

THE WEATHERING PROFILE ALONG THE COASTAL AREA FROM CENTRAL TO KENNEDY TOWN, HONG KONG ISLAND

GEO REPORT No. 187

Phoebe N. Y. Lau

**GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION**

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (<http://www.cedd.gov.hk>) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

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R.K.S. Chan

Head, Geotechnical Engineering Office
August 2006

FOREWORD

During the ground investigation stage for the International Finance Center I in Central District of Hong Kong Island, completely decomposed granite was revealed in a number of drillholes to a depth of –70 mPD. This demonstrated the presence of a zone of deep weathering. Similar deep weathering conditions have been noted further west along the coastal area between Shek Tong Tsui and Kennedy Town. This study was undertaken, therefore, to assess the subsurface geology of the coastal area in the northwest of Hong Kong Island, extending from Central to Kennedy Town, to in particular to confirm the nature and extent of deep weathering within the study area. The data used in this study are held within the Geological Modelling System (GMS) maintained by Planning Division, on behalf of Geotechnical Engineering Office, Civil Engineering Department.

The report was prepared by Miss Phoebe N.Y. Lau of the Hong Kong Geological Survey Section, and reviewed by Dr. S.D.G. Campbell. The data input and digitization of figures were undertaken by technical staff of Planning Division.

The Kowloon Canton Railway Corporation, and their consultants Atkins Meinhardt, are gratefully acknowledged for providing preliminary logs of drillholes that assisted in the completion of this study.



(H. N. Wong)

Chief Geotechnical Engineer/Planning

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1. INTRODUCTION

The highly developed areas along the northern coastal areas of Hong Kong Island are sited to a large extent on reclaimed land. Owing to the dramatic increase in population and rapid development of Hong Kong over the past few decades, many low-rise buildings in this region have been demolished and replaced by high-rise buildings with deep foundations and related infrastructure. To facilitate such construction, an improved understanding of the subsurface geology of the area, derived from ground investigation and other available data, will be beneficial. This is especially so for coastal areas, such as Central and Kennedy Town in northwest Hong Kong Island, where there are few natural exposures of rock and soil.

2. OBJECTIVES

During the ground investigation stage for the International Finance Center I in the Central District of Hong Kong Island, completely decomposed granite was revealed in a number of drillholes to a depth of -70 mPD. This demonstrated the presence of a zone of deep weathering.

The purpose of this study is to assess the subsurface geology of the Central District and in particular to establish the nature and extent of deep weathering within the area. As similar deep weathering conditions have previously been noted further west in the coastal area between Shek Tong Tsui and Kennedy Town, the study area therefore includes the coastal areas of Sai Ying Pun, Shek Tong Tsui and Kennedy Town. In this assessment, weathering of in-situ rock to saprolite (Grades IV to VI) and extending to a depth of -70 mPD or more, is referred to as “deep weathering”. The study area is shown in Figure 1 and is located within Hong Kong Grid 830000E, 817000N and 835500E, 815000N.

3. METHODOLOGY

The present study is largely based on a review of existing ground investigation data (drillhole records), mainly held in the Geotechnical Information Unit of the Civil Engineering Department. Some further data in Ground Investigation Reports held by the Island Division of the Geotechnical Engineering Office, Civil Engineering Department have also been reviewed. Preliminary drillhole logs, provided by the Kowloon Canton Railway Corporation and their consultants Atkins Meinhardt, were also used.

The review of drillhole records is summarised and displayed in the form of a rockhead contour map for the study area (Figure 4). These contours should be regarded as an approximation only of ground conditions, and should not be used for site specific purposes. In an engineering sense, and within the scope of the Government Term Contract for Ground Investigation works, rockhead is defined as the upper elevation of a rock core of at least 5m long that is made up of Grade III or better rock (Grades I and II). Based on this definition of rockhead, the rockhead level in each of the drillholes has therefore been determined.

In addition to the review of drillholes, spatial data, including geology, structure, topographical data and natural terrain landslide records, were extracted from the Geological Modelling System (GMS), maintained by Planning Division of the GEO. Drillholes selected

from the GIU were also stored in the GMS for further Geographical Information System (GIS) applications. The GIS platform was used to manipulate and analyse the large volume of drillhole data, for example to assist in establishing the spatial distribution of superficial deposits within the study area.

4. DETAILS OF THE STUDY

4.1 Geology and Structures

As shown on the 1:100,000-scale geological map of Hong Kong (series HGM100) (Sewell et al., 2000), the inland areas to the south of the reclaimed areas at Central, Sheung Wan, Sai Ying Pun, and Shek Tong Tsui are underlain by equigranular medium-grained biotite granite of the Lion Rock Suite (Figure 2). This is consistent with earlier geological mapping of the area at 1:20,000-scale (GCO 1986) (Figure 3). Most of the drillhole logs within these areas show rock cores logged as medium- to coarse-grained granite, with a minority as coarse- or medium-grained granite. Further west at Kennedy Town, mostly tuff with minor tuffite has been recovered from drillholes. This is again consistent with the geology shown on the published geological map and memoir (GCO, 1986 & Strange et al, 1986 respectively). Rock cores recovered along a valley between Shek Tong Tsui and Kennedy Town comprise silicified tuff, altered/meta-tuff and fault gouge.

As shown on the 1:20,000-scale geological map (GCO, 1986, Sheet 11, Series HGM20), folding is present in volcanic rocks of the Repulse Bay Volcanic Group over the Mid-levels area. The volcanic rocks in contact with the granites were thermally metamorphosed by subsequent granite intrusion of the Lion Rock Suite (Sewell et al., 2000).

Three prominent NE-SW striking faults occur in the study area. These faults are mainly sub-vertical to steeply dipping and were dominated by sinistral strike slip movements (Sewell et al., 2000).

4.2 Study of Drillhole Records

The study area is highly developed and numerous ground investigations have been carried out over the past few decades.

Among the drillholes reviewed, 1700 were deep enough to penetrate Grade III or better rocks and terminated beyond rockhead levels. These rockhead data were compiled to produce a rockhead contour map for the study area, shown in Figure 4. These contours should be regarded as an approximation only of ground conditions, and should not be used for site specific purposes. In certain areas, some drillholes were terminated in saprolite, despite having reached -70 mPD or deeper. Nevertheless, these drillholes have also been considered in determining the minimum rockhead level. The Ground Investigation reports that have been reviewed are contained on file in the Planning Division of GEO (file reference no. GCP 1/10/138).

4.3 Aerial Photograph Interpretation

Four high-level (12500 feet) aerial photographs taken in 1963 (No. Y12826-Y12829) were reviewed. Figure 5 shows the general breaks in slope within the study area as in 1963. Rock outcrop was also identified in the Mid-levels area. The remaining area was either covered by dense vegetation or obscured by development. The northernmost line of break in slope shown in Figure 5, roughly conforms to the original coastline of Hong Kong Island prior to the initial reclamation in 1863.

The aerial photograph interpretation confirms that the ground profile has changed little since 1963.

5. FINDINGS OF THE STUDY

5.1 General (Weathering Profile)

Generally, drillholes located on reclaimed land mainly comprise fill, marine deposits, alluvium, saprolite (weathered volcanic rock/granitic rocks) and in-situ rock (volcanic/granitic). Drillholes located further inland mainly comprise fill, marine deposits, colluvium, saprolite and in-situ rock. Marine deposits were generally found in Victoria Harbour and beneath reclaimed land.

A rockhead contour map indicating the variable depth of Grade III or better rocks is shown in Figure 4 (contours are incomplete in areas with limited drillhole data). The weathering profiles in both the granites and tuffs within the study area generally conform with the topographic highs and lows, i.e. deeper weathering penetration occurring in valleys, and less extreme penetration occurring along the ridges and spurs of slopes. However, there are several areas within the study area where deep zones of weathering have been identified.

5.2 Specific (Zones of Deep Weathering)

Altogether, three anomalously deep weathering zones have been identified within the study area, which are located:

- (i) in Central District, partly beneath reclaimed land,
- (ii) beneath reclaimed land between Sai Ying Pun and Shek Tong Tsui, and
- (iii) beneath reclaimed land between Shek Tong Tsui and Kennedy Town.

Zones (i) and (ii) occur in granite while zone (iii) is developed within tuff. None of the deep weathering zones were found along previously inferred faults or impinge on the intersections of such faults. Details of each deep weathering zone are further discussed below.

5.3 Deep Weathering Zone in Central District

5.3.1 General Description

As shown in Figure 4, anomalously deep weathering occurs in Central District, mainly beneath reclaimed land along the original coastline as in 1863. This zone of deep weathering is roughly triangular in shape and covers an area of about 0.3 km². The deepest rockhead level proven in the zone is at -141.6 mPD in a drillhole beneath Connaught Road Central northeast of “The Centre (99, Queen’s Road Central)”.

5.3.2 Rockhead Contours Adjoining the Deep Weathering Zone

Rockhead to the east and southeast of the deep weathering zone is steeply inclined. Very steeply inclined rockhead is also found further upslope in the Mid-levels area. Extensive rock outcrop is present near to the crest of the catchment, slightly below the Peak.

5.3.3 Lithology and Structures

As revealed on the 1:20,000-scale geological map, the deep weathering zone is developed in granite. It is bounded to its northwest and southeast by a NE-SW striking fault and photolineament respectively. The southwest side of the zone is sub-parallel to the intrusive contact between granite and fine ash vitric tuff, which is located near the Peak. The tuff around the granitic intrusion is thermally metamorphosed.

5.3.4 Superficial Deposits

A narrow zone about 30 m wide, which trends NW-SE, can be identified across the central part of the deep weathering zone. Within this narrow zone, both colluvium and alluvium have been identified in drillholes. The distribution of the colluvium and alluvium are unclear and appear to grade into one another. Drillholes located to the northeast of the narrow zone nearly all contain alluvium. Drillholes located near Mid-levels on the southwest side of the deep weathering zone mostly contain colluvium.

5.3.5 Aerial Photograph Interpretation

As shown in Figure 5, the terrain that overlooks the Central District zone of deep weathering has contrasting topography and drainage compared with adjacent terrain and thus can be defined as a discrete geomorphological unit. This unit is separated from the adjoining terrain unit by pronounced concave breaks in slope.

Both Natural Terrain Landslide Inventory (NTLI) and Large Landslide Study (LLS) features have been noted in the catchment of this deep weathering zone. A large relict landslide is present immediately beneath the rock outcrop on the Peak. Smooth and planar rock faces dipping out of the slope can be seen on the rock outcrop in aerial photographs.

5.3.6 Review of Ground Investigation Reports

No unusual ground conditions have been reported in any ground investigation reports within the zone of deep weathering. A Consultants' Geotechnical Review Report (Maunsell 1993; GEO Island Division file reference no.: f7 in GCI 3/4/2064/89 Pt.1) was prepared in response to questions raised by the Geotechnical Engineering Office with respect to foundation plans submitted for approval by the Building Authority for the proposed high rise development at Gilman Plaza (i.e. The Centre) in the late 1980s. The report found nothing in the ground investigation that suggested the site ground conditions were unusual and noted:

- (i) Chemical weathering was progressively less developed with depth and the depth of weathering lay in the range of 100 to 130 m.
- (ii) No sign of alteration or the effects of faulting were observed.
- (iii) Soil samples were typical of those near shoreline sites where weathering is relatively uniform with depth and unaffected by faulting.
- (iv) The total fines content of the completely decomposed granite ranged from 22 to 43 % and the clay content tended to decrease with depth with a maximum of 15 %. These results are typical of completely decomposed granite at many other sites.

5.4 Deep Weathering Zone between Sai Ying Pun and Shek Tong Tsui

5.4.1 General Description

A zone of deep weathering occurs between Sai Ying Pun and Shek Tong Tsui, and underlies most of the reclaimed land there. This weathering zone is elongate in shape and extends roughly sub-parallel to the original coastline as in 1863 for about 1.5 km. The deepest rockhead level encountered in drillholes within the zone was at -89.5 mPD. The ground above this deep weathering zone has now been occupied by the "Western Park Indoor Games Hall". As shown in Figure 4, the rockhead contours that define this semi oval-shaped zone appear to have closed off in the offshore area. However, no drillholes were found further offshore area to confirm this.

5.4.2 Lithology and Structures

As shown on the 1:100,000-scale geological map (Sewell et al., 2000), this deep weathering zone is developed in granite. It is bounded to its northwest and southeast by two NE-SW striking faults. The drillholes located further inland to the south of the deep weathering zone mostly contain colluvium, up to 20 m thick. No gradation of colluvium into alluvium is observed.

5.4.3 Superficial Deposits

The majority of the drillholes in this area comprise alluvium. Colluvium is absent in the drillholes within the deep weathering zone, but is present further inland to the south of the original coastline.

5.4.4 Aerial Photograph Interpretation

The terrain that overlooks the deep weathering zone between Sai Ying Pun and Shek Tong Tsui can be viewed as a discrete geomorphological unit, and different from the adjoining terrain in terms of the patterns of drainage and breaks in slope. The extent of the deep weathering zone is comparable to that of the overlying geomorphological unit (Figures 4 and 5).

No landslide features were recorded in the terrain located immediately above the deep weathering zone. However, some relict and recent landslides have been noted in the NTLI and LLS databases near to the crest of the catchment.

5.4.5 Review of Ground Investigation Reports

No unusual ground conditions have been noted in the ground investigation reports.

5.5 Deep Weathering Zone between Shek Tong Tsui and Kennedy Town

5.5.1 General Description

A series of oval-shaped depressions in rockhead are present beneath the reclaimed land between Shek Tong Tsui and Kennedy Town. These indicate a third zone of weathering, albeit the smallest of the three identified in this study. The review of drillhole records and core photographs has revealed that the contact between granite and tuff lies within the deep weathering zone. In Figure 4, the deep weathering zone covers an area of about 0.06 km² (c. 200 m x 30 m), located beneath the “Temporary Belcher Bay Garden” to the northwest of Kennedy Town Praya. The maximum depth of rockhead within the zone is uncertain as the deepest drillhole encountered within this region was terminated within completely to highly decomposed rock at -70 mPD.

5.5.2 Lithology and Structures

As shown on the 1:100,000-scale geological map (Sewell et al., 2000), this deep weathering zone is bounded to its northwest and southeast by two NE-SW striking faults, and to its west by a NNW-SSE trending valley. Some of the core samples recovered from drillholes located along the valley were described as fault gouge, fractured rocks and meta/altered tuff. Based on this evidence, a NNW-SSE trending fault may be present along the valley. It appears that the development of the western extent of the deep weathering zone in this area is limited by the inferred NNW-SSE trending fault.

5.5.3 Superficial Deposits

Most of the drillholes within this deep weathering zone contain alluvium less than 5 m thick. A number of small areas of colluvium were found further upslope above the deep weathering zone.

5.5.4 Aerial Photograph Interpretation

By overlapping Figures 4 and 5, it is apparent that the deep weathering zone is located approximately beneath a semi-circular shaped concave break of slope, which has been observed on aerial photographs. The lateral extent of the deep weathering zone is roughly comparable in size to the geomorphological unit above, although it is slightly more elongate.

No landslide features have been recorded in the NTLI and LLS databases in the catchment of the deep weathering zone.

5.5.5 Review of Ground Investigation Reports

No unusual ground conditions have been noted in the ground investigation reports for this zone.

6. CONCLUSIONS

Based on the review of drillhole records, three deep weathering zones have been identified within the study area. They occur (i) in Central District, (ii) beneath reclaimed land between Sai Ying Pun and Shek Tong Tsui, and (iii) beneath reclaimed land between Shek Tong Tsui and Kennedy Town. The deepest rockhead levels encountered in (i) and (ii) are at -141.6 mPD and -89.5 mPD respectively. At (iii), the deepest drillhole was terminated at -70 mPD within saprolite and so the rockhead at this location is deeper than -70 mPD.

The following were commonly noted:

- (i) The deep weathering zones are largely located beneath reclaimed land to the north of the original coastline, as in 1863.
- (ii) The deep weathering zones appear to be irregular in shape (e.g. triangular or oval), rather than linear as might be expected if an individual fault/fault zone was the dominant control.
- (iii) Deep weathering is often associated with faults in which highly fractured rock masses or weak zones are located along traces of faults. However, based on the review of the drillhole records, the NE-SW striking faults within the study area do not appear to produce negative topography, although

the three deep weathering zones occur between faults, and are locally bounded by them.

- (iv) Apart from the deep weathering, no unusual ground conditions have been noted in the drillhole records.
- (v) Drillholes within the deep weathering zones mostly contain alluvium.
- (vi) The deep weathering zones are overlain by areas with distinctive geomorphology compared to adjoining areas. There appears therefore to be a broad relationship between the geomorphology and the development of deep weathering within the study area. In particular the area of deepest weathering in Central appears to be spatially related to the area of exposed rock below Victoria Peak, lying directly downslope from it.

The potential impact of deep weathering on foundation design within the study area should be carefully considered. However, the actual extent of deep weathering must be confirmed on site by further ground investigation.

Further study of the weathering profile beneath the reclaimed coastal areas between Wan Chai to Chai Wan, and around the Kowloon Peninsular, is considered worthwhile. Areas of low lying ground beneath Lion Rock and Fei Ngo Shan in Kowloon should also be assessed. The results of these further reviews may help to understand the development of deep weathering zones defined in this study.

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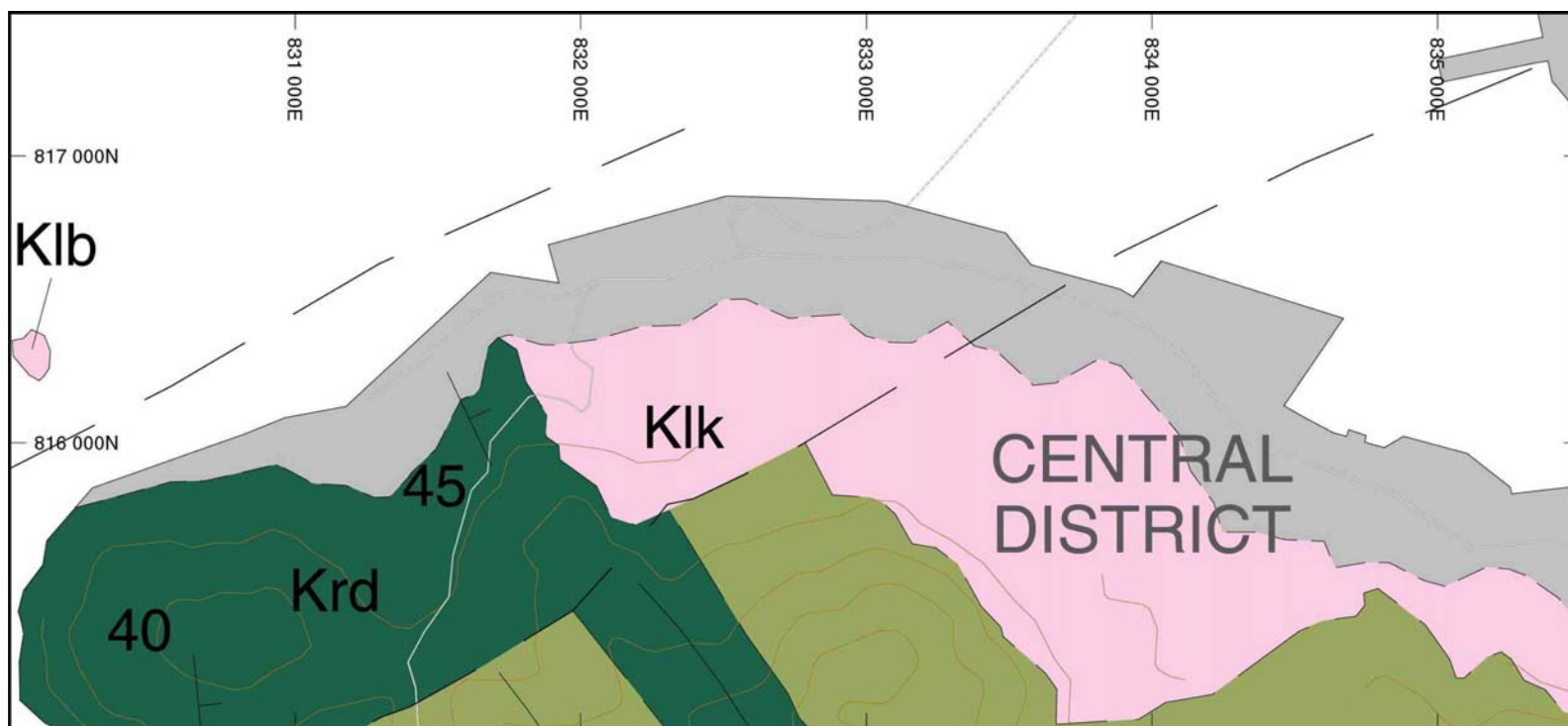


Figure 2 - Enlarged Extract from 1:100,000-scale Geological Map (Sewell et al. 2000) Covering the Study Area

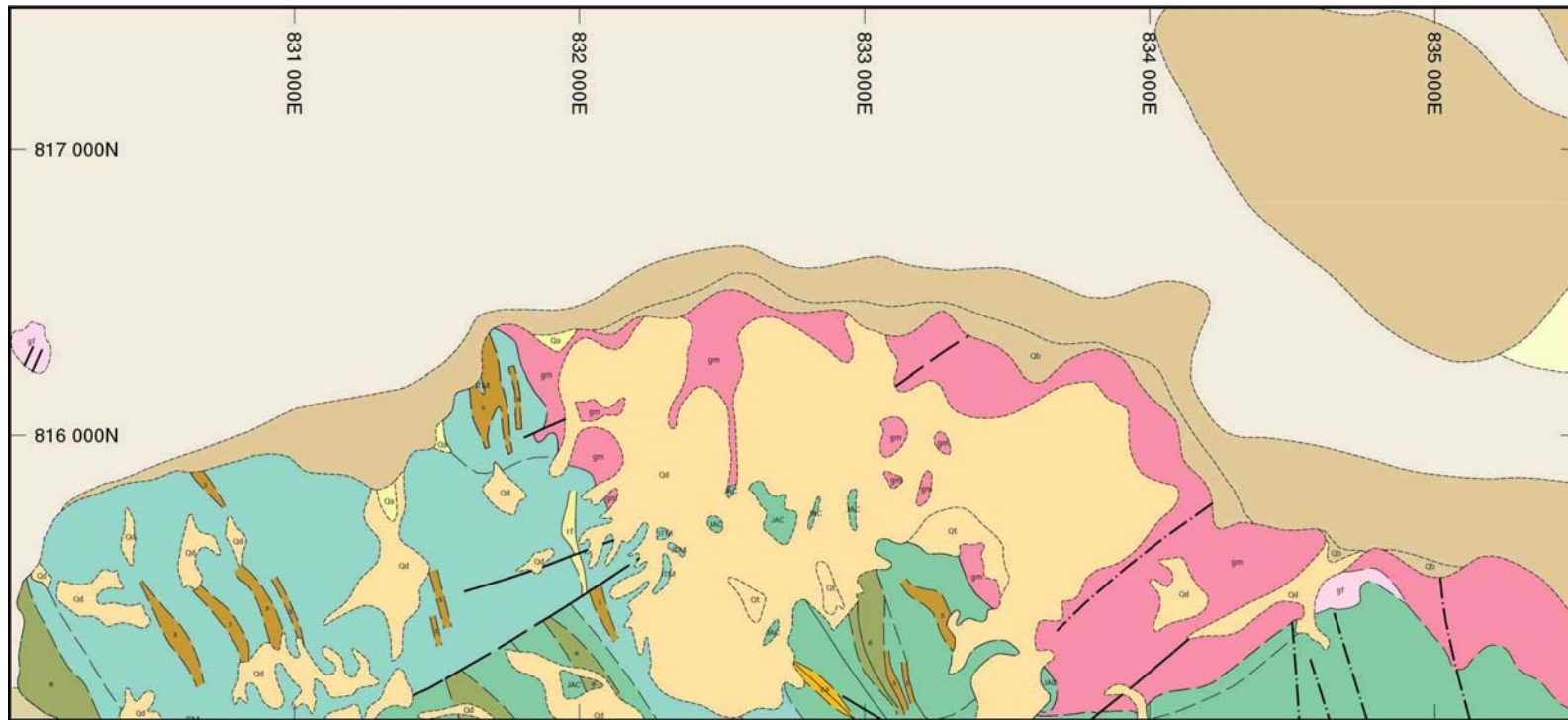


Figure 3 - Reduced Extract from 1:20,000-scale Geological Map (GEO 1986) Covering the Study

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斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1 Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2000).

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Geospec 1 Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).

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TECHNICAL GUIDANCE NOTES

TGN 1 Technical Guidance Documents