Chapter 8
Superficial Deposits and Weathering

Classification and Distribution

Superficial deposits, comprising accumulations of sediment derived from the weathering and erosion of older rocks, are widespread in both onshore and offshore parts of the district. They mantle an often deeply weathered rock surface and vary from discontinuous veneers of slope debris and alluvium in onshore areas, to laterally extensive mud and sand sheets up to several tens of metres thick in offshore areas. The environments of deposition are shown in Figure 10.

In onshore areas, the superficial deposits on the higher ground consist mostly of colluvium (slope debris, etc) much of which is derived from processes of mass movement. Downslope, the colluvium grades into, and interdigitates with, alluvium which infills the major valleys. The boundary between the two deposits is often difficult to define as many of the superficial deposits in the larger valleys have been disturbed by cultivation.

The offshore superficial deposits of the district comprise four formations; the Tung Chung Formation, the Chek Lap Kok Formation, the Sham Wat Formation and the Hang Hau Formation. They have been identified on lithological, palaeontological and geotechnical evidence from borehole cores and on the basis of seismic character as displayed on shallow seismic reflection records (Fyfe *et al.,* 2000).

Correlation between onshore and offshore superficial deposits is problematic. The onshore Pleistocene alluvial deposits can generally be matched with Pleistocene alluvial deposits now offshore (Chek Lap Kok Formation). However, there is no such straight-forward correlation between onshore Pleistocene mass wasting deposits (slope debris, debris flow deposits, etc) and potential lateral equivalents now lying offshore. Fyfe *et al.,* (2000), have tentatively linked these onshore mass wasting deposits with occasional thin colluvial interbeds in the offshore Pleistocene alluvial deposits. Holocene colluvial deposits, described variously as debris flow deposits, slope debris, slide deposits, and talus deposits on 1:20 000-scale geological maps, have recently been assigned to the Fan Ling Formation (Fyfe *et al., op. cit.*) and are considered to be contemporaneous with the Hang Hau Formation. However, on the 1:5 000-scale map series, the lithostratigraphic units are the same as those in the 1:20 000-scale map series.

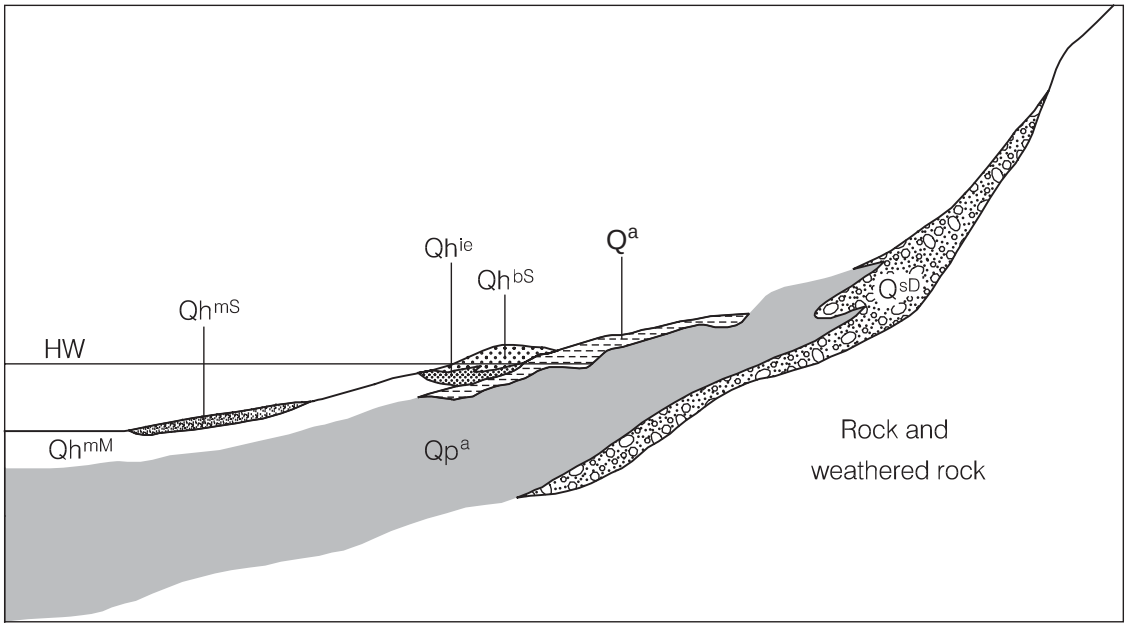

Figure 10 - Schematic Section Showing the Relationship between Superficial Deposits and the Different Environments of Deposition
Qp = Pleistocene; Qh = Holocene; Q = Quaternary (undivided);
a = alluvial; b = beach; e = estuarine; i = intertidal; m = marine;
D = debris; S = sand; M = mud; HW = high-water level

Offshore superficial deposits within the district are dominated by mud and sand of the Hang Hau Formation. These marine deposits form a thick blanket overlying estuarine deposits of the Sham Wat Formation and alluvial sediments of the Chek Lap Kok Formation. The Chek Lap Kok Formation comprises sand banks and sand sheets to the north of Lantau Island. The sand banks have been extensively dredged and the sand used as fill material for reclamations. Beneath the Chek Lap Kok Formation, the deposits of the Tung Chung Formation infill local depressions in the weathered rock surface. The thickest accumulation of these coarse- and fine-grained sediments lies in the vicinity of the type locality at the Tung Chung reclamation, and immediately to the north of Lantau Island between Tung Chung and Yam O. At the type locality, the sediments infill three separate sub-circular basins with diameters of *c*. 200 m, 300 m and 600 m, and reach up to 96.5 m in thickness (Fyfe *et al.,* 2000). Subparallel with the coastline to the north of Lantau Island, the sediments locally infill a series of discontinuous deep basins which follow a northeast-trending fault-controlled depression (Kirk *et al.,* 2000). Contours on rockhead (Grade III or better) suggest that a palaeovalley once formed the axis of the depression and this feature is thought to have captured water draining from northwest-trending and west-trending valleys during a low sea level stand.

Onshore Superficial Deposits

Slope Debris

Slope debris consisting of locally derived material (debris flow deposits, talus deposits, etc,) is considered to be the product of mass movement processes. This material, also referred to collectively as colluvium, is commonly generated during periods of high rainfall. The mass movements, such as debris flows and debris slides, may be initiated on slopes inclined at only a few degrees. Slope debris deposits commonly form aprons on the middle to lower slopes of high ground and may grade downslope into alluvium. They comprise a structureless mixture of silt, sand, gravel, cobbles and boulders, often embedded in a gravelly, sandy silt to silty clay matrix. The colour of the matrix varies from yellowish brown, through brownish grey to pink; white kaolin streaks and spots are common. The rock fragments generally show a weathered rind consistent with significant post-depositional weathering. The slope debris in the middle to lower slopes is generally up to 10 m thick, but a maximum thickness of 17.5 m has been recorded in a borehole (TRL103/3608, 1256 1662) near Tai Po.

Distinction between Pleistocene (Chek Lap Kok Formation) and Holocene (Fan Ling Formation) slope debris is based on the general criteria used by Lai & Taylor (1984) and Lai (1997, 1998) for the subdivision of colluvium. These criteria include superposition, colour, and the degree of decomposition of the clasts. In general, Pleistocene slope debris are poorly sorted, with a reddish brown or dark yellowish brown to orangish red, slightly mottled slightly clayey sandy silty matrix containing subangular, slightly to moderately decomposed boulders and cobbles. In contrast, the Holocene colluvial deposits have a fresher appearance, without the distinctive mottling of the matrix. They are described as poorly sorted, with a light yellowish brown, slightly clayey sandy silt to gravelly silty sand matrix containing subangular to angular slightly decomposed boulders with weathering rinds only a few millimetres thick.

The distribution of slope deposits within the district has been determined by surface morphology. Pleistocene slope debris deposits have been mapped in the middle to lower reaches of the major valleys (e.g. Tin Sam, Tung Chung, and Wong Lung Hang), and as thick fan aprons on the northwest-facing slopes above Tai Po, east of Tung Chung. In the lower parts of the main valleys, the slope deposits are commonly gradational into, or overlain by, Pleistocene alluvium. In places (e.g. Tin Sam valley), the Pleistocene slope debris deposits extend almost to the coastline.

Holocene slope debris within the district is mostly confined to the upland areas and heads of stream courses. In the upland areas, the Holocene debris forms discontinuous veneers on the weathered bedrock. In the heads of stream courses, the slope debris forms minor dendritic networks. Deposits of slope debris which almost reach sea level are thought to be the products of large debris flows.

Alluvial Sediments

Alluvial deposits of the district are generally thicker and more widespread than the slope debris deposits. The alluvium infills the floors of many of the larger valleys and has, in many cases, been significantly modified by cultivation.

Both the Pleistocene and Holocene alluvial deposits have been mapped in the district mainly by aerial photograph interpretation. In general, the Pleistocene alluvial deposits form elevated terraces which have been incised by recent streams, whereas Holocene alluvial deposits are largely confined to the beds of recent stream courses. The alluvial deposits consist mostly of well-sorted to semi-sorted clay, silt, gravel and sand.

Pleistocene alluvial deposits have been mapped in several of the major valleys in the district, and are commonly associated with Pleistocene slope debris deposits. Extensive deposits of Pleistocene alluvium, now modified by cultivation, form the floors of valleys at Sha Lo Wan, Tin Sam, Tung Chung, Wong Lung Hang, and Pak Mong. In the Tung Chung area, the Pleistocene alluvium consists of cobbles and boulders surrounded by a mottled red and yellow sandy silt with some lenses and layers of sand. Thicknesses of alluvium recorded in boreholes vary from 5 to 20 m. The Pleistocene alluvial deposits were laid down under various conditions of deposition, but mostly formed as fans and deltas at the bases of extensive debris deposits. During periods of active erosion of nearby hills, coarse sandy material was deposited near to the source area. At other times, a quieter environment existed, allowing far-travelled silts and muds to be laid down.

Holocene alluvial deposits within the district mainly occupy the beds of recent streams and form small fan deltas where these streams enter the sea. The largest deposits are found at Sha Lo Wan, Tung Chung, Wong Lung Hang and Pak Mong. The Holocene alluvium consists mostly of gravelly sand with subrounded cobbles and boulders in the stream courses, or yellowish-brown, well sorted clayey sand or silt in the deltas. In the Tung Chung valley, Holocene alluvium forms a series of narrow strips along the present stream courses. These are incised into the Pleistocene alluvial terraces.

Beach Deposits

Beach deposits are exposed in many of the areas of remaining natural coastline, particularly the sheltered bays to the west of Tung Chung. These deposits consist of unconsolidated, mainly sand-sized material and occupy the narrow strip of land extending from the low-water mark to the upper limit of wave action, usually delineated by either a cliff line, or storm beach. Prior to reclamation, beach deposits occurred along a large portion of the natural coastline between Pak Mong and Lau Fau Sha.

At Sha Lo Wan and Hau Hok Wan, broad (100 m wide) sand beaches have developed consisting of clean, yellowish brown, fine- to medium-grained sand. Small pockets of beach sand have also accumulated in gaps along the rocky coastline between these two beaches. At Tin Sam, a narrow (25 m wide) sand beach has developed on the edge of the small delta.

Intertidal Deposits

Intertidal deposits of mixed alluvial and marine origin have been mapped between Tin Sam and Tung Chung Wan (Plate 8). They consist of soft dark grey to yellowish brown clayey silty sands with plant remains, and dark grey, organic silt with shell fragments, and are generally confined between the low and high water marks. At Tung Chung Wan, the intertidal deposits are characterised by mangrove-lined channels and sandy splays.

Offshore Superficial Deposits

Tung Chung Formation

The Tung Chung Formation (Kirk, 2000; Fyfe *et al.,* 2000) is the name given for coarse- and fine-grained sediments which infill local depressions offshore in the weathered rock surface near Tung Chung and along the north coast of Lantau Island. These sediments were first identified on the basis of their seismic character and were previously termed “Pre-Chek Lap Kok Formation Deposits” (Langford *et al.,* 1995).

The Tung Chung Formation has been formally defined from boreholes at the Tung Chung reclamation (Fyfe *et al.,* 2000). At the type borehole (CC10/WO2893, 1215 1704), the formation comprises boulders of completely decomposed fine-grained granite and feldsparphyric rhyolite, intercalated with yellowish brown silty sand, reddish brown sandy silt, matrix-supported gravel conglomerate, and brown, fine-grained micaceous sand with minor clay laminae. The formation unconformably overlies Mesozoic or older rocks, and is conformably overlain by the Chek Lap Kok Formation.

Plate 8 - Tung Chung Wan from the Northwest Showing Quaternary Superficial Deposits Composed of Intertidal Deposits in the Foreground, and Beach Deposits and Alluvial Deposits in the Background. (Photo taken on 5.12.1989)

Northwest of Yam O Wan, the sediments of the Tung Chung Formation partly infill a north-trending depression or channel about 1100 m by 800 m in area (1954 2251). The deposits, which have been confirmed by boreholes, were originally identified on the basis of their seismic character (Sewell & James, 1995) and comprise relatively strong reflectors which tend to be parallel to the base of the unit, are synclinal in form in the depression, and are more horizontal at the margins. Several marine boreholes, drilled as part of the Tai Lam Chung to Siu Ho Wan water mains project (GIU No. 16271), penetrated these sediments below the base of the Chek Lap Kok Formation alluvium *(c.* -38 mPD). They are interpreted here as fine alluvial sediment. The maximum thickness of the Tung Chung Formation in this area has been proved to be 50 m.

Gravity and marine borehole data acquired during the Northshore Lantau Development Feasibility Study (Scott Wilson (HK) Ltd., 2001) have revealed that the Tung Chung Formation locally infills a fault-controlled depression that trends northeastward from Tung Chung along the northern Lantau coast. The depression coincides with the boundary between Palaeozoic metamorphic rocks (marble of the Yuen Long Formation) and Mesozoic volcanic and granitic rocks. Between Tai Ho Wan and Ha Kok Tsui, the formation has so far been detected in three S-shaped basins (Figure 11). The largest of these lies in the north, and is in probable continuity with the north-trending depression described above. The thickness of the formation, proven by boreholes, varies from 40 m to over 110 m. The Tung Chung Formation has been interpreted to be sediment that was deposited in a Late Tertiary to Middle Pleistocene karst environment (Kirk, 2000; Fyfe *et al.,* 2000). Solution of the marble/limestone (karst formation) is likely to have been facilitated by water flowing along the faulted boundary between marble, and volcanic and granitic rocks.

Chek Lap Kok Formation

The Chek Lap Kok Formation (Strange & Shaw, 1986) is widespread in the offshore parts of the district. It comprises a diverse assemblage of Pleistocene gravel, sand, silt and clay of dominantly alluvial origin, but also includes intercalations of colluvium (e.g. debris flow deposits, etc.) that can be related to the onshore Pleistocene succession. The formation mostly rests on bedrock, except for isolated areas at the Tung Chung reclamation and along the North Lantau coast, where it rests on the Tung Chung Formation.

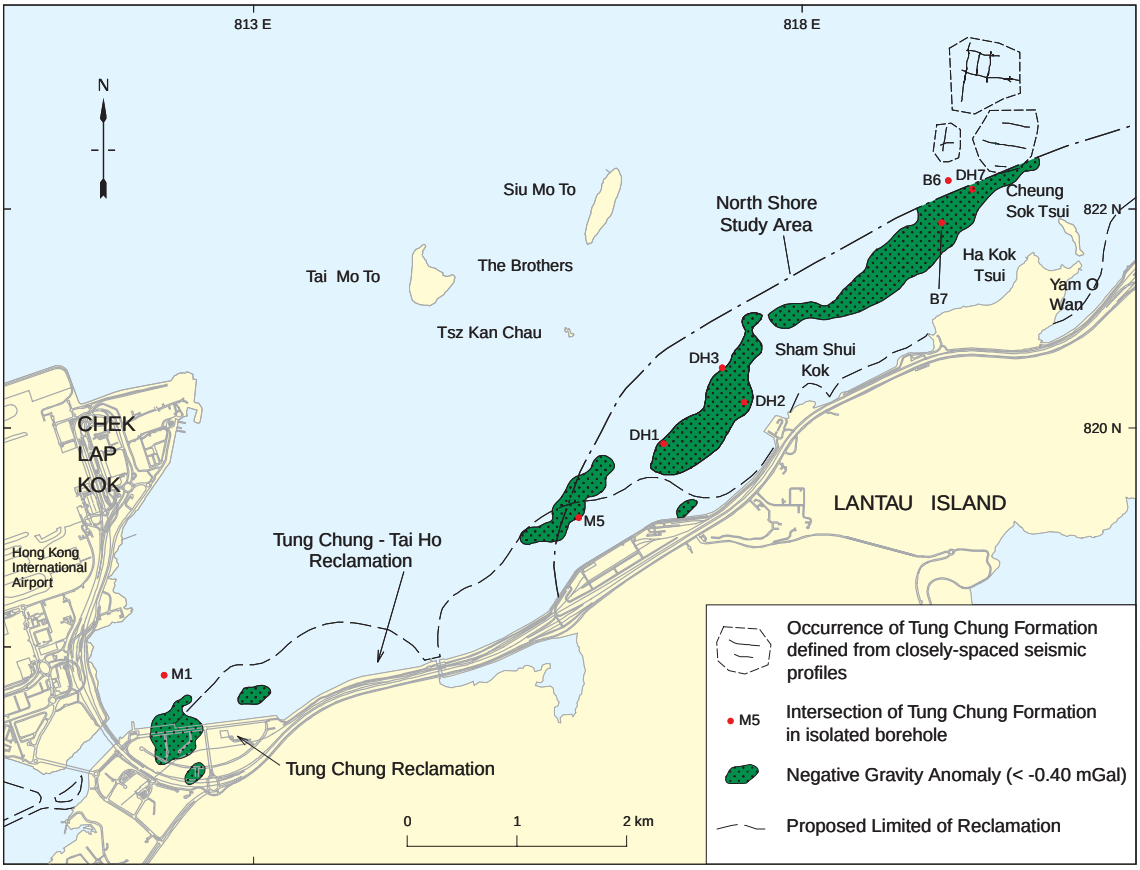

Figure 11 - Location Map Showing the Distribution of the Tung Chung Formation Determined from Interpretation of Gravity and Borehole Data (Modified after Kirk et al., 2000)

North of Lantau Island, the formation is generally between 15 and 20 m thick, but may vary from 7 m to more than 40 m thick according to the form of the underlying rock surface. The formation is variable in terms of its seismic character, which is often chaotic and complex, with indistinct channel forms, well-developed erosional channels and strong parallel reflections. The sediments are generally light bluish grey to yellowish brown and comprise fine to medium gravel, coarse to fine quartz sand, sandy silt and silty clay.

The type section of the formation has been designated as Borehole B13/B13A (Strange & Shaw, 1986, 1870 1029), drilled on the test embankment at Chek Lap Kok prior to the development of the airport. The lithologies described from this borehole show a wide range of grain sizes from gravel to clay. Unlike the overlying Hang Hau Formation (see below), the clay in the Chek Lap Kok Formation tends to be firmer with uncompressive strengths between 30 and 90 kPa. Overall, the succession fines upward from a basal sequence of gravels, through silts, to clay-dominated layers with abundant organic material. However, there are also interbedded coarsening-upward layers, as well as sporadic massive, moderately sorted sands.

Several large channels within the Chek Lap Kok Formation have been determined from seismic records and from boreholes. North of The Brothers islands and Yam O Wan, a large east–west trending channel above the formation has restricted its thickness from less than 5 m to 10 m. Around The Brothers islands its thickness is governed by higher areas within the rock surface, as well as north–south trending channels incised into its upper surface.

Although the Chek Lap Kok Formation is considered to be dominantly fluvial, there is evidence of a marine influence suggesting that the sediments were deposited under variably estuarine, intertidal, and fluvial conditions. A floodplain environment is generally envisaged, with fluvial and alluvial deposits intercalating with colluvium on steeper slopes and the heads of valleys. Using both radiocarbon and luminescence techniques, a number of absolute ages have been obtained for the formation from offshore boreholes. The ages range from 16 420 years BP at Chek Lap Kok to 80 000 ± 9000 years BP (Borehole A5/2) east of the Soko Islands (Fyfe *et al.,* 2000).

Sham Wat Formation

The formation, known only in subcrop, was first described in the district by James (1993) and Langford *et al.* (1995) during mapping of the area north of Lantau Island.

The type section of the formation, designated as borehole ESC 17, lies two kilometres west of the district, where the sequence is 17 m thick. However, the formation thins rapidly towards the east, and occurs only in the extreme western part of the district, where it is a few metres thick. The formation was proved in many of the boreholes in the western part of site now reclaimed for Chek Lap Kok airport and is interpreted to underlie the area surrounding this part of the reclamation (Fyfe *et al.,* 2000).

The formation comprises soft to firm silty clay with some sand, and is medium grey in colour with pale yellowish grey oxidized patches, some laminations, nodules and sparse mottles. Shell fragments and sparse plant fragments are consistent with a marginal marine, probably estuarine environment varying to fully marine conditions.

The formation has a distinctive seismic character but intra-formational reflections may be confused with those of the Pok Liu Member of the Hang Hau Formation, which also usually has an irregular channelled base. Resolution of this problem depends on close examination of the stratigraphical relationships along seismic reflection profiles.

The base of the formation is represented by a strong reflection with a distinctive undulating form that in part defines the seismic character. This basal surface is commonly deeply incised into the underlying Chek Lap Kok Formation as a series of channels. The interfluves between the channels exhibit a distinctly planated crest, representing the remnants of an older erosion surface. Intra-formational reflections are of low to moderate amplitude and their geometry is controlled by the morphology of the channels. The reflections are continuous, sub-parallel to the planated crest of the interfluves and drape down into the deeper channels. At the top of the sequence, the internal reflections are truncated by the reflection marking the erosional base of the overlying Hang Hau Formation.

The age of the formation has not been confidently established but available evidence is consistent with a Late Pleistocene age.

Hang Hau Formation

The Hang Hau Formation (Strange & Shaw, 1986) forms a blanket of marine mud and sand over large parts of the offshore area (Figure 12). The formation is mostly Holocene in age and is the youngest offshore Quaternary stratigraphic unit in the district. Fyfe *et al.* (2000) described four member units within the Hang Hau Formation, although none of these members is distinguished in the district.

The Hang Hau Formation comprises mostly very soft to soft, olive grey clayey silt and is relatively homogeneous throughout the district. Shear strengths in the undrained state vary from less than 3 to 20 kPa. Minor silt and sand lenses are locally present throughout the sequence. Disarticulated and articulated bivalves are common, as is comminuted shell debris ranging in size from less than 0.1 to 20 mm.

West of Chek Lap Kok, the formation is mostly between 5 and 10 m thick, but it reaches 15 m thick in the area between Chek Lap Kok and The Brothers islands to the east. A zone of acoustic turbidity (or gas blanking) is present to the east of Chek Lap Kok and this has obscured the seismic reflectors. The gas blanking is thought to originate from the release into the sediment of biogenic gas produced by anaerobic bacteria feeding on decaying organic matter at depth.

In Tung Chung Wan, the formation is generally 5 m thick and consists of very soft, dark grey clay and silt with occasional shells. On the small delta at Tin Sam, a layer of firm, brown fine sandy clay interpreted as a marine deposit was found intercalated with alluvium in two boreholes. The marine deposit is approximately 5 m thick and is encountered at a depth of *c.* -5.0 mPD.

The seismic signature of the Hang Hau Formation is distinctive, with very extensive, laterally continuous, horizontal to subhorizontal, moderate to low amplitude reflectors. The base of the formation is marked by a high amplitude reflector. Long, low amplitude reflectors predominate at the margins of the main tidal current channels, and an extensive intra-formational reflector is present in many of the channels. The reflectors tend

Figure 12 - Distribution and Isopachs (in Metres) of the Hang Hau Formation. Prior to Reclamation at the International Airport, up to 10m of Hang Hau Formation was Dredged to form a New Seabed at -15mPD (Pinches et al., 2000)

to infill depressions and channels with little or no indication of truncation and overlap.

North of Lantau Island the thicker sequences of the formation infill a deep channel within Yam O Wan (2070 2130) to a maximum depth of over -22 mPD, and also infill a number of channels south of The Brothers islands to depths of -25 mPD. The formation also forms a number of bar-like features, over 20 m thick, on the margins of the east-west trending tidal channel running from The Brothers islands to Kap Shui Mun. Sand banks, up to 15 m thick, formed of silty sand, occur sporadically within the formation. To the north of Yam O Wan, these have been dredged for reclamation works (Choot, 1988).

Most of the sediment of the Hang Hau Formation is thought to have been derived from the Pearl River. The formation is generally considered to be an estuarine to marine sequence with at least some sediment, at the base of the formation, related to the marine transgression which occurred during the rise in sea level following the last glaciation. Most of the muddy sediments forming the bulk of the formation, appear, however, to have been deposited in water depths similar to the present day.

A radiocarbon age of 7960 ± 85 years BP was obtained for the base of the formation from a borehole near Chek Lap Kok (James, 1993). This is considered to be the maximum age of the formation in the district and is similar to that obtained from another borehole at Junk Bay (8080 ± 130 years BP, Strange & Shaw, 1986).

Weathering

Differential weathering among the different rock types exerts an important geomorphological control within the district. As described above, faults commonly host zones of weak rock which are more susceptible to weathering. Granite generally weathers more rapidly than volcanic rocks, which explains why the highest peaks of the district are capped by volcanic rocks. Zones of hydrothermal alteration within the volcanic rocks are also more susceptible to weathering than unaltered zones. This might help to explain the large valley system developed in the Wong Lung Hang area in the eastern part of the district, which hosts a broad zone of hydrothermally altered rock (see above). Localised deeep weathering in the vicinity of Tung Chung and along the north coast of Lantau Island is discussed in detail in chapter 9.