SECTION 8 : AGGREGATE PROPERTIES OF VOLCANIC ROCK TYPES FROM 'SPUN' SITES AT MOUNT DAVIS AND CHAI WAN

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FOREWORD

In order to help provide the Materials Division and the Hong Kong Geological Survey of the Geotechnical Control Office with much needed data on the charterisation 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 two sites selected for sampling on this occasion were from the 'SPUN' Project which is investigating the potential use of underground space in Hong Kong. These two potential cavern sites are both very likely to be within volcanic bedrock.

The rock types involved and described in this report are fine and coarse ash crystal tuffs and eutaxites from the two 'SPUN' sites at Chai Wan and Mount Davis.

The author wishes to acknowledge the role played in the field sampling and sample preparation by GE P.G.D. Whiteside and TO C.C. Mak, in the laboratory testing by GE T. Fung and in the report production by M.W. Yuen (STO/EG). The cooperation and assistance of the consultants for the 'SPUN' Project, Ove Arup and Partners, is also acknowledged.

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CONTENTS

1. INTRODUCTION

The Geotechnical Control Office initiated the Fresh Rock Testing Programme (FRTP) in 1985 in order to produce reliable and much needed high quality data on the index and aggregate characterisation properties and possible usage of each of the major rock types of the Territory.

The Programme, which is ongoing, involves selecting and sampling sites containing typical and representative members of a particular individual or suite of rocktypes. The fresh (unweathered) block samples are then crushed to form aggregate or otherwise prepared for selected laboratory index and aggregate testing. A report is then prepared which presents the results and discusses them in relation to other rock types and typical aggregate acceptance standards.

Most of the reports in this Programme have dealt with granites but with the increased usage of local and imported volcanic rocks as concrete aggregates in particular, it has become important to undertake studies of these rocks and their particular problems. Indeed the first report dealing with volcanic rocks has recently been produced in the Planning Division by S.T. Gilbert and T.Y. Irfan. This useful, discussive report is numbered SPR 6/89 and is entitled, "Suitability of Volcanic Rocks for Concrete Aggregates in Hong Kong."

The current report is the second to cover volcanic rocks and the opportunity has been taken to link this FRTP work to a 'SPUN' Project requirement. The GCO 'SPUN' Project is aimed at investigating the potential use of underground space in Hong Kong where two of the potential project cavern sites are located in volcanic bedrocks. The purpose of the current FRTP investigation is to assess whether the rock likely to be produced in cavern excavation would be suitable for processing and sale as aggregate.

This report thus presents and discusses the results of selected physical index and aggregate testing on laboratory crushed fine ash and lapilli/coarse ash crystal TUFF samples from cavern sites at Chai Wan and Mount Davis. The results are compared with typical granite values and the suitability of the materials as aggregate is assessed in relation to normal acceptance values for various uses.

2. SITE DESCRIPTION AND SAMPLING

2.1 Chai Wan

The sampling at the Chai Wan site took place on the 16th March 1989 and was carried out by staff from both GCO (Burnett and Whiteside) and Ove Arup and Partners (Fowler).

The general location of the site near Chai Wan is shown in Figure 1 and the detailed positions of the alternative cavern sites and the actual sampling locations is given in Figure 2. It can be seen from the latter figure and Figure 3 that the possible SPUN underground facilities lie to the south of the new Siu Sai Wan construction platform deep in the hillside beneath Cape Collinson Road at a position midway between Pottinger Peak and Cape Collinson.

As the proposed Government Supplies Store facility is likely to be some 100 m underground, the surface outcrop sampling attempted to take into account the known local geological structure and single regional rocktype to obtain samples reasonably representative of the anticipated cavern materials. The general area was already covered by a spread of hand specimen sampling taken for the Hong Kong Geological Survey and which confirmed the presence of a single rocktype. Thus only three extra 'SPUN' hand specimen samples were taken (SPUN 1,2,3) plus one bulk sample (SPUN 4) comprising about 40 kg of broken fresh lumps. Figure 2 shows the actual sampling locations and Plates 1 & 2 illustrate the site and the bulk sampling operations which comprised selecting large representative fresh boulders of blasted rock from the site formation works at a portal position and further breaking these by sledgehammer for bagging and labeling.

2.2 Mount Davis

The sampling operations at the Mount Davis took place on two separate days, notably, the 16th March and the 6th April 1989 and again involved the same GCO and Ove Arup & Partners staff as for the Chai Wan site sampling.

Figures 1 and 4 show respectively the general and detailed locations of the sampling and the proposed underground facilities. The elevation of the facilities is planned to be between about +10 and +40 mPD and its position to lie immediately beneath Mount Davis Path between the coast line and Mount Davis.

At the Mount Davis locality surface geological mapping by Strange (1986) had shown two volcanic rocktypes to be present in the area of the 'SPUN' proposed underground Refuse Transer and Sewage Treatment facilities.

On the basis of the Hong Kong Geological Survey surface mapping and existing hand speciman samples it was desided that two bulk samples (SPUN 6 and 7) and four extra hand specimens (SPUN 5,8,9,10) were required and were subsequently taken. Each bulk sample again comprised about 30-40 kg of sledgehammer broken fresh lumps of rock representative of the two major rocktypes on the site, namely eutaxite and coarse ash crystal tuff. Plate 3 shows the (SPUN 6 bulk sampling location on Victoria Road; Plate 4 shows the Mount Davis Reservior SPUN 7 bulk sample location.

3. GEOLOGY

3.1 Chai Wan

3.1.1 Site Geology

Description of the geology of the Chai Wan site falls into three categories, namely Lithology, Intrusive History and Structure.

Lithologically the site comprises Upper Jurassic rocks of the Repulse Bay Volcanic Group which are dominated by tuffs. In this region of the Territory the Group has been divided into four formations, each of which displays specific distinctive characteristics to the skilled observer and which has allowed their recognition and identification in the field. The generalised sequences of the rocks comprising these formations is shown in Figure 6, (Strange & Shaw, 1986). Essentially the formations comprise considerable thicknesses of structureless fine ash or coarse ash crystal tuff interspersed with minor, laterally impersistent yet mappable, units of eutaxite, tuff-breccia, siltstone and sandstone.

The Shing Mun Formation within which the Chai Wan site falls is characteristically a rather variable formation and on the hill slope to the east of Siu Sai Wan bluish grey fine to coarse ash welded tuff with subhedral plagioclase crystals (1-2 mm) are noted to included dark grey lava lapilli. Southwards towards Cape Collinson Training Centre these very dark tuffs contain an increasing amount of subangular to angular black aphanitic lapilli up to 40 mm in size.

A strong feature-forming welded tuff (eutaxite) layer forms the approximately east-west trending Pottinger Peak ridge and many boulders of welded tuff and other impersistent layers of the same rocktype indicate that eutaxites should not be unexpected in the proposed underground excavation.

There is no evidence of granite intrusion outcrop in the Siu Sai Wan/Pottinger Peak area and this fact together with a consideration of the general disposition of this particular volcanic roof pendant leads to the belief that even at the proposed +5 to +30 mPD underground elevations of the works, granite will not be encountered.

Structurally while no clear impression of the overall dip of the strata can be ascertained the Shing Mun Formation at this locality is heavily fractured by closely spaced joint sets and probably also faults. The local drainage pattern clearly depicts this structural geological control and illustrates the primary joint set directions of N-S, NW-SE and ESE-WNW.

3.1.2 Description of Bedrock Samples

From an engineering geology viewpoint the main rock (JSM) at this location as represented by the bulk sample SPUN 4 may be described as an extremely strong dark grey crystalline fine- to very fine-grained TUFF occasionally displaying welding and or volcanic lithic lapilli. Plate 5 shows a close-up of a typical hand specimen example of this material.

The geological petrographic description of bulk sample SPUN 4 and as summarised in Table 5 is as follows :

Hand Specimen - dark grey to black, slightly greenish and altered with abundant small (< 2 mm) feldspars and dark greenish grey rounded lithic fragments of < 20 mm size.

Thin Section - feldspars (< 4 mm), embayed quartz (< 2 mm)and mafic (< 1 mm) crystals set in an aphanitic groundmass. The quartz is often bipyramidal or shardic; a small patch comprising green-brown pleochroic hornblende with elongate crystals of size about 0.7 mm exists in a groundmass showing snowflake (devitrified) features. Feldspars, microcline and microperthite are present as is chloritized biotite and zoned oligoclase.

Final Identification - crystal coarse ash bearing, vitric TUFF.

3.2 Mount Davis

3.2.1. Site Geology

The Mount Davis underground facility site is likely to be more complex than that at Chai Wan because two volcanic rocktypes are mapped at outcrop as stradding the site and in addition the proximity of granite outcrop indicates that it might also be encountered underground in the proposed excavations.

Stratigraphically, as can be seen from Figures 4 and 6, the site lies largely within the Upper Jurassic Tai Mo Shan Formation of the Repulse Bay Volcanic Group of rocks. This comprises essentially a coarse ash crystal tuff of remarkably uniform and structureless appearance in outcrop apart from the interspersed occasional presence of dark angular lithic lapilli up to 30-40 mm in size. Abundant quartz and some biotite crystals can be seen in hand specimen as illustrated in Plate 6.

Epiclastic layers appear to be a common characteristic of the formation in this district (Strange & Shaw, 1986). These take the form of moderately steeply dipping sandstone lenses up to 25 m thick and extending laterally for 100 to 300 m.

To the west of Victoria Road, the Tai Mo Shan (JTM) rocks in the vicinity of the site are overlain by a thick band of eutaxite (flow banded welded tuff) dipping some 40-65^{o} to the west. This rocktype is finer-grained and more vitric in appearance as shown in Plate 7 and displays a parataxitic fabric and is also thermally metamorphosed due to the proximities of the granite. This eutaxite, although not totally representative of the classic Ap Lei Chau Formation eutaxites was sufficiently distinctive to also warrant being sampled in bulk for testing as the SPUN 6 sample.

The likelyhood of encountering the top of the granite pluton in the proposed undergrained excavations cannot be discounted in this facility and should not be overlooked.

The structural geology of the site is rather confusing and not easy to predict with any certainty. The schematic sections shown in Figure 5 probably represent a reasonable estimate of the local structure based on the dips of the main rocktypes as mapped (GCO 1986).

3.2.2 Description of Bedrock Samples

The engineering geology description of the coarse ash crystal tuff (JTM) at this site and as represented by the SPUN 7 bulk sample is : extremely strong mid to greenish grey equigranular crystalline coarse ash to lapilli TUFF containing occasional well dispersed volcanic lithic lapilli. Plate 6 iullustrates this material in hand specimen.

The SPUN 6 bulk sample represents a material which can be described as extremely strong light greenish grey slightly flow banded in places fine ash TUFF. Plate 7 shows a close-up view of a hand specimen of the SPUN 6 sample.

The petrographic descriptions of both these samples is summarized in Table 5 and a fuller description is given below.

SPUN 6

Hand Specimen - Grey with white feldspars (< 3 mm), brown quartz (< 2 mm) and black mafic flakes (< 1 mm). The rock is dominated by crystals in a fine groundmass.

Thin Section - Cloudy feldspars of < 3 mm size and quartz of < 4 mm size occur in a fine matrix. Most crystals are subhedral with much dark mineral. Pleochroic biotite flakes of < 1 mm size are noted as are perthitized potassium feldspar and zoned oligoclase. The matrix comprises recrystallised quartz 85%; most quartz shows signs of granulation but is still strained - indicating thermal metamorphism.

Final Identification - Thermally metamorphosed ash crystal TUFF.

SPUN 7

Hand Specimen - Light grey, speckled white and black, with white feldspars (< 3 mm), thin mafic flakes (< 2 mm) and dominated by crystals.

Thin Section - Quartz (< 3 mm), feldspars (< 3 mm) and mafic minerals (about 0.5 mm) in a finely crystalline groundmass. The quartz is subhedral and/or bipyramidal, embayed and shardic. The feldspar is subhedral and cloudy but the plagioclase is zoned and fresh. Zoned serizitised microcline and mircoperthite is present. Muscovite and small pleochroic biotite flakes are present. All are dominated by a fine (about 0.05 mm) crystal groundmass.

Final Identification - Ash crystal TUFF

4. AGGREGATE TESTING AND CHARACTERIZATION

4.1 Sample Preparation and Testing Methods

All ten samples taken in this study i.e. both hand specimens and the bulk samples, were given 'SPUN' numbers in the field and these temporary numbers were then converted to 'HK' numbers for permanent registration and curation in the Hong Kong Rock Collection of the Hong Kong Geological Survey.

Nine of the ten samples were submitted for thin sectioning; only SPUN 9 (HK 8510) was not as it was slightly to moderately weathered and hence not representative of the fresh rock anticipated in the proposed underground excavations. All ten hand specimens and the nine thin sections together with the photomicrographs (in plane, crossed polarised, and 1/4 Lambda wavelength light) of the sections are available for inspection and reference in the Hong Kong Geological Survey.

The three field collected bulk samples, each comprising about 40-60 kg of bagged, broken fresh lumps, were converted into aggregate by processing through a small laboratory/field jaw crusher and hand sieving. Plate 11 shows these operations by which standard 10-14 mm, and 10-20 mm size aggregates were prepared in preparation for testing.

The rock index tests undertaken on each of the three bulk samples (14-10 mm size) included bulk density, grain specific gravity (< 150 mm), water absorption, effective porosity and total porosity.

The aggregate physical tests undertaken included aggregate crushing value (ACV), aggregate impact value (AIV), ten per cent fines value, Los Angeles abrasion value (LAAV), flakiness index (I_F), and elongation index (I_E). All the above tests were performed in the North Point Public Works Laboratory of the GCO to full British Standards Institution (BSI)(1975) and American Society for Testing Materials (ASTM)(1981) standards.

In order to make a preliminary assessment of the potential alkali reactivity of the aggregate, Test C289 of ASTM (1981) was also carried out in triplicate on 10 mm aggregate from each bulk sample.

4.2 Classification and Charaterization 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. In addition, a more detailed petrographic evaluation of the aggregates produced from three bulk samples has also been made. The results of these classification techniques are presented in Tables 1 to 3.

4.3 Test Results

The results of the rock index and aggregate laboratory testing on the aggregates produced from the three representative SPUN bulk samples are summarised in Table 5 which also shows the results of a typical Hong Kong granite and the British Standard and other concrete acceptance values for comparison.

5. DISCUSSION OF TEST RESULTS

5.1 Rock Index and Aggregate Properties

Table 4 shows that the grain specific gravities of all three SPUN samples volcanic rocktypes is consistant and dense and averages about 2.70 with a range 2.69 to 2.71. The oven-dried density of these tuffs averages 2.65 and varies between 2.63 and 2.65 g/cc. These values are notically up on equivalent values for granites which tend to average 2.60 g/cc.

The considerable strength and density of the tuffs lead to very low and uniform water absorption and effective porosity values of 0.4% and 1.1% respectively. While these values are possibly only marginally better than equivalent fresh granite values they are very well within the 3% maximum usually specified for concrete aggregate.

As far as the flakiness and elongation indices are concerned the normally required acceptance criteria are 35 and 30% maximum respectively. The average values for the three tuff samples of about 19 and 24 for flakiness and elongation respectively are thus well within the usually specified values, even bearing in mind the fact that the samples were "artificially" produced using a small field/laboratory jaw crusher - the type of which are thought to increase flakiness/elongation in comparison to competent full scale quarry crushing.

Each of the mechanical test properties of the SPUN volcanic aggregates are consistantly and tightly grouped, better than the normal granite spread of values and well within the general purpose concrete specification and even the heavy duty/wearing surface concrete acceptance criteria as shown in Table 5.

These favourable mechanical test results as defined by the aggregate crushing, impact, 10% fines value and Los Angeles abrasion values are not unexpected bearing in mind the high strengths determined by Irfan (1985) for the entire volcanic group of rocks. Irfan reported, after a reasonably comprehensive point load testing programme, that for fresh, mainly pyroclastic, volcanic rocks an average (from 154 tests) point load strength of 10.2 mPa with a standard deviation of 2.6 mPa resulted.

It is clearly concluded that the volcanic tuffs are distinctly mechanically superior to their typical granite equvalents and equally clearly will provide very suitable concrete (and other) aggregates from the mechanical property viewpoint.

No polished stone value tests were undertaken on the three SPUN samples in this study but other sources (Gilbert & Irfan, 1989) indicate that volcanic rocks are slightly superior to Hong Kong granites in this respect. This data source also indicates that local volcanic rocks are also far more resistant, i.e. sound to chemical attack weathering than local granites and fall very well within the usual $MgSO_4$ and $NaSO_4$ soundness criteria. The durability of the volcanic tuffs thus appears to be very favourable based on the results of the present and other laboratory tests undertaken to date.

Despite the fact that no clearly deleterious mineral phases or minerals appear to be present in the three SPUN tuffs tested it is well known that some doubt hangs over these volcanic rock types for reasons of their potential alkali-aggregate reactivity. For this reason the American Society of Testing Materials Potential reactivity of aggregate (Chemical Method) Test C289 was called for and undertaken. Table 4 presents the results of this indicative chemical test which are also plotted on the usual dissolved silica (Sc) versus reduction in alkalinity (Rc) graph in Figure 7.

The three SPUN sample results plot on the "innocuous aggregate" side of the graph and thus provide an initial indication that the aggregates are not deleterious. The few previous volcanic rock test results all plot in the same general vicinity of the graph, thus apparently showing a considerable degree of consistancy throughout the volcanic suite of rocks.

5.2 Suitability of Rocks as Aggregate

The test results and petrographic examinations described above tend to indicate that the rock types sampled as being representative of the materials likely to be excavated in the 'SPUN' sites should be satisfactory as normal or even special purpose concrete aggregates.

The physical and mechanical tests are clearly very satisfactory with only a slight query hanging over the brittleness and hence crushed rock particle shape of any future aggregate. The soundness (to salt attack) of the materials is also very good.

Regarding the alkali silica reactivity potential of the rock types tested, while the ASTM C289 quick chemical test results were encouraging it is known that no single test taken in isolation is foolproof or a substitute for long term servicibility experience. These tuff rocks are also known to contain (or certainly originally contained) the potentially deleterious substances of volcanic glass, crypto- to microcrystalline silica and strained quartz. While most of the former glass and silica appear to have devitrified this is interpreted by difficult and imperfect observational methods only (petrographic examination) and hence some doubts must remain, however slight, regarding the aggregate suitability. Reference is made for a relevent and fuller discussion on alkali reactivity to the Gilbert and Irfan (1989) report.

5.3 Recommendations for Further Tests

In the light of the importance of the use of volcanic rock aggregates in general and from these samples/sites in particular, it is suggested that it would be worthwhile for parties interested in the use of these materials to arrange for the remaining, and thus far untried, long term mortar bar tests (ASTM C227) to be undertaken on these three SPUN samples. Confirmatory expert petrographic examination, as far as this pertains to appraisal of aggregate suitability, would also be prudent.

6. CONCLUSIONS

The three SPUN tuff rock types sampled and relatively thoroughly tested have given every indication thus far of producing a perfectly suitable aggregate for concrete purposes.

Confirmatory and additional testing and evaluation, in the form of mortar bar tests and expert aggregate petrographic examination, should provide the necessary confidence for full-scale use of these materials, whereafter long term, in-service monitoring will provide the final conclusive proof of the materials suitability.

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LIST OF TABLES

Table 1 - Classification, Description and Petrographic Evaluation of Aggregate Produced from the SPUN 4 Bulk Sample

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)	Crystal coarse ash-bearing, vitric TUFF											
GEOLOGICAL AGE/ COLOUR/ GRAIN SIZE/ FISSILITY	Upper Jurassic Dark greyish grey Fine-grained											
Comment (if any)												

Compiled by: A.D. Burnett, GCO Date: 14/5/89

CADAM – CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/Pit address: Chai Wan field sample Operator: - Sample: Type SPUN 4 Bulk block Size 40 kg Preparation Laboratory crushed Supplied by field sampling	Grid Ref. 43900/13530	Date Rec'd -
		Date of sampling 16/03/89	Sampling Cert. No. -

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	SPUN 4 (HK 8504) Chai Wan, HK 43900E 13530N 16/03/89	SAMPLE SIZE/WEIGHT About 40 kg of bulk sample - processed to aggregate in laboratory. (10-14 mm and 10-20 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Angular (Hand specimen photograph at Plate 6)	
Surface Texture (BS 812:1975)	Rough	
Coating	None	
Cleanliness (Dust etc)	Clean	
GEOLOGICAL PROPERTIES Rock Type (GSS Classification)	Shing Mun Formation - Repulse Bay Volcanic Group JSM - crystal coarse ash-bearing, vitric TUFF	
Mineralogy Major Constituents	Crystal/Matric content : c. 55%/45% Crystals : white feldspar (30%) embayed quartz (15%), mafic (10%) Matrix : aphanitic i.e. 0.01 mm - devitrified?	
Minor Constituents	Chloritized biotite	
Cementing Materials	Crystalline - not cemented	
Expansive Minerals		
Weathering of Particles	Little to none	
Organic Material Content	None	
GENERAL COMMENTS	Appears to be a strong sound rock with no evidence of weathering. Any previous glass now apparently devitrified.	Compiled by A.D. Burnett Date 14/05/89
ADDITIONAL INFORMATION	See Plate 9 for photomicrograph	

Table 2 - Classification, Description and Petrographic Evaluation of Aggregate Produced from the SPUN 6 Bulk Sample

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)	Thermally metamorphosed, ash crystal TUFF
GEOLOGICAL AGE/ COLOUR/ GRAIN SIZE/ FISSILITY	Upper Jurassic Grey Fine-grained
Comment (if any)	

Compiled by: A.D. Burnett, GCO Date: 14/5/89

CADAM – CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/Pit address: Mount Davis field sample Operator: - Sample: Type SPUN 6 Bulk block Size 40 kg Preparation Laboratory crusher Supplied by Field sampling	Grid Ref. 30160/15230	Date Rec'd -
		Date of sampling 16/03/89	Sampling Cert. No. -

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	SPUN 6 (HK 8506) Mount Davis, HK 30160E 15230N 16/03/89	SAMPLE SIZE/WEIGHT About 40 kg of bulk sample - processed to aggregate in laboratory (10-14 mm and 10-20 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Angular (Hand specimen photograph at Plate 7)	
Surface Texture (BS 812:1975)	Rough	
Coating	None	
Cleanliness (Dust etc)	Clean	
GEOLOGICAL PROPERTIES Rock Type (GSS Classification)	Repulse Bay Volcanic Group - Ap Lei Chau Formation? Eutaxite - slightly thermally metamorphosed, ash crystal TUFF	
Mineralogy Major Constituents	Crystal/matrix content : c. 55%/45% Crystals : white feldspars (25%), brown quartz (20%), mafic flakes (10%) Matrix : mainly recrystalline quartz (40%) - 0.05 - 0.1 mm	
Minor Constituents	Biotite	
Cementing Materials	Crystalline - not cemented	
Expansive Minerals		
Weathering of Particles	Little to none	
Organic Material Content	None	
GENERAL COMMENTS	Appears to be a strong sound rock with no signs of weathering. Any former glass now devitrified.	Compiled by A.D. Burnett Date 14/5/89
ADDITIONAL INFORMATION	See Plate 11 for photomicrographs	

Table 3 - Classification, Description and Petrographic Evaluation of Aggregate Produced from the SPUN 7 Bulk Sample

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: Igneous	/	Sedimentary		Metamorphic		Miscellaneous Material. (Correct name to be given below)

Petrological name (if known)	Ash crystal TUFF
GEOLOGICAL AGE/ COLOUR/ GRAIN SIZE/ FISSILITY	Upper Jurassic Light grey - speckled black and white Fine to medium
Comment (if any)	

Compiled by: A.D. Burnett, GCO   Date: 14/5/89

CADAM – CLASSIFICATION and DESCRIPTION of AGGREGATE MATERIAL

LOCATION AND SAMPLE DETAILS	Quarry/Pit address: Mount Davis Field sample Operator: - Sample: Type SPUN 7 Bulk block Size 40 kg Preparation Laboratory crusher Supplied by Field sampling	Grid Ref. 30600/15050 Date of sampling 26/03/89	Date Rec'd - Sampling Cert. No. -

PETROGRAPHIC EVALUATION OF AGGREGATES

SAMPLE REF LOCATION/GRID REF SAMPLING DATE	SPUN 7 (HK 8507) Mount Davis, HK 30600E 15050N 26/03/89	SAMPLE SIZE/WEIGHT About 40 kg of bulk sample - processed to aggregate in laboratory (10-14 mm and 10-20 mm)
AGGREGATE PROPERTIES Particle Shape (BS 812:1975)	Angular (Hand specimen photograph at Plate 7)	
Surface Texture (BS 812:1975)	Crystalline	
Coating	None	
Cleanliness (Dust etc)	Clean	
GEOLOGICAL PROPERTIES Rock Type (GSS Classification)	Repulse Bay Volcanic Group - Tai Mo Shan Formation JTM - ash crystal TUFF	
Mineralogy Major Constituents	Crystal/matrix content : c. 60%/40% Crystals : white greenish feldspar (30%), quartz (20%), mafic (10%) Matrix : finely crystalline (0.05 mm) mainly quartz and feldspar	
Minor Constituents	Muscovite and biotite	
Cementing Materials	Crystalline - not cemented	
Expansive Minerals		
Weathering of Particles	Little to none	
Organic Material Content	None	
GENERAL COMMENTS	Apparently a strong sound rock with little weathering or alteration	Compiled by A.D. Burnett Date 14/5/89
ADDITIONAL INFORMATION	See Plate 10 for photomicrographs	

Table 4 - Petrographic Description of Sample SPUN 4, SPUN 6 and SPUN 7

SPECIMEN NUMBER	HK 8504	FINAL IDENTIFICATION	Crystal Coarse Ash-bearing Vitric Tuff
Thin Section / Photomicrograph / Modal Analysis / Silicate Analysis / Partial Analysis / Normative Analysis / Palaeontology	GEOLOGIST'S LOCALITY REF.: S P/L D/4 Chai Wan, HK	DATE: 1 6 0 3 8 9	
1:10 000: 11 SE	HK GRID EAST: 4 3 9 0 0	NORTH: 1 3 5 3 0	AERIAL PHOTO: ; YEAR: 19
FIELD NAME:	ROCK UNIT: JSM		

FIELD OCCURRENCE: Blast boulders from cut slope formation works. Bulk sample also taken for SPUN project.

HAND SPECIMEN: Dark grey - black; slightly greenish altered, white fd < 2 mm, abundant; rounded lithic < 20 mm, dark greenish grey;

PETROGRAPHIC DESCRIPTION—See back for details Feldspar < 4 mm; embayed quartz < 2 mm; mafic ~ 1 mm; set in aphanitiz groundmass; qz bipyramidal or shardic; small patch comprising green-brown pleochroic hornblende; elongate crystals ~ 0.7 mm; some snowflake texture; feldspar microcline microperthite; chloritized biotite; zoned oligoclase

GCO 108 — GEOLOGICAL SURVEY 48

SPECIMEN NUMBER	HK 8506	FINAL IDENTIFICATION	Thermally Metamorphosed Ash Crystal Tuff
Thin Section / Photomicrograph / Modal Analysis / Silicate Analysis / Partial Analysis / Normative Analysis / Palaeontology	GEOLOGIST'S LOCALITY REF.: S P/L C/6 Victoria Road, HK	DATE: 1 6 0 3 8 9	
1:10 000: 11 SW	HK GRID EAST: 3 0 1 6 0	NORTH: 1 5 2 3 0	AERIAL PHOTO: ; YEAR: 19
FIELD NAME: metamorphosed entaxite	ROCK UNIT: e		

FIELD OCCURRENCE: Rock in road cutting, east side of Victoria Road. Bulk sample also taken for SPUN project

HAND SPECIMEN: Grey; white fd < 3 mm; brown qz < 2 mm; mafic flakes black, < 1 mm; dominated by crystals in fine groundmass

PETROGRAPHIC DESCRIPTION—See back for details Cloudy fd < 3 mm; Qz < 4 mm; fine matrix; most crystals subhedral; much dark mineral; pleochroic light-dark brown bi flakes < 1 mm; perthitiz K-fd; zoned oligoclase; matrix recryst qz & bi 0.05 - 0.1 mm; most fd cloudly; most qz showing signs of granulation; but still strained; thermal metamorphism? greizenization

GCO 108 — GEOLOGICAL SURVEY 48

SPECIMEN NUMBER	HK 8507	FINAL IDENTIFICATION	Ash Crystal Tuff
Thin Section / Photomicrograph / Modal Analysis / Silicate Analysis / Partial Analysis / Normative Analysis / Palaeontology	GEOLOGIST'S LOCALITY REF.: S P/L C/7 Mt. Davies, HK	DATE: 2 6 0 3 8 9	
1:10 000: 11 SW	HK GRID EAST: 3 0 6 0 0	NORTH: 1 5 0 5 0	AERIAL PHOTO: ; YEAR: 19
FIELD NAME:	ROCK UNIT: JTM		

FIELD OCCURRENCE: Rock cutting forming part of west end of Mt. Davies Reservoir. Bulk sample also taken to SPUN project.

HAND SPECIMEN: Light grey, speckled white and black; white fd < 3 mm; thin mafic flakes < 2 mm; greenish fd < 3 mm; dominated by crystals

PETROGRAPHIC DESCRIPTION—See back for details Qz < 3 mm; td < 3 mm; mafic ~ 0.5 mm; finely crystalline groundmass; some muscovite qz subhedral bipyramidal, embayed or shardic; fd subhedral, cloudy; plag zoned, fresh; zoned serizitized microcline microperthite; muscovite & pleochroic bi flakes, small; dominated by crystalline groundmass ~ 0.05 mm; some opaque

GCO 108 — GEOLOGICAL SURVEY 48

Table 5 - Laboratory Test Results for SPUN Bulk Samples (Together With Typical Granite Results and Normal Concrete Acceptance Criteria for Comparison)

Aggregate Property		Volcanic Rocks: Chai Wan SPUN 4	Volcanic Rocks: Mount Davis SPUN 6 (Victoria Rd Site)	Volcanic Rocks: Mount Davis SPUN 7 (Reservoir Site)	Typical Granite[n] (FRTP)	Acceptance Criteria for Concrete	Reference
Mechanical Properties							
Aggregate Crushing Value (ACV)	%	13	18	15	21-29	Max 20[c] Max 30[d]	Higginbottom (1976)
Aggregate Impact Value (AIV)	%	14	21	16	15-31	Max 25[c] Max 30[c] Max 45[d]	BS : 882 (1983)
Los Angeles Abrasion Value (LAAV)	%	15	22	16	28-44	Max 40[c] Max 30[f] Max 25[g] Max 35[d]	ASTM C131 Australian Standard 2785.1 (1985) Shergold (1948)
10% Fines Value	kN	290	200	280	100-200	Min 100[c] Min 150[e] Min 50[d]	BS 882 (1983)
Polished Stone Value (PSV)		-	-	-	50[b]	-	-
Physical Properties							
Water Absorption	%	0.4	0.4	0.4	0.3-0.7	Max 3	Higginbottom (1976) BS5337 : 1976
Effective Porosity	%	1.1	1.1	1.0			
Flakiness Index (I_F)	%	17	19	20	7-26	Max 35	BS882 (1983)
Elongation Index (I_E)	%	21	17	34	28-44	Max 30	Fookes (1984)
Density (Oven dried)	g/cc	2.63	2.65	2.65			
Grain Specific Gravity		2.69	2.71	2.69			
Chemical properties							
Soundness	with $MgSO_4$	-	-	-	10-15[b]	Max 18[h] Max 15[j]	PSA (1979) ASTM C33
% loss (5 cycles)	with $NaSO_4$	-	-	-	-	Max 12[f+j] Max 10[i] Max 9[g] Max 6[k]	ASTN C33 Australian Standard 2785.1 (1985)
Reactivity Aggregate Reactivity (AAR)[m] (millimoles/litre)	Dissolved Silica S_c	14.0 14.0 16.0	15.7 16.0 14.7	21.3 23.0 21.3	-	See Figure 7	ASTM C 289
	Reduction in Alkalinity R_c	50 55 45	0 0 0	30 20 20	-	See Figure 7	

Note :
a. Tests carried out by PWDTL.
b. Results from Hindley (1984)
c. Wearing surfaces.
d. General purpose concrete.
e. Heavy duty concrete.
f. Protected concrete.
g. Moderate exposure.
h. Airfield pavements (Coarse and fine aggregate).
i. Fine aggregates.
j. Coarse aggregates.
k. Severe exposure.
m. Triplicate analyses
n. See Gilbert & Irfan (1989)

LIST OF FIGURES

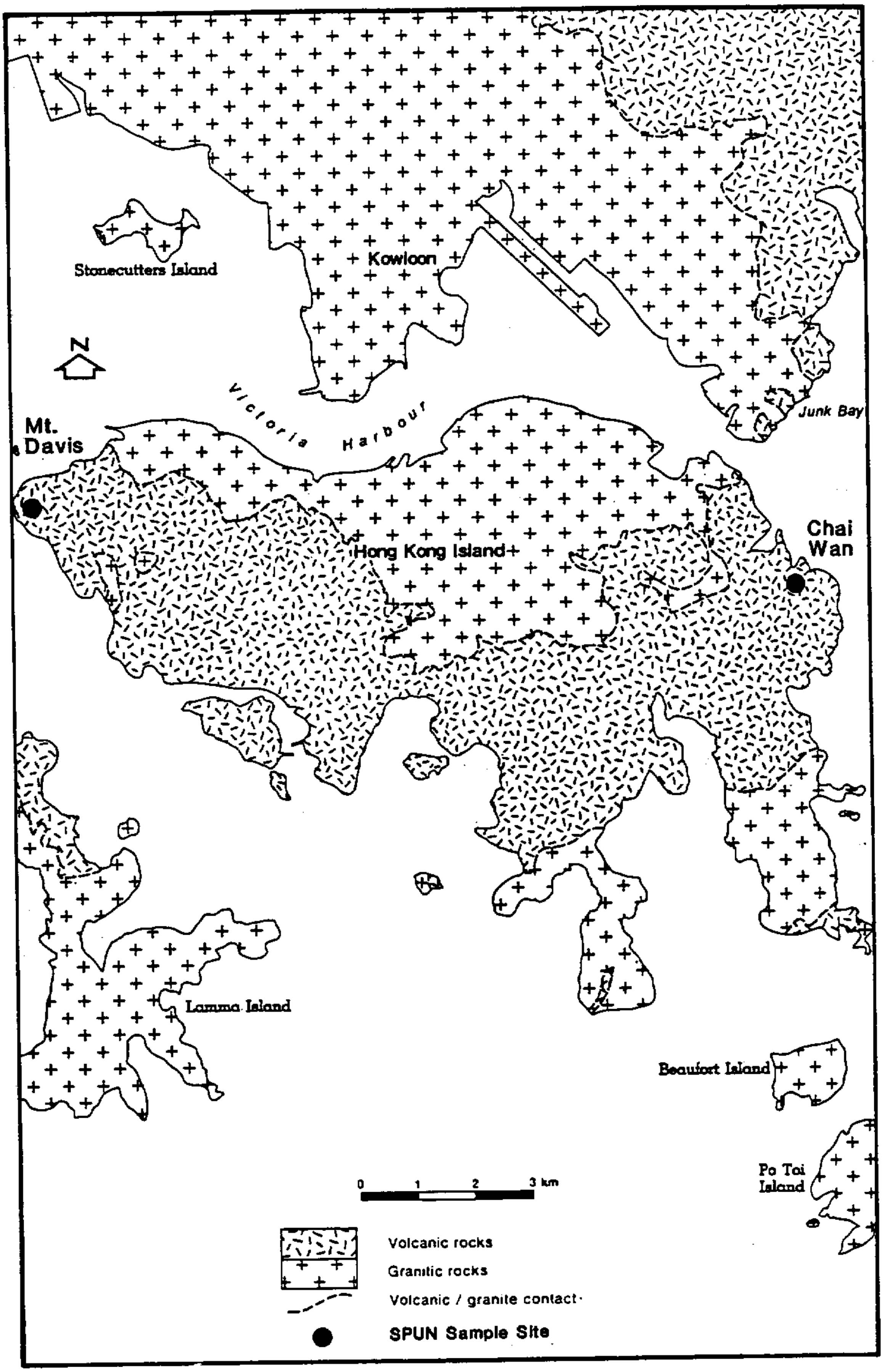

Figure 1 - General Location and Geology Map (After Strange & Shaw, 1986)

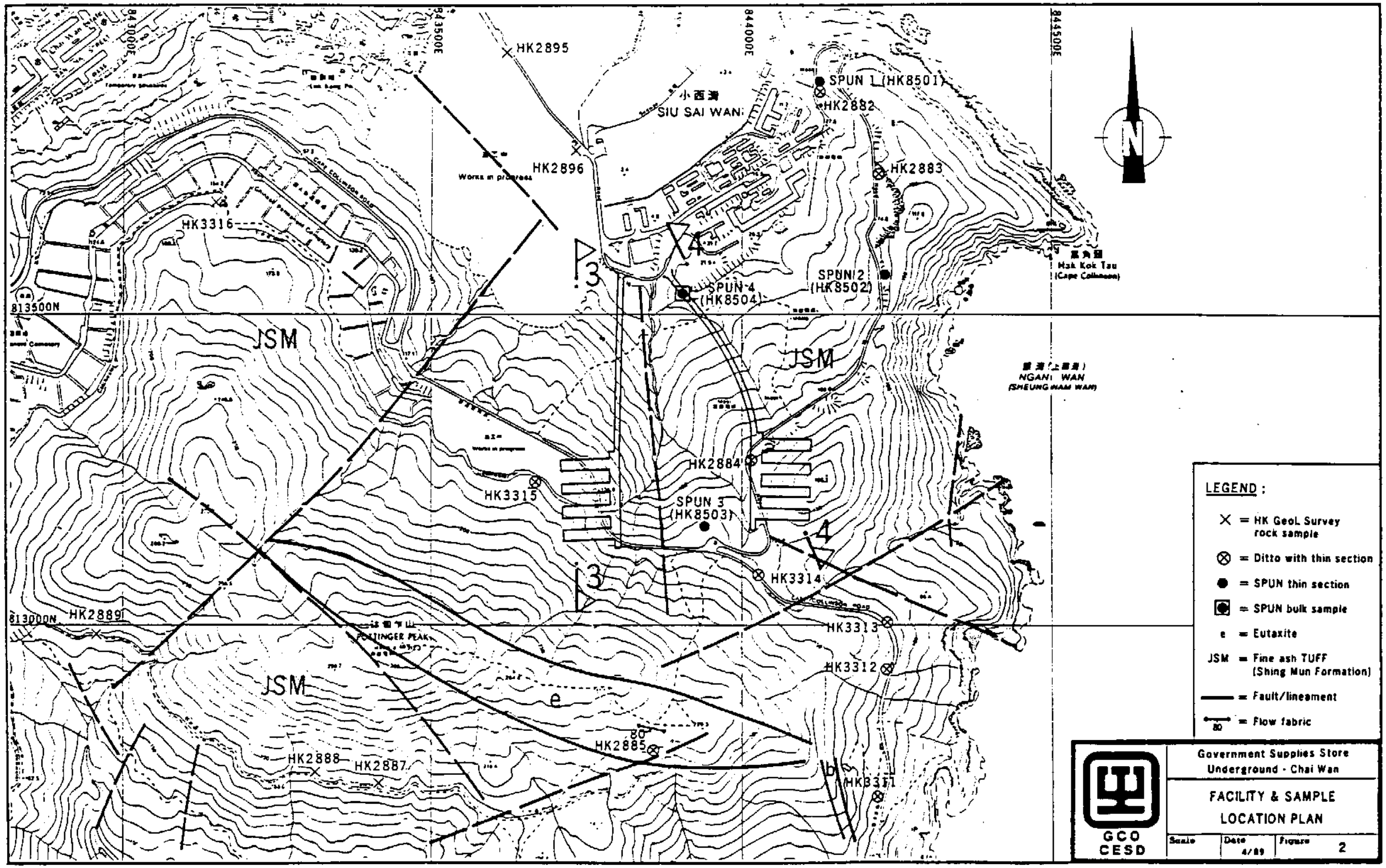

Figure 2 - Geology and Sample Location Plan - Proposed Chai Wan Underground Facilities (Approx. Scale 1 : 6000)

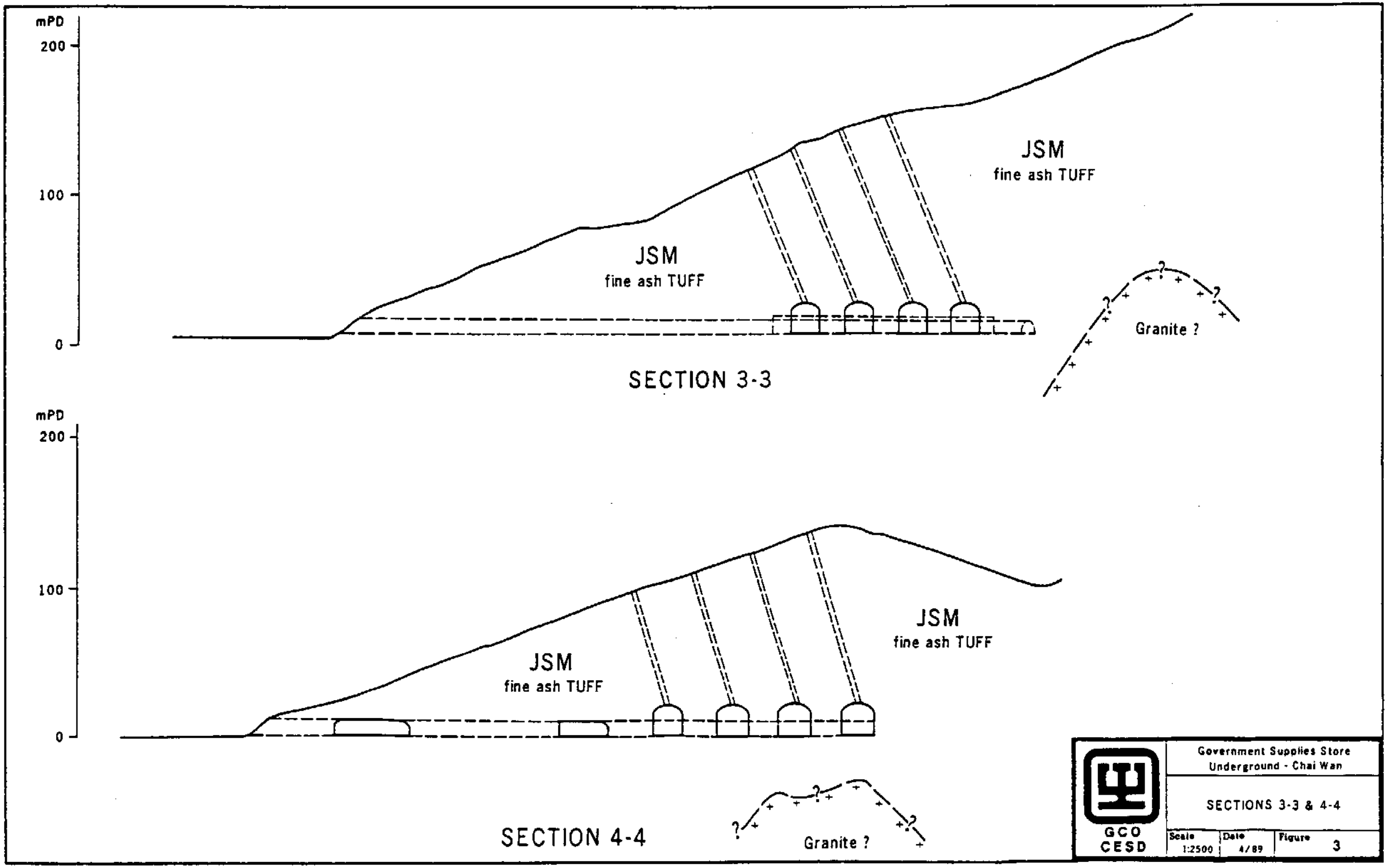

Figure 3 - Cross-section - Proposed Chai Wan Underground Facilities

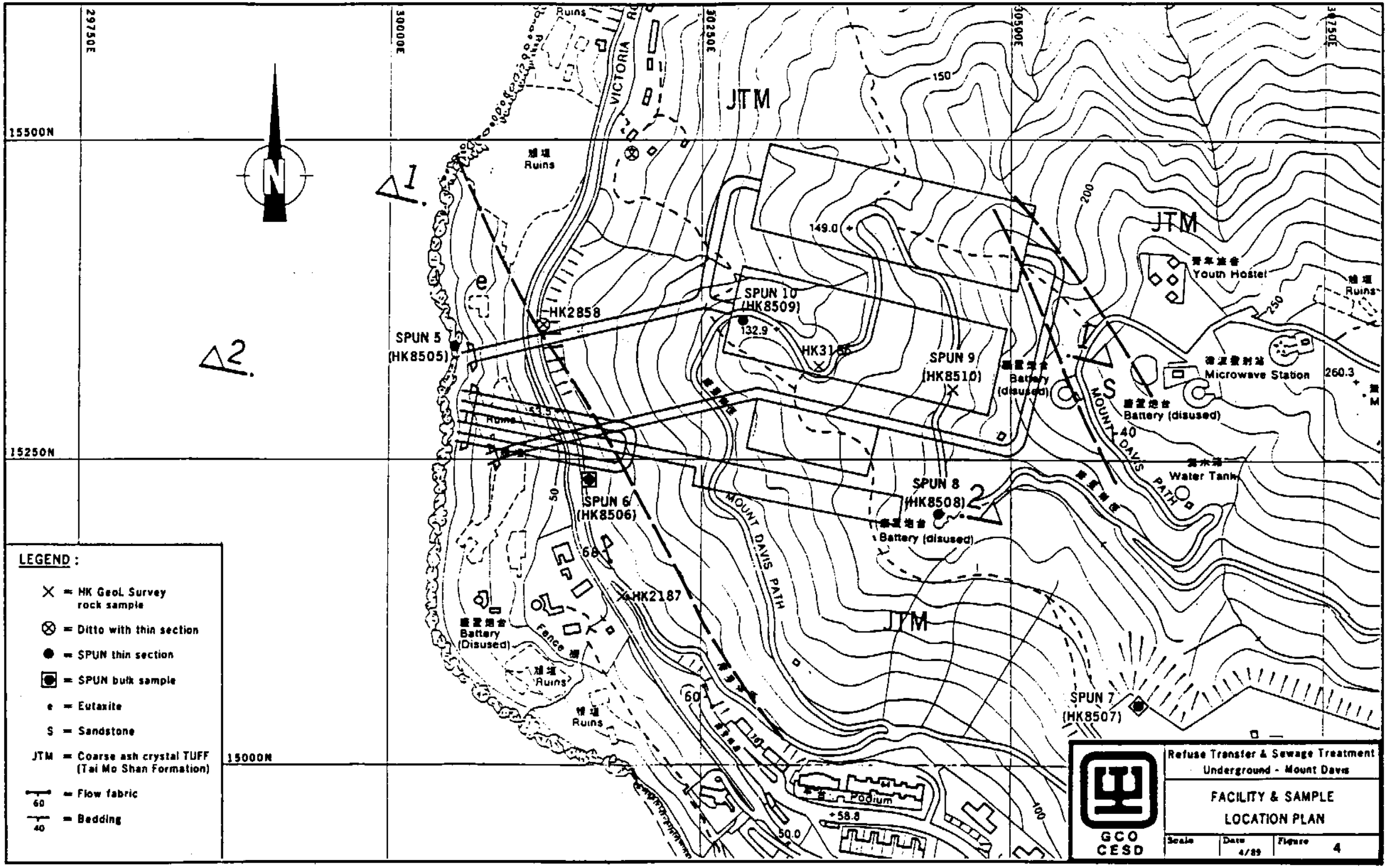

Figure 4 - Geology and Sample Location Plan - Proposed Mount Davis Underground Facilities (Approx. 1 : 3000)

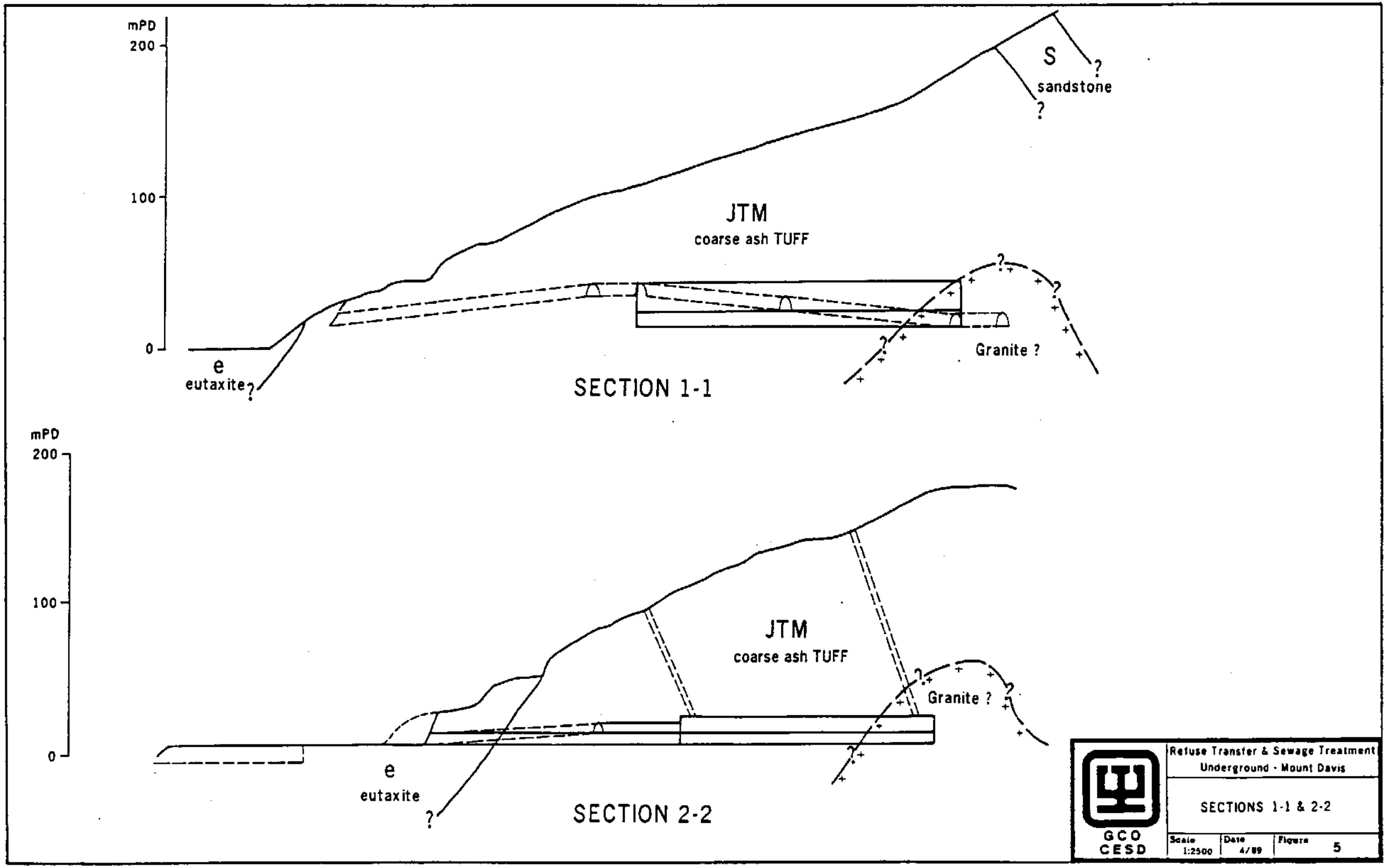

Figure 5 - Cross-section - Proposed Mount Davis Underground Facilities

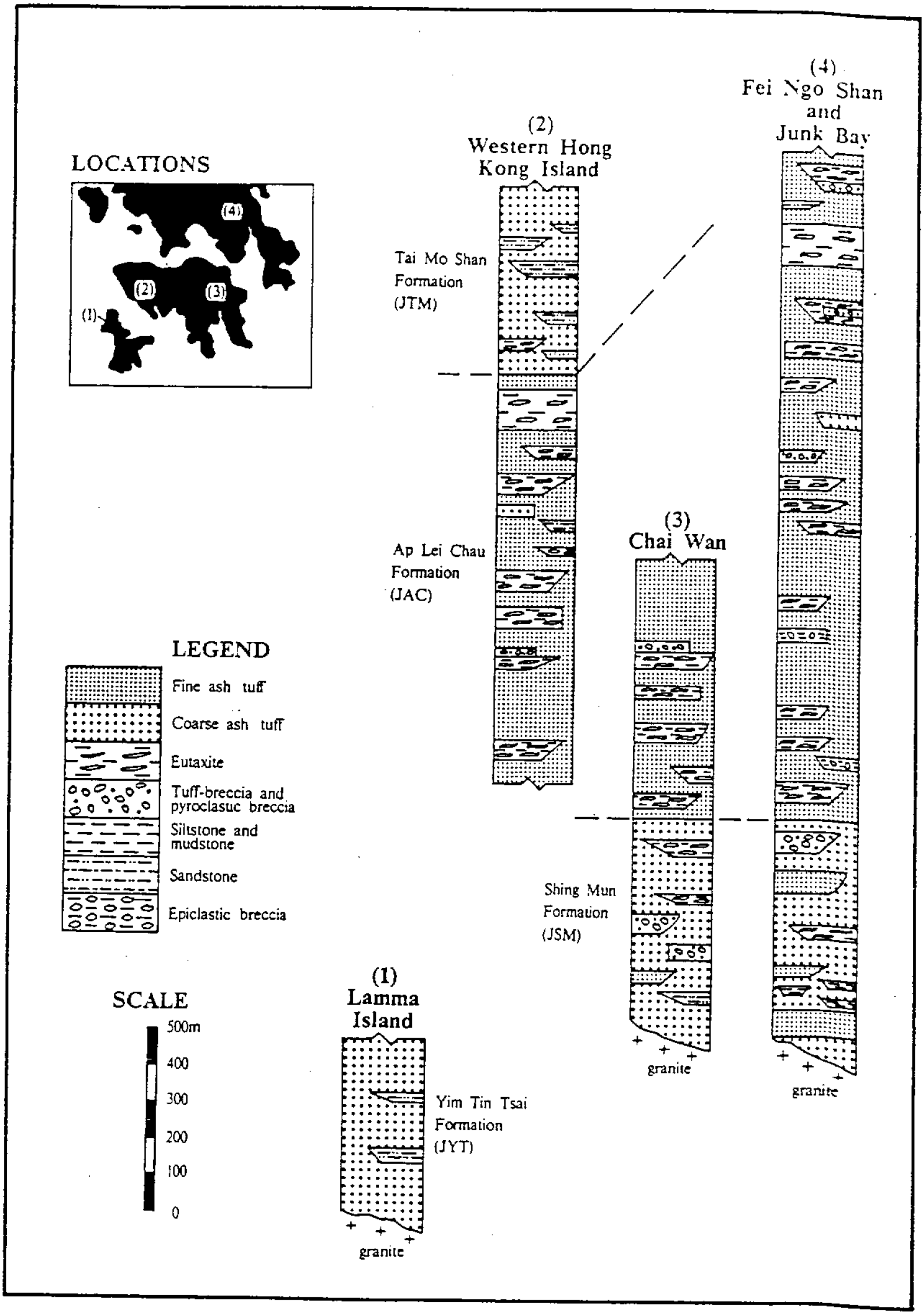

Figure 6 - Generalized Sequences of Repulse Bay Volcanic Group Rocks (After Strange & Shaw, 1986)

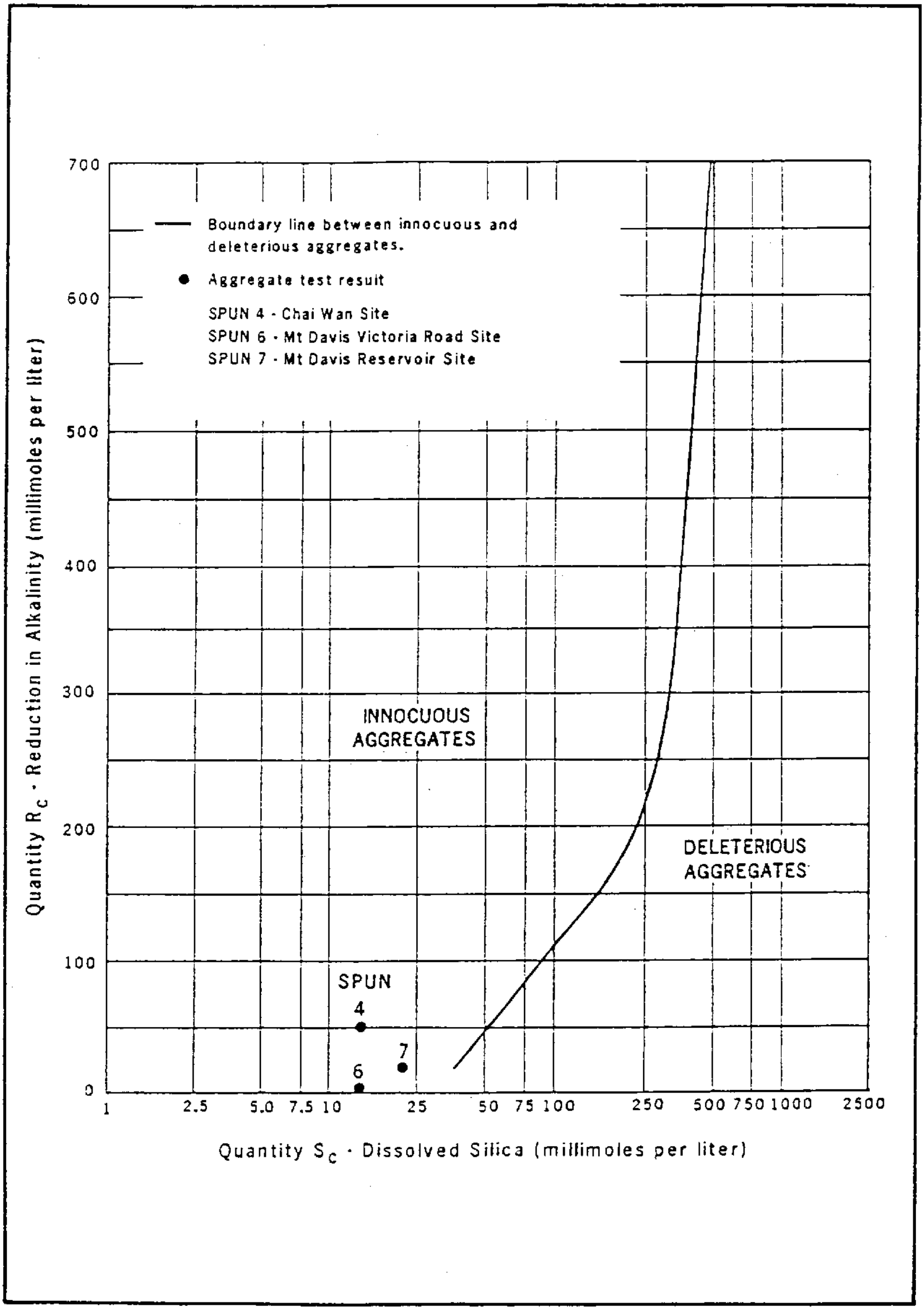

Figure 7 - Potential Reactivity of the SPUN Sample Aggregates by the ASTM C289 Chemical Method

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Plate 2 - Sampling Operations for the SPUN 4 Bulk Sample; Chai Wan Site

Plate 3 - General View of the SPUN 6 Bulk Sample Location on Victoria Road, Mount Davis

Plate 4 - General View of the SPUN 7 Bulk Sample Location at Mount Davis Reservoir

Plate 5 - Production of Aggregate for Testing by Field Crushing and Hand Sieving

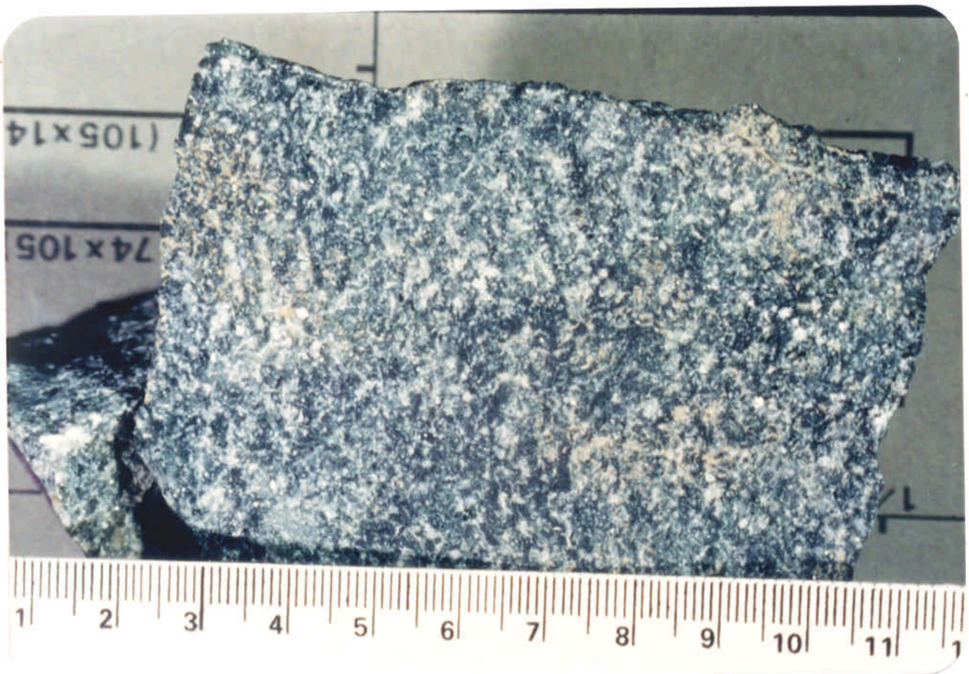


Plate 6 - Close-up of SPUN 4 Bulk Sample Fine Ash Tuff Lithology (HK 8504)

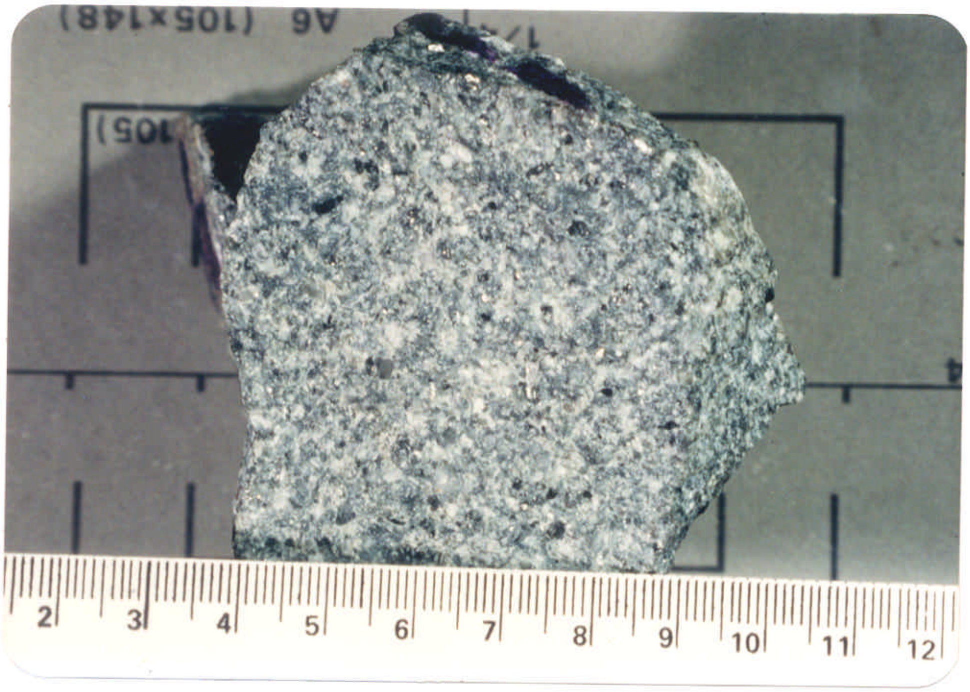
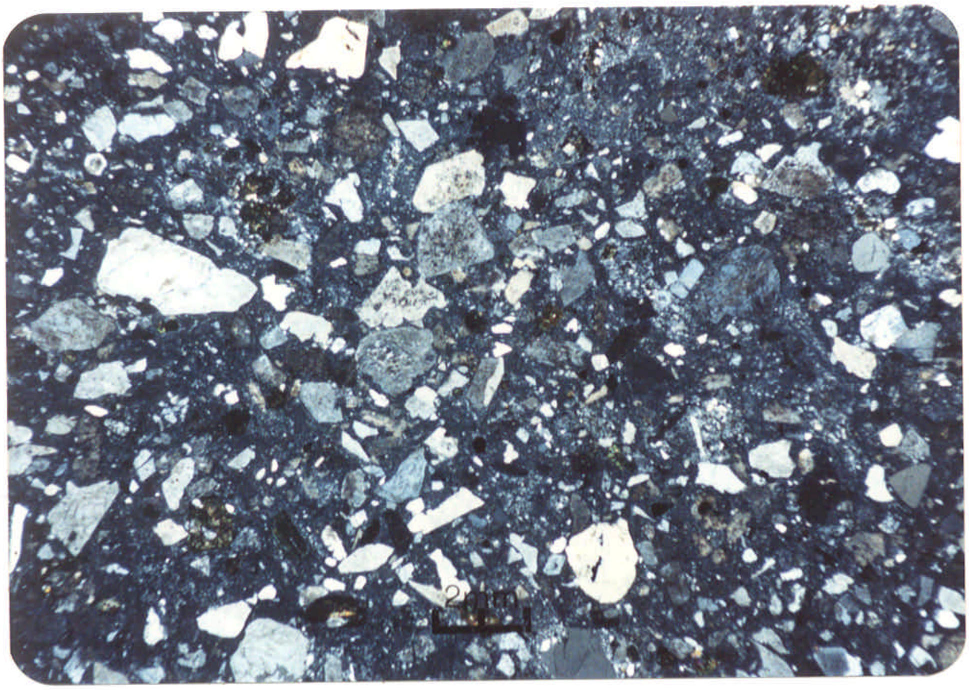
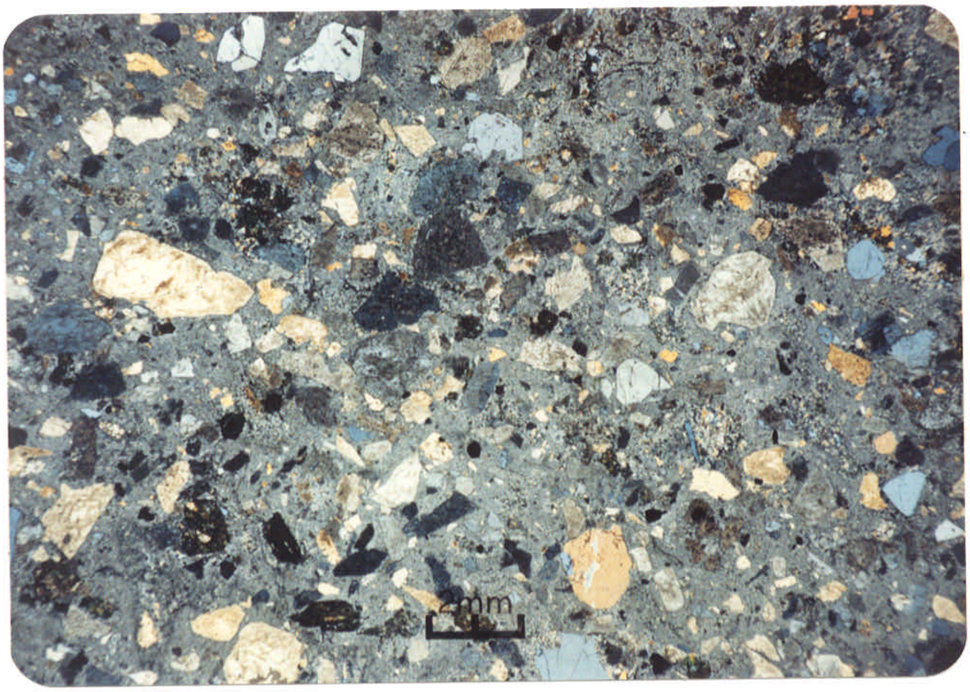


Plate 7 - Close-up of SPUN 7 Bulk Sample Coarse Ash Tuff Lithology (HK 8507)

Plate 8 - Close-up of SPUN 6 Bulk Sample Fine Ash/Eutaxite Tuff Lithology (HK 8506)

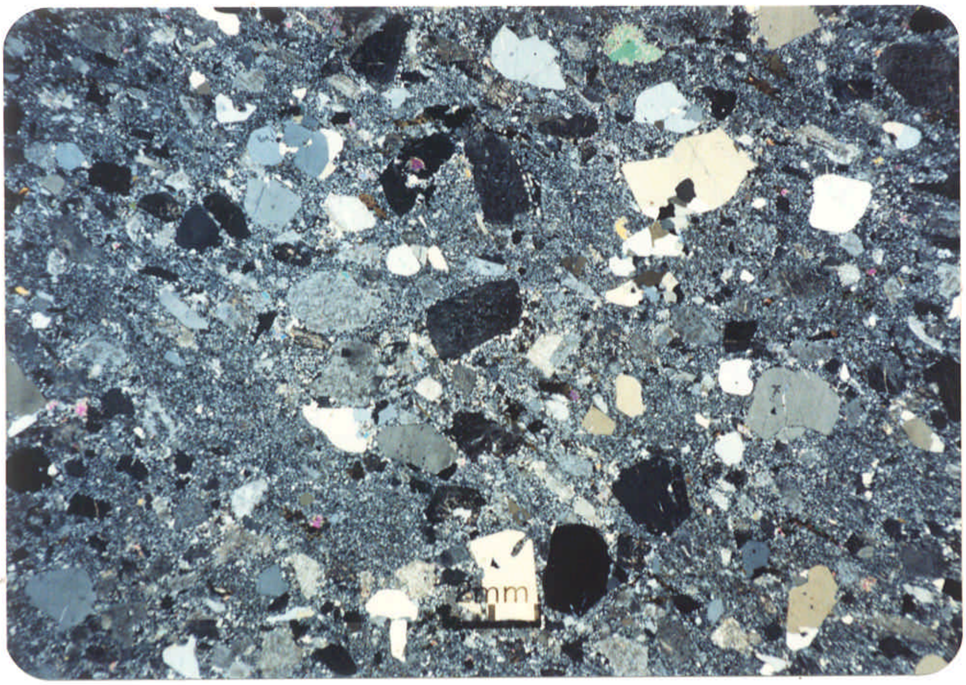


Crossed polars

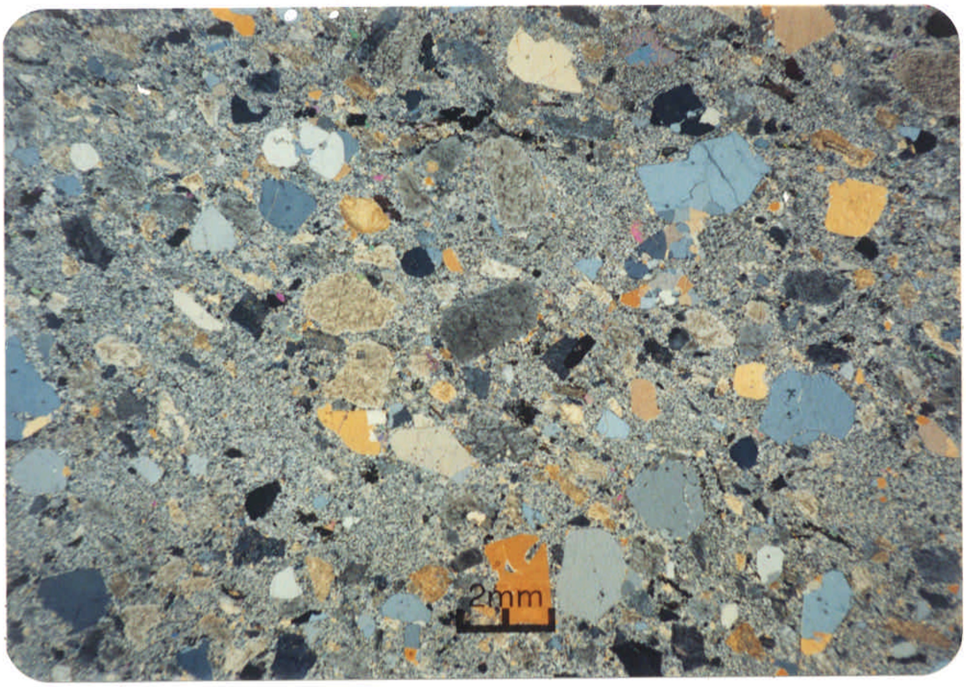


Cross polars plus 1/4 lambda plate

Plate 9 - Photomicrographs of SPUN 4 Lithology - Fine Ash Tuff (HK 8504)

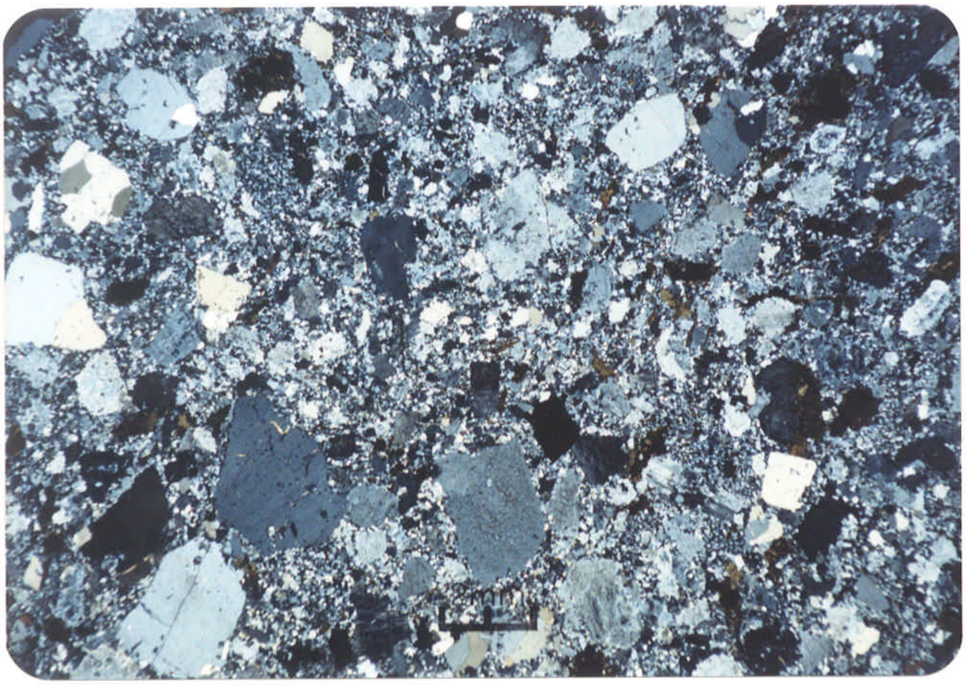


Crossed polars

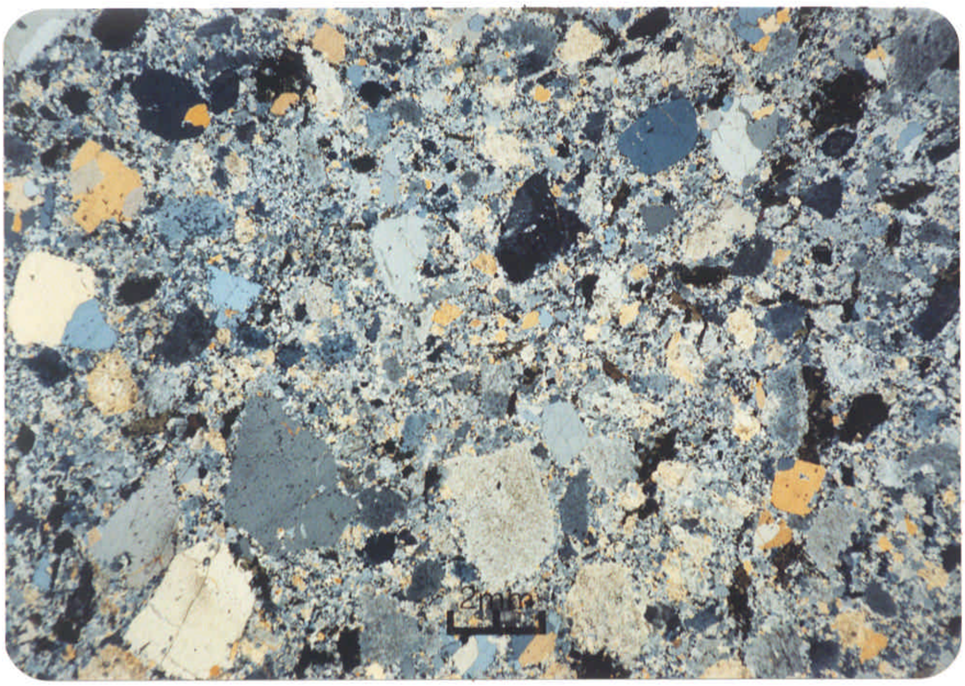


Crossed polars plus 1/4 lambda plate

Plate 10 - Photomicrographs of SPUN 7 Lithology - Coarse Ash Tuff (HK 8507)



Crossed polars



Crossed polars plus 1/4 lambda plate

Plate 11 - Photomicrographs of SPUN 6 Lithology - Fine Ash Tuff/Eutaxite (HK 8506)