

Chapter 2

Outline of Geology

The main part of the district lies across the northern faulted boundary of the Lantau Caldera (Langford *et al.*, 1995) which separates Mesozoic volcanic rocks in the south from Mesozoic sedimentary and intrusive rocks in the north. The volcanic rocks are composed mostly of rhyolite lava and tuff with minor intercalated volcanoclastic sandstone and siltstone, tuffite and tuff breccia. The intrusive rocks consist mostly of granite and quartz monzonite plutons in the west and feldsparphyric and quartzphyric rhyolite dykes in the east (Table 2, Figure 5). Representative whole-rock geochemical analyses of the rock types are given in Table 3.

Palaeozoic sedimentary rocks of the San Tin Group are the oldest rocks in the district. They are exposed only on Tze Kan Chau (1585 2090) in the northeast, but are known to underlie parts of the offshore area to the south and east of The Brothers islands. On Tze Kan Chau, the rocks comprise mainly quartz metasandstone and graphitic metasilstone of the Carboniferous Lok Ma Chau Formation, whereas offshore they consist of marble belonging to the Yuen Long Formation. Limestone of Permian age, together with sandstone and siltstone, has been identified in boreholes at Tung Chung. These rocks have also been encountered in boreholes farther north offshore and have been tentatively assigned to the Tolo Harbour Formation (Sewell *et al.*, 2000).

Metasilstone and sandstone are exposed in the far west of the district against the fault marking the boundary of the Lantau Caldera. Previously, these rocks were considered to be of Carboniferous age and assigned to the Lok Ma Chau Formation (GEO, 1994; Langford *et al.*, 1995). However, following the discovery of Jurassic fossils in these rocks near Tai O (Ng *et al.*, 1997), they have been reassigned to the Lower Jurassic Tai O Formation (Sewell *et al.*, 2000). The Tai O Formation forms a northeast-trending outcrop along the coast of Lantau Island from Tai O to San Shek Wan.

Lapilli-bearing coarse ash crystal tuff of the Yim Tin Tsai Formation (Tsuen Wan Volcanic Group) is stratigraphically the oldest Mesozoic volcanic rock in the district and is confined to offshore boreholes along the North Lantau coast from Sham Shui Kok to Kwai Shek. These rocks have been dated elsewhere (Sewell *et al.*, 2000) at 164.5 Ma and they conformably overlie lapilli-bearing coarse to fine ash crystal tuff of the Shing Mun Formation. They are intruded by porphyritic fine- to medium- and medium-grained granite belonging to the Tai Lam Granite and Lantau Granite plutons of the Lamma Suite (Sewell *et al.*, *op. cit.*). In the western part of the district, the fine-grained Chek Lap Kok Granite (Lamma Suite) intrudes porphyritic fine- to medium-grained Lantau Granite.

Eastnortheast-trending feldsparphyric and quartzphyric rhyolite dykes of the Lantau Dyke Swarm intrude granites of the Lamma Suite in the northeastern and northwestern parts of the district. The dykes have been dated at approximately 146 Ma and are truncated by the fault marking the boundary of the Lantau Caldera. The dykes were emplaced in at least two phases (Li *et al.*, 2000) and may vary internally from feldsparphyric rhyolite to porphyritic microgranite. Quartzphyric rhyolite dykes are considered to have been emplaced mostly during the younger phase.

Welded lapilli- to block-bearing crystal tuff, tuff breccia, tuffite and flow-banded rhyolite lava, with intercalated volcanoclastic sedimentary rocks infill the Lantau Caldera. Previously, these rocks were named as the Lantau Formation (Langford *et al.*, 1995), but they have now been reassigned to the Lantau Volcanic Group (undifferentiated) (Sewell *et al.*, 2000). These rocks have been dated at approximately 146 Ma and represent the products of a number of discrete eruptions.

The volcanic and granitic rocks of the district are intruded along the caldera-bounding fault by quartz monzonite belonging to the Lion Rock Suite. Minor basalt, microdiorite and aplite dykes occur sporadically in the northern part of the district intruding the granitic rocks and rhyolite dykes. These mafic and felsic dykes are considered to be of Cretaceous age.

The geological structure of the district is complex, owing to the close proximity of intersecting regional fault trends and faults related to the caldera boundary. The dominant regional fault trend is to the northeast. These

Table 2 - Summary of the Onshore and Offshore Stratigraphy of the District

Stratigraphic Divisions		Lithostratigraphy and Genetic Classification		Principal Materials	Map Sym
Superficial Deposits					
QUATERNARY	Holocene	Fill Alluvium Intertidal deposits Estuarine deposits Beach deposits		Natural earth and waste Silt, sand and gravel with boulders Mud and sand Mud and sand with peat Sand	Qh ^F Q ^a Q ⁱ Qh ^{ie} Qh ^{bs}
	Holocene and Pleistocene	Hang Hau Formation	Marine mud Marine sand	Soft to very soft mud; some sand Sand, some gravel and mud	Qh ^{mM} Qh ^{mS}
		Slope debris and Debris flow deposits (Colluvium)		Sand, gravel, cobbles Cobbles in fine matrix	Q ^{sD} Q ^{Dep}
	Pleistocene	Sham Wat Formation	Estuarine to marine deposits	Clay, silt and some sand	
		Chek Lap Kok Formation	Alluvium, terraced alluvium, slope deposits	Clay, silt, sand, and gravel Sand, gravel, cobbles	Qp ^a Qp ^{at} Qp ^{sD}
		Tung Chung Formation	Karst-related deposits	Silt, sand and gravel with boulders	Qp ^{kD}
Volcanic and Sedimentary Rocks					
MESOZOIC	Jurassic	Lantau Volcanic Group	Undifferentiated	Tuff and lava, siltstone, sandstone, tuff and tuffite, crystal tuff, mudstone	Jlu, sl, s, tt, t, m
		Tsuen Wan Volcanic Group	Yim Tin Tsai Fm.	Coarse ash crystal tuff	Jty
			Tai O Formation	Metasiltstone with metasandstone	Jo
	Permian		Tolo Harbour Fm.	Marble	Pt
	Carboniferous	San Tin Group	Lok Ma Chau Fm. Yuen Long Fm.	Metasiltstone with metasandstone Marble	Csl Csy
Major Intrusive Rocks					
MESOZOIC	Jurassic-Cretaceous	Fine-grained quartz monzonite, Fine-grained granite and fine- to medium-grained granite Medium-grained granite			mqf gf, gfm gm
Minor Intrusive Rocks					
CRETACEOUS		Basalt, lamprophyre, microdiorite and andesite			b, l, μD, a
MESOZOIC	Jurassic-Cretaceous	Feldsparphyric and quartzphyric rhyolite, aplite, porphyritic microgranite			rf, rq, ap, μg

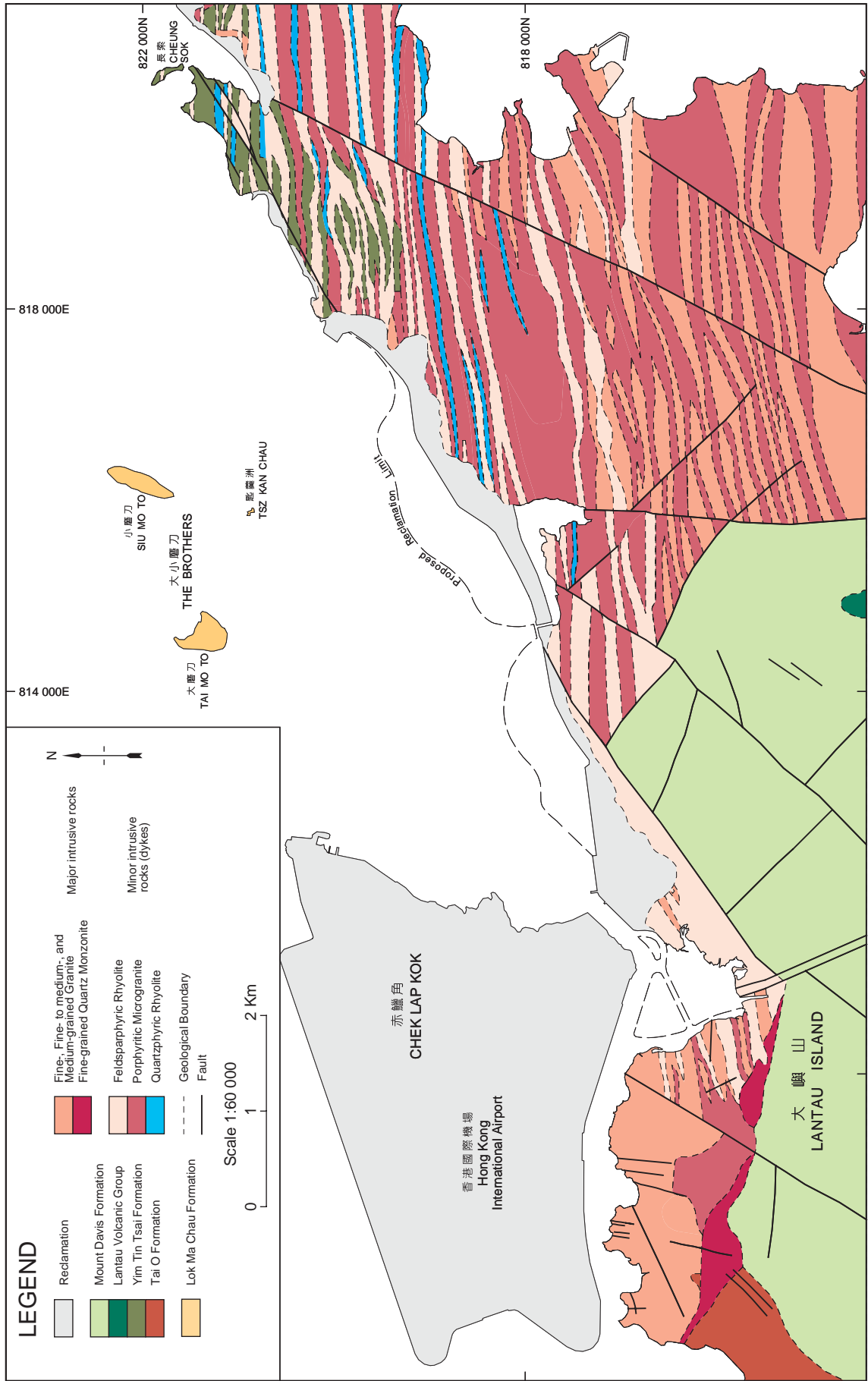


Figure 5 - Simplified Onshore Geology of the District

Table 3 - Whole-rock Major- and Trace-element Geochemistry for Representative Rock Types in the Tung Chung District. Major Oxides in wt%, Trace Elements in ppm

Sample Unit	HK10067 mq	HK11052 Jlu	HK9213 gm	HK9249 gfm	HK9250 gfm	HK8342 Jlu	HK9598 Jlu	HK10005 Jlu	HK10007 Jlu	HK10286 Jlu
SiO ₂	65.88	77.10	74.84	76.11	67.78	74.91	75.90	70.36	70.52	70.07
TiO ₂	0.47	0.12	0.18	0.79	0.57	0.21	0.21	0.41	0.40	0.55
Al ₂ O ₃	16.08	12.20	13.27	12.82	14.96	12.70	12.34	14.30	14.43	13.91
Fe ₂ O ₃ *	3.89	1.66	1.57	4.26	4.00	1.88	1.66	3.22	3.83	4.40
MnO	0.10	0.04	0.04	0.01	0.13	0.05	0.02	0.05	0.04	0.14
MgO	0.98	0.12	0.25	0.72	1.24	0.36	0.21	0.33	0.39	1.73
CaO	2.57	1.12	1.37	0.05	4.20	1.20	0.86	1.77	1.40	2.17
Na ₂ O	3.42	0.35	2.63	0.05	2.14	2.54	2.35	2.79	2.03	0.79
K ₂ O	5.84	5.84	5.07	4.22	3.88	4.97	5.58	5.72	5.95	4.16
P ₂ O ₅	0.16	0.02	0.03	0.04	0.14	0.05	0.04	0.11	0.11	0.09
Total	99.39	98.57	99.25	99.07	99.04	98.87	99.17	99.06	99.10	98.01
LOI**	0.45	1.06	0.50	0.83	0.66	0.78	0.55	1.74	0.83	1.81
Cr	25	34	27	24	28	22	26	25	22	68
Ni	3	8	8	8	14	11	12	9	11	33
Co	5	2	-	4	-	4	5	4	5	11
Cu	2	1	-	-	-	1	1	1	1	1
Pb	22	24	46	39	47	19	23	20	25	11
Zn	37	20	27	22	22	28	32	23	28	50
W	3	4	30	8	11	2	3	1	1	14
Rb	173	362	346	367	423	222	274	235	265	474
Ba	875	101	232	219	40	412	325	767	605	317
Sr	288	36	100	82	28	143	75	141	125	87
Ga	17	15	17	17	20	14	15	15	16	16
Nb	14	19	18	15	20	20	20	20	21	14
Zr	283	148	95	97	89	149	203	285	275	190
Y	33	47	40	47	63	62	79	42	41	31
Th	18	41	35	35	41	33	40	30	32	18
U	2	6	11	21	12	4	5	3	5	4
La	46	39	30	18	11	58	118	55	61	30
Ce	87	84	70	51	27	110	171	141	130	82
F	967	664	1871	2631	2553	1109	940	1041	1539	7688

* total iron as Fe₂O₃

** loss on ignition (LOI) at 1000°C

Mg# is 100Mg / Mg + Fe²⁺

1.	HK10067	Porphyritic quartz monzonite	808120E	816330N	Sha Lo Wan
2.	HK11052	Porphyritic rhyolite lava	812005E	815460N	Tung Chung
3.	HK9213	Fine- to medium-grained granite	808145E	817110N	Sha Lo Wan
4.	HK9249	Fine- to medium-grained granite	808455E	817100N	Sha Lo Wan
5.	HK9250	Fine- to medium-grained granite	808615E	817030N	Hau Hok Wan
6.	HK8342	Rhyolite lava	813725E	816495N	Por Kai Shan
7.	HK9598	Porphyritic rhyolite lava	807620E	815080N	Sha Lo Wan
8.	HK10005	Porphyritic rhyolite lava	809424E	815097N	Nei Lak Shan
9.	HK10007	Porphyritic rhyolite lava	809764E	815018N	Nei Lak Shan
10.	HK10286	Lapilli tuff	809025E	815435N	Nei Lak Shan

faults offset the caldera boundary faults and an earlier set of north- to northnorthwest-trending faults. However, the northeast-trending faults have themselves been offset by reactivation of northnorthwest-trending faults. Northeast- to northwest-trending quartz veins are present in the northwestern part of the district, mainly close to granite intrusions. However, they are also found in close proximity to the caldera margin fault, intruding volcanic rocks, and commonly contain traces of mineralization including arsenopyrite, chalcopyrite, galena, magnetite, molybdenite, pyrite and wolframite.

Superficial deposits within the district cover most of the low-lying ground and large tracts offshore (Figure 6). The onshore deposits comprise dominantly debris flow deposits on the higher ground and alluvial sediments on the valley floors. In the larger valleys, these have been disturbed by cultivation. Close to the coast, the superficial deposits comprise beach deposits of sand. Areas of deep weathering have been detected in boreholes beneath the Tung Chung reclamation and in a northeast-trending zone subparallel to the North Lantau coast extending from Tai Ho Wan to Ha Kok Tsui. These areas are associated with unusually thick superficial deposits (Tung Chung Formation) comprising an assortment of debris flow deposits, laminated sediments, and block breccias. These deposits are thought to be associated with collapse of karst-related cavities (Kirk, 2000; Fletcher *et al.*, 2000) formed from blocks of marble encased within granite and dyke intrusions.

The offshore superficial deposits on the seabed in the district consist mostly of intertidal and estuarine deposits of sand and mud, and marine mud and sand of the Hang Hau Formation. A small area of marine sand belonging to the Chek Lap Kok Formation has been identified in the extreme northeastern part of the district north of Yam O Wan. Extensive subcrop of the Chek Lap Kok Formation, and of estuarine to marine deposits of the Sham Wat Formation, have also been identified.

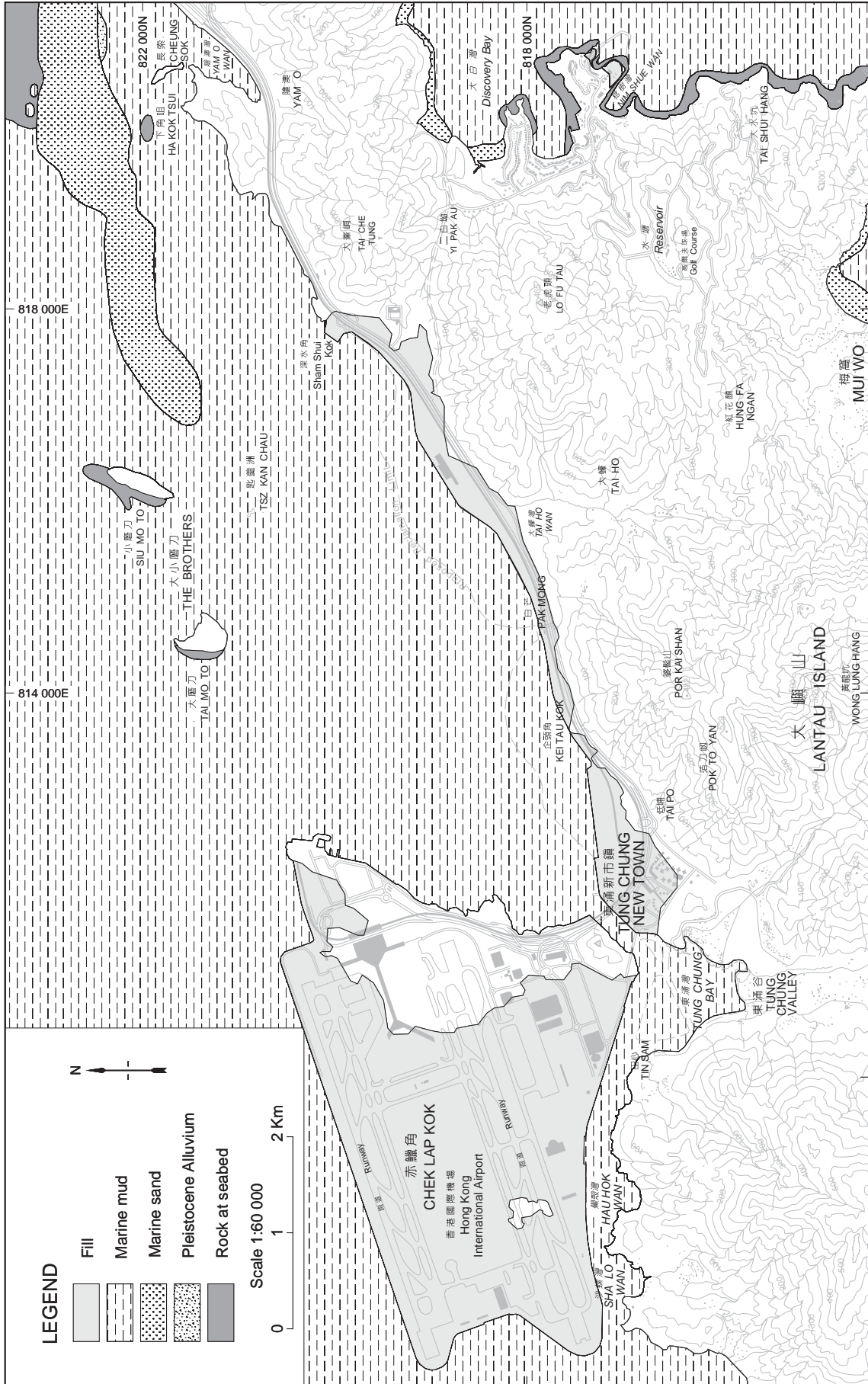


Figure 6 - Simplified Seabed Sediment Map of the District