Comments on proposed Wheatly Quarry rock
4 February 1993

Grave Johnston and Associates
35 Scott Street
Wolumla  NSW  2550

Attention:  Mr R J Johnston
Engineer Manager

Reference:  Your letter TEST WHEAT of 4.1.93

Dear Mr Johnston

PROPOSED WHEATLEY QUARRY

Mr Chris Turner of our Canberra Testing Laboratory has asked me to comment upon the petrographic and engineering properties reports on the samples of rock submitted for analysis and testing in conjunction with above proposed quarry.

Please find attached my comments on these reports as requested in point 9 of your letter. Should you have further questions in regard to my comments I should be pleased to provide answers. You might raise any such questions, in the first instance, with Chris Turner.

Yours faithfully,

Denis Byrne
BSC, B.E., B. APP. SC. (Geology)
Engineering Geologist
COMMENTS ON (PROPOSED?)
WHEATLEY QUARRY ROCK

References

- Letter Grave Johnson & Assoc. to Canberra Testing Services dated 4.1.93
- C.T.S. Report 93/22124 dated 22.1.93
- Letter Coffey to Bombala Shire Council dated 13.9.88
- Petrographic Report (Hensel) dated 7.9.88

1. I note that there is a gap of nearly 4½ years between date of the petrographic examination and report of (more weathered) surface spalls and the engineering laboratory testing of "shot-hole" rock from 1.5 m below ground level.

I assume, although this is not explicitly stated, that the two sets of data refer to essentially the same body of rock. The following comments are made on the assumption and to the extent that the data duly represents the body of rock intended for the quarry.

2. The rock type is described, petrographically as a microgranite. As such, and from the very detailed petrographic hand-specimen and thin section descriptions, this rock has a fabric texture and mineral assemblage which should incline it in unweathered condition towards a very strong, tough, durable and unreactive rock for engineering purposes in general.

3. This potential is borne out by the C.T.S. engineering tests of January 1993. Wet-Dry Strength variation of 16% with Dry Strength 290 KN and Wet Strength of 245 KN are typical for Granitoid rocks and, indeed, somewhat better than average. Los Angeles Abrasion loss of 15% is also a good result as indeed is sodium sulphate loss of less than 0.1%. All these "Texture toughness" type test results for this rock are consistent in Fresh Rock with its small grain size and closely interlocked matrix of essentially quartz and (both types of) feldspar mineralogy.

Bulk Density (fabric density or S-G) and Water Absorption were not, it appears, tested. These tests would, almost certainly, give results in the range 2.62 to 2.65 and 1.0% to 2.0% respectively, both of which would be normal and acceptable value ranges for this rock type.

4. The "Processing Properties" of grading, particle shape, and Average Least Dimension are significantly dependent on the crushing, screening and possibly washing processes employed in the manufacture of a crushed rock product from the quarried rock.
As such, I am disinclined and it may be misleading to comment on the values obtained from a trial crushing of a small quantity of the rock. The rock fabric texture, as petrographically described, makes no mention of any microfabrics or microfracturing which might incline the rock to a poor particle shape. This rock should, therefore, be able to produce crushed aggregate of good particle shape, assuming use of appropriate crushing techniques. Product grading is then a function of screening process and, possibly, washing.

5. Concrete Aggregate

This rock, in its fresh state and appropriately processed, should make good concrete aggregate. The strength and validity of any Feasibility Study (and certainly any later stage study) would be enhanced by a second series of testing. These tests should comprise, at least, Bulk Density, Water Absorption, Wet Strength/Dry Strength/Variation tests and a Mielzenz Test for potential reactivity (although the present petrographic descriptions do not alert to the presence of any potentially reactive mineralogy.

6. Sealing Aggregates

The petrographic report alerts to the possibility that bonding problems may arise because of the presence of secondary white mica (sericite in the modal analysis) and clays. I would not consider that the accessory to trace proportions of these minerals present in this modal analysis would have been of great concern. Nonetheless, this aspect can be and should be checked on typical crushed aggregate intended as sealing aggregate by the Bitumen adhesion (Resistance to stripping of cover aggregates and Binder) test. This test should be conducted with and without precoat adhesion agent to check on the hydrophilic properties of this rock type and the polarity differences between the rock and bitumen.

Microgranite as a fine-grained and hard rock with plentiful quartz content may be susceptible to polishing under traffic, but this susceptibility is influenced by many factors including road geometry and traffic density. It is most reliably judged in service.

7. Crushed Road Base

Crushed fresh rock with or without the addition of fines (perhaps from the more weathered zones) is, of course used as road base or subbase in road pavement construction. This rock would seem to have the potential to produce or form the basis of good quality crushed road base.
If this is an intended market I would strongly recommend carrying out the necessary Grading, Atterberg, Particle Shape and Wet/Dry Strength tests required by, for example, RTA (NSW) Specification 3051 Table 1 to establish compliance with this Specification for a typical crushed product.

Additionally, consideration might be given to carrying out Texas Triaxial Tests on representative material to enable compliance with RTA (NSW) Specification 3051 Table 2 to be also established. I understand that Current RTA pavement design is tending to use Table 2 Criteria rather than Table 1.

D A Byrne  
Engineering Geologist  
4 February 1993
# Concrete Aggregate Test Results

**Client:** Grave Johnston & Associates  
**Project:** Proposed Wheatly Quarry Site  
**Location:** Bega, NSW  
**Date:** 22/1/93  
**Job No:** CTS1088

## Sample Details
- **Sample No:** 22124  
- **Aggregate Source:** Proposed Wheatly Quarry Site, Bega, NSW  
- **Sample Received On:** 4/1/93  
- **Date Tested:** January 1993

## Test Results

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Range Tested</th>
<th>Test Result</th>
<th>A.S. Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Mass</td>
<td>g/cm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk Density</td>
<td>kg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Absorption</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve Analysis</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Finer</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle Shape</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate Crushing Value</td>
<td>mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance to Abrasion by Los Angeles Machine</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soundness (by use of sodium sulphate solution)</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Particles</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friable Particles</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Impurities Other Than Sugar</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential Reactivity of Aggregates (Chemical Method)</td>
<td>mmol/l</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polished Aggregate Friction Value</td>
<td>50 (tested by others)</td>
<td>(Sc)</td>
<td>mmol/l</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Rc)</td>
<td>mmol/l</td>
</tr>
</tbody>
</table>

### Remarks
- Polished Aggregate Friction Value = 50 (tested by others)
- Separate certificate

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This laboratory is registered by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with the terms of registration. This document shall not be reproduced except in full without the prior approval of the laboratory.
CLIENT: Coffey Partners International

PROJECT: Testing of spalls for P.A.F.V.

PRODUCT: Spalls

LOCATION: Unknown

SIZE OF AGGREGATE: -13.2 + 9.5 mm

LAB. SAMPLE NO: 87

DATE RECD: 12.1.93

Samples were prepared as per AS1141.41 and tested in a wet condition as per AS1141.42 prior to and after polishing. The samples were polished using the procedure of AS1141.41.

A reference aggregate sample, "Panmure Basalt" is included with each testing run. This sample acts as a control on test performance and is used to standardise the sample results. After polishing the samples were again tested in the wet condition according to AS1141.42.

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS1141.41 /42-1984</td>
<td>Sample mean friction value corrected for temperature before polishing</td>
</tr>
<tr>
<td></td>
<td>73</td>
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<tr>
<td></td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Sample mean friction value corrected for temperature after polishing</td>
</tr>
<tr>
<td></td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Polished aggregate friction value (PAFV) after polishing</td>
</tr>
<tr>
<td></td>
<td>50</td>
</tr>
</tbody>
</table>

The air temperature during the friction test was 24°C. The sample mean friction value corrected for temperature 23°C.

Sample submitted by client.
C. Turner, File, Ref: Rep.013

Richard Bawer

Date 22-1-93 Serial No. 0001

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soundness of aggregate

client: GRAVE JOHNSTON & ASSOCIATES
principal: 
project: PROPOSED QUARRY SITE
location: BOMBALA, NSW

date: 20/1/93
job no: CTS 1088
tested by: MC
checked by: JR

office: Sydney

lab no: Lab No.22124

aggregate source: CTS—Canberra
material description: Aggregate

solution used: Anhydrous Sodium Sulphate

test procedure: AS1141 Sect.24-1974

<table>
<thead>
<tr>
<th>sieve size</th>
<th>% passing (as received)</th>
<th>% loss after test</th>
<th>weighted loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.2mm</td>
<td>78</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>9.5mm</td>
<td>62</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>4.75mm</td>
<td>26</td>
<td>0.09</td>
<td>0.04</td>
</tr>
<tr>
<td>2.36mm</td>
<td>17</td>
<td>0.26</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Total Weighted % Loss = 0.08

examination of particles greater than 19mm

no. of pieces before test:
no. of pieces after test:
type of failure observed:

remarks:

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J. RUSSELL 30/1/93
Authorised Signature
test results

principal: /Client: GRAVE JOHNSTON & ASSOCIATES
project: PROPOSED QUARRY SITE
location: BOMBALA, NSW
date: 27/1/93
job no: CTS1088

average least dimension

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab No 22124</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Note: Sample supplied by CTS - Canberra

This laboratory is registered by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with the terms of registration. This document shall not be reproduced except in full without the prior approval of the laboratory.

J. RUSSELL 29/1/1993
Authorised Signature
Shire Engineer
Bombala Shire Council
Council Chambers
17 Caveat Street
BOMBALA N.S.W. 2632

Attention: Mr W. van Leenwen

Dear Sir,

RE: PETROGRAPHIC ANALYSES OF SUPPLIED ROCK SAMPLES - PROPOSED QUARRY SITE, BOMBALA, N.S.W.

Please find enclosed the results of petrographic analyses performed on two supplied rock samples, including comments on potential uses of the quarried rock.

The rock samples are understood to have been obtained from the ground surface, occurring as spalls or outcrop. As such, the rock samples are weathered and altered. On the basis of these two rock samples alone, potential uses are very limited.

In addition to the above rock samples, drill chippings were supplied from four boreholes, designated 2L, 2R, 3L and 3R. The drill chippings have been visually examined, and based solely on this visual examination, the rock appears to become slightly weathered or fresh at the following depths:

Will follow up results of worked rock slopes sent to Coffey's

Please find enclosed results of worked rock slopes sent to Coffey's.

27/10/88

CN 1441/88

let me know what happens.
Quarrying of the slightly weathered and fresh rock is likely to extend the potential uses, into possibly concrete aggregates, base and sub-base materials in road constructions, and road sealing aggregates.

Please contact this office for any further information concerning this report.

Yours faithfully,
COFFEY & PARTNERS PTY LTD

[Signature]
DR G. K. SPENCER
At your reference
Date 24th. October, 1988

Shire Engineer
Bombala Shire Council
Council Chambers
17 Caveat Street
BOMBALE NSW 2632

Attention: Mr W. van Leenwen

Dear Sir,

RE: PETROGRAPHIC ANALYSES OF SUPPLIED ROCK SAMPLES
PROPOSED QUARRY SITE, BOMBALE, N.S.W.

Please find attached the results of petrographic analyses performed on three rock samples, selected from a number of samples supplied, including comments on potential uses of the quarried rock.

Please contact this office for any further information concerning these results.

Yours faithfully,
COFFEY & PARTNERS PTY LTD

[Signature]

Dr G. K. SPENCER
COMMENTS

These two samples of felsic igneous rock are strongly weathered and altered. They appear to be surficial spalls and therefore are not truly indicative of the physical characteristics and properties of the underlying rock. It is strongly recommended that a sample of fresh rock - such as that to be quarried or excavated for its intended application - be examined to establish more-applicable and representative characteristics. A bore-core, which presumably has been sunk to establish reserves, would be quite appropriate for testing.

Based only on the samples supplied the following comments can be made on its durability and potential use.

The fine grain size and interlocking texture give the rock considerable strength and toughness. This translates into good durability and suitability for a range of applications. The amount of carbonate is of some concern because of its mobility in solution. However, the concern does not extend to reaction with sulphide because of the apparent paucity of the latter. The high percentage of brownish hydrated iron oxide as films, infillings and veinlets detracts from its appearance because of the mobility of the iron in solution (results in staining). Furthermore, the iron oxide films reduce the adhesion between rock and bonding substances, such as bitumen and cement. Additional bonding problems could arise with the high proportion of secondary white mica and clays because of their flaky morphology and water exchange capacity.

It could be expected that the rock would be substantially less-altered at shallow depth and that some of the shortcomings for its use in concrete and as sealing aggregate may disappear.

Depending on the field occurrence the fresh equivalent of this rock might be particularly desirable as a building stone for use in external and internal wall cladding, excellent for paving, reconstructed granite panels, aggregate and road base.

Assuming the rock remained as altered as the samples provided the best applications would be road base and sea-wall or retaining wall constructions.

Dr. H. D. Hensel
(7th Sept., 1988)
Macroscopic description of rock

A hard, weathered, bleached and apparently leached, fine-grained, dominantly pink-coloured granitic rock with numerous vugs and pits. The sample is strongly stained and obviously represents a surface spall. Most of the pits and vugs are solution cavities but some appear to be miarolitic cavities produced during high-volatile, high-fluid intrusive activity. A dense sprinkling of a green mineral and patches of a soft, whitish mineral indicate considerable hydrothermal activity during and/or after emplacement.

Petrographic description of thin-section

This is an unusual felsic igneous rock consisting basically of numerous, roughly circular micrographic structures, relatively large euhedral crystals of plagioclase feldspar and abundant interstitial patches of late-formed minerals. The rock is highly altered through both deuteric and surficial processes.

The micrographic structures strongly resemble radiating rosettes common in felsic extrusive rocks. There appear to be two common sizes - one around 1mm in diameter, the other close to 0.4mm. The centres of both are extremely fine-grained - from unresolvable to around 5μ. Grainsize increases rapidly outward forming the classic micrographic intergrowth of quartz and alkali feldspar. Many of these structures are composite containing 5-8 separate, poorly formed and generally very fine-grained units. In some parts, relatively large (up to 2mm long) plagioclase feldspar crystals are randomly distributed. Because they crystallized earlier than the alkali feldspar these long crystals appear to constitute nuclei for the later, composite structures.

The plagioclase feldspar is thoroughly altered such that only in a few instances is any of the original mineral preserved. Although mostly unresolvable it appears that the replacement products are sericite, carbonate, hydrated iron oxide and clay. A second generation of plagioclase feldspar is present in the late-stage interstitial infillings. Its composition is albite with rudimentary twins.

Most of the quartz, and similarly the alkali feldspar, is tied up in the intergrowths. However, a small proportion has crystallized late as free quartz and alkali feldspar crystals. In most of these interstitial patches it is clear that crystallization occurred under water-saturated conditions with well-formed crystal faces and bipyramidal terminations on the quartz not uncommon.

Associated with these saturated conditions is carbonate, biotite and chlorite. None of the original iron-rich biotite remains intact having been completely chloritized. The carbonate is likely to have originated by the decalcification of the plagioclase feldspar although an external derivation cannot be ruled out.

A small amount of carbonate is distributed randomly throughout the rock as rhombs indicating substantial fluid mobility through the rock after crystallization. There is also a small scattering of a ferromagnesian mineral throughout the rock that crystallized early. Although likely to have been biotite there is also a possibility that some hastingsitic amphibole crystallized under these conditions.
The redness in the rock is due mainly to the presence of abundant small concentrations, veinlets and films of hydrated iron oxide - probably goethite. In places entire plagioclase feldspar crystals have been replaced by goethite-stained secondary minerals.

Slender, subhedral crystals of zircon and small specks of magnetite and/or ilmenite are the main primary accessories.

**Mode of rock**

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>quartz</td>
<td>28%</td>
</tr>
<tr>
<td>alkalifeldspar</td>
<td>38%</td>
</tr>
<tr>
<td>plagioclase feldspar</td>
<td>20%</td>
</tr>
<tr>
<td>secondary albite</td>
<td>2%</td>
</tr>
<tr>
<td>sericite</td>
<td>1%</td>
</tr>
<tr>
<td>carbonate</td>
<td>3%</td>
</tr>
<tr>
<td>chlorite</td>
<td>5%</td>
</tr>
<tr>
<td>original biotite</td>
<td>1%</td>
</tr>
<tr>
<td>hydrated iron oxide</td>
<td>1%</td>
</tr>
<tr>
<td>accessories</td>
<td>1%</td>
</tr>
</tbody>
</table>

**Name of rock**

Altered micrographic granite
Macroscopic description of rock

Very similar comments to sample 1 with the exception that there is a decrease in the proportions of greenish mineral and soft whitish mineral and a slight tendency towards a pale yellowish-green.

Petrographic description of thin-section

In most respects this rock is very similar and closely allied genetically with sample 1. For this reason only the most obvious differences are highlighted. Texturally there is little difference between the two because of the dominant radiating micrographic structures, interstitial patches and indistinguishable grain size. Similarly, the extent and type of alteration of the feldspathic material is virtually identical.

However, there are some mineralogical differences. Most conspicuous is the presence of fluorite accompanying the late-stage minerals crystallizing from a fluid-enriched system. Another is the development of clay “balls” in some of the interstices, not infrequently accompanied by goethite. These clay balls (<0.5mm) appear to be composites of illite plus kaolinite variably stained by hydrated iron oxide. Another is the dramatic decrease in the amount of deep green chlorite. Furthermore, the alteration of original biotite is clay (±smectite) dominated rather than through chloritization. Collectively, these features indicate a lower temperature during the deuteritic and surficial alteration stages. The presence of the clay and fluorite as late-stage infillings may be contributing to a slight decrease in the proportion of carbonate in this rock.

A primary mineralogical difference, which could perhaps be sampling-related, is the presence of slightly more, euhedral plagioclase crystals around which the radiating structures have nucleated. Whereas in sample 1 it was difficult to find remnants of original plagioclase feldspar in this rock there are several crystals with only moderate alteration. The alteration also in this sample is, in places, quite coarse white mica (accompanied by some goethite). Another primary feature is the decrease in the amount of long, thin ferromagnesian crystals that may have been hastingsitic amphibole.

As in sample 1 the principal accessories are zircon (both elongate and small subrounded varieties) and magnetite. The paucity of sulphide in this and probably sample 1 may well be real; however, the extent of alteration is likely to have removed most, if not all, existing sulphide and replaced it with hydrated iron oxide.
Macroscopic description of rock

A hard, tough, very fine-grained, greenish-pink rock with very thin veinlets and a scattering of small, clear patches.

Petrographic description of thin-section

This rock consists mainly of small micrographic structures, free quartz and albite feldspar around miarolitic cavities, carbonate filling these cavities, a small amount of white mica and chlorite and minor iron oxides.

Alteration is principally hydrothermal and may have occurred at any stage after the crystallization of the rock. The main effects of the alteration have been to convert the biotite to chlorite, introduce carbonate and pepper the feldspathic components of the rock with secondary white mica (sericite).

The micrographic structures dominate the rock. The majority range in size from 0.1mm to 0.6mm with a few larger ones extending this range to 1.0mm. Few are rounded because of the rapid nucleation and impingement during crystallization. Intergrowths are quite fine with a typical size at the perimeter of 0.01mm wide and 0.07mm long. Although there is some coarsening outward many of these structures show little gradation in the size of the intergrowths.

Small, single, euhedral plagioclase feldspar crystals occur near the cores of quite a few of these micrographic structures. Scattered large crystals may exceed 3mm. Small albite feldspar crystals may also accompany some of the quartz in the miarolitic cavities confirming late-magmatic hydrothermal activity. Most of the feldspar is mildly to moderately altered and replaced by sericite. In zones of relatively intense sericitization grain size may approach 0.05mm, especially in the thin, convoluted, discontinuous veinlets. For the remainder of the rock much of the sericite is around 1-5μ, and not unlike the type of alteration associated with kaolinization.

Chlorite is virtually restricted to late-stage fluid-rich patches and miarolitic cavities. It forms small greenish clusters (to 0.4mm) and is quite iron-rich. In several instances it clearly replaces biotite pseudomorphing the original shape.

There are also sparse opaques (to 0.2mm) that appear to be partly altered low-Ti magnetite and a scattering of very elongate prismatic crystals that now appear to be replaced by hydrated iron oxides.

Carbonate (calcite) occupies the miarolitic cavities and also forms small isolated rhombs within the micrographic structures. Interestingly, quite large zircons (to 0.2mm) may accompany the carbonate in some of these cavities. Other zircon is reasonably abundant and there is a strong association with magnetite.
<table>
<thead>
<tr>
<th>Mode of rock</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>free quartz</td>
<td>5%</td>
</tr>
<tr>
<td>free feldspar</td>
<td>2%</td>
</tr>
<tr>
<td>micrographic structures</td>
<td>75%</td>
</tr>
<tr>
<td>plagioclase feldspar</td>
<td>5%</td>
</tr>
<tr>
<td>chlorite</td>
<td>3%</td>
</tr>
<tr>
<td>carbonate</td>
<td>4%</td>
</tr>
<tr>
<td>sericite</td>
<td>4%</td>
</tr>
<tr>
<td>zircon</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>opaques</td>
<td>1%</td>
</tr>
<tr>
<td>hydrated iron oxide</td>
<td>1%</td>
</tr>
<tr>
<td>vugs</td>
<td>1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of rock</th>
<th>Microgranophyre</th>
</tr>
</thead>
</table>
Macroscopic description of rock

A hard, weathered, bleached and apparently leached, fine-grained, dominantly pink-coloured igneous rock with numerous vugs and pits. The sample is strongly stained and obviously represents a surface spall. Most of the pits and vugs are solution cavities but some appear to be milarolitic cavities produced during high-volatile, high-fluid intrusive activity. A network of one or more dark-coloured minerals and sparse patches of a soft, whitish mineral indicate considerable hydrothermal activity during and/or after emplacement.

Petrographic description of thin-section

This moderately altered, strongly iron-stained felsic igneous rock consists basically of numerous, roughly circular micrographic structures, a scattering of relatively large plagioclase feldspar crystals, concentrations of quartz around cavities and a sprinkling of muscovite.

Although the alteration to this rock is both deuteric (late-stage magmatic) and surficial it appears to have had only a minor effect on the overall chemical stability and strength characteristics.

The micrographic structures which are an intergrowth of alkali feldspar and quartz are very similar to radiating rosettes common in felsic extrusive rocks. The principal difference is that elevated thermal conditions at the time of emplacement or extrusion allowed relatively slow crystallization and therefore a coarsening of the intergrowth. The micrographic structures in this rock are typically between 0.4mm to 1.0mm across. Centres tend to be very fine-grained coarsening outward. Because of their abundance general development has been restricted and many appear to be confined.

Euhedral plagioclase feldspar crystals are randomly scattered throughout the rock and cut across several of these micrographic structures. Most crystals are around 0.5 to 1.0mm but several others exceed 2mm. Because of their early crystallization these well-formed feldspars acted as centres for the nucleation of the micrographic structures. The plagioclase feldspar varies in its freshness from mildly altered and retaining twinning features to totally sericitized and kaolinized.

Most of the quartz, and similarly the alkali feldspar, is tied up in the intergrowths. However, a small proportion has crystallized late as free quartz around milarolitic cavities. In these interstitial patches crystallization occurred under water-saturated conditions with some well-formed crystal faces.

Although no longer present biotite was probably the only ferromagnesian mineral to crystallize. It has been totally replaced by hydrated iron oxide and secondary white mica. There has been a substantial introduction of hydrated iron oxide (probably goethite) into this rock via a network of fractures. Many of these fractures are between 0.03mm and 0.10mm wide. The extent and frequency of these fractures may be an important consideration in the eventual application of this rock.
A few rhombic shapes are scattered throughout the rock but mostly occur within the cores of micrographic structures. They almost certainly represent carbonate that has been removed by solution.

The extent of hydrated iron oxide introduction coupled with the hydrothermal activity effectively mask any original iron-titanium oxides that may have crystallized.

**Mode of rock**

- free quartz: 4%
- micrographic structures: 78-80%
- plagioclase feldspar: 5%
- hydrated iron oxide: 6%
- cavities: 4%
- white mica: 2%

**Name of rock**

Altered micrographic sub-volcanic intrusive (microgranophyre)
Macroscopic description of rock

A greenish-pink, altered igneous rock with numerous small cavities some of which are filled with a soft whitish mineral. Bands of brownish-coloured alteration traverse the rock.

Petrographic description of thin-section

Texturally this rock is similar to the previous 2 in that its primary mineralogy consists mainly of numerous patches of micrographic intergrowth, a small amount of free quartz and albite feldspar associated with mafic cavities and fluid concentrations, early crystallized but generally well-altered plagioclase feldspar, opaque oxides and some zircon. Its secondary assemblage consists of sericite, illite and smectite clays, probable kaolinite, and hydrated iron oxide (goethite).

Because most of the primary mineralogical features of this rock have been detailed in previous descriptions only the differences will be highlighted.

The most significant feature of the rock is its advanced alteration. The rock has clearly undergone a couple of cycles of alteration such that earlier secondary minerals (e.g. carbonate) have been dissolved and replaced by illite. Thus illite occupies the mafic cavities, small patches near quartz-feldspar pods and in other interstitial areas. Sericite replaces mostly the sodic oligoclase feldspar but its pattern and intensity appear haphazard. Some clusters of plagioclase feldspar are totally replaced by sericite whilst nearby crystals are virtually unaffected. Sericite also replaces original ferromagnesian minerals (principally biotite) where it may be joined by smectite. Hydrated iron oxide is introduced via fluids at any time after emplacement of the rock. In this case the goethite occupies numerous little fractures, coats cavities and quartz-feldspar patches, replaces other oxides or ferromagnesian minerals, or simply occupies the grain boundaries between the micrographic structures.

Kaolinitization of the alkali feldspar throughout the rest of the rock appears widespread; however, its precise extent is masked by the abundance of tiny flakes of sericite.

Mode of rock

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<tbody>
<tr>
<td>free quartz</td>
<td>4%</td>
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<tr>
<td>free feldspar</td>
<td>2%</td>
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<tr>
<td>micrographic structures</td>
<td>65%</td>
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<tr>
<td>plagioclase feldspar</td>
<td>12%</td>
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<tr>
<td>sericite</td>
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<tr>
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<td>hydrated iron oxide</td>
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Name of rock: Altered microgranophyre