SECTION 7 : AGGREGATE PROPERTIES OF FINE-, MEDIUM-, AND MEGACRYSTIC GRANITES FROM LAMMA ISLAND

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FOREWORD

In order to provide industry and Government with reliable and high quality test data concerning the index and aggregate properties and possible uses of each of the Territory's major rock types, the Geotechnical Control 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 types described in this report are the fine-grained, medium-grained and megacrystic granites from the Pok Tung Wan Quarry, Lamma Island.

The testing was carried out under the supervision of Dr T.Y. Irfan when he was Senior Geotechnical Engineer/Engineering Geology Section and the report was written after he moved to the Special Projects Division in April, 1981.

The assistance of the technical staff of the Engineering Geology Section with the field sampling and sample preparation and the staff of the Materials Division with the testing is acknowledged.

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CONTENTS

1. INTRODUCTION

The Fresh Rock Testing Programme (FRTP) was initiated in 1985 in order to provide reliable and high quality test data for industry and the Government on the index and aggregate properties and possible uses of each of the major rock types in Hong Kong. Typical and representative fresh rock samples from each of the major rock types are selected from a particular site, including currently operating quarries, and are subjected to selected index and aggregate property tests.

Three of the four major granite types of the Territory, namely the fine-grained granite (grain size 0.06 to 2 mm), the fine- to medium-grained granite (average grain size 2 mm) and the medium-grained granite (grain size 2 to 6 mm) occur in and around the Pok Tung Wan Quarry, Lamma Island (Figure 1, Plate 1). This report presents and discusses the results of selected physical index and aggregate testing on laboratory crushed fine-grained granite, medium-grained granite and megacrystic granite samples from the Pok Tung Wan Quarry. The results are compared with routine test values available for quarry run material and test results on granites from other sites. The suitability of each of the rock types as aggregate is assessed in comparison with typical international acceptance values for various uses.

2. SITE DESCRIPTION AND SAMPLING

The Pok Tung Wan Quarry is a government contract quarry which is administered by the Materials Division of the Geotechnical Control Office. The contract with Lamma Rock Products Ltd who operate the quarry commenced in 1978 for an initial period of 10 years with the option of an extension not exceeding 5 years.

An engineering geological study was undertaken by the Planning Division in 1986 relating to a major extension and landforming proposal by the Materials Division. The geotechnical aspects of the proposed extension, as well as the influence of geology on the type, quality and distribution of aggregate resources are discussed in detail in a report by Choy and Irfan (1986).

As part of the current study a limited number of block samples of the fine-grained and the medium-grained granite were collected from the excavated rock stockpiles at different locations of the Pok Tung Wan Quarry. A couple of block samples were also selected from the megacrystic granite variety which occurs as isolated outcrops in the quarry. Care was taken to select samples which were typical and representative of the granite types in the quarry.

3. GEOLOGY

3.1 Site Geology

The quarry site is entirely underlain by granite. The granite is variable in both grain size and texture over the site. On the new 1:20 000 scale geological map (GCO, 1987), the quarry and the neighbouring areas are shown to be composed of three types of granite; a medium-grained granite surrounded by a fine-grained and fine- to medium-grained granite (Figure 1). The detailed engineering geological mapping at 1:1 000 scale undertaken during the 1986 study identified the areas of various granite types in the quarry

(Figure 2).

The most common type of granite found in the quarry is a grey to pinkish grey, equigranular to inequigranular, fine- to medium-grained granite with average grain size of 1.5 to 2.5 mm. The equigranular, medium-grained granite generally occurs towards the north and west. Isolated outcrops of a megacrystic granite type are present in the far east face of the quarry and in the faces below the crest of the hill. This latter rock contains roughly aligned feldspar crystals, up to 30 mm in length, in a dark grey finer grained groundmass. The fine-grained granite is pinkish grey, equigranular and although gradation occurs near the contact with other types it has a grain size of less than 1 mm. This fine-grained granite is present in the southwestern corner of the quarry where it was initially quarried in the late 1970's. It also occurs towards the north of the present quarry and is usually seen intruding into other granite types with rather sharp but very irregular contacts.

Choy and Irfan (1986) reported that kaolinization and chloritization of granite is present along some of the N-S, NE-SW and WNW-ESE trending fault zones. The major near vertical joint systems also follow the direction of the major fault sets.

A more detailed account of the geology and weathering characteristics in the Pok Tung Wan quarry is given in Choy and Irfan (1986).

3.2 Description of Test Samples

3.2.1 Fine-Grained Granite

The rock is an extremely strong, light grey to pinkish grey, crystalline, fresh to slightly decomposed, fine-grained GRANITE with a grain size of 0.1 to 1 mm, occasionally up to 3 mm (Plate 2). The joint surfaces of the blocks are stained light yellowish brown with some migration of discoloration, up to 4 mm, into the rock from the joint surface. There are a few "veins" of coarser grained granite. The larger feldspars, 1 to 3 mm size, are pink coloured indicating slight hydrothermal (?) alteration.

Petrographical description. The major constituents of the granite are quartz, plagioclase and alkali feldspars with some biotite (Plate 6). Small amount of accessory minerals (e.g. sphene) and alteration products (e.g. chlorite) are also present. Quartz forms 35.3% of the rock, feldspars 61.9% and biotite 2.5%. The results of modal analysis carried out on two thin sections are given in Table 1. The rock has an inequigranular texture with quartz and feldspars occurring as large crystals, 0.5 to 1 mm and sometimes up to 3 mm in size, and also as finely crystalline grains with diffuse boundaries in the groundmass, 0.05 to 0.25 mm in size. Biotite occurs as individual small flakes. Most large feldspars show slight alteration to individual flakes of sericite and clay minerals, about 1.7% of the rock, whereas the feldspars in the groundmass are generally unaltered. Biotite is generally partially or wholly replaced by chlorite.

Very few microcracks, mostly intragranular in large quartz and feldspars are present. The grain boundaries are tight and unstained, except at the outer edge of the block samples.

3.2.2 Medium-Grained Granite

The rock is a very strong, light pinkish grey, crystalline, fresh to slightly decomposed, medium-grained GRANITE with equigranular texture and a grain size of 2 to 5 mm (Plate 3). Some of the joint surfaces are discoloured light yellowish brown. In hand specimen, alkali feldspars are pink and some plagioclases are greenish grey indicating slight alteration of the rock.

Petrographical description. The major constituents of the granite are quartz, plagioclase and alkali feldspars with some biotite (Plate 7). Small amounts of accessory minerals and secondary alteration products (sericite, etc.) are present. The quartz content (22.5%) is lower than that of the fine-grained granite and the biotite content is higher (5.6%). Feldspars form about 71.8% of the rock. The results of modal analysis carried out on two thin sections are given in Table 1. The rock is equigranular with quartz and feldspars having grain sizes of 1 to 4 mm; occasionally feldspars are as large as 8 mm. Most plagioclase shows slight alteration to individual flakes of sericite and clay minerals. Alkali feldspars are generally fresh. Biotite occurs as individual grains and shows a small amount of alteration to chlorite and hydrous mica. The amount of feldspar alteration is about 1.6% of the rock (Table 1).

The grain boundaries are tight and interlocking. Microcracks are few, less than 1 per 10 mm length, single, tight and mostly intragranular within the quartz and some feldspars.

3.2.3 Megacrystic Granite

The rock is a very strong, light pinkish grey to dark grey (biotite rich), crystalline, fresh to slightly decomposed, megacrystic-GRANITE with inequigranular and variable texture and grain size. The block sample shows variation in texture and colour across the sample. The dark grey, biotite rich granite forms about 80% of the block sample and has a megacrystic texture with up to 20-30% megacrysts of feldspars set in a fine- to medium-grained groundmass. It has a very high biotite (and minor hornblende) content of over 20%. The pinkish grey areas are less megacrystic and more typical of the fine- to medium-grained granite occurring in the quarry. Fine-grained patches/veins of granite also occur in the block sample.

Petrographical description. Thin sections were taken from both the dark coloured and light coloured areas. In thin section, the light coloured megacrystic granite has an inequigranular texture with partially recrystallized finer grained patches in a medium-grained groundmass. Strange and Shaw (1986) regard this fabric to be due the modification of the medium-grained granite by later intrusion of fine-grained granite. The modal analysis (Table 1) carried out on two thin sections of the light coloured granite gave the following mineralogical composition : quartz (31.1%), feldspars (66.5%), biotite (2.2%), accessory minerals (0.2%). The great majority of the plagioclase feldspar megacrysts show slight alteration to sericite and clay minerals whereas the perthitic alkali feldspars are fresh. Biotite occurs as clusters of grains as well as individual crystals. Only a few biotite grains show partial alteration to chlorite. Most quartz shows strained extinction. Finely crystalline quartz and feldspars have a grain size of 0.05 to 0.25 mm and the "older" grains are 0.5 to 3 mm, occasionally up to 10 mm in grain size.

The modal analysis carried out on two sections of the dark coloured megacrystic granite showed about 10.3% biotite and 2.2% accessory minerals including iron-oxides (Plate 8). The quartz content is 22%, i.e. lower than that of the light grey coloured granite. The feldspars comprise about 65% of the rock and show a higher degree of alteration (about 3.5%). Small amounts of hornblende, generally in association with biotite and chlorite are also present. The texture is inequigranular with megacrysts of mainly feldspars up to 10 mm in grain size in a fine- to medium-grained groundmass.

The grain boundaries are generally sharp and interlocking except in areas of recrystallization where the grains have rather diffuse boundaries. A few transgranular microcracks are present, some are slightly open.

4. AGGREGATE TESTING AND CHARACTERIZATION

4.1 Sample Preparation and Testing Methods

Cores of 50 mm diameter were drilled (Plate 5) from the block samples using a diamond coring machine at a contract laboratory. Selected physical and rock index tests were performed on the cores at the Public Works Central Laboratory. The remainder of the samples were broken into smaller pieces using a sledge hammer and a laboratory rock breaker. Standard size (10 to 14 mm) aggregates were prepared from the smaller pieces of rock using a laboratory jaw crusher. Two to four thin sections were prepared from each of the rock types for microscopic examination.

The rock index tests undertaken on the core samples included the determination of bulk density, porosity, water absorption and sonic velocity (ISRM, 1981). Point load strength testing was carried out on 20 to 30 irregular lumps of rock (ISRM, 1985). Schmidt hammer rebound values were obtained on block samples by using an N-type hammer.

The aggregate tests undertaken included the determination of aggregate crushing value (ACV), aggregate impact value (AIV), water absorption, flakiness index (I_F), elongation index (I_E), relative density and 10% fines value (BSI, 1983) on standard size aggregates. The Los Angeles abrasion value (LAAV) was determined on fine aggregate (5 to 10 mm size) instead of the standard nominal 20 mm aggregate (ASTM, 1981) because of insufficient material in the latter size.

4.2 Classification and Characterization of Aggregates

The CADAM scheme, as recommended by the Geological Society Working Party on Aggregates (Collis & Fox, 1985) is used to describe and classify the aggregates (Tables 2 to 4). In addition, a more detailed petrographic evaluation of the aggregates produced from each of the granite types has also been made (Tables 2 to 4).

4.3 Test Results

The results of the rock index tests on cores and irregular lumps of three granite types are summarised in Table 5. The results of the aggregate tests are given in Table 6 which also shows the range of test results obtained on other granites in the FRTP and the acceptance values for concrete and roadstone for comparison. A summary of the test results on 20 mm nominal size quarry crushed aggregates carried out at the Public Works Central Laboratory and the Contractor's laboratory is given in Table 7.

5. DISCUSSION ON TEST RESULTS

5.1 Rock Index and Aggregate Properties

The results of index tests carried out on the selected samples given in Table 5 indicate that all three granite types from the Pok Tung Wan quarry are very strong to extremely strong rocks in the fresh to slightly decomposed state with point load strengths over 5.6 MPa (corresponding to uniaxial compressive strength of about 140 MPa). They have very low effective porosity, less than 0.7%, and water absorption, less than 0.3%, characteristics.

The fine-grained granite is the strongest and the medium-grained granite the weakest of the three granites with respective point load strengths of 11.2 MPa and 5.6 MPa. The variation in strength is also reflected in the Schmidt hardness values, SHV, (a measure of strength of rock) of these rocks with the former rock type having a SHV of 60 and the latter SHV of 57. In terms of sonic velocities, the fine-grained granite has the lowest value and the medium-grained granite the highest value, 4605 m/s and 5235 m/s respectively. This rather unexpected result can be explained when the density and porosity of the granite types are considered. The fine-grained granite has a lower density, d_d = 2.60 Mg/m^3 and a higher porosity, n_{eff} = 0.65%, when compared with those of the medium-grained granite, d_d = 2.62 Mg/m^3 and n_{eff} = 0.5%. In addition to porosity and density, the mineralogy and weathering state of the rock may also affect the strength and velocity results.

The index values of these three granite types are comparable to the similar granite types tested from elsewhere in the Territory (see for example Irfan 1987a; Irfan & Nash, 1987; Cipullo & Irfan, 1988; Irfan & Cipullo, 1987).

The variations in index properties, particularly in strength values, amongst the three granite types is also reflected in the aggregate properties. The mechanical properties of the fine-grained granite are superior to the medium-grained granite with ACV = 16%, AIV = 20%, LAAV = 22% and 10% fines value = 210 kN for the former type and 25%, 20%, 33% and 140 kN respectively for the latter. Only one aggregate crushing value and aggregate impact value were determined for the megacrystic granite due to small amount of sample available for this type. It appears to have intermediate values, but nearer to those of the fine-grained granite with ACV = 19% and AIV = 20%. Only one flakines index and elongation index determination was carried out on each of the three granite types. These indicate that the aggregates from the fine-grained granite are more flaky and elongated than those of the other two types as would be expected from their relative grain size.

The fine-grained granite which is finer grained than any granite type tested thus far in this programme, including the fine-grained granite from Anderson Road (Irfan & Cipullo, 1987), has the most superior mechanical aggregate property values in terms of ACV (16%), LAAV (20%) and 10% fines value (210 kN) (Table 6).

5.2 Suitability of Rocks as Aggregates

A comparison of the laboratory crushed aggregate test results with the mean values of quarterly results available from the PWC Laboratory and the limited results available from the quarry contractor's own laboratory on quarry run material (Table 7) show very similar properties in terms ACV (21%), AIV (17%), 10% fines value (215 kN), water absorption (0.7%) and elongation index (30) to those of the fine-grained granite. The type of granite tested by the two laboratories was however not specified for any of the test results. The detailed engineering geological mapping (Figure 2) indicated that the dominant rock type in the quarry is fine- to medium-grained granite followed by fine-grained granite. It is therefore not surprising that the quarry test results are more characteristic of the fine-grained granite. In addition, the early production in the late 1970's, early 1980's came from the southwestern portion of quarry where the rock is dominantly fine-grained (Choy & Irfan, 1986).

A comparison of the laboratory test results with typical, mainly UK and Australian, aggregate acceptance values (Table 6) indicate that the properties of the laboratory crushed (and the quarry run) aggregate prepared from the three granite types are all within the acceptable values for both general use in concrete and as roadstone. The medium-grained granite, as discussed previously, has values nearer to the marginally acceptable limits than those of the fine-grained variety. The very low, i.e. favourable values obtained on the fine-grained granite in terms of AIV and LAAV and very high, i.e. also favourable 10% fines value indicate that this granite is suitable for special purposes such as heavy duty concrete and concrete to be used under moderate to severe exposed conditions.

No polished stone values, which give a measure of susceptibility of stone to polishing when used in a wearing surface of a road (BSI, 1975), were determined on the samples. Skid resistance is provided by the roughness of a road surface and a suitable aggregate should retain a high degree of roughness in service. Because of their dense texture and hardness, the granites usually do not have high polishing values in the fresh state. Fine-grained igneous rocks or igneous rocks with a small percentage of soft minerals (i.e. slightly decomposed state) may accept a high polish resistance (Collis & Fox, 1985). Therefore, the fine-grained granite and the megacrystic granite are expected to have reasonably high polishing values in slightly decomposed state.

No tests were carried out to determine the alkali-silica reactivity potential of the three granite types. Although some strained quartz crystals and microcrystalline quartz which may be potentially reactive (Table 1 in Gilbert & Irfan, 1989) are present, respectively, in the medium-grained and the fine-grained granites, this type of reaction is not expected to be a potential problem for these granites. No cases of silica-alkali reactivity have been reported in Hong Kong where granitic aggregates from the Hong Kong quarries have been used in abundance since at least the 1950's.

6. CONCLUSIONS

The laboratory test results for laboratory crushed aggregates of fresh to slightly decomposed fine-grained granite from the Pok Tung Wan quarry are well within the commonly accepted limiting values for general use in concrete and as roadstone. The lowest values in terms of ACV and LAAV and the highest value in terms of 10% fines value obtained so far in the Fresh Rock Testing Programme on the fine-grained granite make this rock type very suitable for special uses such as wearing courses and heavy duty concrete floors.

The medium-grained granite also has acceptable aggregate properties but nearer to the limiting values. While the aggregates produced from this granite are hence suitable for general concrete and roadstone uses, high ACV, AIV and LAAV values make them rather marginal or unsuitable for some specific uses. Limited test results on the megacrystic granite indicate intermediate aggregate property values but nearer to those of the fine-grained granite. Although suitable in terms of mechanical properties for general and also possible for some specific uses, the dark grey colour may make this granite type rather unattractive in concrete. Other properties which are likely to adversely influence the use of this granite type as an aggregate source or a facing stone are very variable texture and grain size and the relatively rapid weatherability observed on site if the granite is already in a moderately decomposed state. It also has very limited occurrence in the quarry.

The mean values of quarterly and other aggregate tests on quarry run material, which are very near to those of the fine-grained granite obtained in this programme, also confirm the suitability of the dominant rock types in the quarry, i.e. the fine- to medium-grained and the fine-grained granite, for general and also some specific concrete uses.

No chemical reactivity tests or sulphate soundness tests were carried out to determine the alkali-silica reactivity or the durability of the aggregates. The reason for this omission is that the rocks tested were basically fresh with slight decomposition near the joint surfaces and the aggregates from fresh to slightly decomposed 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 is significant. Although strained quartz and/or microcrystalline silica, which may indicate potential for silica-alkali reactivity, occur in some of the rock types tested, the long service record of the granitic aggregates from this quarry, and generally unreactive nature of granitic rocks, indicate that this process is not likely to be a potential problem. A more detailed assessment of the quarry resources with respect to a potential major expansion programme is given by Choy and Irfan (1986).

7. REFERENCES

ASTM (1981). Test for resistance to abrasion of small size coarse aggregate by use of the Los Angeles machine. Test Designation C131-81. American Society for Testing Materials.

BSI (1975). Methods for Sampling and Testing of Mineral Aggregates, Sands and Fillers (BS 812 : Parts 1 to 3). British Standards Institution.

BSI (1983). British Standard Specification for Aggregates from Natural Sources for Concrete (BS 882 : 1983). British Standards Institution, London, 7 p.

Choy, H.H. & Irfan, T.Y. (1986). Engineering Geology Studies for the Extension of Pok Tung Wan Quarry, Lamma Island. GCO Report No. ADR 18/86, 60 p. plus drawings.

Cipullo, A. & Irfan, T.Y. (1988). Aggregate Properties of Medium-grained Granite from Diamond Hill. GCO Report No. TN 3/88, 24 p.

Collis, L. & Fox, R.A. (1985). Aggregates : Sand, Gravel and Crushed Rock Aggregates for Construction Pruposes. Geological Society Engineering Geology Special Publication No. 1. The Geological Society, London, 200 p.

Fookes, P.G. (1984). An introduction to concrete in the Far-East-Part 1. Concrete, July issue, pp 38-41.

GCO (1987). Hong Kong and Kowloon, Solid and Superficial Geology (1 : 20 000 map). Hong Kong Geological Survey Map Series HGM 20, Sheet 15, Geotechnical Control Office, Hong Kong, 1 map.

Gilbert, S.T. & Irfan, T.Y. (1989). Suitability of Volcanic Rocks for Concrete Aggregates in Hong Kong. GCO Report No. SPR 5/89, 54 p. plus Appendix.

Higginbottom, I.E. (1976). Section 11.1. General requirements for rocks and aggregates. In Applied Geology for Engineers, H.M.S.O., 378 p.

ISRM (1981). Rock Characterization Testing and Monitoring. ISRM Suggested Methods (ed. E.T. Brown). Commission on Testing Methods, International Society for Rock Mechanics, Pergamon Press, 211 p.

ISRM (1985). Suggested method for determining point load strength. International Society for Rock Mechanics Commission on Testing Methods. International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts, vol. 22, No. 2, pp 51-60.

Irfan, T.Y. (1987a). Aggregate Properties of Fine- to Medium-grained Granite from Mau Yau Tong. GCO Report No. TN 9/87, 24 p.

Irfan. T.Y. (1987b). Aggregate Properties of Coarse-grained Granite from Lai King. GCO Report No. TN 4/87, 23 p.

Irfan, T.Y. & Cipullo, A. (1987). Aggregate Properties of Fine- and Fine- to Medium-grained Granites from Anderson Road. GCO Report No. TN 11/87, 34 p.

Irfan, T.Y. & Nash, J.M. (1987). Aggregate Properties of Medium-grained Granite from Turret Hill Quarry. GCO Report No. TN 2/87, 23 p.

Shergold, F.A. (1948). A review of available information on the significance of roadstone tests. Road Research Technical Paper 10. DSIR, H.M.S.O., London.

Standards Association of Australia (1985). Aggregates and Rock for Engineering Purposes. Part 1 - Concrete Aggregates (Australian Standard 2758.1 - 1985). Standards Association of Australia, 16 p.

Strange, P.J. & Shaw, R. (1986). Geology of Hong Kong Island and Kowloon. Geotechnical Control Office, Hong Kong, 134 p. (Hong Kong Geological Survey Memoir No. 2).

LIST OF TABLES

Table 1 - Modal Analysis of Granites from Pok Tung Wan Quarry, Lamma Island

Mineral	Fine-grained Granite	Medium-grained Granite	Megacrystic Granite	
			Light Coloured	Dark Coloured
No. of Thin Sections	3	2	2	2
Quartz	35.3	22.2	31.1	22.1
Feldspars[1]	61.9 (1.7)	71.8 (1.6)	66.5 (1.8)	65.0(3.5)
Biotite[2]	2.5 (2.0)	5.6 (0.6)	2.2 (0.5)	10.5(2.9)[4]
Others[3]	0.3	0.3	0.2	2.3

Notes :

1. The number in brackets is the percentage of altered feldspars (kaolinite, sericite, etc.) per thin section.
2. The number in brackets is the percentage of altered biotite (chlorite, muscovite) per thin section.
3. Other minerals include accessory minerals (e.g. sphere, zircon, magnetite).
4. Small amount of hornblende (<2%) is present in megacrystic granite.

Table 2 - Classification, Description and Petrographic Evaluation of Aggregate Produced from the Fine-Grained Granite

AGGREGATE FORM	Crushed Rock ✓	Gravel	Natural / Crushed / Mixed		Sand	Natural / Crushed / Mixed		Land-won / Marine Dredged	
CLASS (or MISCELLANEOUS)	Carbonate Class	Quartz Class	Silicate Class: Igneous ✓	Sedimentary	Metamorphic			Miscellaneous Material (correct name to be given below)	
Petrological name (if known)	GRANITE								
GEOLOGICAL AGE/ COLOUR/ GRAIN SIZE FISSILITY	Mesozoic/Light pinkish grey/Fine to medium-grained/Slightly megacrystic/ Fresh to slightly Decomposed/No fissility								
Comment (if any)									

Compiled by : T.Y. Irfan G.C.O. Date : 6.9.1989

CADAM - CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/Pit address : Pok Tung Wan Lamma Island Operator : Sample : Type Blocks Size 100 kg Preparation Lab. crushed Supplied by EG Section	Grid Ref.	Date Rec'd
		Date of sampling 1985	Sampling Cert. No. EG040

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	EG040 Pok Tung Wan Quarry, Lamma Island 1985	SAMPLE SIZE/WEIGHT About 100 kg of bulk sample - processed to aggregate in laboratory (10 to 14 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Angular to irregular	
Surface Texture (BS 812:1975)	Crystalline	
Coating	None	
Cleanliness (Dust etc)	Clean	
GEOLOGICAL PROPERTIES Rock Type (GSS Classification)	Fine-grained GRANITE (gf)	
Mineralogy		
Major Constituents	Quartz (35%), Feldspars (62%), Biotite (2.5%)	
Minor Constituents	Sericite, chlorite	
Cementing Materials	None	
Expansive Minerals	None	
Weathering of Particles	Generally fresh, some lightly discoloured (slightly decomposed)	
Organic Material Content	None	
GENERAL COMMENTS	Inequigranular fabric, slightly megacrystic, grain size 0.05 to 0.5 mm, occasionally up to 2 mm	Compiled by T.Y. Irfan Date 6.9.1989
ADDITIONAL INFORMATION		

Table 3 - Classification, Description and Petrographic Evaluation of Aggregate Produced from the Medium-Grained Granite

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 pinkish grey/Coarse-grained/Fresh to slightly decomposed/ No fissility										
Comment (if any)											

Compiled by : T.Y. Irfan   Date : 6.9.1989

G.C.O.

CADAM - CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/Pit address : Pok Tung Wan. Lamma Island Operator : Sample : Type Blocks Size 50 kg Preparation Lab. crushed Supplied by EG Section	Grid Ref.	Date Rec'd
		Date of sampling 1985	Sampling Cert. No. EG041

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	EG041 Pok Tung Wan Quarry, Lamma Island 1985	SAMPLE SIZE/WEIGHT About 50 kg of bulk sample - processed to aggregate in laboratory (10 to 14 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Angular to irregular	
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	Quartz (22%), Feldspars (72%), Biotite (6%)	
Minor Constituents	Sericite (2%)	
Cementing Materials	None	
Expansive Minerals	None	
Weathering of Particles	Fresh to slightly decomposed, slight staining around biotite grains	
Organic Material Content	None	
GENERAL COMMENTS	Equigranular fabric, grain size 2 to 5 mm	Compiled by T.Y. Irfan Date 6.9.1989
ADDITIONAL INFORMATION		

Table 4 - Classification, Description and Petrographic Evaluation of Aggregate Produced from the Megacrytic Granite

AGGREGATE FORM	Crushed Rock ✓	Gravel	Natural / Crushed / Mixed	Sand	Natural / Crushed / Mixed	Land-won / Marine Dredged	
CLASS (or MISCELLANEOUS)	Carbonate Class	Quartz Class	Silicate Class: Igneous ✓ / Sedimentary / Metamorphic			Miscellaneous Material (correct name to be given below)	
Petrological name (if known)	GRANITE						
GEOLOGICAL AGE/ COLOUR/ GRAIN SIZE FISSILITY	Mesozoic/Light pinkish grey to dark grey/Medium to coarse-grained/Megacrystic/ Fresh to slightly Decomposed/No fissility.						
Comment (if any)	Variable texture and grain size, contains over 10% of dark ferromagnesian minerals.						

Compiled by : T.Y. Irfan G.C.O. Date : 6.9.1989

CADAM - CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/Pit address : Pok Tung Wan, Lamma Island Operator : Sample : Type Blocks Size 50 kg Preparation Lab. crushed Supplied by EG Section	Grid Ref. Date of sampling 1985	Date Rec'd Sampling Cert. No. EG042

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	EG042 Pok Tung Wan Quarry, Lamma Island 1985	SAMPLE SIZE/WEIGHT About 25 kg of bulk sample - processed to aggregate in laboratory (10-14 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Angular to irregular	
Surface Texture (BS 812:1975)	Crystalline	
Coating	None	
Cleanliness (Dust etc)	Clean	
GEOLOGICAL PROPERTIES Rock Type (GSS Classification)	Megacrystic fine- to medium-grained GRANITE (gfm)	
Mineralogy	Megacrysts of feldspars compose 20-30% of the rock	
Major Constituents	Quartz (22 to 31%), Feldspars (65 to 67%), Biotite (2 to 20%)	
Minor Constituents	Magnetite, hornblende (2%), sphere, sericite	
Cementing Materials	None	
Expansive Minerals	None	
Weathering of Particles	Generally fresh, some are slightly decomposed	
Organic Material Content	None	
GENERAL COMMENTS	Inequigranular and variable fabric with feldspar megacrysts (up to 10 mm) set in a finer grained groundmass, 1 to 3 mm	Compiled by T.Y. Irfan Date 6.9.1989
ADDITIONAL INFORMATION	Biotite rich areas are dark grey coloured and dioritic(?) in composition	

Table 5 - Rock Index Properties of Granites from Pok Tung Wan Quarry, Lamma Island

Rock Index Property			Fine-Grained Granite EG040	Medium-Grained Granite EG041	Megacrystic Granite EG042
Mineral Grain Specific Gravity,		Mg/m^3	n.d.	n.d.	n.d.
Bulk Density	Dry	Mg/m^3	2.60 (2.59-2.61)	2.62 (2.62-2.62)	2.60 (2.60-2.62)
	Saturated	Mg/m^3	2.61 (2.60-2.61)	2.63 (2.62-2.63)	2.61 (2.61-2.62)
Water Absorption		%	0.25 (0.23-0.29)	0.19 (0.17-0.21)	0.16 (0.10-0.25)
Porosity	Total	%	n.d.	n.d.	n.d.
	Effective	%	0.65 (0.59-0.76)	0.50 (0.45-0.55)	0.41 (0.26-0.65)
Sonic Velocity		m/s	4605 (4460-4710)	5235 (5050-5350)	5020 (4840-5220)
Schmidt Hammer Value[1]			60 (58-61)	57 (57-58)	59 (59-60)
Point Load Strength[2]	$I_{s(50)}$	MPa	11.2	5.6	7.8

Notes :
1 Determined on blocks
2 Determined on irregular lumps, average of 20-35 tests
( ) Range of values
Other index tests - average of 3 to 5 tests on cores.

Table 6 - A Comparison of Aggregate Test Results on Granites from Pok Tung Wan Quarry with Other Granites and Acceptance Values

Aggregate Property		Fine-Grained Granite	Medium-Grained Granite	Megacrystic Granite	Other Granites (FRTP)	Acceptance Value	Use	Authority
Aggregate Crushing Value, ACV	%	16	25	19*	21-29	Max 20[2] Max 30[1]	C. C.R.	Higginbottom (1976) Higginbottom (1976)
Aggregate Impact Value, AIV	%	20	27	20	15-31	Max 20[4,5] Max 30[2] Max 40[2] Max 45[1]	C. C.R. C. C.R.	Fookes (1984) BS 882 (1983) ASTM C-131 BS 882 (1983)
Los Angeles Abrasion Value, LAAV	%	22**	33**	n.d.	28-44	Max 30[5] Max 35[4] Max 40[3] Max 35[1]	C. C. C. R.	Australian Standard (1985) Australian Standard (1985) Australian Standard (1985) Shergold (1948)
10% Fines Value	kN	210	140	n.d.	100-200	Min 50[1] Min 100[2] Min 150[6]	C. C. C.	BS 882 (1983) BS 882 (1983) BS 882 (1983)
Water Absorption	%	0.8	0.6	0.5	0.3-0.7	Max 3[1] Max 3 Max 1.5[4,5]	C.R. C. C.	Higginbottom (1976) BS 5337 (1976) Fookes (1984)
Flakiness Index,	I_F	26*	17*	21*	7-26	Max 25[4,5] Max 35	C. C.R.	Fookes (1984) BS 882 (1983)
Elongation Index,	I_E	38*	26*	45*	28-44	Max 30[4,5]	C.	Fookes (1984)

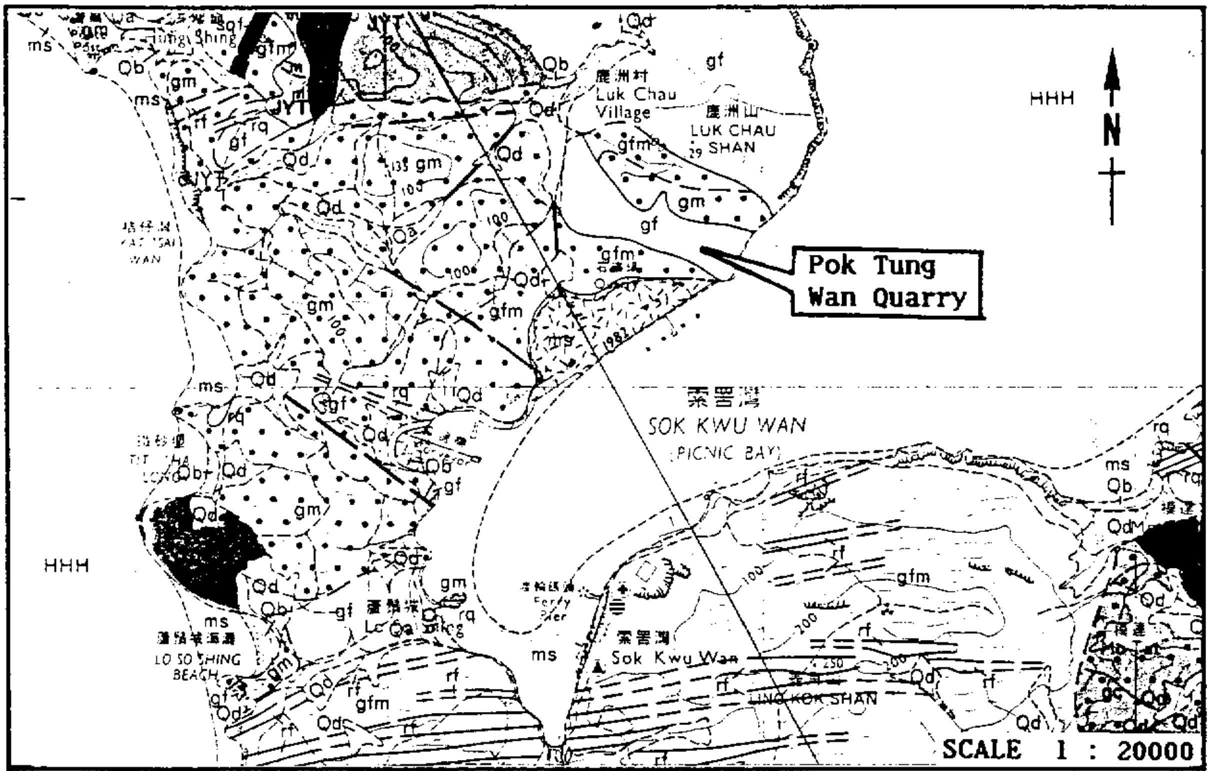
Notes :
C. = Concrete; R. = Roadstone
n.d. = Not determined
* = One test result, others average of two tests
** = On 5-10 mm aggregate, others on 10-14 mm aggregate
FRTP = Fresh Rock Testing Programme (see references in this report for detailed results)
1. = General use; 4. = Moderate exposure
2. = Wearing surfaces; 5. = Severe exposure
3. = Protected concrete; 6. = Heavy duty concrete

Table 7 - Test Results on Quarry Crushed Aggregate (20 mm Aggregate) from Pok Tung Wan Quarry, 1981-1986

Aggregate Property			PW Central Laboratory[1]	Contractor's Laboratory[2]
Aggregate Crushing Value,	ACV	%	n.d.	21
Aggregate Impact Value,	AIV	%	17	n.d.
10% Fines Value		kN	215 (190-260)	180
Water Absorption		%	0.7 (0.6-0.9)	0.7
Relative Density		Mg/m^3	2.61 (2.60-2.62)	2.63
Flakiness Index,	I_F	%	11 (6-16)	15
Elongation Index,	I_E	%	30 (22-45)	19

Notes :
n.d. not determined
1 6 series of tests, 1981 to 1986
2 Average of 2 series of tests carried out in 1986
( ) Range of test values

LIST OF FIGURES



LEGEND :

SOLID GEOLOGY

gf	Fine-grained granite, <2 mm
gfm	Fine- to medium-grained granite
gm	Medium-grained granite, 2-6 mm
(fill pattern)	Fill
rq	Quartzphyric rhyolite

GEOLOGICAL LINES

— — — Fault

NOTE : The geological map is extracted from the published sheet 15 of the 1 : 20000 geological map series of Hong Kong. Not all the geological symbols are given in the legend.

Figure 1 - Location Map Showing Geology of the Sampling Site and Adjacent Areas

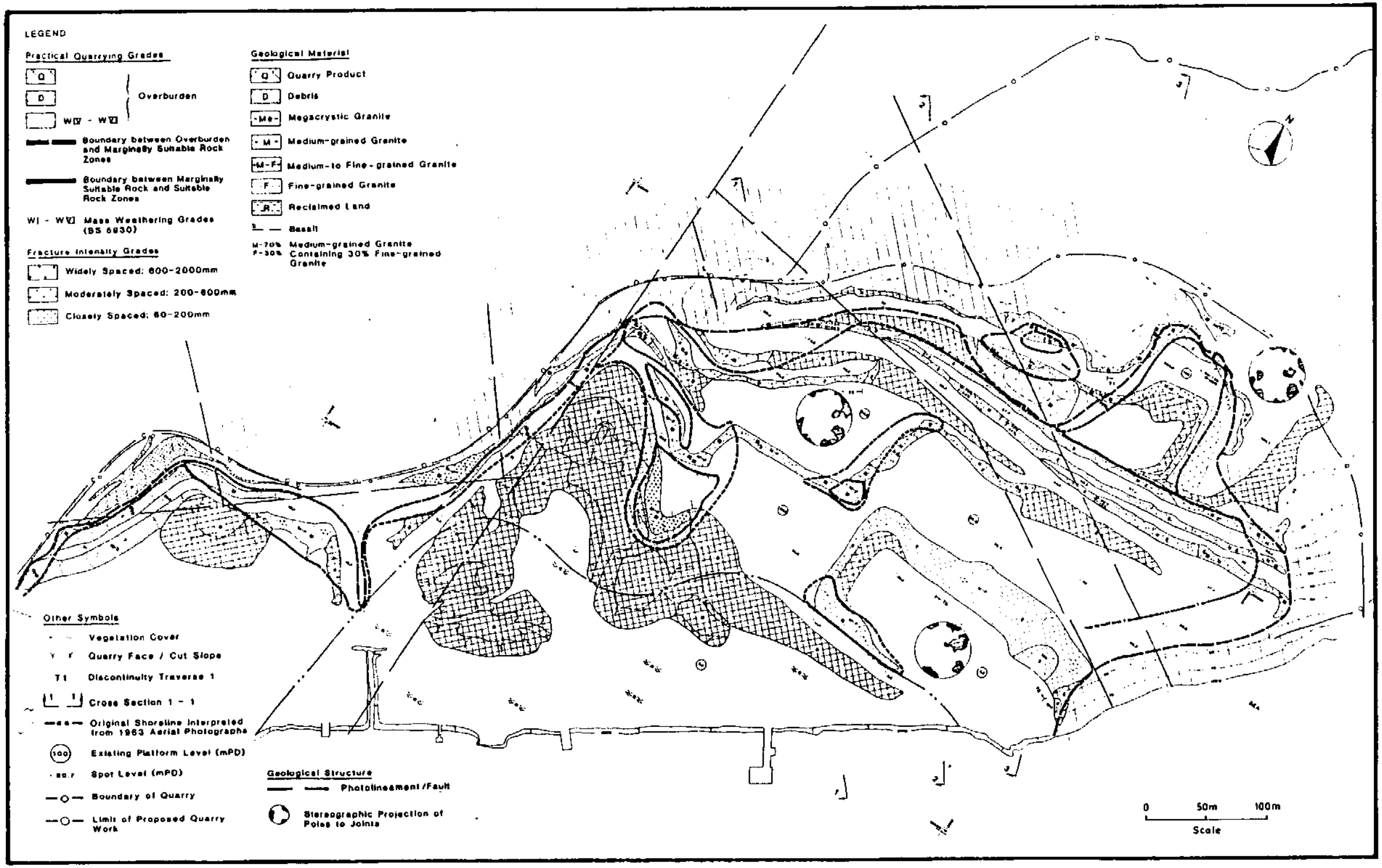


Figure 2 - Engineering Geological Map of the Pok Tung Wan Quarry (from Choy & Irfan, 1986)

LIST OF PLATES

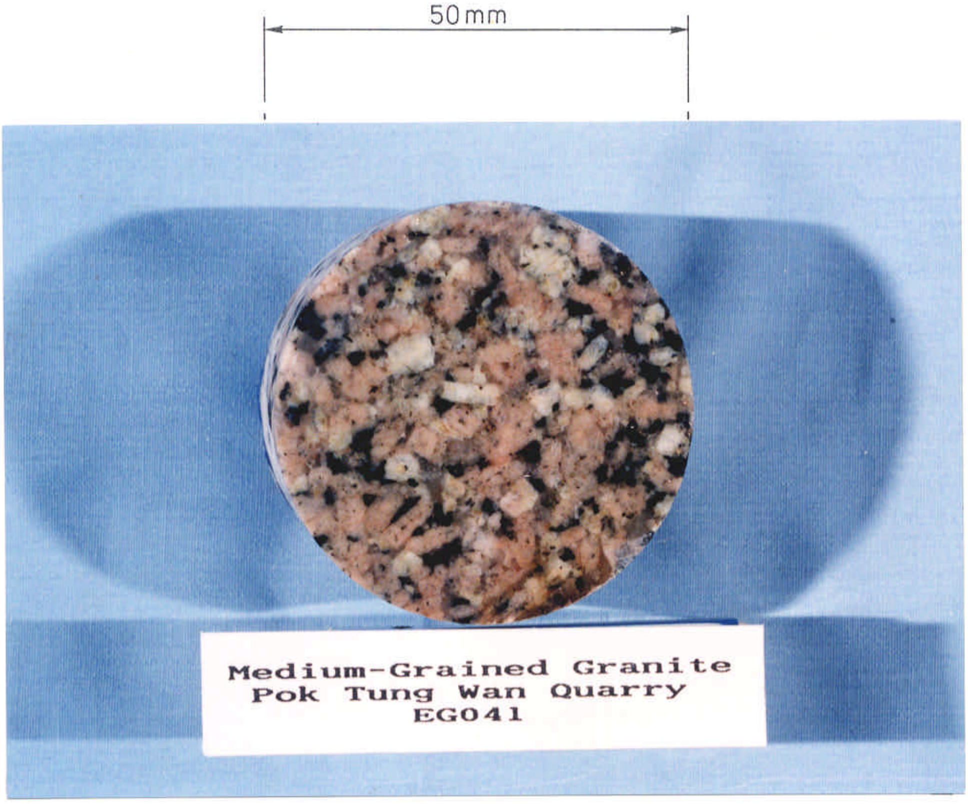
Negative No. EG 8504015 & 16

Plate 1 – Pok Tung Wan Quarry

Negative No. SP 8908907

Negative No. SP 8908936A

Plate 2 - Hand Specimen of the Fine-Grained Granite



Negative No. SP 8908906

Plate 3 - Hand Specimen of the Medium-Grained Granite

60 mm 50 mm

Negative No. SP 8908904

50 mm

Negative No. SP 8908936

Plate 4 - Hand Specimen of the Megacrystic Granite

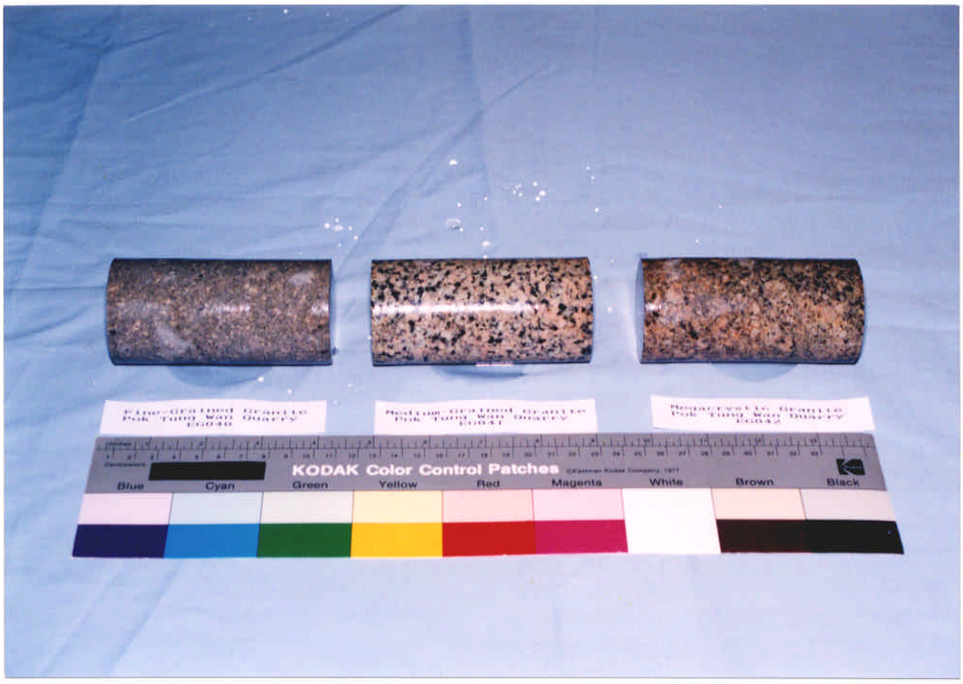


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Plate 5 - Core Specimens of the Fine-Grained, the Medium-Grained and the Megacrystic Granites

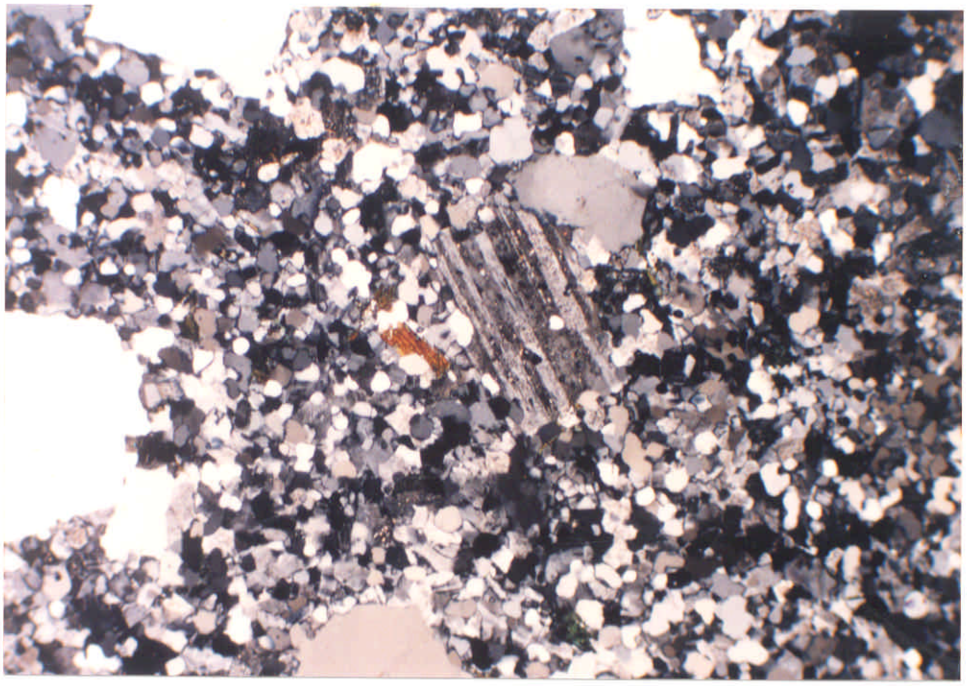

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Plate 6 - Photomicrograph of the Fine-Grained Granite

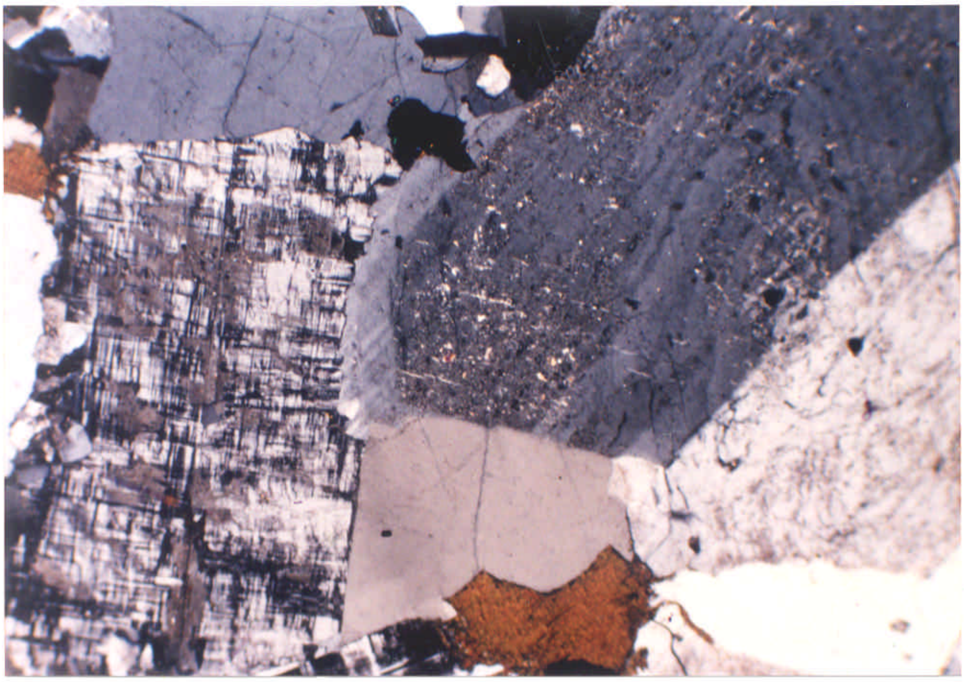

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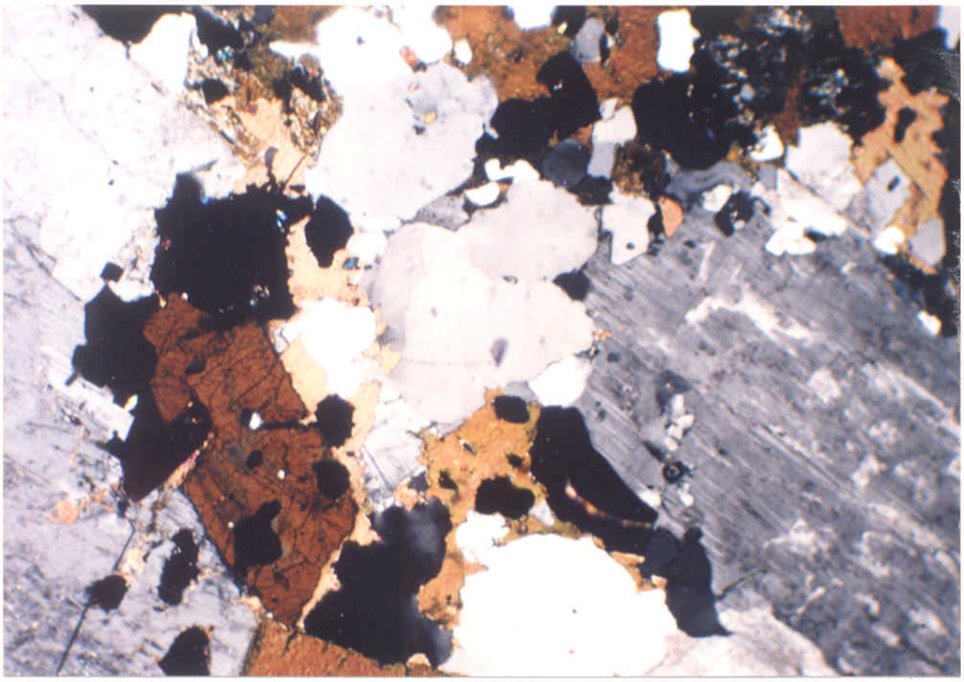
Plate 7 - Photomicrograph of the Medium-Grained Granite



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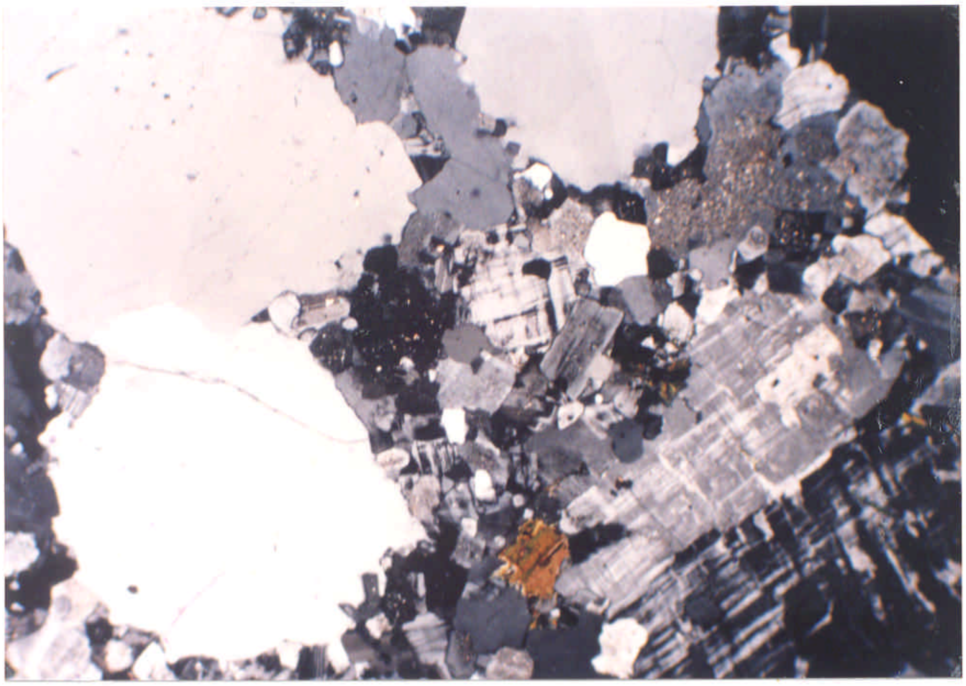

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Plate 8 - Photomicrograph of the Megacrystic Granite