# Hong Kong Landscapes

## Shaping the Barren Rock

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*Cover photograph*: Easterly view of Lantau Peak from Por Kai Shan, Lantau Island
*Title page photograph*: Ngong Ping Plateau, Ma On Shan Country Park

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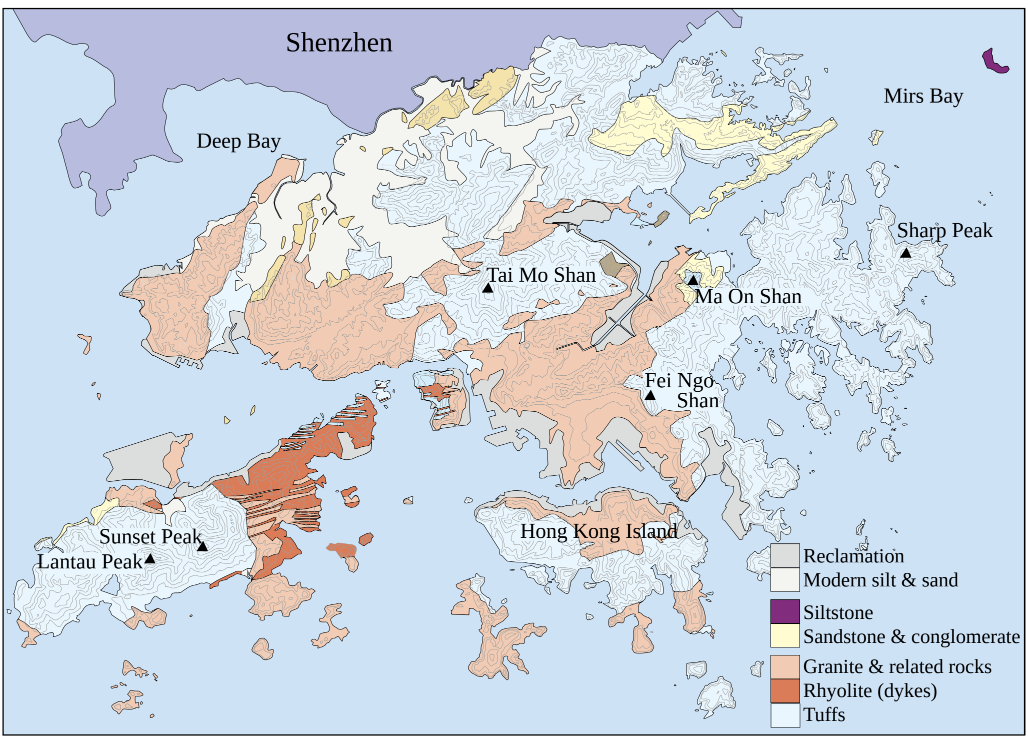
# Rugged Mountain Landscapes: A Story of Ancient Volcanic Eruptions

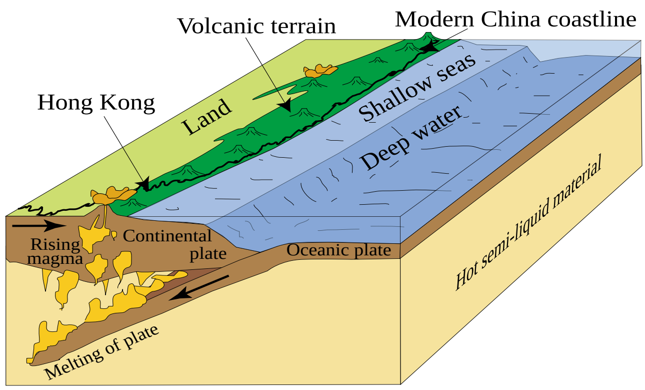
Long-extinct volcanoes have left an indelible footprint on Hong Kong's landscape. Large parts of the territory were influenced by volcanic activity that produced relatively hard rocks. Today, these commonly form the foundations of the most prominent peaks, including Tai Mo Shan (Big Hat Mountain), which rises to 957 m and is the highest summit in Hong Kong. Other high points underlain by volcanic rocks include: Sunset Peak, Lantau Peak, Fei Ngo Shan, Sharp Peak, and Ma On Shan (p. 12). Although tall cliffs are rare, there are many steep slopes, narrow ridges, and scattered rocky outcrops interspersed with more gentle grassy and wooded areas. Surface boulders are common, resting on relatively thin, stony soils. These rugged mountainous landscapes occur widely in the New Territories, Lantau Island, southern Hong Kong Island, eastern Hong Kong, and throughout most of the Country Parks. The influence of volcanic rocks on the shape of the land surface can also be observed along the more dramatic coastlines, with their steep cliffs and angular, rocky shorelines.

The volcanic rocks were created, not by slow moving lava flows, but by violent eruptions that took place mostly between 165–140 million years ago. Fragments thrown out of these volcanoes originated from hot sticky magma that accumulated




*Hong Kong is dominated by volcanic rocks called tuffs (IN02, p. 15) that originated as ash thrown violently out of multiple volcanoes. Today, these igneous rocks are exposed at the surface over about 50% of the territory, mainly occurring in the eastern and northern New Territories, western Lantau, and southern Hong Kong Island.*

*Volcanic rocks in Hong Kong were originally formed as a result of subduction along a plate boundary. This occurred when one rigid plate was forced below another and melted as it descended into the earth's interior, where it reached areas of higher temperature. Magma was produced, which then rose through the overlying rocks to form magma chambers below volcanoes. Occasionally, this material reached the surface, giving rise to violent eruptions.*



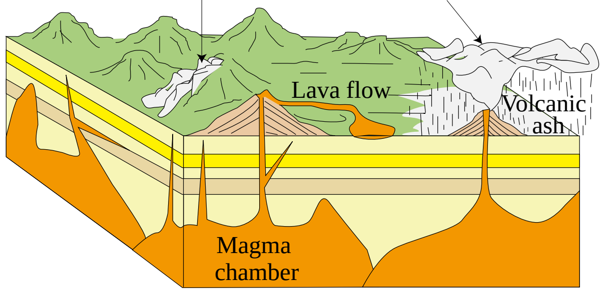

*The photograph above shows the northern slopes of Ma On Shan viewed from a northern ridge on Buffalo Hill. The photograph below is of Sharp Peak—the dramatic backdrop to several superb beaches along the eastern coastline of the East Sai Kung Country Park. Neither of these mountains are especially high (705 m and 468 m respectively), but they both illustrate the rugged, angular nature of the terrain that forms on volcanic rocks.*

in reservoirs deep below the surface. These volcanoes were part of an extensive volcanic terrain along, what is today, the south China coastline. The eruptions took place along a linear plate boundary (figure above). In this region, the southern plate was driven northwards, melting as it descended deeper below the northern plate, producing magma.

Similar plate boundaries occur today around the edges of the Pacific Ocean and are responsible for the active volcanoes in places such as the Philippines, Japan, and New Zealand. The rate of supply of the magma controls the eruption frequency. Magmas produced in these settings are rich in silica, which makes them very viscous (sticky). Consequently, they tend to resist movement (flowing), so that eruptions are particularly violent. Lava flows are infrequent and of small volume, travelling only short distances. Another factor in the explosiveness of these eruptions is the expansion of dissolved gas, which is released as the magma rises through the crust and ambient pressures are reduced. Eruptions of this kind generate large quantities of pulverised rock and clouds of ash.

In Hong Kong, the bulk of the erupted material formed fiery clouds of volcanic ash (about 85%), with rhyolite lavas (IN02, p. 15) being less common. The ash was

## IN02 Extrusive Igneous Rocks



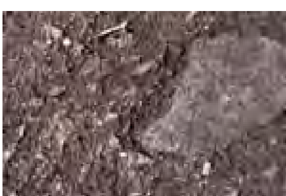

Igneous rocks originate from the cooling and solidification of hot liquid magma, which is a complex mixture of many elements, dominated by silicon and oxygen. The rocks that form are very varied in their appearance and primarily depend on the chemistry of the original magma and the geological environment in which they cool. Two major types are recognised. Extrusive rocks are formed at the surface, whereas intrusive rocks remain within the earth's crust (IN04, p. 22).

Hong Kong's extrusive rocks are dominated by tuffs. Lava flows are relatively rare. Tuffs form from layers of ash that settled to the ground surface after being erupted violently into the atmosphere. In some cases, ash mixed with gases from an erupting volcano and the atmosphere to produce a hot dense glowing cloud (a nuée ardente) that flowed down the flanks of the volcano, hugging the ground. The resulting deposit is a particular type of tuff called an ignimbrite.

*Extrusive Rocks in Hong Kong:*

*Crystal tuffs are dominated by mineral fragments. Larger crystals may occur, surrounded by smaller minerals that are too small for the eye to see.*

*Ignimbrites contain flat volcanic fragments that lie parallel to each other. These were formed when the ash was still hot, loose, and squeezed under its own weight.*



*A large proportion of the tuffs in Hong Kong consist of a mixture of small mineral and larger, angular rock fragments. Most are a speckled grey colour.*

*Modern weathering and rock decay pick out larger volcanic fragments on rock surfaces. This photograph shows a volcanic bomb that was thrown out of a volcano and which settled into finer-grained ash.*

*Rhyolite lava contains minerals with a high silica content. This example from Sai Kung is dark grey and fine-grained, with minerals that are too small to see, except for some larger scattered feldspar crystals.*

mostly fine-grained, consisting of angular crystals, volcanic glass, and rock fragments ripped from the sides of the vent. Two main styles of eruption occurred. Some of the material was thrown out as vast, billowing, fiery clouds (nuées ardentes, IN02, p. 15) that flowed at high velocity down the flanks of the volcanoes. Alternatively, air-fall eruptions occurred, during which ash was blown out vertically, up to hundreds or even thousands of metres into the atmosphere, before falling back to the ground. After subsequent events buried the ash, increasing temperature, pressure, and fluids within the rocks caused the loose particles to change into solid tuff. It is this rock that dominates Hong Kong's volcanic landscapes and rugged mountains.

*The Stone Trail, in eastern Sai Kung, follows a stream that drops over several large waterfalls. The photograph shows one of the smaller falls, about 7 m high.*

Variations in the size of particles within tuffs produce contrasting landscape types. For example, the most angular and

*Tuffs are formed from loose volcanic ash that has been turned into solid rock. Tuff is hard and resistant to erosion, forming steep slopes and narrow gorges such as along the Stone Trail (above) in eastern Sai Kung Country Park.*

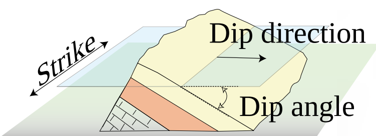
*These large rounded boulders, along a Lantau Island footpath, were formed by weathering of solid rock and removal of the fine-grained decayed material (mainly clay). This particular boulder field may also have been involved in a landslip. Boulder fields on hillsides are a common feature of areas underlain by coarser-grained volcanic rocks.*

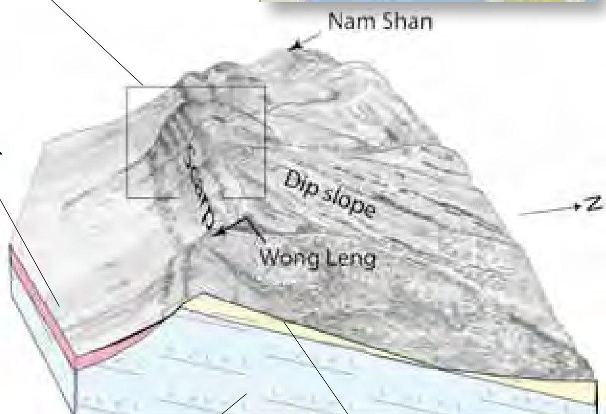
craggy areas are generally developed on fine-grained tuffs, which are more resistant to both chemical and physical decay (IN51, p. 177), and to erosion. In some places, rivers cut through these rocks to form narrow gorges. An excellent example occurs along the Kap Man Hang, a stream in eastern Sai Kung Country Park. The Stone Trail (photographs, p. 16), a difficult walking route, follows part of this river as it passes through several tight gorges and descends a series of spectacular waterfalls. In contrast, coarse-grained tuffs are more easily weathered and tend to produce more rounded hills. The weathered layer at the surface is thicker, and boulder-fields (IN10, p. 39) are strewn across the ground, resulting in an appearance similar to that of granite landscapes (p. 21).

In parts of Hong Kong, such as the Pat Sin Leng in Plover Cove Country Park, volcanic and sedimentary rocks occur together. Both have been tilted by past earth movements, giving rise to steep, rocky inclines on one side of the mountain

*The steep southern scarp face of the Pat Sin Leng is shown here cutting across inclined layers of volcanic and sedimentary rocks. The highest point in the photograph is Wong Leng, which rises to 639 m above sea level.*

# IN03 Escarpments and Cuestas

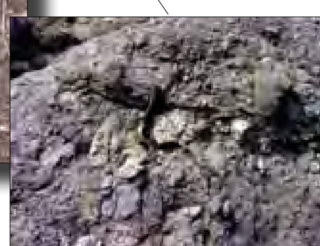




*Thin slope debris*

Inclined layers of volcanic or sedimentary rocks tend to produce distinctive landforms. Ping Fung Shan provides a good example, with a thin layer of conglomerates and sandstones overlying a thick sequence of tuff. These layers dip to the north and form the gentle slopes that descend to Sha Tau Kok Hoi. The steep southern slopes cut across these rock layers and form a craggy scarp slope.

*Volcanic tuff*



*Conglomerate/sandstone*

*These steep slopes, above the small beach at Long Ke Tsai (southeastern Hong Kong), are underlain by volcanic rocks. At the coast, erosion by the sea has produced a laterally extensive fringe of rocky outcrops up to about 10 m high and which locally form steep cliffs.*

and gentle slopes on the opposing side that follow dipping rock layers. These asymmetrical ridges are called cuestas (IN03, p. 18).

Volcanic rocks also form many of the coasts of Hong Kong. Where they are exposed to the South China Sea, they tend to form prominent vertical cliffs. In these settings, powerful ocean waves undercut the tuffs, which then collapse. However, because the rocks are hard, they remain upstanding, except where they have been weakened by faults (IN08, p. 35) or joints (IN09, p. 37). The best examples of these landscapes can be seen along the southern and eastern shorelines of Hong Kong.

The rugged mountains of Hong Kong constitute its most dramatic natural settings. However, there are other landform types that also demonstrate the relationship between scenery and rock type, including rounded hilly landscapes (underlain by granitic rocks), as noted in the next section.

*The cliffs of Bluff Island, in southeast Hong Kong, were formed by high energy waves that eroded the tuffs along the exposed coastline. Where faults or joints (cracks) occur, the rocks are weaker and more easily eroded, and sea caves develop.*

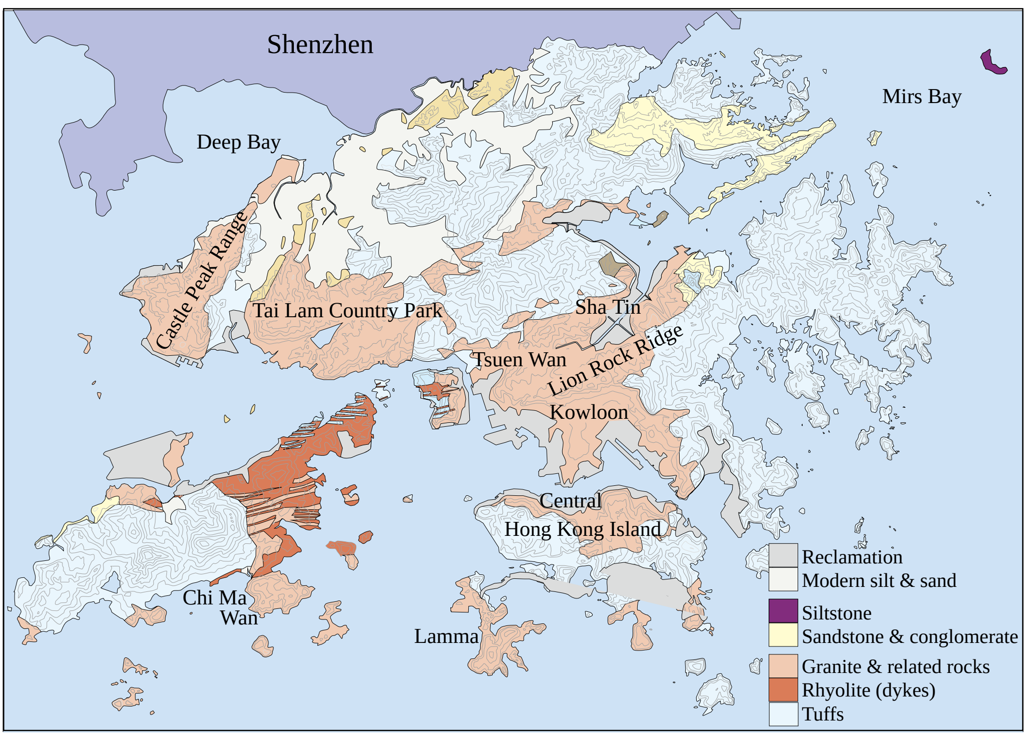
# Rounded Hilly Landscapes: The Roots of Volcanoes

Today, the roots of ancient volcanoes create very distinctive landscapes in Hong Kong. These roots were the magma chambers that were once located 1–2 km below the ancient land surface. Over time, the hot molten magma cooled and solidified to form the rock granite. Millions of years of subsequent erosion stripped away the overlying rocks (IN04, p. 22), exposing the granite over one-third of the land area of Hong Kong, forming bold, rounded rock surfaces.

These granite regions tend to be lower and more gentle in appearance than the volcanic landscapes described in the previous section. Rounded boulders are generally strewn across the surface (p. 20). In some areas, there are dense networks of deep gullies cut into the upper layer of chemically decayed (weathered) rock.

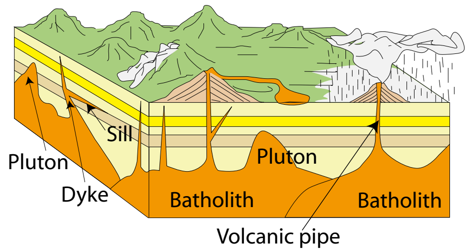
The granitic rocks that underlie these areas extend across much of the western New Territories, including the Tai Lam Country Park and the Castle Peak Range. They also make up the Lion Rock Ridge, the Chi Ma Wan Peninsula, and parts of the southern offshore islands. Granite also forms the flat ground and isolated hills below urban Kowloon and Central.

The hot, humid, sub-tropical summers in Hong Kong cause chemical breakdown of granites. Consequently, granite terrains are usually characterised



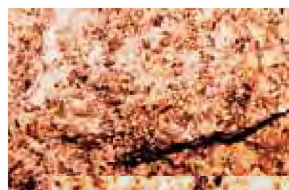

*Granitic rocks cover about 35% of the land area of Hong Kong, mainly forming gently rounded hills, although they also underlie the relatively flat areas of Kowloon and the steep slopes of northern Hong Kong Island.*

## IN04 Intrusive Igneous Rocks



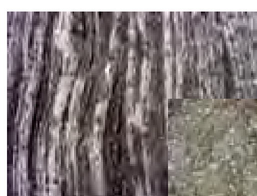

Igneous rocks solidify from magma that has cut its way into the crust or which has erupted at the surface. Rocks formed in the former manner are referred to as intrusive. They may have cooled within small-scale, sheet-like dykes (cutting across the rock layers) or sills (lying parallel to the rock layers). Larger bodies of magma form plutons, and the largest accumulate in batholiths. Most magma in Hong Kong originated in plutons. The mode of intrusion is important to the appearance of the rocks. Small intrusions cool relatively quickly, and crystals only grow to a small size. Larger intrusions cool very slowly, and crystals can grow larger. The chemistry of the magma also controls the final rock type. Magma that developed in Hong Kong originated from melting along a plate boundary (p. 14; IN23, p. 105); it is rich in silica. Upon cooling, this magma type generates granite (in plutons) and rhyolite (in dykes and sills).

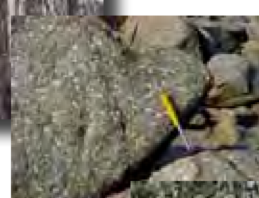
*Intrusive Rocks in Hong Kong:*

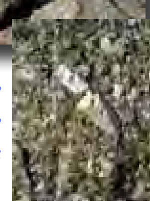


*Granitic rocks form through slow cooling of magma in major intrusions. Crystals can grow very large. The minerals are dominated by several types of feldspar (white/grey to pink), less commonly by quartz (glassy, grey), and by a small percentage of dark minerals, usually hornblende or biotite. Variation in the proportions of these minerals is the basis for recognising different kinds of granitic rock. Granite (left) contains mainly alkali feldspars that are rich in sodium and potassium. Granodiorite (top right) has a little more calcium-rich feldspar (plagioclase), whereas monzonite (lower right) has less quartz and roughly equal proportions of alkali and plagioclase feldspars.*

*Basalt is a dark grey-to-black, very fine-grained rock. It is rare in Hong Kong, occurring in dykes, as in this photograph. In other parts of the world, basalt is much more common, forming mainly as lava flows at the surface.*







*Rhyolite forms as a lava or within dykes. In Hong Kong, it is mainly present in dykes. When weathered, rhyolite may develop parallel striations on the surface (top left) caused by minerals that lined up parallel to one another as the magma was intruded. In some cases, large feldspar crystals have grown within a finer-grained matrix (centre and lower right).*

*The rounded hills, strewn with granite boulders behind Lung Kwu Tan (western New Territories), are typical of granite landscapes.*

by thick sequences of loose, chemically decayed rock, called a weathering profile (IN51, p. 177). In some cases, the layer of decayed rocks can be well over 100 m thick. These loose and weak materials are particularly susceptible to erosion and gullying, especially after vegetation has been removed. Deforestation has occurred widely in Hong Kong in the past, and this has resulted in severe erosion of many granitic areas, although reforestation efforts since World War II have reduced the problem and hidden many of the old scars on the landscape.

Boulders are commonly strewn across granite hills. They are unaltered, rounded rocks that formed as corestones (IN10, p. 39), surviving the weathering process and remaining on the land surface as the surrounding, decayed material was removed by erosion. The boulders form a distinctive element of the granitic hills in Hong Kong: piles of rock called tors.

*Gully erosion can be very deep, as can be seen along this old military road in the Castle Peak Range.*

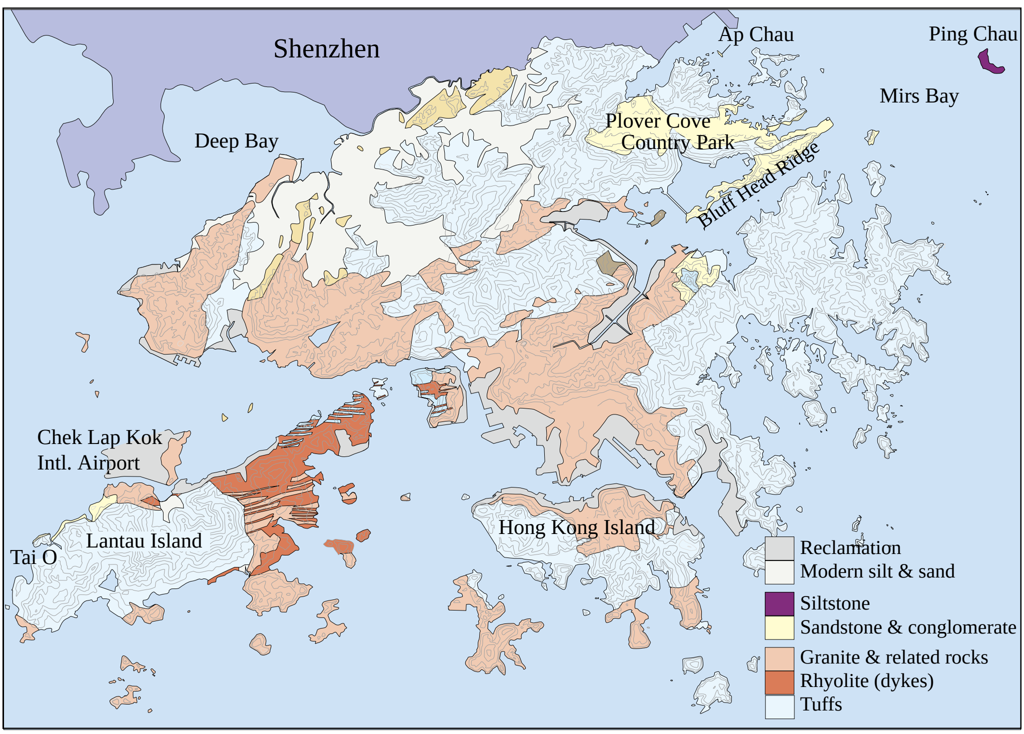
*The Castle Peak Range, in western Hong Kong, shows dramatic erosion, particularly along ridge tops. Many other granitic areas in Hong Kong experienced similar erosion, but extensive reforestation since World War II has been gradually hiding the scars on the landscape.*

*Granite tors are common in the western New Territories.*

# Ridges and Colourful Landscapes: Ancient Seas, Rivers, Lakes, and Deserts

Over the last 400 million years, environments in Hong Kong have changed radically (p. 7–10). There have been several phases of volcanism, but at other times, ancient seas, river plains, lakes, and deserts have developed. Sediments that accumulated in these varied settings were subsequently buried and then transformed into rocks. Today, these layered rocks form beds (IN05, p. 26) that later earth movements have tilted to varying degrees. In some cases, the layers are gently sloping and form asymmetrical ridges, or cuestas (IN03, p. 18). In other instances, the beds have been upturned so that they are almost vertical. The vertical beds, in turn, produce distinctive linear ridges. These sedimentary rocks are confined to the mainland and islands of northeast Hong Kong (p. 24), and small parts of northern Lantau. They underlie about 5% of the total land area of Hong Kong.

*The Bluff Head Ridge to the south of Plover Cove (above) is underlain by very steeply dipping sandstones and mudstones that were formed in river systems about 400–360 million years ago.*



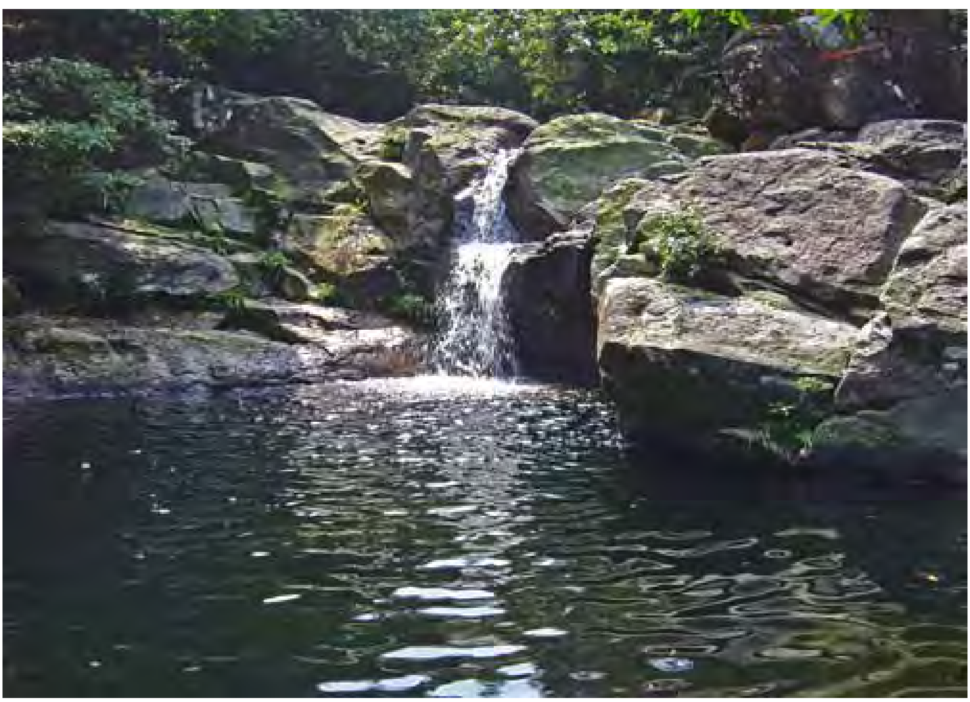

*Sedimentary rocks in Hong Kong mainly occur in northeastern Plover Cove Country Park and on the island of Ping Chau. Sedimentary rocks are also present along the northern coast of Lantau, between Tai O and Chek Lap Kok.*

## IN05 Beds, Bedding Planes, and Time

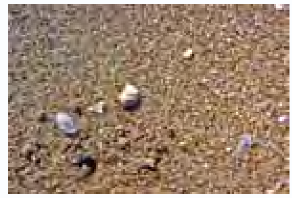
*Thin, steeply dipping, mudstone beds control the shape of this hillside on Shek Uk Shan, Sai Kung Country Park.*

Sedimentary rocks originate as a series of layers or beds. Each bed represents a single depositional event. The laying down of the sediment may have been rapid, taking only a few seconds to occur, or the bed might represent the slow accumulation of fine-grained clay and silt over a long uninterrupted period.

The beds are separated by discontinuities called bedding planes. These are breaks along which the rocks tend to split relatively easily. They usually indicate a period when no sediment was being deposited. There is no easy way to determine how long that time period was. It could range from several seconds to many years. Geologists believe that most of geological time is represented by these gaps in the record. Beds may also vary substantially in thickness from a few millimetres to several metres. Beds can produce a stepped-appearance as the ground follows the rock layers. The thickness of beds controls the size of these steps and the general appearance of the landscape. Note the contrast between the thin, steeply dipping (sloping) beds in the upper right photograph with the scenery in an area of thickly bedded and gently dipping sedimentary rocks (below).



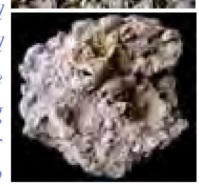
*The sandstone beds above (Ping Fung Shan, Plover Cove Country Park) are thicker than the sedimentary layers in the top photograph. They are also more gently inclined, imparting a different texture to the two landscapes.*

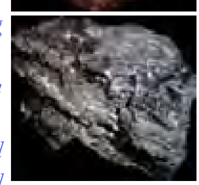
| *Grain Size (mm)* | *Name of the Size Class* | *Sediment Name* | | *Rock Name* | | *Example* |
|---|---|---|---|---|---|---|
| >256 | *Boulders* | *Boulders, cobbles, pebbles, granules* | | *Conglomerate if round in shape, or breccia if the particles are angular* | |  |
| 64–256 | *Cobbles* | | | | | |
| 4–64 | *Pebbles* | | | | | |
| 2–4 | *Granules* | | | | | |
| 1–2 | *Very coarse sand* | *Sand* | | *Sandstone* | |  |
| ½–1 | *Coarse sand* | | | | | |
| ¼–½ | *Medium sand* | | | | | |
| ⅛–¼ | *Fine sand* | | | | | |
| 1⁄16–⅛ | *Very fine sand* | | | | | |
| 1⁄16–1⁄256 | *Silt* | *Silt* | *Mud (a mixture of silt & clay)* | *Siltstone* | *Mudstone* |  |
| <1⁄256 | *Clay* | *Clay* | | *Claystone* | | |

*Classification of detrital sediments and sedimentary rocks. Both systems use grain size. Loose pebble and sand deposits are shown on the upper and centre right. The rock siltstone (lower right; with white calcite) is composed of finer particles.*

Sediments can be divided into chemical, biochemical, and detrital types. After they are laid down, processes associated with burial will turn the loose materials into solid rocks. Chemical rocks initially precipitate from a solution; they are rare in Hong Kong. Examples occur on Ping Chau (northeastern Hong Kong), where salts were laid down, together with mud, in a desert lake that periodically dried out. Biochemical rocks, such as limestone, originate from an accumulation of the skeletons of organisms. Coal is another example because the carbon originates from plants that extracted carbon dioxide from the atmosphere.

Sedimentary rocks and sediments that occur in Hong Kong are mostly detrital in origin and are distinguished by the size of their constituent particles (table above). Detrital sediments result when older rocks are eroded into fragments. These are then washed down rivers, blown by the wind, transported by glaciers, or moved in other ways. The particles eventually come to rest in rivers, lakes, seas, or other settings.





*Shell accumulations often develop on beaches and when partially consolidated are called coquinas (top right). The solid rock equivalent is limestone (second right; small arrows show individual fossil shells). Limestone is found rarely in Hong Kong. However, when this rock is subjected to high pressure and temperature, it changes to marble (centre), with all evidence of the original fossils being lost. This latter rock occurs in several parts of Hong Kong but only underground, below Yuen Long, Ma On Shan, and Tung Chung. Coal (right) once occurred but long ago was changed by pressure and heat (due to deep burial) to graphite schist (bottom right), which occurs on West Brother Island, north of Lantau.*

*The rocks along the northern side of Tolo Channel are made up of sedimentary sandstones and mudstones, laid down in river channels and on floodplains around 350 million years ago. Originally, they were horizontal, but earth movements have altered their orientation so that they now stand near-vertically. The photograph shows alternating sandstones (light colours) and mudstones (dark) at Bluff Head.*

*Colours in sedimentary rocks vary considerably. The upper photograph shows dark grey shales interbedded with red- and orange-coloured siltstones caused by iron reacting with oxygen in the atmosphere. The lower left photograph shows red oxidised iron that has accumulated along cracks (joints). In contrast, the black colours in the lower right photograph are caused by manganese oxides.*

The layering of sedimentary rocks exerts a pronounced control over the shapes of hills and islands (IN03, p. 18), but these rocks are also characterised by a wide variety of colours that add to the beauty of their landscapes. Iron is particularly important in determining colour. Depending on its precise chemical combinations, it may be red, brown, yellow, green, grey, or even black. Only small quantities of iron are required to generate strong colours. For example, many of the sandstones in the Pat Sin Leng and Port Island Formations (IN06, p. 29), in northeastern Hong Kong, were originally laid down in rivers that periodically dried out. These have deep red colours due to iron combining with oxygen in the atmosphere. Associated finer-grained mudstones and siltstones tend to have purple colours, which also developed at a time when there was a dry landscape (100–80 million years ago). Red colours can also develop in other environments. For example, iron-rich minerals decay near the surface during weathering, releasing iron into water. Then, the water flows along cracks (joints) and, if oxygen is present, iron oxides, such as haematite ($Fe_2O_3$) and limonite ($FeO.nH_2O$), may be deposited along the joints, as illustrated in the lower left photograph.

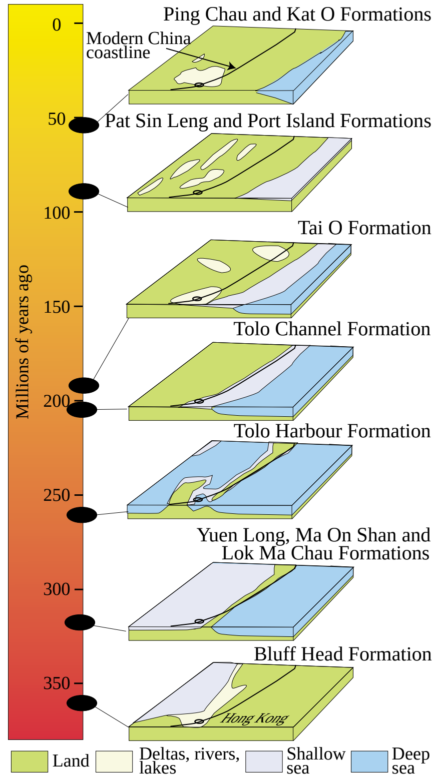
Other elements may also add distinctive hues and variety to landscapes. Manganese, for example, tends to produce black, brown, and purple colours. Carbon usually results in black. Copper tends to yield a range of green colours.

Geologists often group rocks together into formations (IN06, p. 29) based on a variety of evidence. The grain size, composition, colours, and fossils, allow geologists to work out the original settings in which they were laid down. They do

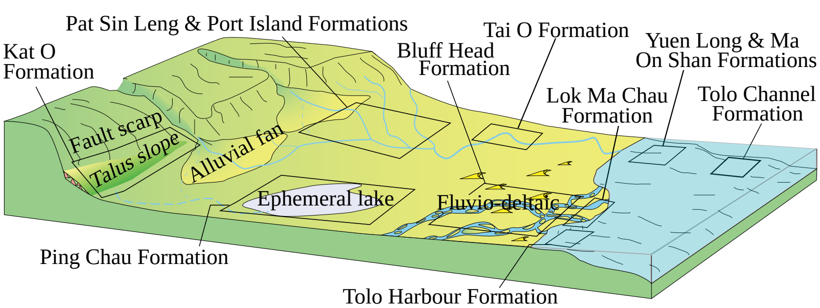
# IN06 Sedimentary Formations

Geologists will often group rocks into formations that display similar characteristics and which can be mapped across an area of interest. A formation may range from less than 1 m to several thousand metres in thickness. Sedimentary formations can be distinguished by their grain size, structures, or any other criteria that is useful. Each formation is given a name, usually based on the location where its properties are best exemplified and the rocks are best exposed. The sedimentary rocks in Hong Kong have been divided into eleven formations. The adjacent figure shows the distribution of land and sea when each of these formations were deposited. The modern China coastline and Hong Kong are shown for reference.

Some of the sedimentary rocks formed on the land, and others below the sea. The lower diagram shows the environment in which each formation developed. The Bluff Head Formation (400–360 million years old) (conglomerates, sandstones, and mudstones) was laid down in deltas and rivers near the sea. The Yuen Long and Ma On Shan Formations (360–320 million years old) (marble) were formed in shallow seas. The Lok Ma Chau Formation (organic-rich mudstones) accumulated in swampy deltas. Mudstones of the Tolo Harbour Formation (290–250 million years old) were laid down in shallow water. The Tolo Channel Formation




(210–190 million years old) mudstones were deposited in relatively deep water (>20 m), whereas the Tai O Formation sandstones and siltstones were laid down on a river plain. The Pat Sin Leng and Port Island Formations (about 100–80 million years ago) (conglomerates and sandstones) were formed in rivers. The Kat O (breccias) and Ping Chau Formations (within the period 80–50 million years ago) (mudstones and siltstones) were deposited in arid locations. The former developed when large blocks of rock accumulated at the base of a cliff. The Ping Chau Formation originated in a very shallow, ephemeral, salty lake.



*Differential erosion operates at a variety of scales. The left photograph was taken on Ma Shi Chau in Tolo Harbour. A series of beds occur that dip (slope) to the right. The harder siltstones stand about 5–10 cm above the softer mudstones, producing a series of small parallel ridges. On a larger scale, the right photograph shows a prominent cliff and ridge formed by hard conglomerates, also dipping to the right, in western Sai Kung Country Park. Note the band of conglomerates (table, p. 27) continuing into the background and controlling the form of the hillside. The softer rocks here are volcanic in origin.*

this by comparing the ancient rocks with similar deposits accumulating in analogous modern environments. This process of comparison has been carried out for the rock formations in Hong Kong. The results indicate that there have been many changes in the prevailing environments over the last 400 million years (p. 7–10).

Landscapes in areas underlain by sedimentary and other layered rocks exhibit distinctive topographical features caused by differential erosion (IN07, p. 31). The combined effects of dipping sedimentary beds (IN05, p. 26) and the occurrence of alternating hard and soft layers produce ridges on a variety of scales, ranging from the Ping Fung Shan Range (IN03, p. 18), at over 600 m, to smaller irregularities, such as those on the islands of Ping Chau and Chek Chau in Mirs Bay (adjacent photographs).

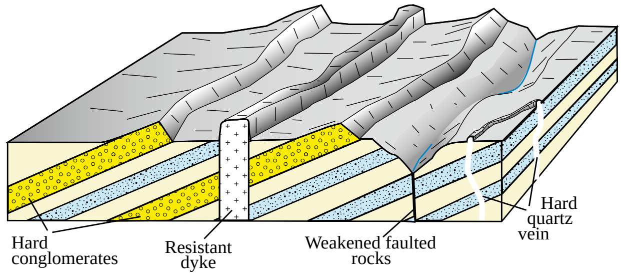
Differential erosion affects the various types of rocks in other ways. They may be fractured by cracks (joints), or by faults. Differential erosion commonly lowers the land surface along these lines of weakness, which is the subject of the following chapter.

*Chek Chau lies at the entrance to Tolo Channel and consists of dipping (sloping) volcanic rocks overlain by red sedimentary sandstones (above). The latter originally formed on a dry plain crossed by ephemeral rivers.*


*Ping Chau consists of gently dipping fine-grained mudstones and siltstones. These form thin layers that control the shape of the island. Note (above) the step-like pattern of the wave-cut platform. The overall shape of the island follows these sloping rocks.*

## IN07 Differential Erosion

The word rock is usually synonymous with "hard". However, some rocks are less hard than others. Sedimentary rocks, such as mudstone, shale, and siltstone, are relatively soft, whereas sandstone or conglomerate are generally harder. Natural weathering and erosion processes tend to emphasise these differences. This differential erosion is a powerful force in landscape evolution. Consequently, resistant layers will eventually stand proud above a landscape, whereas softer rocks will form lower areas. The effect occurs at all scales from a small outcrop to the highest mountains. Commonly, rocks that form mountain peaks are harder than the surrounding foothills, those that make ridges are harder than the rocks that comprise valleys, and any upstanding outcrop is harder than adjacent depressions.




*The diagram shows a series of inclined sedimentary rocks. Some layers, such as the conglomerates, tend to be harder than others and stand proud at the surface. Other rocks, such as the dyke and the quartz vein, are also resistant to erosion and form upstanding elements in the landscape. In some cases, rocks can be weakened by faulting, in which case they are preferentially removed by erosion to produce valleys.*

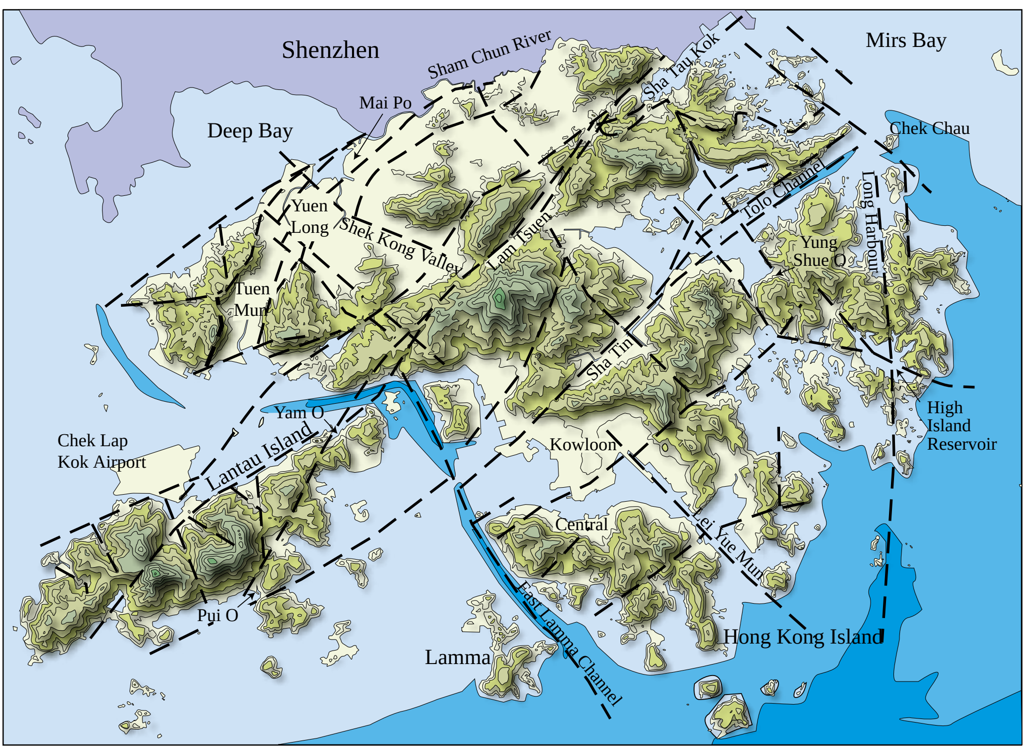
*Harder rock layers are sometimes caused by secondary effects. Here a prominent siltstone ridge stands about a metre above its surroundings. This layer has been made resistant by a network of quartz (white) veins, as shown in the inset.*

# Lowlands and Valleys: Fractured Rocks and Rivers

Faults, large and small, are zones of weakness in the earth's crust that control the locations of Hong Kong's rivers and plains. Most valleys reflect the combined influence of fracturing of rocks by faulting and erosion by rivers. This is apparent when the pattern of faults is overlain on a topographical map (figure below).

There are three main fault orientations in Hong Kong. The largest valleys follow a NE-SW alignment, as shown by the Sha Tin Valley and its extension along Tolo Channel (a flooded river valley). Other faults that run parallel to this trend control the configuration of several valleys on Lantau (Pui O to Yam O Wan), the Lam Tsuen Valley, and the Sha Tau Kok Inlet. Similar NE-SW faults extend from the border to Tuen Mun, and have contributed to the formation of the lowlands near Yuen Long and the mangrove-fringed coastal plains of Mai Po (p. 32). These latter lowlands are underlain by marble (IN11, p. 51) and also owe their existence, in part, to a faster lowering of the surface of these rocks (IN07, p. 31).

Other valleys (e.g. Shek Kong; and below the High Island Reservoir; along the Lei Yue Mun Gap; and the East Lamma Channel follow a NW-SE fault direction. A third fault trend, N-S, guides the orientation of, for example, Long Harbour and the sea floor topography in southeastern Hong Kong.



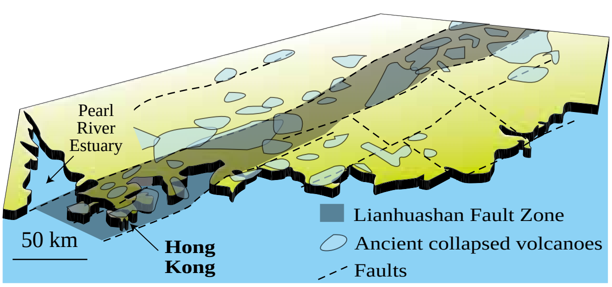

*Faults control the orientation of valleys, plains, and sea floor channels in Hong Kong. This can be seen in both the onshore and offshore topography, which displays three major orientations: NE-SW, NW-SE, and N-S.*


*Shek Kong lies at the upper end of a fault-controlled valley that extends through Kam Tin to the Yuen Long Plain in the left background. The peaks of Kai Kung Leng, Tai To Yan, and Kwun Yam Shan are dominated by volcanic rocks.*

*The inset shows white clay (kaolin) along a fault (IN08). The clay formed as a result of decay of feldspars in the crushed rock.*

Movement along faults causes rocks to fracture or even melt due to frictional heating. Faults may occur as sharp breaks, form wide zones of crushed rock (IN08, p. 35), or occur as sets of closely spaced fractures. They promote an increase in the depth of weathering because they create planes along which water can flow and enhance chemical decay (left photograph). Faults may be small-scale, just a few metres long and with a displacement of only a few centimetres, or they may be much larger extending over tens of kilometres and with much larger movements. Most faults are steeply inclined and form straight valleys, such as occur at Shek Kong and Kam Tin (photograph above).

Hong Kong faults form part of a much more extensive structural trend. This is referred to as the Lianhuashan Fault Zone, which extends along the coast of southeast China and controls the regional orientation of many of its landforms.




*The Lianhuashan Fault Zone follows a long NE-SW trend across much of southern China and Hong Kong.*

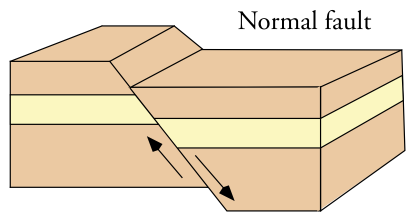
Several types of faults can be distinguished, based on their style of movement (IN08). As noted earlier, the dominant faults in Hong Kong follow a NE-SW

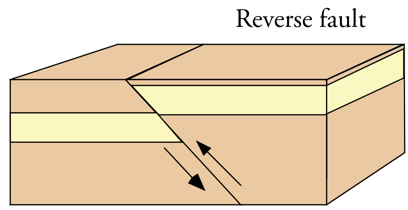
## IN08 Types of Fault

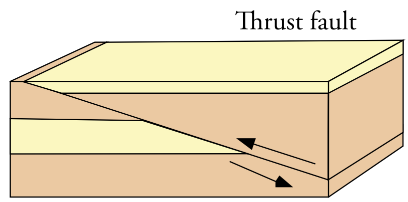
Faults are fractures in rocks caused by movements of the earth's crust. They also involve movement of the rocks on one or the other side of the fault plane. Several types can be distinguished, depending on the direction of movement. A normal fault occurs when the rock above a fault plane moves downwards. In contrast, reverse faults display an upwards movement of the rocks above the fault plane. A thrust fault is similar to a reverse fault, except that the fault plane lies at a more gentle angle. Strike-slip faults involve only lateral movement. In some situations, both vertical and horizontal movements can take place and the term "oblique fault" is applied.

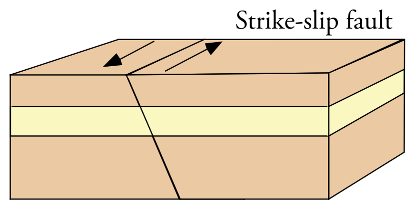
The type of fault that develops depends on the stresses within the rocks. Normal faults occur when rocks are pulled apart (tension), whereas reverse and thrust faults form when rocks are squeezed (compression). Strike-slip faults occur where stresses are mainly lateral.

Faults may be sharp breaks (right photograph), or they may be associated with wide zones of crushed rocks (lower photograph). Sometimes they are filled by mineral veins formed at a later stage.



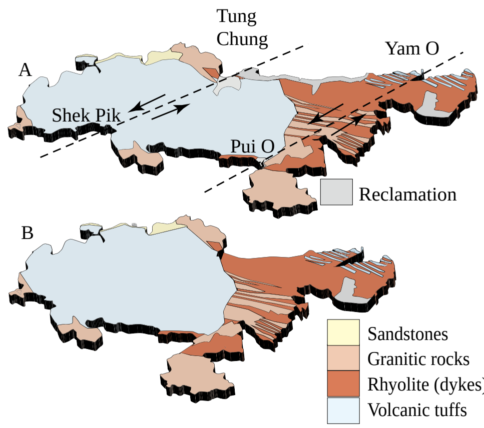




*A crush zone (between the lines) marks a fault. The offset is an illusion caused by a flat platform.*

*The photograph above shows a vertically oriented fault immediately below the summit of a small hill on Chek Chau (northeastern Hong Kong). Note the sharp break with a distinct offset in the dipping sandstones on either side of the fault.*

orientation and control the alignment of the major valleys. These particular faults are mainly of the strike-slip type (IN08, p. 35) and are spaced about 6–12 km apart. Movement along the fault planes has been predominantly sideways (horizontal) and has occurred intermittently through the last 300 million years or so. Total movements, up to 3 km, have been responsible for changing the relative position of rocks on either side of the faults and for determining the shape of the ground. Lantau Island provides a good example. It is crossed by two major strike-slip faults that have caused displacement of the rocks (A and B in the adjacent figure) and have elongated the shape of the island.

Faults are not the only kinds of fractures that affect landscapes. Joints (IN09, p. 37) are also cracks, but they do not involve movement on either side of the fracture surface. They tend to produce



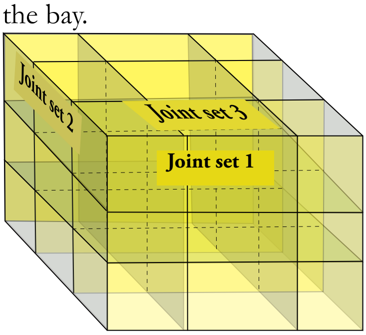

*Strike-slip faulting has changed the shape of the land that is now Lantau Island. Repeated slow movements along two NE-SW-trending faults have shifted the rocks sideways by up to 3 km (Figure A). If the effects of these movements are removed, the original relationships of the rocks can be reconstructed. This has been done in Figure B. Note the resulting circular shape for the outcrop of the tuffs on western Lantau, which reflects their accumulation within an ancient caldera (a circular depression created by the collapse of a volcano).*

*This photograph shows a series of well-developed, parallel joints in a volcanic tuff on Yim Tin Tsai (Plover Cove). These near-vertical joints act as planes of weakness that are opened up by weathering and erosion. Smaller joints and other cracks within the rock are responsible for the crisscross patterns on the rock surface.*

## IN09 Joints in Rock

Joints are smooth, planar fractures in rocks that extend from a few metres to several kilometres. Several types occur. Columnar joints result from cooling or shrinkage (IN40, p. 136). Sheeting joints develop parallel to the ground surface as erosion removes the overlying materials, thereby reducing the pressure and allowing expansion and cracking of the rocks. Usually these joints exhibit a gentle curvature.

Tectonic joints develop in response to earth movements, and are the most common, mainly occuring as a series of multiple, parallel, flat, intersecting cracks. They commonly control the shape of small rock outcrops. Excellent examples can be seen at Waterfall Bay on southern Hong Kong Island (top right and right), where three sets of joints intersect (figure below left). Note in the photographs how the joints (and a fault hidden behind the waterfall) control both the rock form and the overall rectangular shape of the bay.





*Three sets of parallel joints can be seen in the block (above left). Two are vertical and one is horizontal. All intersect at right angles. Note in the photograph and sketch (right) how similar joint planes appear in reality.*

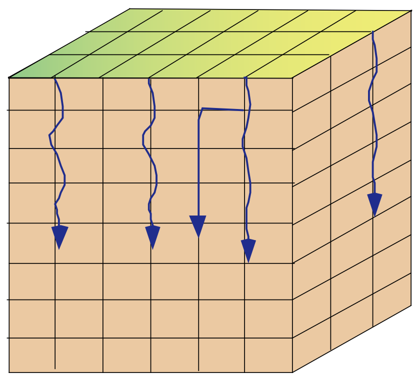
blocky, angular shapes in outcrops (IN09, p. 37). Joints mostly develop while rocks are buried under several kilometres of overlying materials. Their formation reflects the brittle nature of rocks and the stresses that are imposed on them by earth movements.

Similar to faults, joints are planes of weakness that influence the weathering and breakdown of rocks and, in turn, the development of landscape. They often intersect nearly at right angles, with streams, valleys, and coastlines commonly following these rectilinear patterns. Intersecting joints (IN09, p. 37) also add texture to valley sides and hilltops through the formation of blocky rock outcrops and the development of boulder fields (IN10, p. 39).

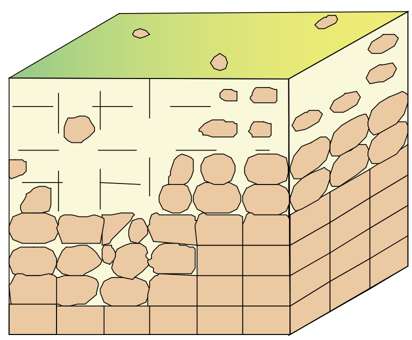
*Boulder fields form where several joint sets (at least three or more) intersect (IN09, p. 37; IN10, p. 39). Commonly the rocks are also characterised by relatively large grain sizes and minerals, such as feldspars, that can be easily broken down chemically. The example above shows a boulder field formed from volcanic rocks on Luk Chau Shan in the northern part of the Ma On Shan Country Park. Boulder fields are usually best developed on granitic rocks. Excellent examples of the latter can be found on the western slopes of the Castle Peak Range in the western New Territories (below). In this area, abundant, well-rounded boulders are spread across many of the hillsides.*

## IN10 Boulder Fields and Joints

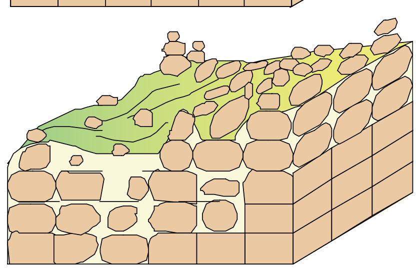
Boulder fields are loose accumulations of large, usually rounded, detached boulders that lie strewn across a land surface. They begin to develop when water slowly percolates down joints, weathering and weakening the original rock material on the edges of joint blocks and leaving a central rounded corestone of relatively undecayed material. The process that leads to the formation of corestones is called spheroidal weathering (adjacent photograph). When the rock is exposed at the surface, erosion begins to remove the surrounding loose rock debris, leaving behind fresh corestones over the land surface.



Stage 1. *Fresh jointed granite or coarse-grained tuff. Rain seeps down intersecting joints and begins chemical weathering along these planes of weakness. Weathering is greatest at corners where the water can promote chemical breakdown from three sides. Weathering is moderately strong at edges, with only two sides to attack, and slowest in the middle of a block face. The result is that weathering gradually makes the fresh joint block rounder, producing the typical form of a corestone boulder.*



Stage 2. *Chemical weathering causes rock to decay mainly by the breakdown of minerals such as feldspars to new minerals, typically clays. In Hong Kong, this is usually to a white clay called kaolin. As the process continues, rounded boulders develop that are more common and larger in the lower part of the profile. Isolated fresh boulders accumulate on the surface as the ground is lowered by erosion.*



Stage 3. *Further erosion removes most of the loose, weathered material. Exhumed corestones of fresh unweathered rock gradually accumulate on the surface, which by now has been considerably lowered. In some instances, boulders will be left resting on top of each other to form a feature called a tor.*

# Coastal Landscapes: Cliffs, Beaches, and Mud Flats

Coastlines reflect the interplay between geology (rock type, faults, and joints) and marine processes (erosion and deposition). These factors vary from place to place, resulting in the variable development of cliffs, beaches, and tidal mud flats along different sections of the coastline. Hong Kong's highly indented coast is about 350 km long and shows a marked contrast between west and east. The western shores tend to have a more subdued appearance (photograph below), with gentler slopes and either rocky or muddy coasts. In contrast, eastern areas tend to be much more rugged, with abrupt, near-vertical rocky cliffs (p. 40) and sandy bays.

## The Western Region

Shorelines in this region are generally low-lying and depositional. Deep Bay, in the northwest, is very shallow, with extensive mud flats and fringing swamps, especially near the Sham Chun River mouth. An important mangrove community is established on the mud flats, with a rich and varied fauna, particularly of shellfish. Mangrove stems slow the tidal currents in the area, which promotes settling of the fine-grained suspended sediments and the seaward extension of the mud flats.

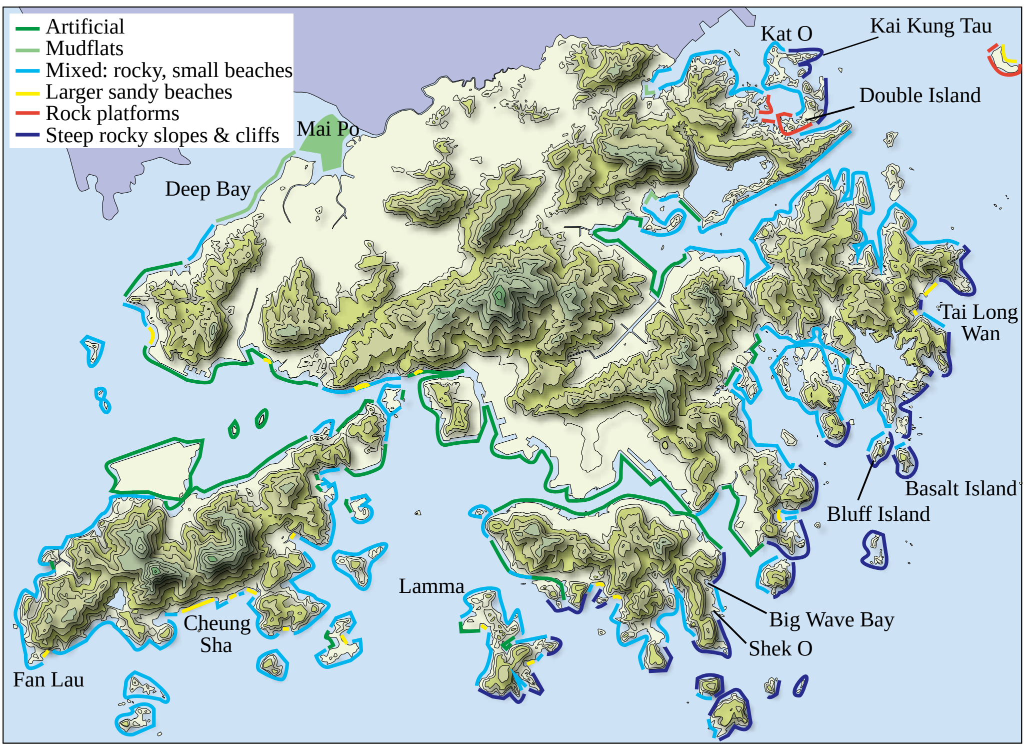
In contrast, the coastline adjacent to the granite uplands of the Castle Peak Range


*Extensive tidal flats form the northwest coastline of Hong Kong. These can be seen just beyond the fringe of Mai Po mangroves next to the road. The area also includes fish ponds and gei wei wetlands where shrimps are harvested.*

is comprised of a narrow, low-lying, coastal zone. Several sandy beaches, of varying size, alternate with accumulations of large rounded boulders derived by slope failure from the adjacent hillsides.

Lantau, the largest of Hong Kong's 262 islands, has a varied coastline (map below). In the north, volcanic and sedimentary rocks have produced rocky shorelines, with beaches and mudflats in bays protected from waves. During the last decade, much of the north has been altered by reclamation for the North

*Small beaches (and a few larger ones) alternate with areas of large well-rounded boulders along parts of the southern Deep Bay coastline. The boulders originated on the neighbouring granitic slopes and have been moved to the shoreline by landslides.*




*Hong Kong coastlines vary with exposure to the sea, local rock types, and the degree of human intervention. The map shows the dominance of sea cliffs and steep rocky slopes in the southeast. Northwesterly shores tend to consist of steep rocky slopes plunging into the sea (without cliffs) or areas of mud- or sand-flats. Several types of wave-cut platforms occur in the northeast. Beaches are best developed on southeasterly facing shores. Artificial coastlines occur around Victoria Harbour, northern Lantau, inner Tolo Harbour, and the western New Territories. Place names indicate the locations of coastal features shown in photographs in this section.*

Lantau Expressway. In contrast, the south is less developed. These coasts are exposed to stronger waves from the South China Sea and are characterised by rocky shores and extensive beaches, including Cheung Sha Beach, the longest in Hong Kong. In the southwest, granitic rocks (photograph below) have produced beaches and rocky, boulder-strewn coasts.

## The Central Region

Hong Kong Island displays similar variety to that of Lantau. Most of the north shore has been reclaimed for urban development over a period of more than a century. There several prominent peninsulas in the south, notably Stanley and Cape D'Aguilar, that have a gently sloping rounded form on their higher slopes. These inclines tend to become steeper lower down and, locally, may form sea cliffs. Commonly, large piles of boulders lie at the base, having fallen from above. Similar rounded hills and coastal

*Lantau Island has been experiencing a radical change in its coastal landscapes since the development of the Chek Lap Kok Airport, In recent years, the northern shores have been significantly altered by infrastructure developments such as the expressway shown in the photograph above. Pressures on the area are increasing with several schemes for additional reclamation having been proposed.*

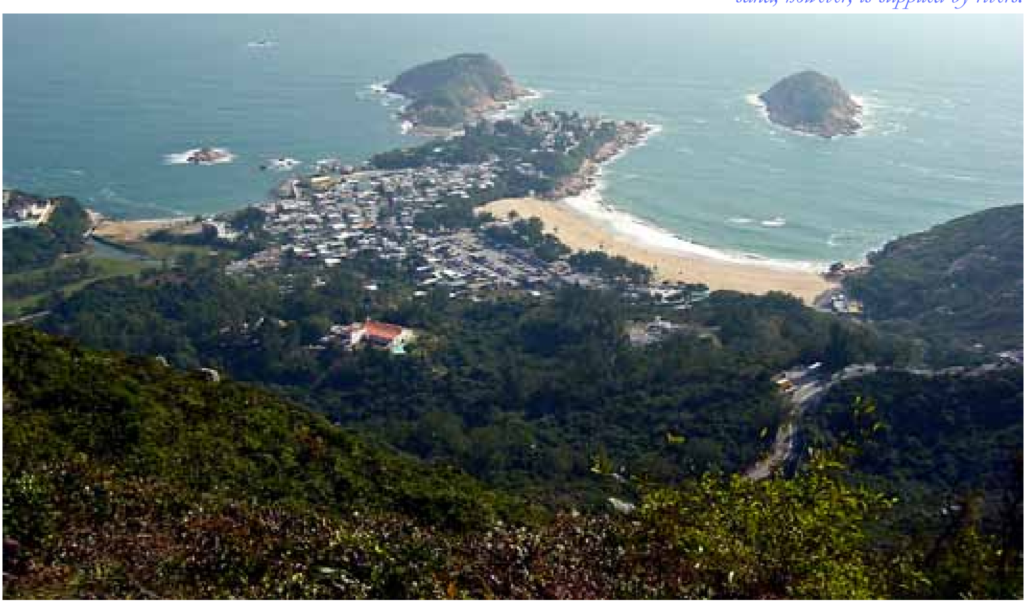
*The southwestern tip of Lantau, Fan Lau, consists of a remote, rocky, granite promontory, isolated beaches, and bouldery shorelines. Several islands belonging to mainland China can be seen along the horizon. These have suffered considerably from aggregate quarrying in recent years.*

cliffs are also present on neighbouring Po Toi, Beaufort Island, and Lamma.

The southern headlands on Hong Kong Island also enclose bays with extensive beaches, such as Sham Shui Wan (Deep Water Bay), Heung To Wan (Shek O), Tin Shui Wan (Repulse Bay), and Tai Long Wan (Big Wave Bay). The sand here owes its existence to the southerly facing coast, which has exposed these shores to strong ocean waves. However, in the past, major typhoons removed large volumes of sand from parts of these coastlines. The beaches were replenished artificially in the early 1990s.

*Victoria Harbour is surrounded by artificial coastlines and high-rise buildings and offers one of the most exciting human landscapes in the world.*

*Coastlines on southern Hong Kong Island consist of eroded headlands, and bays where deposition occurs. Waves move the eroded material to the head of adjacent bays, such as those at Shek O (below), where it contributes to the beaches. Most of the sand, however, is supplied by rivers.*



## The Eastern Region

Shorelines in the east and southeast are generally erosional. The coast is mostly made up of fine-grained volcanic rocks that, in some places, have well-developed vertical joints (IN09, p. 37; IN40, p. 136). The action of the sea on these rocks has created a distinctive coastline with high, precipitous cliffs, especially in the extreme southeast. For example, Bluff Island (photograph below) is rimmed by the tallest cliffs in Hong Kong, which reach over 140 m high.

*The southeastern coastline is characterised by high and rugged cliffs, such as those shown above, on Wam Tam Shan (Basalt Island), and below, on Sha Tong Hau Shan (Bluff Island). The cliffs are particularly distinctive because of the numerous vertical columns that occur in this area. These originally formed by cooling of hot volcanic ash, which causes hexagonal vertical joints to develop (IN40, p. 136). Today, they are being attacked by powerful ocean waves, with the columnar shapes guiding the form of the cliffs.*

In many places, the cliff faces are penetrated by sea caves. Sea arches develop where extreme erosion has occurred. Collapsed arches have, in a number of places, produced small isolated islands called stacks (figure, p. 138). Sea caves

are common along the coast and on many islets between Tai Long Wan and Basalt Island (eastern Sai Kung Country park). Unusually, Tai Chau (adjacent photograph) is penetrated by an underwater cave that runs the entire width of the island.

*Tai Long Wan (above) contains three islands of volcanic rock. Lan Tau Pai is the very small islet to the left. Tai Chau is the large central island, and Tsim Chau lies to the right. An underwater cave runs below Tai Chau.*

Rugged cliffs also occur in the extreme northeast of Hong Kong, such as on parts of Kat O. However, wave erosion on several other islands has cut gently sloping rock platforms into the sedimentary and volcanic rocks. Around Double Haven, most of these platforms occur slightly above the current high tide level (e.g. on Crooked Island, Crescent Island, and Double Island). Elsewhere, such as around Hok Tsui and Ping Chau, these platforms lie below the high tide level.

*Crooked Island, or Kat O, has a finger-like shape. The photograph below shows Kai Kung Tau at the end of one such finger. Note the eroded cliffs on this exposed coastline. Wong Wan Chau, or Double Island (right), lies in more protected water. There, wave erosion and weathering processes have combined to generate flat platforms just above the high tide level.*

# Information Sources and Further Reading

This work has made use of an extensive range of data sources, as well as the authors' own previous works. Major sources are listed in Part I, with other references that have been used less intensively in Part II. Part III includes minor source materials and other books and articles about Hong Kong, grouped into categories for ease of reference. The selection is not comprehensive but will allow readers to pursue individual topics of interest.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*Hong Kong Landscapes, Along the MacLehose Trail* by R.B. Owen & R. Shaw, Geotrails, 2001, 203p.

*The Pre-Quaternary Geology of Hong Kong* by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai, P.A. Kirk, Hong Kong Geological Survey Memoir, 2000, 181p.

*The Quaternary Geology of Hong Kong* by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai, P.A. Kirk, Hong Kong Geological Survey Memoir, 2000, 209p.

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*The Story of Lin Ma Hang Lead Mine, 1915–1962* by T. Williams, Geological Society of Hong Kong Newsletter, 1991, 9(3), pp. 3–27.

## PART II: Publications referred to less extensively

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*Geotechnical Area Studies Programme—Territory of Hong Kong* by K.A. Styles & A. Hansen, Geotechnical Control Office, Civil Engineering Services Department, Hong Kong. GASP Report, 1989. No. XII, 346p plus 15 maps.

*Hong Kong Geological Survey Memoir No. 1: The Geology of Sha Tin* by R. Addison & R.J. Purser, Hong Kong Government Printer, 1986, 85p.

*Hong Kong Geological Survey Memoir No. 2: The Geology of Hong Kong Island and Kowloon* by P.J. Strange & R. Shaw, Hong Kong Government Printer, 1986, 134p.

*Hong Kong Geological Survey Memoir No. 3: The Geology of the Western New Territories* by R.L. Langford, K. W. Lai, R.S. Arthurton & R. Shaw, Hong Kong Government Printer, 1989, 140p.

*Hong Kong Geological Survey Memoir No. 4: The Geology of Sai Kung and Clearwater Bay* by P.J. Strange, R. Shaw & R. Addison, Hong Kong Government Printer, 1990, 111p.

*Hong Kong Geological Survey Memoir No. 5: The Geology of the Northeastern New Territories* by K.W. Lai, S.D.G. Campbell & R. Shaw, Hong Kong Government Printer, 1996, 144p.

*Hong Kong Geological Survey Memoir No. 6: The Geology of Lantau District* by R.L. Langford, J.W.C. James, R. Shaw, S.D.G. Campbell, P.A. Kirk & R.J. Sewell, Hong Kong Government Printer, 1995, 173p.

*Preliminary Vegetation Maps of the World since the Last Glacial Maximum: An Aid to Archaeological Understanding* by J. M. Adams & H. Faure, Journal of Archaeological Science, 1997, 24, pp. 623–647.

*The Influence of the Pearl River on the Offshore Geology of the Macao—Hong Kong area* by R. Shaw & J.A. Fyfe, Proceedings of the International Conference on the Pearl River Estuary in the Surrounding Area of Macao, 1992, pp. 247–255.

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