# SECTION 2 : AGGREGATE PROPERTIES OF MONZONITE FROM TURRET HILL QUARRY

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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 characterisation 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 a quartz-monzonite from the Turret Hill Quarry, Shatin.

The author wishes to acknowledge the role played in the field sampling and sample preparation by GE J.M. Nash and TO's W.C. Lee and M.K. Chan and in the laboratory testing by GE K.H. Lee and other laboratory staff. The cooperation and assistance of the Quarry Management and the Materials Division is also acknowledged.

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## 1. INTRODUCTION

This Technical Note on the aggregate properties of fresh monzonite forms the second report in the series of aggregate properties of selected Hong Kong rocks and is part of the Fresh Rock Testing Programme, the aims of which are explained in the unpublished Technical Note by Irfan & Purser (1985).

The monzonite samples under discussion were collected from the Turret Hill Quarry and were subjected to selected laboratory physical index and aggregate testing. This report presents the results of these index and aggregate tests and discusses the results and suitability of monzonite from this locality as aggregate in comparison with the typical aggregate acceptance values. In assessing the suitability of the rock as aggregate, only the selected rock material properties are considered. Other rock properties such as jointing, weathering and overburden, as well as environmental, operational and haulage factors should also be considered in determining the overall suitability for development of a particular source of material.

## 2. SITE DESCRIPTION AND SAMPLING

The sampling site is the disused Turret Hill Quarry (Plate 1) located on the southwestern flank of Turret Hill (Nui Po Shan), east of Shatin (Figure 1). The site was originally used as a borrow area in the mid-1960's and 70's which was then turned into a granite aggregate quarry in the late-1970's. Rock extraction ceased at the quarry at the end of 1984.

The sampling location is situated near the western end of the quarry on the fourth face from the base of the quarry (Plate 2). Block samples of easily manageable size and weight were collected from the fresh monzonite sill occurring on the face for testing. While this sill material is thus clearly not of sufficient size to form an economic source of monzonite it does provide a typical representative of this rock type for testing and assessment.

## 3. GEOLOGY

### 3.1 Site Geology

The main rock type in the quarry is medium-grained granite (gm) intruded by thin sheets and dykes of fine-grained granite (Addison, 1986). Monzonite occurs as a relatively thin sheet (sill) of 0.8 to 1.2 m width, near the western end of the quarry dipping at about 35$^{o}$ towards southeast (Plate 2). The extent of the sill is not known and on the 1:20 000 geological map it is shown as a discontinuous outcrop. The sill is irregular in shape and the contact with granite is fused. No obvious alignment of feldspar megacrysts is present. The joints are generally medium-to widely-spaced and tight.

### 3.2 Description of Test Sample

Engineering geological description (c.BS 5930:1981). The rock is extremely strong, medium grey coloured, crystalline, fresh, medium- to coarse-grained, quartz-MONZONITE with an inequigranular and porphyritic texture.

Detailed description. The rock consists of phenocrysts of both alkali and plagioclase feldspars (up to 45%) in a medium-grained matrix of feldspars, biotite and quartz. Quartz forms about 13% of the rock and biotite and hornblende about 4.3%, the rest being feldspars. Modal analysis was carried out on one thin section only. The results are given in Table 1. Phenocrysts of feldspars are up to 20 mm but generally 5 to 10 mm in size. Some of the plagioclase feldspars show slight alteration to sericite in thin section (Plate 3). Detailed description of quartz-monzonite occurring in the Shatin area is given in Addison (1986).

## 4. AGGREGATE TESTING AND CHARACTERIZATION

### 4.1 Sample Preparation and Testing Methods

Standard (10-14 mm) and nominal 20 mm size aggregates (Plate 4) were prepared using a laboratory jaw crusher. Selected physical rock index tests were also performed on the larger irregular lumps of rock using ISRM recommended methods. Aggregate testing was carried out according to the methods recommended in BS 812 (BSI, 1975).

The rock index tests included the determination of bulk density, mineral grain specific gravity, porosity and water absorption (ISRM, 1978) and point load testing (ISRM, 1985). The aggregate tests included aggregate crushing value, aggregate impact value, water absorption, flakiness and elongation indices (BSI, 1975) and Los Angeles abrasion value (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 aggregate (Table 2). A more detailed petrographic evaluation of the aggregate is given in Table 3.

### 4.3 Test Results

The results of rock index tests are given in Table 4. The test results on laboratory crushed monzonite aggregate are tabulated in Table 5. Limited aggregate test results from the material quarried between 1979 and 1980 are available but these results are highly likely to be for granite rather than monzonite as the latter has very limited outcrop in the quarry.

## 5. DISCUSSION ON TEST RESULTS

### 5.1 Rock Index and aggregate Properties

The rock index tests given in Table 4 show that the fresh monzonite from Turret Hill Quarry site is an extremely strong rock with a point load strength value of about 12 MPa (or uniaxial compressive strength of about 300 MPa using the normal conversion factor of 25) and has very low water absorption and porosity properties.

In terms of rock index properties including bulk density, the monzonite has very similar properties to the medium-grained granite occurring in the quarry (Table 3 in Irfan & Nash, 1987). The rock specimens tested were isotropic in nature with no apparent alignment of feldspar megacrysts. The rock type tested was not therefore typical of monzonite occurring in the

Territory since the thicker intrusions are generally known to have a well-defined and characteristics feldspar orientation. This usual anisotropy is likely to result in strength differences in directions perpendicular and parallel to the feldspar alignment. Aggregate mechanical properties are also likely to be influenced by this anisotropy and also the presence of feldspar megacrysts.

A comparison of the aggregate test results on the monzonite (Table 5) with those of medium-grained granite from the same locality (Table 6) show that the monzonite has lower and hence more desirable aggregate properties in terms of aggregate crushing value, aggregate impact value and Los Angeles abrasion value. The results in terms of water absorption, flakiness and elongation indices are similar in being better than granite.

No test results are available from the Quarry (or elsewhere in the Territory) to make a comparison between the aggregate properties of laboratory crushed and plant crushed rocks.

## 5.2 Suitability of Rock as Aggregate

The existing aggregate quarries in Hong Kong are all in granite. No commercial monzonite aggregate test results are available and the in-service performance of this aggregate is not known. Aggregate test results and in-service performance records from overseas sources are also not readily available to make a general assessment of the suitability of monzonite as an aggregate source rock. However, monzonite is similar to granite in terms of composition and grain size, except it has a lower quartz content of less than 20%. The monzonite has similar mechanical and physical properties to those of granite and is therefore expected to have similar aggregate properties. Monzonite aggregates may, however, have lower resistance to abrasion due to a lower free silica content. Acid crystalline rocks including monzonite generally show relatively poor performance in relation to adhesion properties with bitumen (p. 170, Collis & Fox, 1985).

In Hong Kong, both the test methods and the acceptance values for aggregates to be used in concrete and as roadstone are generally those recommended in the British Standards (Government of Hong Kong, 1977). A comparison of the test results in Table 5 with typical UK aggregate acceptance values (Table 7) indicates that the aggregates produced from the monzonite in the Quarry are well within the acceptable limits for use in concrete and as roadstone as far as the properties determined in Table 5 are concerned. They are also comparable to those of granite aggregates which are commonly used in Hong Kong.

No polished stone values, PSV, were determined. Soundness tests were not carried out to determine the durability of the aggregate because of the fresh state of the rock. Chemical decomposition generally results in higher PSV's in igneous rocks (Collis & Fox, 1985). However, a considerable degree of resistance to weathering including resistance to disintegration with cycles of wetting and drying or freezing and thawing, during the service lifetime is required for both roadstone and concrete aggregates. Some of the severest cases of failure of roadstone in unbound bases have been associated with physical breakdown of rock already subjected to some degree of chemical weathering (Turner & Wilson, 1956; Day, 1962). Monzonite contains a higher percentage of feldspars (lower quartz) compared to granites and is likely to be more susceptible to further decomposition and disintegration if the rock has already weathered to some degree. It is, therefore, recommended that soundness tests should be carried out and abrasion and polished stone properties be determined if anything but fresh monzonite is to be used as aggregate.

## 6. CONCLUSIONS

The laboratory test results carried out on aggregate produced from fresh quartz-monzonite collected from Turret Hill Quarry are well within the commonly accepted limiting values for general use in concrete and as roadstone. In terms of certain properties such as aggregate impact value, aggregate crushing values and Los Angeles abrasion value, the monzonite aggregates have lower and hence slightly more desirable properties than those of medium-grained granite from the same quarry. The polished stone values were not determined.

Although the mechanical and physical test results indicate that monzonite may be suitable for aggregate production, the monzonite intrusion at this site, however, is not considered as a suitable source rock since it occurs as a very thin sheet-like form of less than 1.5 m thickness and under considerable overburden of granitic rock.

The rock tested in this investigation is also atypical of monzonitic intrusions occurring in the Shatin area and elsewhere in the Territory. It does not show the typical and characteristic fabric anisotropy resulting from the alignment of feldspar megacrysts. Further testing is therefore required on samples collected from other parts of the Territory, particularly from the more common anisotropic variety to determine the overall aggregate potential of monzonite in Hong Kong.

The tests in this investigation were carried out on laboratory crushed fresh rock samples. No test results are available on plant crushed monzonite aggregates for a comparison, since monzonite is rarely used as an aggregate in Hong Kong. In-service performance of monzonite aggregates from outside Hong Kong is also not readily available to the author. They are, however, expected to show similar performance records to those of granites being of similar composition and grain size, except that due to lower quartz contents, the aggregates produced from monzonite may have higher and hence more desirable PSV's but lower resistance to abrasion.

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## LIST OF TABLES

Table 1 - Modal Analysis of Monzonite

| Mineral | Feldspars | Quartz | Biotite | Hornblende | Others |
|---|---|---|---|---|---|
| % | 80.9 | 13.0 | 4.4 | 0.9 | 0.6 |
| Note : Modal analysis carried out on one thin section. | | | | | |

Table 2 - Description and Classification of Monzonite Aggregate by the CADAM System (Collis & Fox, 1985)

| | | | | | | |
|---|---|---|---|---|---|---|
| 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/Medium grey/Fresh/Medium to coarse-grained, porphyritic/No fissibility (see note). |
| Comment (if any) | Large crystals up to 30 mm in a medium- to coarse-grained matrix. |

Compiled by : T. Y. Irfan
SGE/EG

Date : 13.2.87

CADAM - CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

| | | | |
|---|---|---|---|
| LOCATION AND SAMPLE DETAILS | Quarry/Pit address : Turret Hill Quarry, Shatin, N.T.<br>Operator : Disused (Contract Qu.)<br>Sample : Type Blocks<br>Size 50 kg<br>Preparation Lab. crushed<br>Supplied by E.G. Section | Grid Ref.<br><br>Date of sampling 16.5.85 | Date Rec'd<br><br>Sampling Cert. No. 3662 EG002 |

Table 3 - Petrographic Evaluation of the Monzonite Aggregate

| PETROGRAPHIC EVALUATION OF AGGREGATES | | |
|---|---|---|
| SAMPLE REF<br>LOCATION/GRID REF<br>SAMPLING DATE | HK3662 EG002<br>Turret Hill Quarry, Shatin<br>84020E 82760N<br>16.5.1985 | SAMPLE SIZE/WEIGHT<br>Bulk sample 50 kg aggregate<br>sub-sample 1 kg (10-14 mm) |
| AGGREGATE PROPERTIES<br>Particle Shape (BS 812:1975) | Mainly irregular to angular with sharp corners, some percentage of elongated particles | |
| Surface Texture (BS 812:1975) | Crystalline | |
| Coating | None | |
| Cleanliness (Dust etc) | Clean | |
| GEOLOGICAL PROPERTIES<br>Rock Type (GSS Classification) | Quartz-MONZONITE (mq) | |
| Mineralogy | | |
| Major Constituents | Plagioclase feldspars and alkali feldspars in equal proportions (total 81%), biotite | |
| Minor Constituents | Quartz (13%), hornblende | |
| Cementing Materials | Crystalline, no cementing materials | |
| Expansive Minerals | None | |
| Weathering of Particles | Fresh, no staining | |
| Organic Material Content | None | |
| GENERAL COMMENTS<br>ADDITIONAL INFORMATION | Rock in the quarry occurs as a thin sill. Very low quartz content. The texture is porphyritic with feldspar crystals up to 20 mm, set in a medium-grained (less than 2 mm) groundmass. | Compiled by TYI/JMN<br>Date 17.2.1987 |

Table 4 - Rock Index Properties of Monzonite from Turret Hill

| Rock Index Property | | | Average | Range |
|---|---|---|---|---|
| Mineral Grain Specific Gravity | | ($g/cm^3$) | 2.65 | 2.65 |
| Bulk Density | Dry | ($g/cm^3$) | 2.62 | 2.62 |
| | Saturated | ($g/cm^3$) | 2.63 | 2.63 |
| Water Absorption | | (%) | 0.48 | 0.45-0.51 |
| Porosity | Total | (%) | 1.31 | 1.23-1.39 |
| | Effective | (%) | 1.26 | 1.18-1.33 |
| Point Load Strength | | (MPa) | 12.0+ | |

Legend :

+ Limited test results on 6 irregular lumps

Table 5 - Test Results on Laboratory Crushed Monzonite Aggregate from Turret Hill

| Aggregate Property | Test Value |
|---|---|
| Aggregate Crushing Value, ACV (%) | 18<br>(-) |
| Aggregate Impact Value, AIV (%) | 12<br>(-) |
| Los Angeles Abrasion Value, LAAV (%) | (21.5) |
| Water Absorption (%) | 0.5<br>(0.4) |
| Flakiness Index, $I_F$ (%) | 20<br>(25) |
| Elongation Index, $I_E$ (%) | 39<br>(36) |
| Note : Numbers in brackets for 14-20 mm aggregate. | |

Table 6 - Test Results on Laboratory Crushed Medium-Grained Granite Aggregates (10-14 mm) from Turret Hill

| Aggregate Property | Test Value |
|---|---|
| Aggregate Crushing Value, ACV (%) | 23 |
| Aggregate Impact Value, AIV (%) | 24 |
| Los Angeles Abrasion Value, LAAV (%) | 29 |
| Water Absorption (%) | 0.5 |
| Flakiness Index, $I_F$ (%) | 7<br>(20)* |
| Elongation Index, $I_E$ (%) | 41<br>(30)* |

Legend :

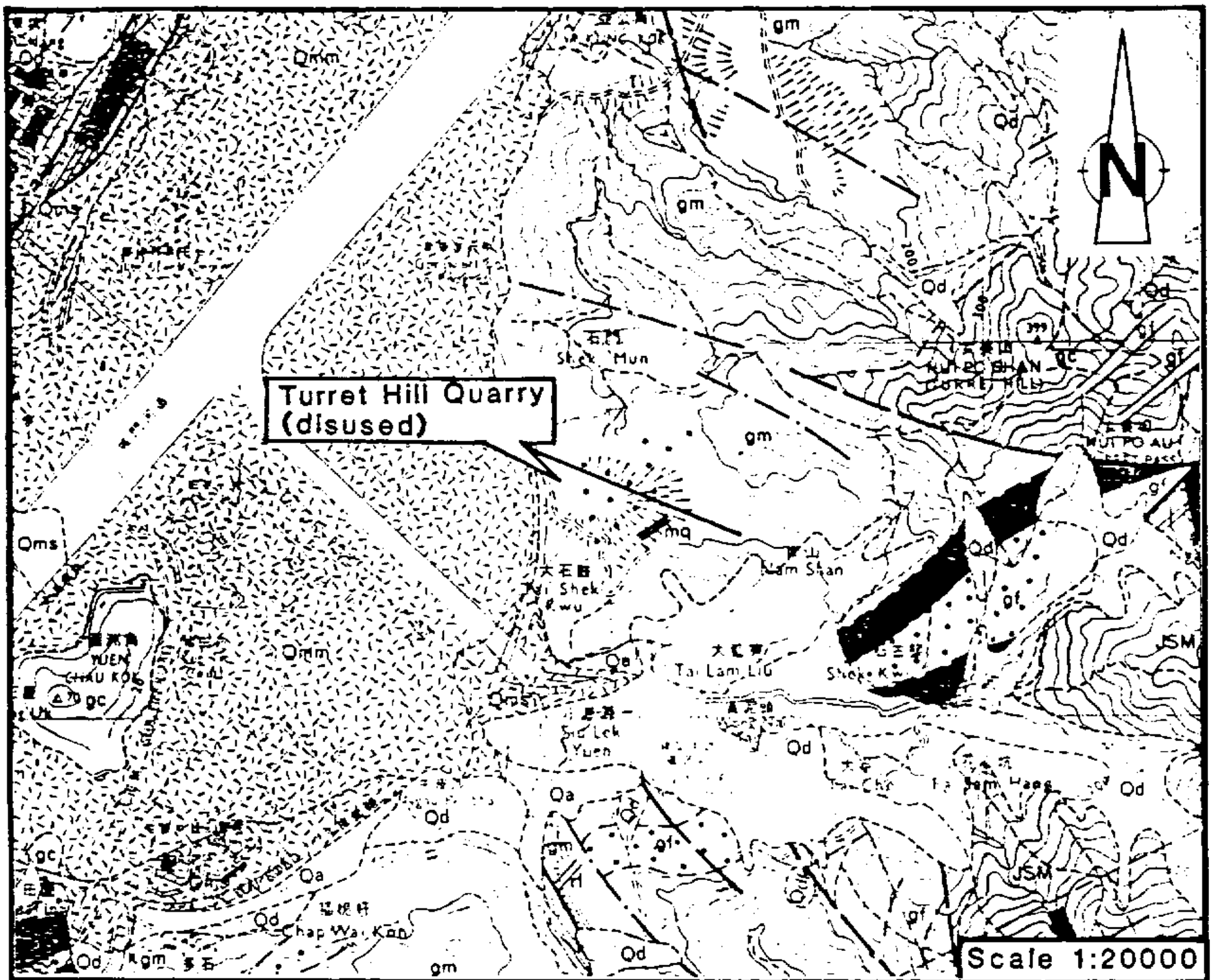
* 14-20 mm aggregate

Table 7 - British Standard and Other Acceptance Values for Test Results on Roadstone and Concrete Aggregates

| Test | Test Value | Use | Authority |
|---|---|---|---|
| Aggregate Crushing Value, ACV (%) | Maximum 30 | C.R. | Higginbottom (1976) |
| Aggregate Impact Value, AIV (%) | Maximum 45+<br>Maximum 30* | C.R. | BS 882:1983 |
| 10% Fines Value (kN) | Minimum 50+<br>More than 100*<br>More than 150* | R.C.<br>R.<br>C. | Hosking & Tubey (1969)<br>BS 882:1983<br>BS 882:1983 |
| Aggregate Abrasion Value, AAV (%) | Maximum 10 (diff. cond.)<br>Maximum 12 (av. cond.) | R. | DoT (1976) |
| Los Angeles Abrasion Value, LAAV (ASTM C-131) | Maximum 30 (diff. cond.)<br>Maximum 40 (av. cond.)<br>Maximum 35* | C.<br>C.<br>R. | Australian Standard 2758.1 (1985)<br><br>Shergold (1948) |
| Water Absorption (Porosity) (%) | Less than 3+ | C.R. | Higginbottom (1976)<br>BS 5337:1976 |
| Bulk Density ($g/cm^3$) | More than 2.60 | C.R. | Higginbottom (1976) |
| Flakiness Index, $I_F$ (%) | Less than 35*** | C.R. | BS 882:1983 |
| Magnesium Sulphate Soundness (%) | Maximum 18 (5 cycles) | C.R. | ASTM C33-81 |
| Sodium Sulphate Soundness (%) | Maximum 12 (5 cycles)<br>Maximum 12 (5 cycles) | C.R.<br>C. | ASTM C33-81<br>Australian Standard 2785.1 (1985) |

Legend : R Road aggregates; C - Concrete aggregates; + General use; * For wearing surfaces; ** For heavy duty concrete floor; *** For C20 and over concrete grade

# LIST OF FIGURES




**LEGEND :**

**SOLID GEOLOGY**

| | |
|---|---|
| Qmm, Qa, Qd, Qdt | Quaternary Superficial Deposits |
| mq | Quartz Monzonite |
| JSM | Crystal and Lithic Tuff, Tuff-breccia and Tuffite |
| gc | Coarse-grained Granite, > 6mm |
| gf | Fine-grained Granite < 2mm |
| gm | Medium-grained Granite, 2-6mm |
| (dots) | Inequigranular Texture |

**GEOLOGICAL LINES**

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

**NOTE :**

The geological map is extracted from the published sheet 7 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 Site and the Adjacent Areas

## LIST OF PLATES

Plate 1 - General View of Turret Hill Quarry

Plate 2 - Sampling Locality on Quarry Bench

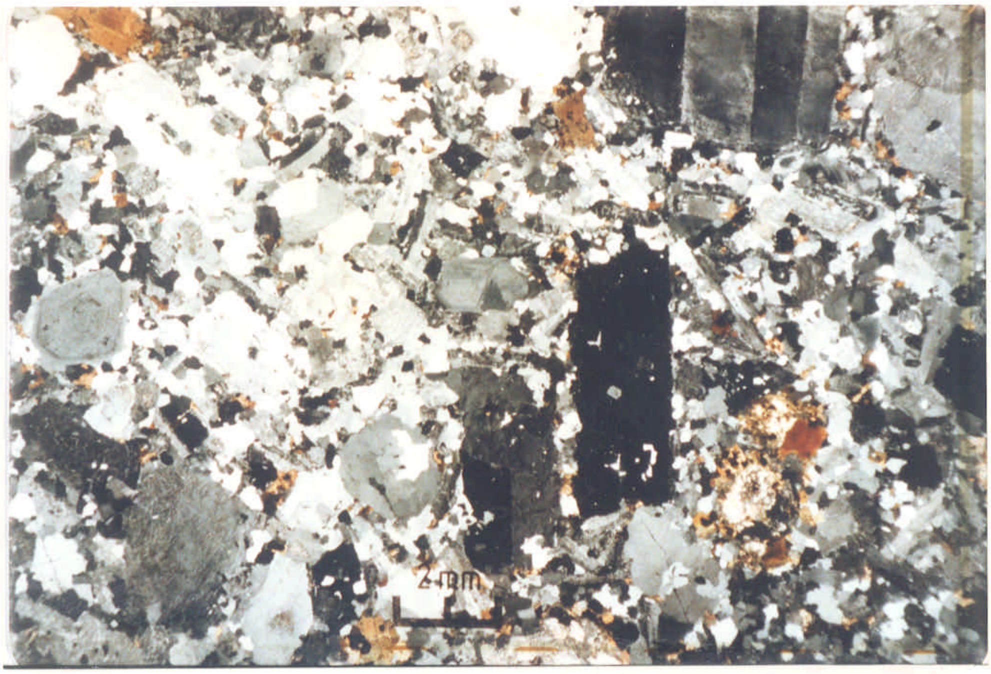



Plate 3 - Photomicrograph of Monzonite Showing Inequigranular and Porphyritic Texture

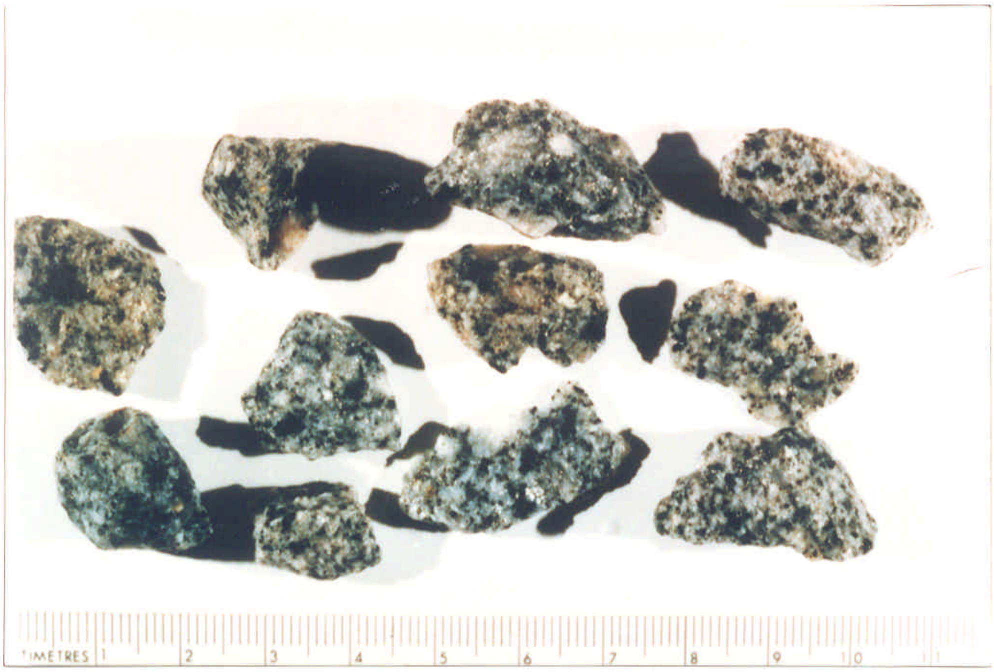


Plate 4 - Crushed Rock Aggregate from Monzonite