SECTION 6 : AGGREGATE PROPERTIES OF MEDIUM- GRAINED GRANITE FROM DIAMOND HILL

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FOREWORD

In order to help provide the Materials Division and the Hong Kong Geological Survey with much needed data on the characterization and possible usage of each of the Territory's major rock types, the Office initiated the Fresh Rock Testing Programme in 1985.

This report forms part of the Fresh Rock Testing programme and is one of a series of reports which presents the results of selected aggregate and index laboratory testing carried out on fresh block samples of discrete rock types.

The rock type described in this report is medium-grained granite from the Diamond Hill Quarry.

The authors wish to acknowledge the role played in the field sampling and sample preparation by J.M. Nash (GE) and M.K. Chan (TO), and in the report production by M.W. Yuen (STO/EG). The cooperation and assistance of the Materials Division is also acknowledged.

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CONTENTS

1. INTRODUCTION

This report presents and discusses the results of selected physical index and aggregate testing on laboratory crushed medium-grained granite samples from the Diamond Hill Quarry. The results are compared with the routine test values available on quarry run material and the suitability of the rock as aggregate is assessed in comparison with the typical acceptance values for various uses.

2. SITE DESCRIPTION AND SAMPLING

The Government quarry site was located on the west facing flank of a northwest-southeast trending hill, rising up to 180 mPD. (Tsuen Shek Shan (Figure 1, Plate 1). Original quarrying operations started in 1952 on the southern side of the hill as a private permit quarry.

Government quarry operations at the western end (Plate 2) commenced in 1962 and production of aggregates ceased by the end of 1986. The quarry site has since been incorporated in a major redevelopment project which will result in the removal of most of the original hill and the formation of a number of platforms for residential purposes. Production of aggregates from the excavated rock material will continue during site formation works.

Medium-grained granite block samples were collected from the newly excavated lower quarry face and were typical and representative of the rock material occurring throughout the quarry (Plate 2).

3. GEOLOGY

3.1 Site Geology

The new Sheet 11 of the geological map series of the Hong Kong Geological Survey (GCO, 1986) shows the quarry area to be underlain by medium-grained granite (gfm) of Mesozoic Age (Figure 2). The granite at this site is light grey with average grain size of 3 to 5 mm, comprising subhedral interlocking grains of quartz, alkali feldspars, subordinate white plagioclase grains and with biotite generally making up only 2% to 3% of the rock (Strange & Shaw, 1986).

No major faults cross the site and joints are predominantly vertical to subvertical, striking mainly northwest-southeast and generally medium to widely spaced.

One large composite basalt dyke, about 7 m wide, cut subvertically through the granite in a ENE direction at the southern end of the site (Plate 1). The mostly subvertical narrow chloritized veins observed in parts of the quarry faces (Plate 3) are thought to result from hydrothermal alteration which has also affected the basalt dyke. Strange & Shaw (1986) give a detailed description of the mineralogical composition and texture of both the medium-grained granite occurring in the Kowloon area and the basalt intrusion at the quarry site.

3.2 Description of Test Sample

(a) Engineering geological description. The rock is very strong, light grey, crystalline, fresh, medium-grained GRANITE, with average grain size of 3 to 5 mm and inequigranular texture.

(b) Detailed description. The major mineral constituents of the granite are quartz, plagioclase and alkali feldspars. Small amounts of biotite and occasional accessory pyrite grains are also present. Alkali feldspars are 2.5 to 5 mm in size, cloudy in polarized light and mostly microperthitic. The sodic plagioclase patches and lenticles are partly chloritized and altered to sericite and clay minerals. Plagioclases are 1.5 to 2 mm in size, cloudy, some with partial alteration to sericite and clay minerals. Quartz grains are, on average, 1.5 to 3 mm in size with occasional individual grains up to 5 mm. Biotite grains are 2 to 4 mm in size, partially chloritized and with alteration rims and minor segregation along cleavage planes. Isolated small (< 1 mm) grains of opaque mineral (magnetite ?) were observed in one thin section. Mineral grains are subhedral with tight, mostly unstained and interlocking boundaries. Hairline cracks are limited to quartz grains, mostly intragranular, tight and unstained with occasional, partial extension into adjacent grains.

The results of modal analysis carried out on three thin sections are given in Table 1 and show that feldspars and quartz are the predominant minerals forming, respectively, about 57% and 40% of the rock. Plates 4a and 4b are photomicrographs showing typical mineral texture and extent of alteration.

4. AGGREGATE TESTING AND CHARACTERIZATION

4.1 Sample Preparation and Testing Methods

Cores of 50 mm and 75 mm diameter were drilled from the block samples using a coring machine at the Public Works Central Laboratory. Selected physical and rock index tests were performed on the cores. The remainder of the samples were broken into smaller pieces using a sledge hammer and a laboratory rock breaker. Standard (10 to 14 mm) and nominal 20 mm size aggregates were prepared from the smaller pieces of rock using a laboratory jaw crusher.

The rock index tests undertaken included the determination of bulk density, porosity and water absorption. Sonic velocity using the PUNDIT equipment (ISRM, 1978) and point load strength testing on irregular lumps of rock (ISRM, 1985) were also carried out. The aggregate tests included

the determination of aggregate crushing value (ACV), aggregate impact value (AIV), water absorption, flakiness (I_F) and elongation indices (I_E), ten percent fines value, relative density (BSI, 1975) and Los Angeles abrasion value (LAAV)(ASTM, 1981).

4.2 Classification and Characterization of Aggregate

The CADAM scheme recommended by the Geological Society Working Party on Aggregates (Collis & Fox, 1985) is used to describe and classify the aggregates (Table 2). A more detailed petrographic evaluation of the aggregates is given in Table 3.

5. DISCUSSION ON TEST RESULTS

5.1 Rock Index and Aggregate properties

The results of rock index tests carried out on the selected samples are presented in Table 4 and indicate that the medium-grained granite from Diamond Hill is a strong rock with an average point load strength value of 6.5 MPa (corresponding to uniaxial strength of 162.5 MPa using a conversion factor of 25) and very low porosity and water absorption properties. The strong nature of the rock is also reflected in the high value of the measured sonic velocity.

The results of tests on laboratory crushed aggregates are presented in Table 5. A comparison of these results with the mean values of results available from Public Works Central Laboratory on quarry run material (Table 6) show that AIV, ACV, I_F, I_E and water absorption determined in the laboratory are slightly lower while relative density and 10% Fines Values are similar. The PSV (polished stone value) shown in Table 6 refers to one test only and it does not allow for significant comments.

In terms of index properties the medium-grained granite from Diamond Hill has similar values to the medium-grained granite from Turret Hill Quarry (Irfan & Nash, 1987) only in terms of bulk density while exhibiting lower porosity and water absorption properties. However in terms of both laboratory and quarry run tests on aggregates the medium-grained granite from Turret Hill Quarry has generally superior characteristics except for relative density and water absorption where the test values are similar. This is probably due to the relatively higher state of hydrothermal decomposition of the feldspars in the Diamond Hill granite.

5.2 Suitability of Rock As An Aggregate

A comparison of the limited laboratory test results with typical, mainly UK, aggregate acceptance values (Table 7) indicate that the properties of laboratory produced aggregate are generally within or at the limit of the acceptable values for both general use in concrete and as roadstone. The lower than required 10% Fines Value and AIV suggest that this rock type is not suitable for special purposes such as high strength concrete and heavy duty concrete floor finishes. The LAAV of 41, although just above the required value, may be acceptable for general concrete purposes but it is well outside the maximum values specified for concrete

exposed to severe conditions. However as the value is derived from a single test it would need to be confirmed by additional tests although the AIV would seem to be in agreement with the above limitation.

The aggregates from Diamond Hill Quarry have been successfully used for many years for general concrete purposes in Hong Kong. The aggregate test values presented in Table 6 are mean values of tests carried out on quarry run material at the Public Works Central Laboratory over the period from 1972 to 1985. The AIV is well below the maximum value acceptable in general use concrete as is the ACV, but just above that for wearing surfaces and well in excess of the maximum required for severe conditions. The 10% Fines Value supports this limitation.

6. CONCLUSIONS

The laboratory test results on laboratory crushed aggregates from fresh, medium-grained granite from the Diamond Hill Quarry are generally within the commonly accepted limiting values for general use in concrete and as roadstone.

The mean values of aggregate tests on quarry run material also indicate the suitability of this rock for general use and confirm the laboratory test results which indicate that the near or above limiting values for ACV and AIV makes the aggregate produced from this rock type less suitable for specific uses such as wearing courses and heavy duty concrete floors.

A comparison with the properties of laboratory produced and quarry run aggregates of medium-grained granite from Turret Hill Quarry indicates that the aggregate produced from Diamond Hill Quarry is of slightly inferior quality. This is probably attributable to the relatively higher state of alteration of the Diamond Hill granite and also slightly larger grain size revealed by the petrographic analysis.

No soundness tests to determine the durability of the aggregate were carried out, for the reason that the rock tested was basically fresh and the aggregates from fresh granites are known to be durable. However it is recommended that soundness tests be carried out if the proportion of discoloured and/or altered rock in significant.

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LIST OF TABLES

Table 1 - Modal Analysis of Medium-Grained Granite from Diamond Hill Quarry

Mineral	Feldspars %	Quartz %	Biotite %	Others %
Thin Section 1	61.4 (5.8)	36.3	2 (0.1)	0.1
Thin Section 2	60.3 (8.1)	35.6	4.1 (0.4)	0.2
Thin Section 3	48.3 (3.3)	48.9	2.6 (1.2)	0.0
Average	56.7 (5.7)	40.3	2.9 (0.6)	0.1

Note : The number in brackets is the percentage of altered feldspars (sericite and clay minerals) and altered biotite (mainly chlorite)

Table 2 - Description and Classification of Aggregate from Diamond Hill Quarry by the CADAM System (Collis & Fox, 1985)

AGGREGATE FORM	Crushed Rock		~~Gravel~~	~~Natural~~		~~Sand~~	~~Natural~~		Land-won
				~~Crushed~~			~~Crushed~~		~~Marine~~ ~~Dredged~~
				~~Mixed~~			~~Mixed~~		
CLASS (or MISCELLANEOUS)	~~Carbonate Class~~		~~Quartz Class~~	Silicate Class					~~Miscellaneous Material~~ (correct name to be given below)
				Igneous		~~Sedimentary~~		~~Metamorphic~~	
Petrological name (if known)	Granite								
GEOLOGICAL AGE COLOUR/ GRAIN SIZE FISSILITY	Mesozoic/Light grey/Medium grained/No fissility								
Comment (if any)									

Compiled by : A. Cipullo — Date : 21.4.1988

GE/EG 1, GCO

CADAM - CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/~~Pit~~ address : Diamond Hill Quarry, Kowloon Operator : Hong Kong Government Sample : Type Blocks Size 50 kg Preparation Lab. Crushed Supplied by E.G. Section	Grid Ref. 838800E 822750N	Date Rec'd
		Date of sampling May 1986	Sampling Cert. No. 3698EG038

Table 3 - Petrographic Evaluation of Granite Aggregate from Diamond Hill Quarry

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	3698 E3038 Diamond Hill Quarry/838800E, 822750N May 1986	SAMPLE SIZE/WEIGHT Bulk Sample 50 kg Sub-sample 1 kg (10-14 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Mainly angular and irregular, few elongated and flaky	
Surface Texture (BS 812:1975)	Crystalline	
Coating	None	
Cleanliness (Dust etc)	Clean	
GEOLOGICAL PROPERTIES Rock Type (GSS Classification)	Medium - grained GRANITE (gm)	
Mineralogy		
Major Constituents	Alkali and Plagioclase Feldspars (56.7%), Quartz (40.3%), Biotite (2.9%)	
Minor Constituents	Chlorite, Occasional fine grains of magnetite	
Cementing Materials	Crystalline, no cementing material	
Expansive Minerals	None	
Weathering of Particles	Fresh, no staining	
Organic Material Content	None	
GENERAL COMMENTS	Granite is inequigranular with grain size 3 to 5 mm and occasional individual feldspars up to a maximum 10 mm	Compiled by A. Cipullo Date 21.4.1988
ADDITIONAL INFORMATION		

Table 4 - Rock Index Properties of Medium-Grained Granite from Diamond Hill

Rock Index Property			Average Value	Range
Mineral Grain Specific Gravity		g/cm^3	n.d.	n.d.
Bulk Density	Dry	g/cm^3	2.61	2.60-2.61
	Saturated	g/cm^3	2.61	2.61-2.62
Water Absorption		%	0.3	0.2 - 0.3
Porosity	Total	%	n.d.	n.d.
	Effective	%	0.7	0.6 - 0.7
Sonic Velocity		m/s	4420+	3700-4800
Point Load Strength, $Is_{(50)}$		MPa	6.5*	5.2 -7.6

Legend :

\+ Determined on 75 mm diameter cores (ISRM, 1978).

* Average of 17 tests on irregular lumps (ISRM, 1985).

n.d Not determined.

Other index tests - Average of three tests on cores.

Table 5 - Test Results on Laboratory Crushed Aggregates (10-14 mm) from Diamond Hill

Aggregate Property			Test Value
Aggregate Crushing Value,	ACV	%	29
Aggregate Impact Value,	AIV	%	29
Los Angeles Abrasion Value,	LAAV*	%	41
Water Absorption		%	0.5
Flakiness Index,	I_F+	%	8
Elongation Index,	I_E+	%	30
10% Fines Value			108
Relative Density (Saturated and Surface Dried)		g/cm^3	2.62

Legend :

* Size fraction tested 10-4.75 mm - One Test

+ One Test

Table 6 - Aggregate Test Results from Diamond Hill Quarry, 1972-1985 (20 mm aggregate)

Aggregate Property			Test Value (Range)
10% Fines Value		kN	104 (90-110)
Aggregate Impact Value,	AIV	%	33 (28-36)
Aggregate Crushing Value,	ACV	%	31 (28-36)
Aggregate Abrasion Value,	AAV	%	n.d.
Water Absorption		%	0.73 (0.6-0.8)
Flakiness Index,	I_F	%	14 (9-19)
Elongation Index,	I_E	%	52 (39-64)
Relative Density (Saturated and Surface Dried)		g/cm^3	2.60 (2.59-2.66)
Polished Stone Value,	PSV+	%	52

Legend :

\+ One test on 10 mm aggregate

n.d. Not determined

Table 7 - A Comparison of Aggregate Test Results from the Diamond Hill Quarry with British Standard and Other Acceptance Value

Aggregate Property			Medium-Grained Granite	Acceptance Value	Use	Authority
10% Fines Value		KN	108	Min 100[2] Min 150[3]	C. C.	BS 882 : 1983
Aggregate Crushing Value,	ACV	%	29	Max 30	C.R.	Higginbottom (1976)
Aggregate Impact Value,	AIV	%	29	Max 45[1] Max 30[2] Max 25[3]	C.R. C.R.	BS 882 : 1983 BS 882 : 1983 BS 882 : 1983
Los Angeles Abrasion Value,	LAAV	%	41	Max 30[3] Max 40[4] Max 35[1]	C. C. R.	Australian Standard (1985) Australian Standard (1985) Shergold (1948)
Water Absorption		%	0.5	Max 3[1]	C.R.	Higginbottom (1976) BS 5337 : 1976
Flakiness Index,	I_F		8	Max 35[5]	C.R.	BS 882 : 1983
Elongation Index,	I_E		30			

Notes :
1 - General use
2 - For wearing surfaces
3 - Difficult conditions
4 - Average conditions
5 - For C20 and over concrete grade

C - Concrete aggregate
R - Road aggregate

LIST OF FIGURES

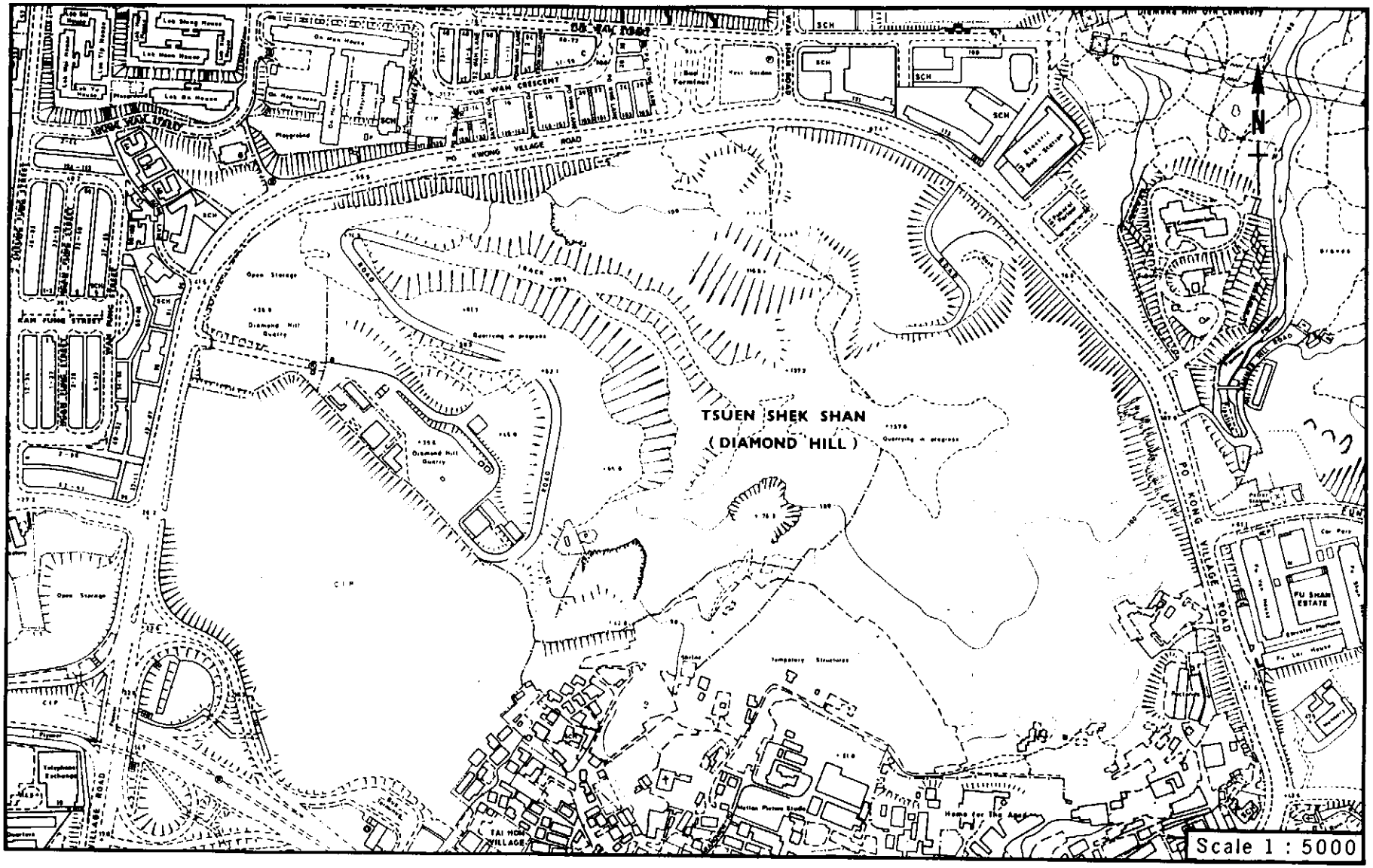
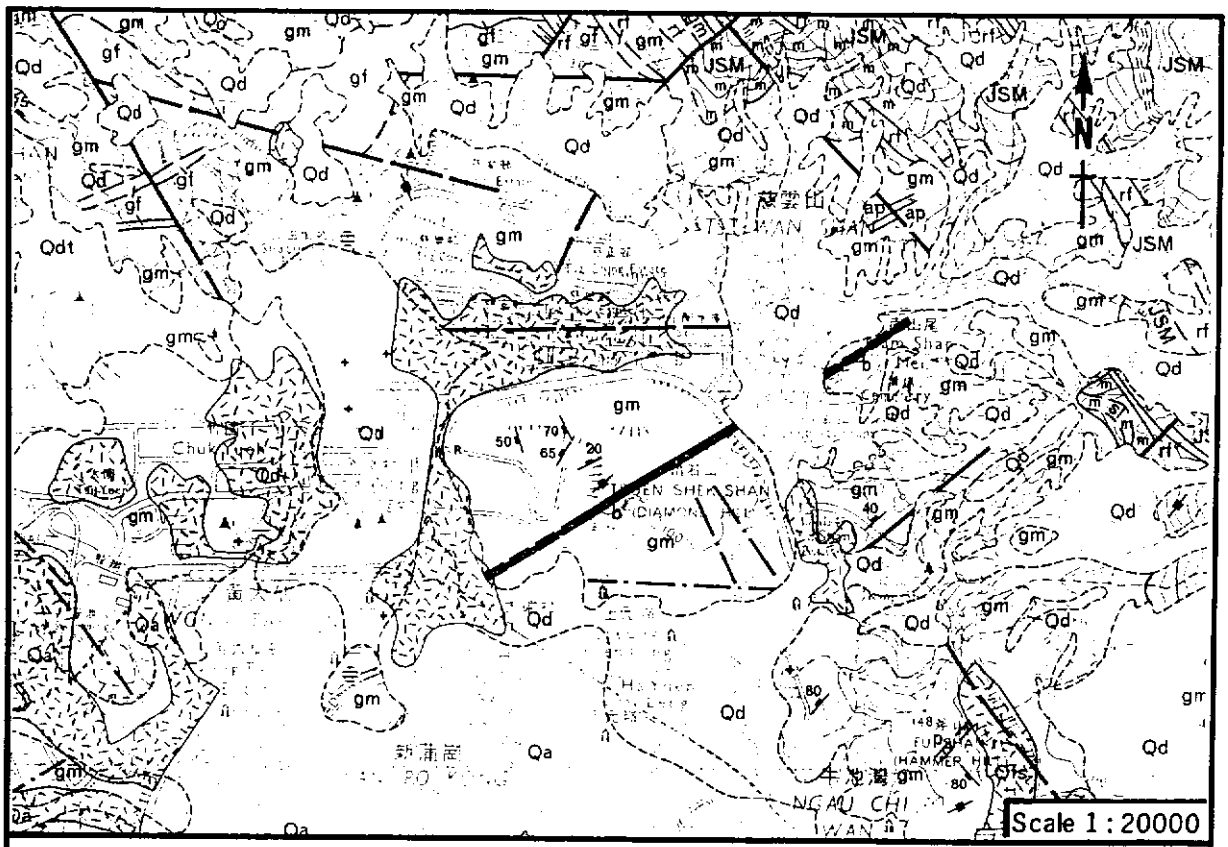


Figure 1 - Location Map



LEGEND :

SOLID GEOLOGY

Qa	Quaternary Superficial Deposits (Onshore)
Qd	
m m m	Hornfels
JSM	Fine Ash to Coarse Ash Tuffs, Tuff Breccia and Tuffite
rf	Feldsparphyric Rhyolite
b	Basalt
ap	Aplite
p	Pegmatite
gf	Fine-grained Granite, < 2mm
gm	Medium-grained Granite, 2-6mm

GEOLOGICAL LINES

- Geological Boundary, Superficial Deposits
- Geological Boundary, Solid Rock
- Fault
- Photogeological Lineament

STRUCTURAL SYMBOLS

	Horizontal	Inclined	Vertical
Jointing	+	20	⊥

NOTE : The geological map is extracted from the published sheet 11 of the 1 : 20000 geological map series of Hong Kong. Not all the geological symbols are given in the legend.

Figure 2 - Geology of the Site and Adjacent Areas

LIST OF PLATES

Plate 1 - General View of the Former Quarry Area Looking Southeast and Showing the Basalt Dyke Intrusion

Plate 2 - Sampling Locality Showing the General Joints Distribution

Plate 3 - Close-Up View of the Sampling Locality Showing Subvertical Chloritized Veins

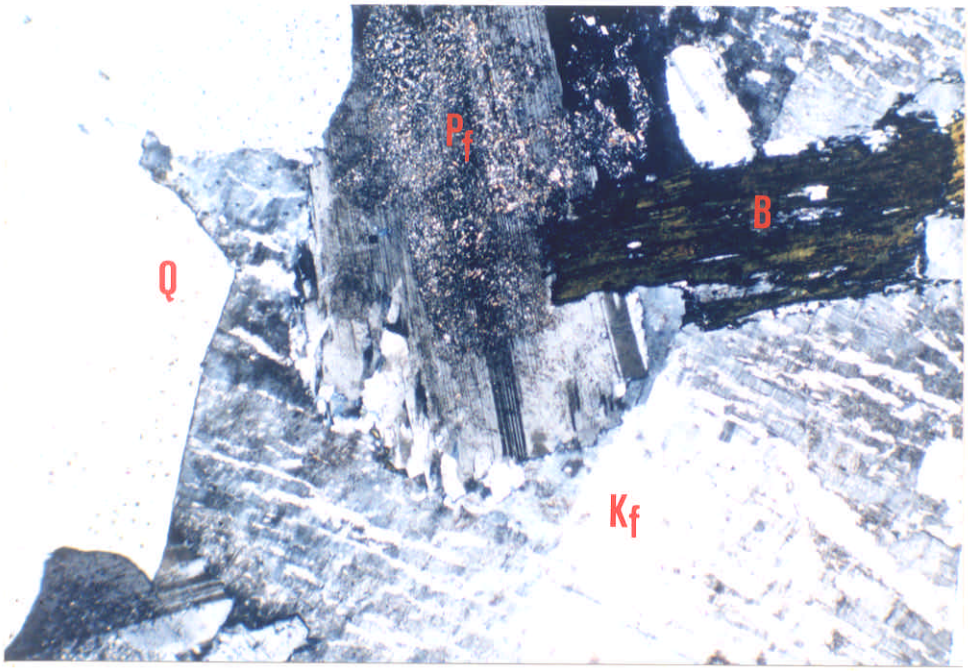


Plate 4a - Photomicrograph of Medium-Grained Granite Showing Alteration in Plagioclase Feldspar (P_f), Partly Altered Perthitic Alkali Feldspar (K_f), Quartz (Q), Biotite (B) and Tight, Interlocking Grain Boundaries (Crossed Polarized Light - Enlarged Approximately 40 Times)

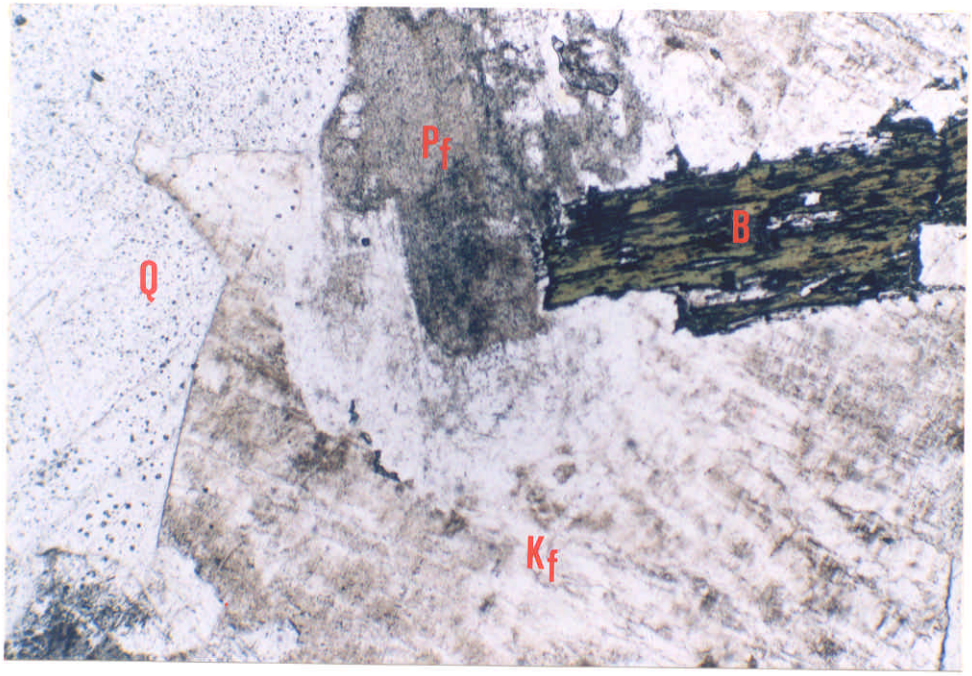


Plate 4b - Photomicrograph of Medium-Grained Granite as Above Showing Cloudy Alteration Patches in Feldspars and Tight, Unstained Intragranular Cracks in Quartz (Plane Polarized Light - Enlarged Approximately 40 Times)