之形成 - (A) 強烈爆發掏空了部份火山之下的岩漿庫；(B) 火山的頂部崩塌，並陷落於掏空的岩漿庫中，形成破火山口。
Figure 6. Formation of a caldera volcano - (A) Explosive eruption partially empties the underlying magma chamber; (B) The summit of the volcano collapses into the empty space left in the magma chamber, forming a caldera.

Depending upon the amount of dissolved gas contained in the erupting magma, the eruptions at stratovolcanoes may vary from minimally explosive (Strombolian-type) to highly explosive (Plinian-type) (Figure 3). The greater the dissolved gas content, the more explosive an eruption will be, and the larger the volume of erupted volcanic ash.

Caldera Volcanoes

Rhyolitic volcanoes in convergent boundary tectonic settings may form **caldera volcanoes**. Caldera volcanoes are ones in which the top part of the volcano has been explosively destroyed following collapse into an underlying drained magma chamber (Figure 6). Caldera volcanoes are the result of very violent eruptions.

The volcanic rocks that occur in Hong Kong are predominantly of rhyolitic composition, consisting mainly of ash. These rocks were formed by violent eruptions of ash from caldera-type volcanoes. Ash clouds from caldera-type volcanoes are commonly so large, that they collapse under gravity and flow over the landscape like a fiery fluid.

Volcanic Hazards

Hazards created by volcanoes can be divided into those that are produced directly from volcanic activity (primary hazards), and those that are produced indirectly from volcanic activity (secondary hazards) (Figure 5).

Primary hazards include: lava flows, pyroclastic flows, lateral blasts, ash-falls, and gas emissions.

Secondary hazards include: lahars (mud flows), floods, fires, and tsunami (large sea waves).

地震

地震與所有種類的板塊邊緣有關。當兩塊相鄰板塊相對地移動，它們之間的壓力不停積聚。當接觸點的壓力超出維繫這兩塊板塊的摩擦引力時，積聚的能量便會突然釋放，導致地震 (圖7)。

於**錯動型板塊邊緣**如加州的聖安德里亞斯斷層，兩塊相鄰板塊的橫向移動可能導致突發的錯動，使地殼裂開，在岩石中的斷裂便被稱為斷層。

在**張裂型**或**聚合型板塊邊緣**發生的板塊活動，可於地面以下的任何深度發生。不過，若地震在俯衝帶發生，則可能與伸延至地面的斷層有關。這些錯動或會帶來突發而劇烈的垂直地殼活動，並引起海嘯。二〇〇四年十二月的印度洋地震就屬於這類地震。

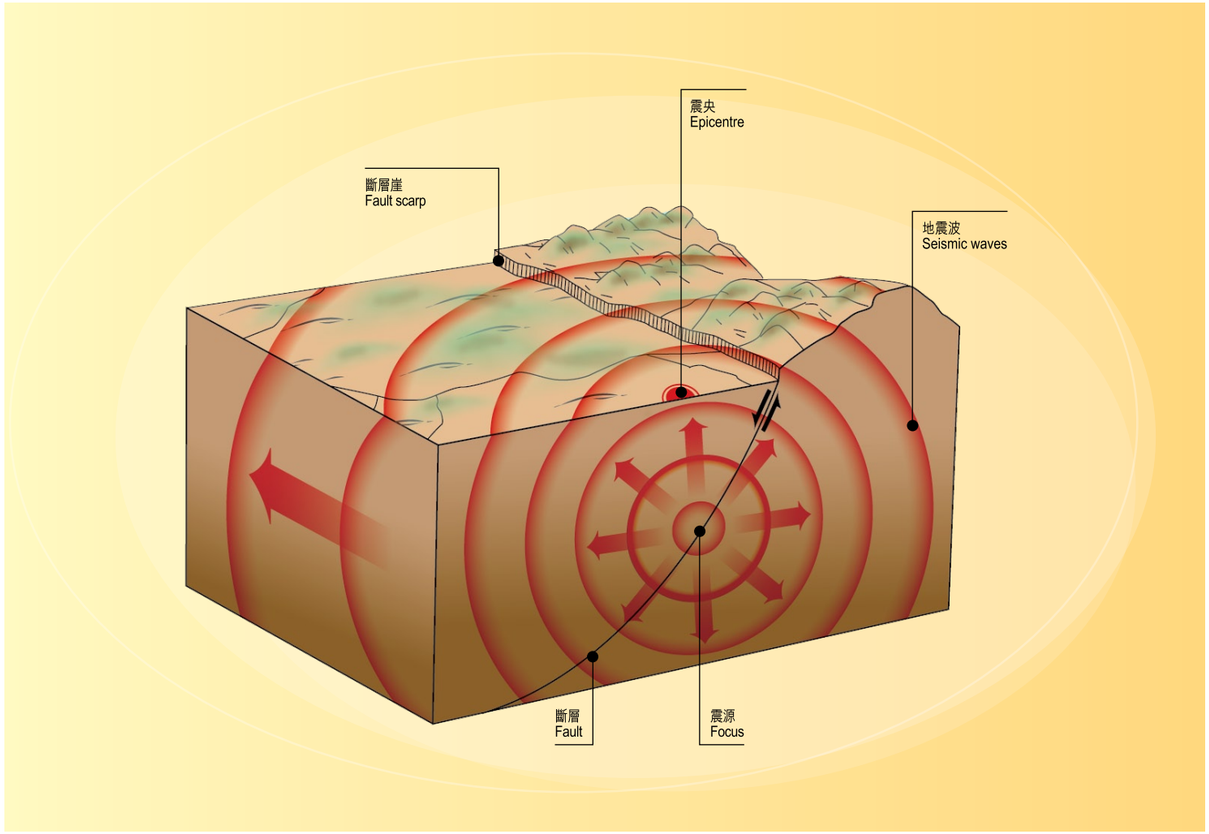


圖7. 沿著地底深處的斷層發生錯動而形成地震波。
Figure 7. Seismic waves generated by movement along a fault deep underground.

斷層與褶皺

脆性變形—斷層

當易碎的岩石受到構造營力影響時，便會沿著斷層破裂，因而引起地震。地震通常發生於板塊邊緣地帶，因為該處的岩石受到最大的構造營力影響。地震較少發生於板塊邊緣以外的地方。

Earthquakes

Earthquakes are associated with all types of plate boundary. They result from the sudden release of energy that occurs when the stress that builds up between two adjacent, moving tectonic plates finally overcomes the friction that holds the two plates together (Figure 7).

At **transform plate boundaries**, such as the San Andreas Fault in California, lateral displacement between two adjacent plates may occur in sudden catastrophic movements that leads to splitting of the Earth's crust at the surface. These ruptures in rock are known as faults.

At **divergent** or **convergent plate boundaries**, the movement between the tectonic plates may occur at any depth below the Earth's surface. However, some earthquakes that occur in subduction zones may be associated with faults that reach the surface. In some cases, these can result in catastrophic vertical movements of the ground and the generation of tsunamis, such as the one that occurred following the December 2004 Indian Ocean earthquake.

Faults and Folds

Brittle Deformation – Faults

When brittle rocks are subjected to tectonic forces, they may break along faults. This fracturing generates an earthquake. Plate boundaries are the most common site of earthquakes, because the rocks in these locations are subject to the greatest tectonic forces. Beyond plate boundaries, earthquakes are less common.

三種主要斷層：正(傾滑)斷層、逆(傾滑)斷層及走滑斷層。

正(傾滑)斷層

當脆性岩石被拉張(即拉張性構造營力)，便會產生正斷層(正傾角/滑落斷層)。沿高角度的斷層平面產生垂直向移動，使上盤沿下盤滑落 (圖8.1)。

逆(傾滑)斷層

當脆性岩石被壓縮(即擠壓性構造營力)，便會形成逆斷層(逆傾角/滑落斷層)，沿高角度的斷層平面發生垂直向移動，使上盤沿下盤向上抬升(圖8.2)。

走滑斷層

當脆性岩石被剪切，便會形成走滑斷層。沿斷層平面會向橫移動：當斷層遠方朝觀察者的左面移動，便稱為左移斷層(圖8.3)；若斷層遠方朝觀察者的右面移動，則稱為右移斷層(圖8.4)。

當脆性岩石裂開但沒有移位，便可能形成稱為節理的構造。岩石的節理成因包括岩漿冷卻(冷卻節理)、岩石內壓釋放(減壓節理)或與斷層活動有關的節理(構造節理)。

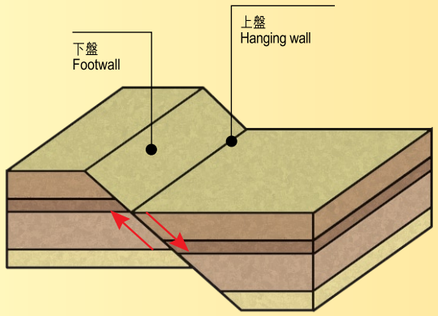


圖8.1. 正傾滑斷層
Figure 8.1. Normal dip-slip fault

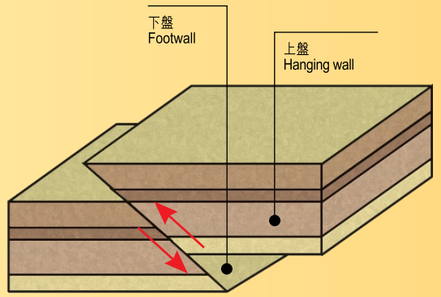


圖8.2. 逆傾滑斷層
Figure 8.2. Reverse dip-slip fault

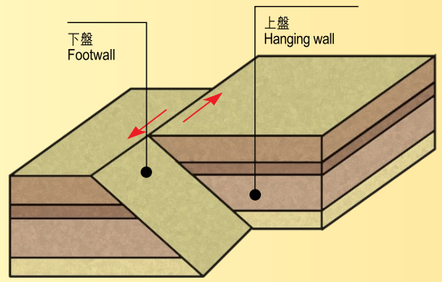


圖8.3. 左移斷層
Figure 8.3. Sinistral strike-slip fault (left-lateral)

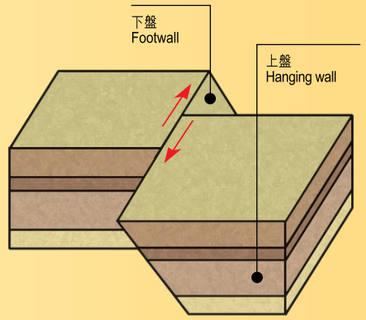


圖8.4. 右移斷層
Figure 8.4. Dextral strike-slip fault (right-lateral)

Three types of fault occur: normal (dip-slip) faults, reverse (dip-slip) faults, and strike-slip faults.

Normal (dip-slip) faults occur when brittle rocks are stretched (*i.e.* the tectonic forces are tensional). Vertical movement occurs along the steeply inclined fault plane such that the hanging wall moves downwards relative to the footwall (Figure 8.1).

Reverse (dip-slip) faults occur when brittle rocks are compressed (*i.e.* the tectonic forces are compressional). Vertical movement occurs along the steeply inclined fault plane such that the hanging wall moves upwards relative to the footwall (Figure 8.2).

Strike-slip faults occur when brittle rocks are sheared (*i.e.* opposing tectonic forces are at right angles to compression and tension directions). Horizontal movement occurs along a fault plane. If the far side of the fault moves to the left relative to the observer it is termed a sinistral strike-slip fault (left-lateral) (Figure 8.3) and if the far side of the fault moves to the right relative to the observer it is termed a dextral strike-slip fault (right-lateral) (Figure 8.4).

Brittle deformation of rock strata may also take place when there is fracturing with no displacement. This produces a structure known as a joint. Joints in rocks may be produced by cooling of molten rocks (magma) (cooling joints), release of stress in rocks (stress relief joints), or joints associated with faults (tectonic joints).

塑性(韌性)變形—褶皺

當塑性岩石受構造性營力彎曲，而非沿斷層斷裂時，這現象稱為**褶皺**。褶皺即岩石平面構造 (如層理面)的彎曲。

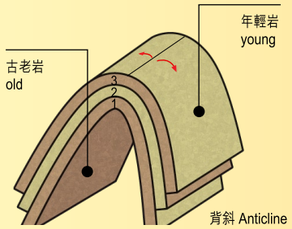
對於年份不明的褶皺岩石，一般如中間向上隆起，而翼部向上成拱形彎曲者，稱為**背形褶皺**；相反，如中間向下凹陷，而翼部向下彎曲者，則稱為同**向形褶皺**。

如褶皺中心位置的岩石年齡較老，此褶皺稱**背斜**；如中心位置的岩石較年輕，則稱**向斜**(圖9.1)。

伏臥褶皺是指兩翼被推至接近至水平的平臥褶皺。

褶皺的幾何結構主要有軸向表面的走向及傾角(圖9.2)及褶皺脊線的走向和傾伏角(圖9.3)。軸向表面是穿過褶皺脊線的假設平面，而褶皺脊線的走向是褶皺脊向傾伏角的方向(方位角)，傾伏角則為褶皺脊線與水平之間的角度(圖9.3)。

褶皺的方位和形狀皆有不同，主要可分為對稱及不對稱(圖9.4)兩種。對稱褶皺的兩翼的長度相同，褶皺面兩邊猶如兩個相同的鏡影；而不對稱褶皺兩翼的長度不等。要明確決定褶皺對稱與否，必須留意轉折點兩翼的整體長度。



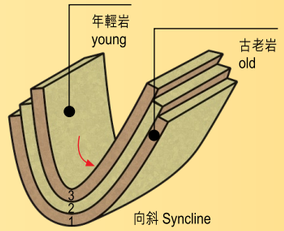
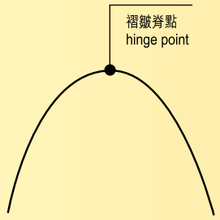
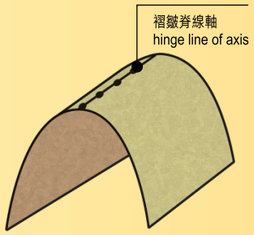


圖9.1. 背斜及向斜。
Figure 9.1. Anticline and syncline.





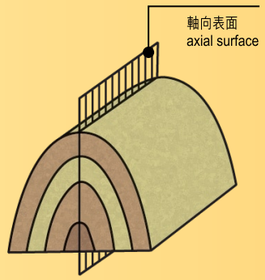
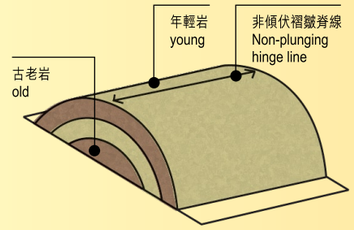
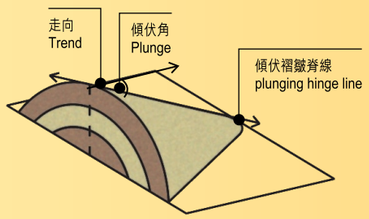
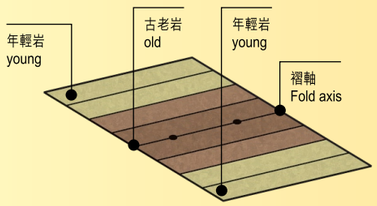


圖9.2. 褶皺的主要元素。
Figure 9.2. Key elements of folds.







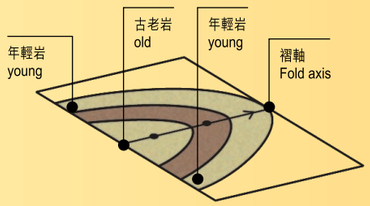
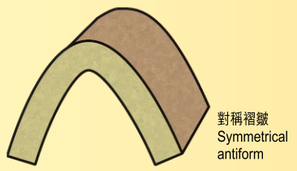


圖9.3. 褶皺及露頭的圖案。
Figure 9.3. Folds and outcrops patterns.



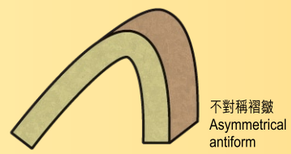


圖9.4. 褶皺的種類。
Figure 9.4. Types of folds.

Plastic (Ductile) Deformation – Folds

When plastic rocks are subjected to tectonic forces they will bend to form folds, rather than break along faults. A **fold** is a bend of a planar structure, such as a bedding plane, in a rock.

If the age succession of the folded rocks is not known, a convex upward fold, with limbs that converge upwards in an arch, is called an **antiform**, and a convex downwards fold, with limbs that converge downwards, is called a **synform**.

Where older rocks occupy the core of a fold, the fold is called an **anticline**, and where younger rocks occupy the core of a fold, the fold is called a **syncline** (Figures 9.1).

A fold with limbs that converge horizontally is called a **recumbent** fold.

Key aspects of the geometry of folds include the strike and dip of the axial surface (Figure 9.2), and the trend and plunge of the hinge line (Figure 9.3). The axial surface is an imaginary plane through the hinge line of the fold. The trend is the compass direction (azimuth) of the hinge line in the direction of plunge, and the plunge is the angle between the horizontal and the hinge line (Figure 9.3).

Not only does the orientation of folds vary, but the shape also varies. Folds may be symmetrical or asymmetrical (Figure 9.4). Symmetrical folds have limbs of equal length, presenting two identical mirror images on each side of the axial surface, and asymmetrical folds have limbs of unequal length. It should be noted that, to definitively determine the symmetry of a fold, it is necessary to see the entire lengths of the limbs on both sides of the hinge.

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