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GEOLOGICAL MAPPING AND INVESTIGATIONS
Environmental Studies

BUILDING AND ORNAMENTAL STONE
Exploration and Evaluation

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PROPOSED RED GRANITE QUARRY SITES IN THE HEEMSKIRK GRANITE, WESTERN TASMANIA

Report prepared by

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EXECUTIVE SUMMARY

This report presents the result of an initial exploration program designed to locate potential quarry sites for high quality red ornamental granite in the Heemskirk Granite near Zeehan in Western Tasmania.

Important criteria considered in this exploration program were access, site workability, the colour, texture and structure of the granite, the spacing of linear jointing fractures (which determine the size of unflawed blocks which can be obtained) and the intensity of micro-fracturing (which controls the strength and durability of the stone).

Excessive microfracturing occurs in an existing quarry near Trial Harbour road; thus a major aim of the work was to determine what variation, if any, exists in the intensity of microfracturing through the granite body.

Red granite outcrops in the eastern part of the Heemskirk Granite. Currently feasible access to the red granite only exists in the northern part (south of Heemskirk Road) and the southern part (around the Trial Harbour Road).

All possible quarry sites in the northern part of the red granite were found to be unsuitable due to excessively close joint fracturing, difficult site topographies, and difficult access.

In contrast, significant areas in the southern part contain red granite of moderate to good quality in terms of the criteria considered. Four promising potential quarry sites have been identified. All four contain large joint blocks of dark red, evenly medium to coarse grained granite having microfracture intensities well below that found in the existing quarry. Scattered quartz/black tourmaline nodules occur at two of the sites, and are absent at the other two. Access and site workability are good at all four sites.

It is recommended that further evaluation work, involving trial excavations and testing of fresh sub-surface samples, be undertaken at the four potential sites with a view to ultimately operating one or more of them as a quarry.

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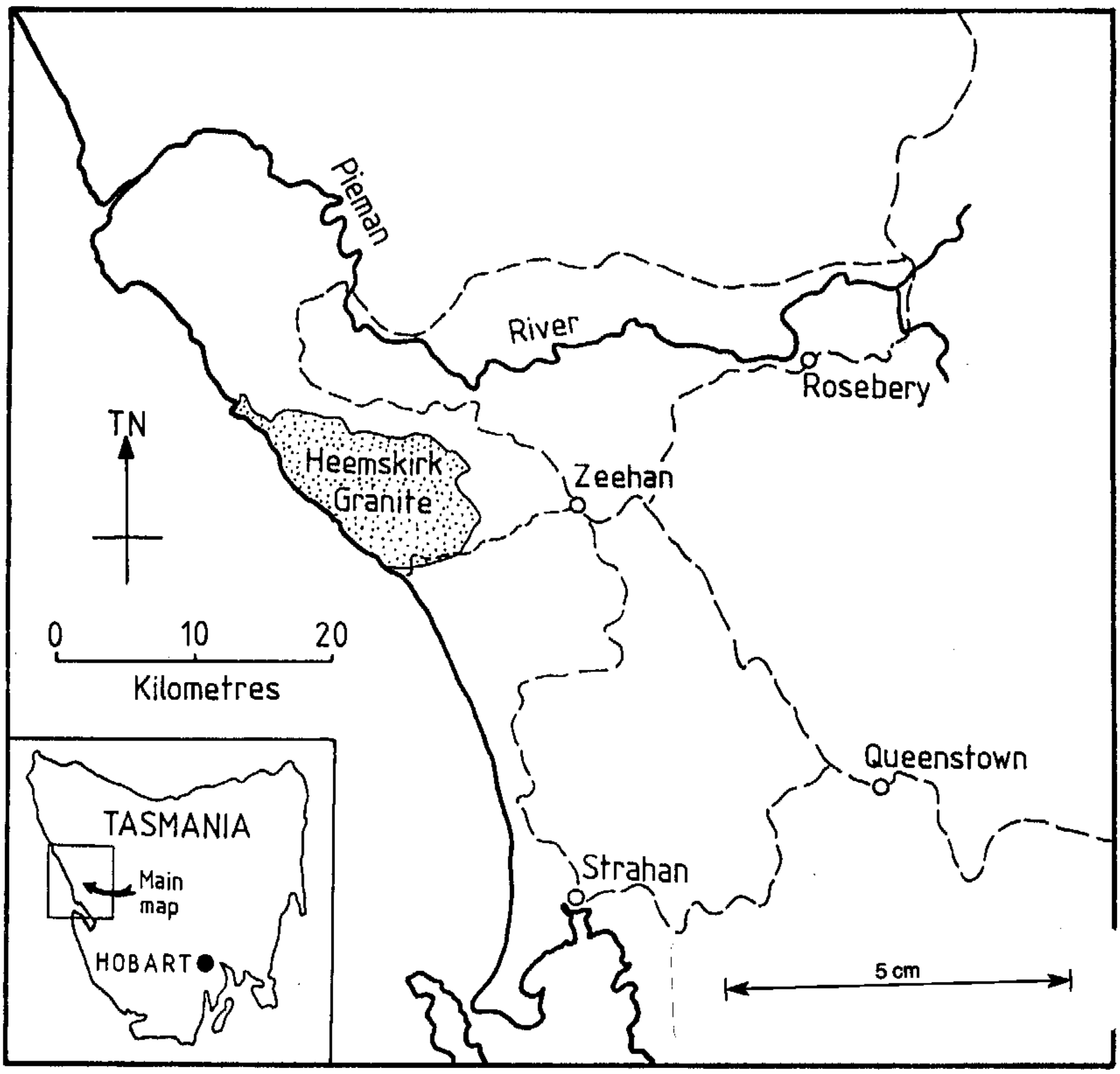
(1.0) INTRODUCTION

This report describes the results of field and laboratory investigations undertaken in the Heemskirk Granite of western Tasmania for the purpose of locating one or more potential quarry sites for red ornamental granite.

The potential of the red Heemskirk Granite as a building and ornamental stone was recognised eighty years ago by Baker (1915); however the only exploitation of the stone for this purpose to date appears to have been the establishment of a small quarry near Trial Harbour (Site 21 of this report) by Dunn Monumental Masons Pty. Ltd. in 1989 (Sharples 1990, p.114).



Map 1: Locality Map - The Heemskirk Granite, Western Tasmania.

The Heemskirk Granite is situated on the west Coast of Tasmania, about 15 kilometres west of Zeehan (see Map 1). The northern and southern parts of the granite are accessed via the Heemskirk and Trial Harbour Roads, respectively, from Zeehan. The central and eastern parts of the granite are rugged areas of the Heemskirk Range with no two-wheel drive access routes.

From Zeehan, the main transport route is via the Murchison Highway to the port of Burnie (120 kilometres on good sealed highway).

(2.0) BUILDING AND ORNAMENTAL RED GRANITE - PRACTICAL AND TECHNICAL PARAMETERS

A significant proportion of natural granite sources are unsuitable for building and ornamental purposes by reason of low strength, low durability, or undesirable aesthetic characteristics.

This section gives a brief listing of both formal standards, and also unofficial, but widely accepted and commonsense, criteria for good granite sources. A fuller discussion can be found in Sharples (1990, Chapters 2 & 6).

It will be noted that some technical specifications such as strength and water absorption have not been determined in the present work. Where this is the case, it is because such criteria are more usefully determined at a later stage of quarry evaluation when fresh sub-surface samples are available.

TECHNICAL AND AESTHETIC CRITERIA

Stone freshness
Granite should be fresh and unweathered, so that it is essentially free of feldspars and micas altering to clay. In a good deposit, such stone is generally found within a metre or so of the original natural outcrop surfaces; where stone is strongly weathered to greater depths, the deposit is likely to be unsuitable for quarrying.

Near-surface granite is commonly of a lighter colour (where not iron oxide stained) than granite at depth, as a result of incipient weathering.

Joint fractures
These are physical breaks in the rock mass, commonly linear and occurring in parallel sets, which have resulted from tectonic stresses (earth movements) imposed upon the rock at various times since it formed. Joints are unacceptable in a finished granite piece, since they result in strength reduction and accelerated weathering. Thus, the spacing between joints in a granite deposit determines the size of unflawed blocks which can be quarried.

Ray (1988) specifies that granite jointing should be spaced widely enough to allow extraction of unflawed blocks of dimensions 2 x 1.3 x 1 metres or larger. In the present work a more rigorous criterion requiring the extraction of unflawed blocks of dimensions 3 x 2 x 1 metres is used; wastages calculated on this more rigorous basis would be less if Ray's criterion were used.

Strong annealled fractures cemented with durable minerals such as quartz (ie, veins) may sometimes be acceptable, and may add aesthetic interest to the stone.

Micro-Fractures
Small fractures, typically only a few millimetres or less in length. These are common in Australian granites, and few if any granites are entirely free of them. Parallel sets of microfractures can cause a distinct strength reduction and anisotropy, can increase porosity and permeability, and can result in differing ability to take polishing in different directions. These effects can make granite unacceptable for external veneers (cladding), although in many cases such stone will still be acceptable for larger dimension blocks or for interior use if oriented correctly. See also discussion in Appendix Three.

Microfracturing intensity should be minimal; however, no specific figures on maximum acceptable intensities are currently available to this writer.

Colour
Red granite is specifically required for the present project. Many other colours, particularly various shades of grey, are found in granites, and are widely exploited.

A uniform colouration is most commonly preferred, although non-uniform colouration (bands, other segregations) can be acceptable or even desirable in some applications.

Structure
Structure refers to large features, such as banding, super-imposed on the texture of a granite. Massive (uniform and isotrophic) structure is generally preferred, but banding or other segregations can be acceptable in some applications:

Xenoliths, veins, dykes, nodules, other structures
These structures include fragments of country rock entrained within the granite magma (xenoliths), late stage igneous intrusions into the earlier granite mass (dykes), chemical precipitates along fractures (veins) or other features such as tourmaline nodules.

Such features may be acceptable in certain applications, or to certain users, on an aesthetic basis. If aesthetically acceptable, these features must be evenly distributed, not contain unstable minerals, and not cause any reduction in strength or durability of the granite.

Texture
Relationships between grains in a granite. Equi-granular and medium to coarse grained granites are most commonly used for ornamental work, although porphyritic varieties are also commonly used for a slightly less uniform appearing stone. See definitions in Section (6.3).

Ability to take polish
For most ornamental applications, the ability to take a high polish is essential. Such ability depends upon the concentration of micro-fractures and unstable or soft mineral grains.

Chemical composition
Rarely of significance in itself, except insofar as chemical composition is related to the mineralogy of the granite.

Mineralogy
Unstable minerals which may weather out, stain, change colour or promote stone decay should be absent or only very minor. Such minerals include:

Pyrite, other metallic sulphides (eg, galena): These may oxidise and produce dark stains. However, Alan Spry (*pers. comm.* 1990) suggests that stone which is quarried with unaltered pyrite will tend not to stain, whereas stone quarried with already partly altered pyrite will stain quickly in buildings.

Siderite
Calcite
Zeolites
Weathered feldspars (feldspar present in all granites)
Altered micas, clays (mica present in most granites)
Tremolite (amphibole)
Smectite (montmorillonite): swelling clay.
Some olivines
Chlorite.

Compressive Strength
131 MPa (dry) minimum (ASTM C 615)

Point Load Strength Index (Is50) = Tensile strength
5.46 MPa (dry) minimum

Flexural Strength / Modulus of Rupture
10.34 MPa (dry) minimum (ASTM C 615)

Effective Porosity (vol. %, 1 Atmosphere)
0.4% maximum (Spry 1988, p.64)

Porosity in granites is significant from the point of view of weathering decay processes, and is also of significance in applications such as paving tiles and bench tops, since greater porosity means greater susceptibility to staining. Granites tend to resist staining, but may absorb engine oil or red wine stains (Spry 1988, p.33).

Dry Bulk Density (tonnes/cubic metre)
2.76 minimum (ASTM C 615)

Note that this minimum figure is greater than the "average" figure of 2.64 for granites in general quoted in Section (6.3) of this report. The ASTM standards can be considered very stringent; actual bulk densities of the Heemskirk Granite have not been measured in the present work.

Abrasion Resistance
Measured as Taber Abrasion Values. The following minimum values are specified for various applications by Spry (1988, p.33):

Use	Taber Abrasion Value (minimum)
Light duty domestic	7
Medium duty commercial	12
Heavy duty	15

Rarely a limiting factor in granites, whose Taber Abrasion Values may range from 10 to 140 (Spry 1988, p.33).

Dimensional Instability
A measure of dimension change with temperature changes and wetting.

0.1% maximum allowable linear dimensional change (Spry 1988, p.68)

PRACTICAL CRITERIA

Accessibility
The economics of building stone operations are such that very few quarry operators can afford to construct new or significantly upgraded access roads over long distances or across difficult terrain. Potential quarry sites need to be close to existing roads and other necessary infra-structure.

In the case of the Heemskirk Granite, boggy terrain is common on flats and in gentle gully bottoms. Gently sloping ridge-top routes offer the best routes in terms of the ease of access track construction and maintenance; however, care must be taken to prepare drainage and erosion control methods in order to avoid washouts and other erosion.

Site workability
Topography, slope angle and overburden determine whether stone can be economically extracted from a site. It is generally uneconomic to remove more than a few metres of overburden (including soil and unsuitable stone) from above a deposit of good quality stone. It is also necessary to be able to form a flat platform at the base and/or top of an outcrop face upon which to commence working.

In long term quarrying operations, the most common method is to work back into a face on horizontal benches whose working faces should ideally be about four metres high.

The ideal quarry site would begin from an outcropping face of good granite with minimal overburden and with horizontal or gently sloping ground below. A rising slope gradient above the face of 1 in 10 is ideally the steepest slope angle which will allow quarry benches to be extended back far enough for economical granite extraction on four metre faces. A higher slope angle means shorter benches, so that new benches must be commenced more often, with consequent higher operating costs.

ENVIRONMENTAL CRITERIA

The ideal quarry site will be one in which the following potential environmental impacts are absent, or are able to be minimised:

- Visual (aesthetic) impact of quarry from roads, dwellings or scenic viewpoints.
- Noise, vibration, dust emissions.
- Effects of vehicular traffic to and from quarry.
- Damage to vegetation and fauna, especially where rare or endangered species are present.
- Erosion and siltation of watercourses.
- Introduction of pests, weeds and plant or animal diseases.

Although wilderness areas and other nature reserves would generally be highly contentious sites for quarry operations, the constraints on available access required by most building stone operations mean that such areas will rarely be considered feasible building stone quarry sites in any case.

(3.0) METHODOLOGY AND CONSTRAINTS

The exploration target was a red granite of good aesthetic, textural, jointing and micro-fracturing characteristics, as outlined in Section (2.0) above. Low micro-fracture intensities were considered an important criterion since granite obtained from the existing quarry (Site 21 of this report) has been considered to have excessive micro-fracturing for some high-stress applications.

The distribution of the Red Granite within the Heemskirk Granite body is shown on Map (2) and described in Section (4.0) below.

From the outset it was recognised that the central and eastern parts of the Heemskirk Red Granite were of excessively difficult access to be considered as exploration targets for red granite quarry sites (see Map 2). The lack of existing access and the rugged mountainous topography would make road construction to these areas very costly, and certainly beyond the budget of the proposed quarry development work.

The small region of red granite to the south-west of the main red granite body (see Map 2) is a predominantly fine-grained stone, and although 4WD access exists the track would need extensive upgrading before being used by trucks.

These considerations narrowed down the prospective areas of the red granite to the northern part, near the Heemskirk Road, and the southern part through which the Trial Harbour Road runs (see Map 2). The northern red granite area was initially preferred due to the fact that the Heemskirk Road is a high quality bitumen road, whereas the Trial Harbour Road is a gravel road which will require minor upgrading prior to any quarry operations.

However, for reasons to be described later in this report the northern area eventually had to be rejected on geological and other grounds.

Given these constraints on the prospective areas, exploration and evaluation of potential quarry sites proceeded as follows:

There are no known means of evaluating ornamental stone prospects by geophysical or geochemical surveys, and short of extensive programs of grid drilling, soil-covered areas cannot be assessed. The only practical means of exploring for suitable sites involve narrowing down prospective areas on the basis of whatever relevant geological data may already exist, followed by field examination of outcropping stone.

In most cases the only available outcrops are naturally weathered ones. Some critical stone properties, including colour, degree of clay-alteration, strength, porosity and micro-fracturing, are commonly altered by weathering within a metre or so of natural outcrop surfaces.

The appropriate approach is therefore to select promising sites on the basis of criteria which can be reasonably assessed in natural outcrops, and to then conduct trial excavations or drilling at the most promising sites to obtain fresh sub-surface samples for more detailed evaluation.

This report describes field and laboratory investigations which have led to the selection of a suite of promising sites on the basis of evaluation of surface outcrops. The next stage in this work will be trial excavations or drilling leading to more detailed laboratory evaluations and selection of the final sites for quarry development.

All parts of both the northern and southern red granite areas which were considered to have feasible access were examined in detail, on foot, during June and July 1991. Two full days were spent traversing the northern area, and three days in the southern area.

Outcrops were evaluated in the field in terms of the following criteria:

- Colour
- Texture
- Other features (eg, veins and nodules)
- Joint fracture spacings and visible micro-fracturing
- Site topography
- Access
- Potential environmental impact of quarrying

The basic field data obtained is recorded in Appendix One and Maps (3) & (4), and discussed in Sections (5.0) & (6.0).

At a number of sites thought likely to have some potential for quarrying, individual joint spacings were measured along two perpendicular surface traverses each approximately 20 metres long, in order to provide statistics for a preliminary calculation of average joint fracture spacings, unflawed block sizes obtainable, and expected quarrying wastage. For comparision purposes, similar measurements were also taken at a few sites considered unlikely to be good quarry sites.

The field data and analysis methods are recorded in Appendix Two, and the results discussed in Section (6.0).

An oriented hand specimen of granite was taken from each promising site (and, for comparision, from several less promising sites) for laboratory evaluation. In this initial fieldwork, it was only possible to obtain samples from the (weathered) surface of natural outcrops, since only hand tools could be used at this stage.

However, at the existing quarry site (Dunns Quarry, Site 21) a sub-surface sample was also obtained from an excavated block, in order to give an indication of the variation likely to occur between surface and sub-surface samples.

Microscope thin sections were prepared from these specimens, and these were then used to statistically determine micro-fracture intensities. The results are recorded and discussed in Appendix Three and Section (6.0).

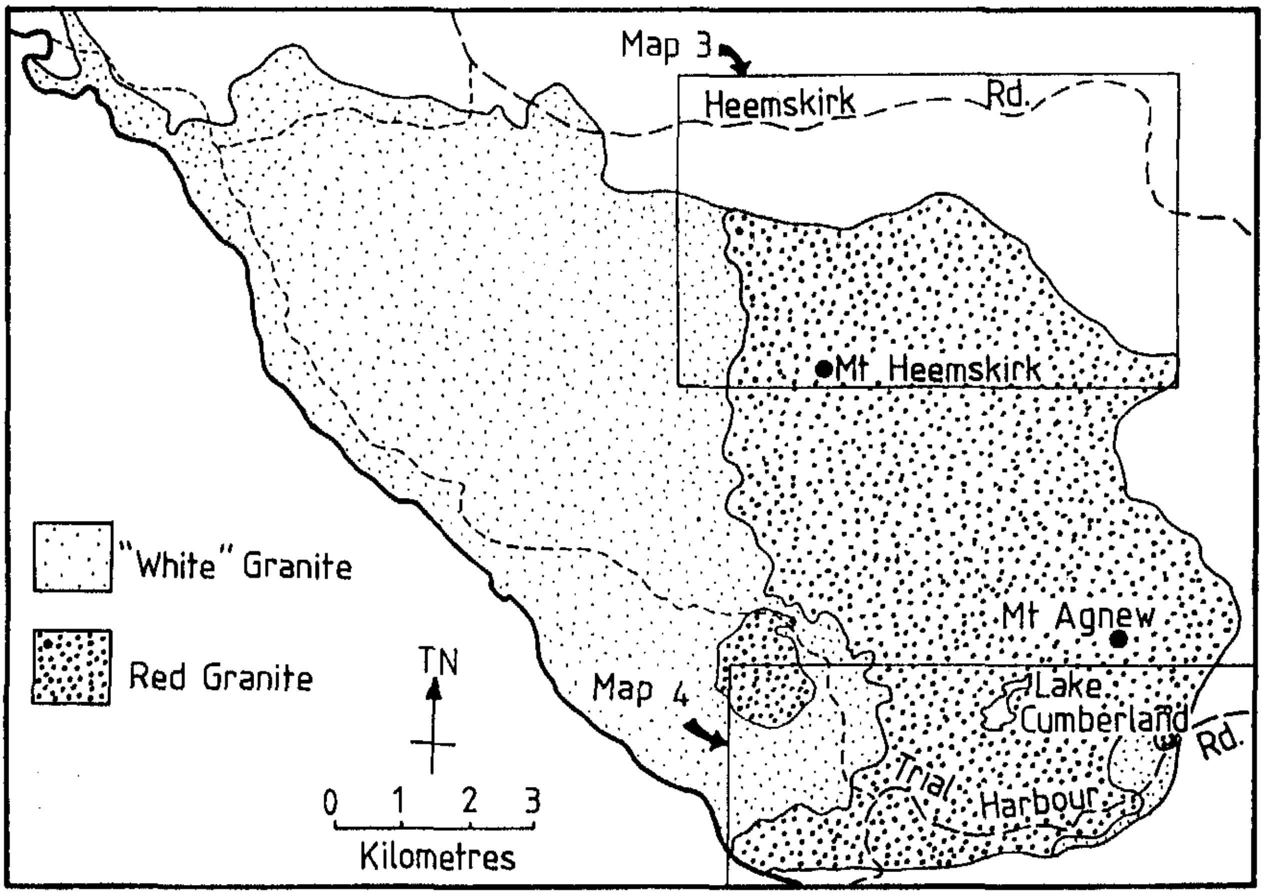
The additional time and expense involved in detailed mineralogical analyses to determine the presence of clay alteration and other unstable minerals was not considered warranted at this stage, since only natural surface samples were available, and these could show a degree of alteration which is not characteristic of subsurface stone.

All of the data obtained as described above was then integrated to select the most promising potential quarry sites for further investigation, as described in Section (6.0).

(4.0) GEOLOGY OF THE HEEMSKIRK GRANITE

The Heemskirk Granite is a composite granitoid intrusion of Devonian/Carboniferous age (approx. 330 - 360 million years old) which intruded into older Precambrian-age quartzites and slates of the Oonah Formation.

The granite body consists of a red granite at the top (eastern half) of the intrusion, which was intruded by a slightly younger "white" (grey) granite which now mostly outcrops in the lower western half of the granite area (McClenaghan *in* Burrett & Martin 1989, p.255). Recent (1990) Geological Survey mapping has confirmed the distribution of the two granite types as previously mapped by Klominsky (1972) and as shown on Map (2) below (M.P. McClenaghan *pers. comm.*).



Map 2: The Heemskirk Granite - Regional Geology (from Klominsky 1972) showing the northern and southern red granite areas which were explored during this project. Outline of detailed maps (3 & 4) indicated.

Both the white and red granites have a predominantly quartz / K-feldspar / plagioclase / biotite / tourmaline mineralogy. Quartz / black tourmaline nodules and veins are abundant in parts of both the white and red granites, particularly towards the top of the white granite intrusion.

The colour of the red granite results from the presence of K-feldspars which have been metasomatised (iron-enriched) at a late stage of the intrusion to produce their red colour. The red colour varies somewhat through the granite body, particularly between masses of different grainsize, but the granite is typically a dark red colour with a tinge of pale green resulting from the presence of scattered pale green (epidote-contaminated?) feldspars.

The red granite is predominantly of a massive (uniform) structure with an equigranular medium to coarse grained texture. Fine and fine to medium grained quartz-porphyritic varieties commonly outcrop in the northern part of the red granite, and Geological Survey mapping (M.P. McClenaghan *pers. comm*) indicates that the granite in that area consists of a succession of individual sheets which intruded in a number of pulses.

Each sheet has a chilled margin at the top, and grainsize varies from medium to coarse near the base to fine or medium to fine and quartz-porphyritic near the top. Since the volatile constituents of the magma migrated upwards during the cooling of each sheet, quartz-tourmaline nodules and veins occur mostly in the upper, finer-grained parts of each sheet (M.P. McClenaghan *pers. comm*).

The red granite is predominantly of medium-coarse grainsize in the southern area. A small separate area of red granite to the south-west of the main body (see Map 2) appears to be a thin sheet of predominantly fine-grained granite (M.P. McClenaghan *pers. comm*).

Narrow linear late-stage intrusions (dykes) of aplite (fine granite) occur sparsely distributed throughout most areas of the red granite, and may vary in width from 0.2 to over 1.0 metres wide.

Several intersecting sets of parallel linear fractures (joints) are present throughout the Heemskirk Granite, although their spacing varies considerably as discussed in later sections of this report. Mapping of major joint features by Klominsky (1972) shows that the distribution of joint patterns is related to the form of the granite. This, together with the observation that the quartz-tourmaline commonly occurs in the form of veins filling joint fractures, suggests that much of the jointing in the granite formed during the later stages of the granite intrusion process.

Jointing is of particular importance in dimension (building and ornamental) stone quarrying, since it determines the size of unflawed blocks which can be obtained, and the amount of waste stone which will be produced.

A feature of the Heemskirk Granite is the presence of microfracturing. This consists of fine cracks which cut individual grains in the granite, and which are typically present in closely-spaced parallel sets aligned with the primary joint direction. Microfracturing accelerates weathering processes, reduces the mechanical strength of granite, and if sufficiently intense can render the stone insufficiently strong for certain types of high-stress building applications such as external veneers. Microfracturing in the Heemskirk granite is discussed and assessed in detail elsewhere in this report.

Xenoliths (fragments of country rock entrained by the intruding granite magma) are rare or absent in the parts of the Heemskirk Granite examined during this work.

(5.0) FIELD INVESTIGATIONS

(5.1) Northern area

All more or less accessible parts of the northern Heemskirk Red Granite were examined in the field, and twenty representative sites are described in Appendix One (Sites 1 - 20). Remaining areas which were not closely examined are all either too steep to be workable quarry sites, have very difficult access, or have very little outcrop upon which to base a reliable assessment of their prospectivity.

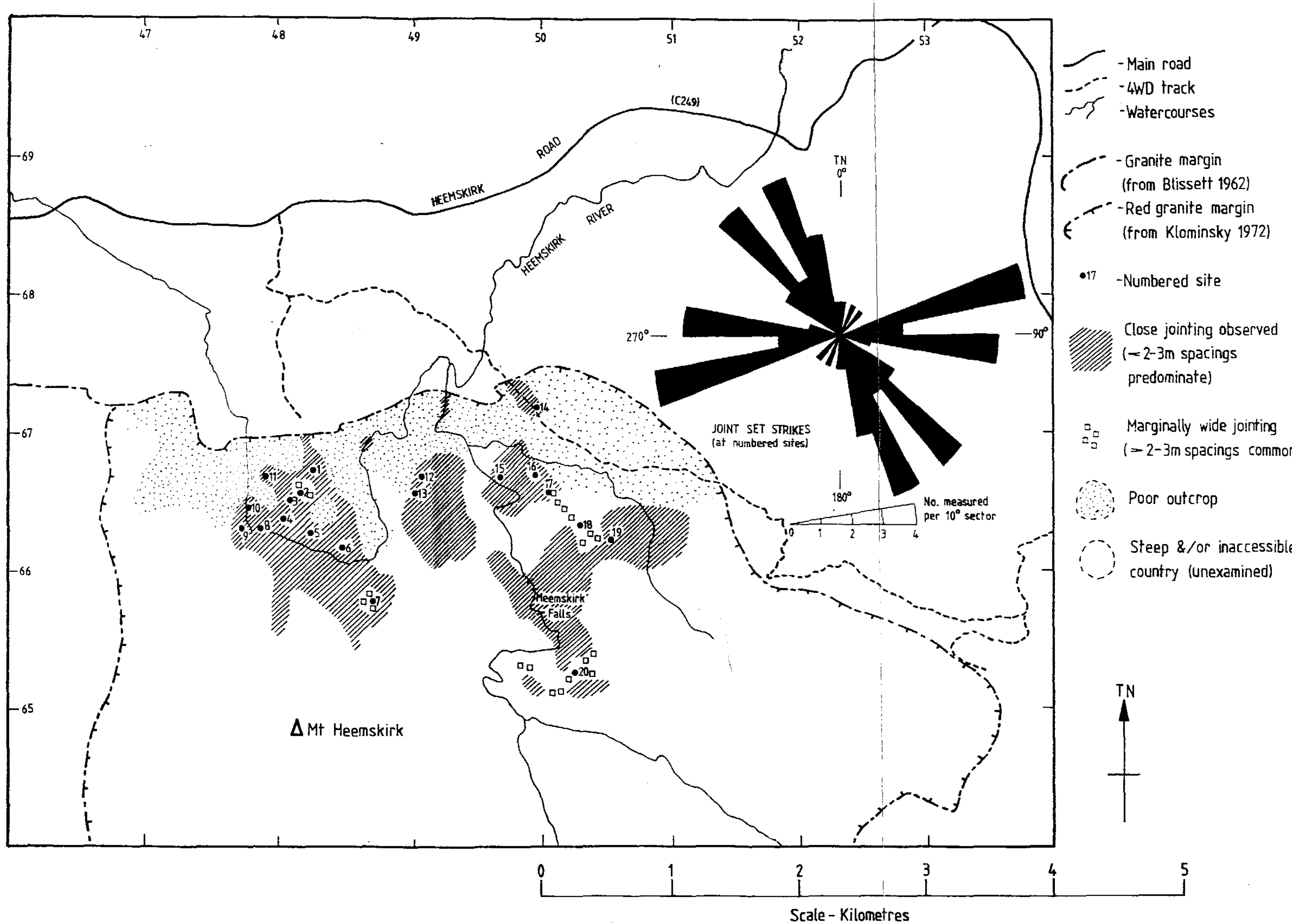
On the basis of this field assessment, it was necessary to reject the entire northern area as a potential granite quarrying area. This rejection was necessary for a number of reasons which are outlined below:

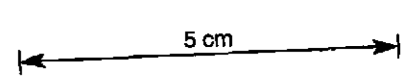
The geology of the northern area is quite variable, with marked alternations between fine-medium and medium-coarse grained red granite occurring over short distances. Quartz/black tourmaline nodules and veins (joint fracture fillings) also vary from abundant to absent over short distances.

As noted in Section (4.0), these rapid alternations appear to result from the red granite having intruded in a succession of pulses, each producing a thin sheet which differentiated during cooling to produce a gradation in grainsize and quartz/tourmaline content over short distances.

The thicknesses of the various sheets were not measured, but it is evident that any quarry sites would contain only limited reserves of granite of a particular desired character. The finer varieties appear generally less suitable for ornamental stone use, being more susceptible to close jointing, and having a greater abundance of black tourmaline which may be regarded as a blemish for some ornamental stone applications.

Closely spaced jointing fractures predominate throughout the northern area (see Map 3), which has clearly undergone more intense regional jointing than the southern area. Most outcrops have few if any joints spaced more than 2 or 3 metres apart, which means that production of reasonable sized blocks would be either impossible, or would involve wastage of over 90% of stone excavated. Such wastages are both environmentally and financially unacceptable.





Map 3: The northern Heemskirk Red Granite; geological observations and locations of sites examined. The Rose diagram indicates the strikes (trends) of parallel linear joint sets measured at the numbered sites examined.

In terms of joint spacings, the best sites located were a small area at Site 2, which is halfway up a very steep and thus unworkable slope, along the ridge between Sites 17 and 18, and on a small hill designated Site 20. Details of these sites are given in Appendix One.

Unflawed blocks 2 - 3 metres wide or more could be obtained from the ridge between Sites 17 - 18, however wastage rates would still be very high, since the wider-jointed granite occurs only as narrow zones within outcrops of predominantly close (0.5 - 1.0m) jointed granite. Access to the ridge is difficult, since it would necessitate the building of a substantial new bridge over the Heemskirk River, in addition to at least one kilometre of new road building.

Site 20 is the most remote part of the northern area which was examined. Wide joint spacings are common at Site 20, but are still interspersed with common closely-jointed zones. Moreover, the widely jointed outcrops occur on steep slopes halfway up a hill, whose top 30 metres or so is almost entirely closely jointed.

The 30 metre thick cap of the hill would need to be entirely removed before quarrying could commence, resulting in both very high costs and a major waste stone disposal problem. In addition, access to the site is very difficult, and would necessitate both a substantial new bridge over the Heemskirk River and at least two kilometres of new road construction over rough terrain.

Finally, any quarry at Site 20 would form the backdrop to the view of the impressive Heemskirk Falls, and would thus constitute a visual intrusion likely to be considered unacceptable, particularly since it would be clearly visible above the falls from the Heemskirk Road to the north (which is a major tourist route).

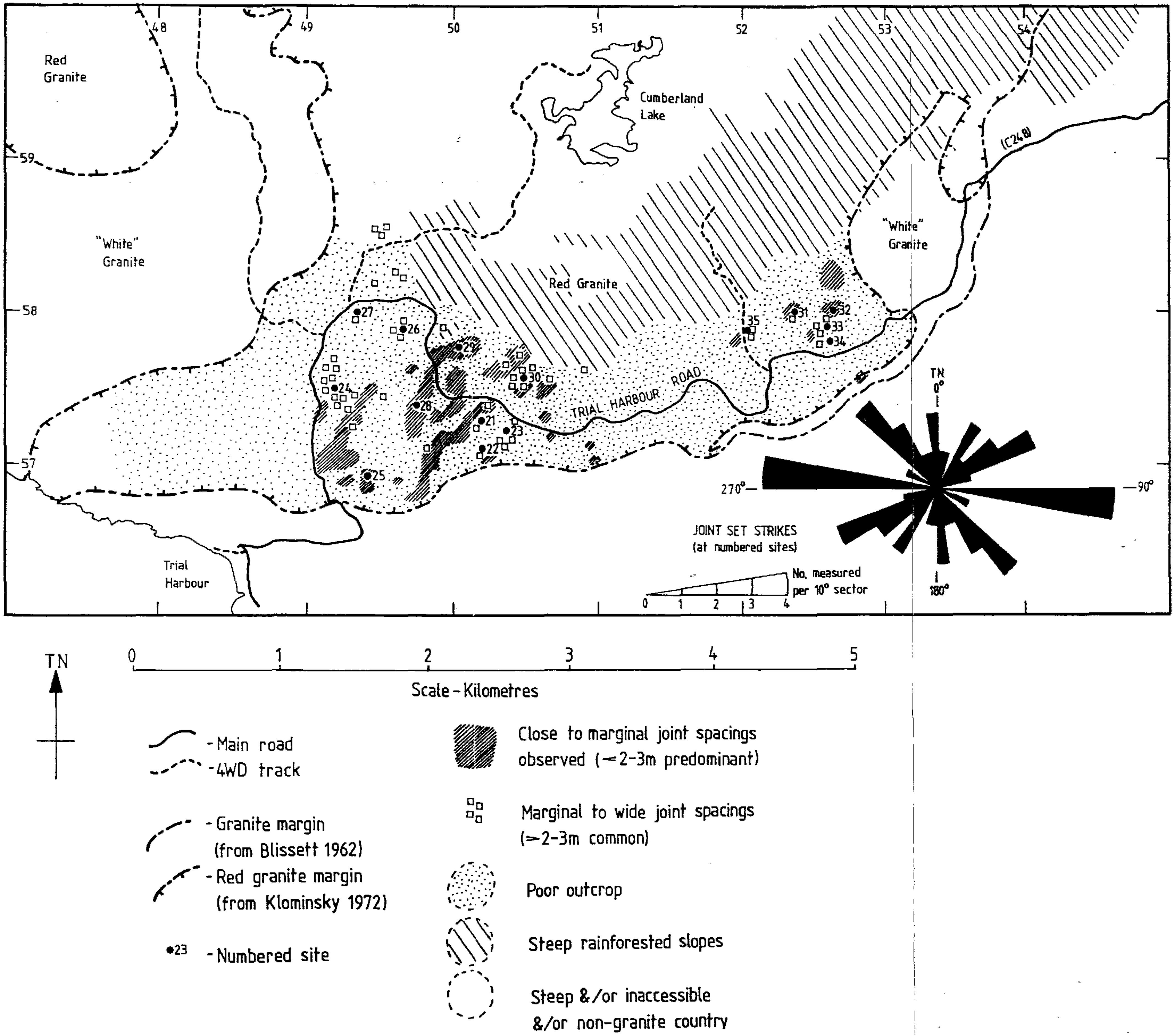
(5.2) Southern area

The portion of the southern Heemskirk Red Granite which is potentially available for granite quarrying is constrained by a number of factors to a relatively narrow strip of land either side of the Trial Harbour Road (see Map 4).

To the south of the road, the available area is delimited by the southern boundary of the granite body. North of the road, steep rainforested slopes are unsuitable because of both their steepness (difficult access and difficult quarry sites) and because of environmental considerations (rainforest is considered to have high conservation value and any mining or quarrying activities within it will in future be subject to the most stringent conditions). Further north, in the Cumberland Lake region, access is via a steep and currently almost impassable 4WD track.

Despite these constraints, the area of available ground straddling the Trial Harbour Road has, on the basis of the current investigations, high potential for acceptable red granite quarry sites.

The area largely comprises gentle rolling ridges and low hills with shallow gravelly soils supporting low buttongrass moor vegetation. Access to most points can be easily



Map 4: The southern Heemskirk Red Granite; geological observations and locations of sites examined. The Rose diagram indicates the strikes (trends) of parallel linear joint sets measured at the numbered sites examined.

obtained by short, dry ridgetop routes, and the gently-angled topography provides numerous workable potential quarry sites. Bold granite bedrock outcrops are common over about half of the available area, permitting confident geological assessments to be made.

The entire available area was examined in detail on foot, and fifteen sites were described (Sites 21 - 35, in Appendix One).

In contrast to the northern area, the character of the granite is relatively uniform throughout the southern area, being a medium to coarse grained, equi-granular and massively (uniformly) structured rock of dark red colour with a slight greenish tinge resulting from the presence of minor pale green feldspars.

Most of the area is entirely free of quartz/black tourmaline nodules and veins, although these are sparsely present at the eastern end of the area (in the area of sites 31 - 35). Minor aplite (fine-grained granite) intrusions (dykes) occur throughout the region, but are not sufficiently abundant as to cause a significant quarrying problem.

Although a large zone having predominantly closely-spaced joints occurs in a belt trending south-west to north-east from around Site 25 to Site 29 (see Map 4), areas of outcrop having predominantly widely-spaced (>2-3m) jointing fractures are common, giving good potential for quarry sites with minimal wastage resulting from closely fractured stone.

On the basis of field observations, six sites (no.s 22/23, 24, 26, 30, 33/34 and 35) were initially identified as the most promising potential quarry sites in the available area. At these sites (and for comparision, at a number of clearly inferior sites), jointing measurements were taken, and samples collected for further study. For further comparision, measurements and samples were also taken at the existing quarry (Site 21).

The analysis of these measurements and samples has allowed the prospective quarry sites to be narrowed down to a suite of four most promising sites. The analysis, and discussion of the sites, is detailed in the following Section (6.0).

(6.0) EVALUATION OF POTENTIAL QUARRY SITES

This section outlines the data analysis which was used to identify the most promising quarry sites in the southern Heemskirk Red Granite, and then gives a description and discussion of the four sites determined to be most promising.

(6.1) Joint fracture analysis

For the purpose of being able to statistically characterise the joint spacings found at each potential quarry site, actual joint spacings were measured according to the method described in Appendix Two. These measurements were carried out at sites considered promising on the basis of field observations (22/23, 24, 26, 30, 33, 35), at the existing quarry (21), and at two sites considered in the field to be unpromising (25, 29). The field measurements are recorded in Appendix Two.

The measurements obtained were used to calculate average joint spacings at each site, the percentage of stone at each site which is present in unflawed blocks of dimensions greater than 2 x 3 metres, the number of unflawed 2 x 3 m blocks which could be quarried from the sampled area at each site, and the percentage of wasted stone which would be left after the quarrying of such blocks. The results of these calculations are tabulated in Table (1) overleaf, illustrated in Figures 1, 2 & 3, and the methods of calculating them described in Appendix Two.

These calculations should be regarded as preliminary and indicative only. They are based on (in most cases) only two 20 metre traverses at each site; at a later stage of detailed quarry planning it would be desirable to run a grid of traverses over the entire quarry site at a traverse spacing of five metres or less, so as to obtain very detailed and accurate jointing data.

Furthermore, the calculations assume that only unflawed blocks having horizontal dimensions of 2 x 3 metres will be usable; in reality many somewhat smaller blocks will also be usable (see Section 2.0), which will result in significant reductions in the amount of wastage encountered.

The jointing calculations given here are therefore to be regarded as preliminary indications of the minimum block numbers, and maximum wastages, which are likely to be obtained at each site. As such they are a useful means of comparing the quality of different sites at this initial stage of quarry planning, but can only be considered preliminary data for the purposes of detailed quarry planning.

Bearing these points in mind, the data in Table (1) can be used to rank the sites in order of their suitability for quarrying in terms of the wastage anticipated from each site due to natural joint fractures. Minimal wastages are preferred, since all wasted stone requires time, energy and therefore financial expenditure for its separation from usable stone blocks, and also creates waste stone disposal problems.

Site No.	21	22	23	24	25	26	29	30	33	35
Perpendicular to primary joint set:										
(A) Sample traverse length (metres):	18.8	19.7	19.9	25.0	20.0	30.5	19.9	19.2	19.4	19.7
(B) Average joint spacing (= av. unflawed block size):	1.9	1.3	1.8	1.9	1.3	3.05	1.3	3.2	2.4	1.97
(C) Block widths > 2.0 m (% of sample traverse):	76.1	37.5	67.8	62.8	47.5	92.4	44.2	91.1	75.8	75.6
(D) Actual No. of unflawed 2.0 m block widths in sample traverse:	5	3	5	6	4	9	4	7	5	6
Parallel to primary joint set:										
(E) Sample traverse length (metres):	11.0	23.3	19.6	20.0	20.0	18.1	20.0	18.8	19.9	20.0
(F) Average joint spacing (= av. unflawed block size):	1.6	3.8	2.2	3.3	2.2	3.62	2.0	4.7	3.3	3.3
(G) Block lengths > 3.0 m (% of sample traverse):	0.0	77.2	35.2	67.0	60.5	73.5	65.0	100.0	67.3	56.5
(H) Actual No. of unflawed 3.0 m block lengths in sample traverse:	0	4	2	4	3	4	3	5	3	3
Wastage calculations:										
(I) No. of unflawed 2m x 3m blocks (D x H) obtainable from sample area (A x E):	0 (6*)	12	10	24	12	36	12	35	15	18
(J) Total wastage (% of sample area A x E) after winning of unflawed 2 x 3 m blocks (I):	100 (83*)	84	85	71	82	61	82	42	77	73

Table 1: Joint block sizes and wastages at evaluated sites in the southern area of the Heemskirk Red Granite (calculated on random sample traverses - see Appendix Two for field data and explanation of analysis).
* : Alternative figures calculated from field data on the basis of cutting blocks with 3m dimension perpendicular and 2m dimension parallel to primary joint set.

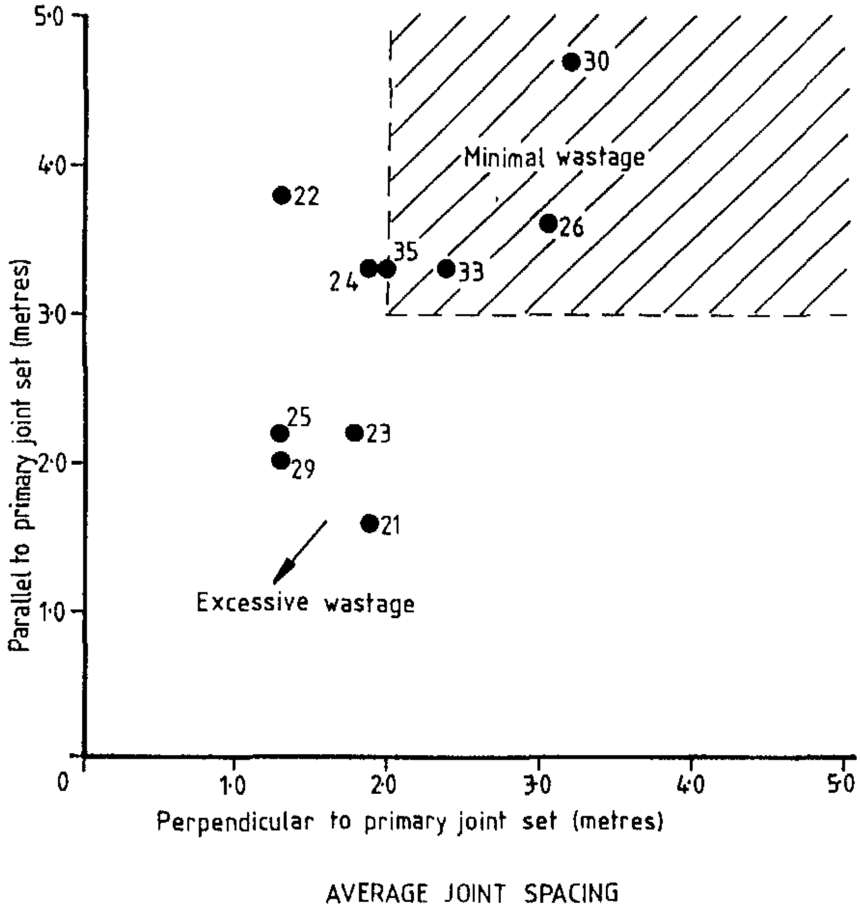


Figure 1: Average joint spacings at measured sites. The indicated "minimal wastage" field indicates sites with average joint spacings greater than the nominal required 2 x 3m block size.

On the basis of this data, the suitability of the sites measured can be ranked as follows:

Best sites: (best sites in terms of all jointing/wastage criteria)	30, 26
Moderate quality sites: (ranking between these three varies depending upon criteria used, but all three fall consistently into "next best" category)	33, 35, 24
Worst sites: (ranking between these varies depending upon criteria used, but all fall consistently into "worst" category)	21, 22, 23, 25, 29

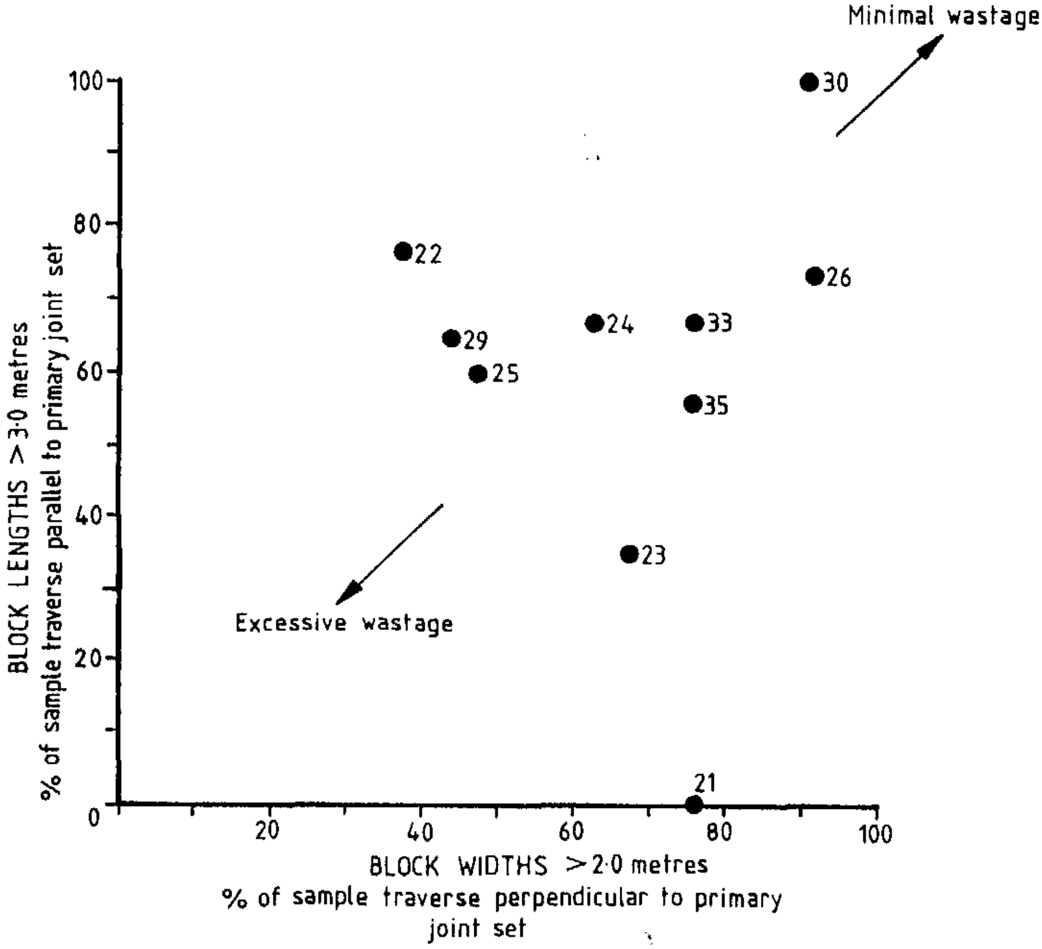


Figure 2: Percentage of sample joint traverses consisting of unflawed joint blocks of dimensions greater than the nominal required 2 x 3m block size.

As was expected from field observations, sites 25 & 29 are shown to be low quality sites having close average joint spacings and high expected wastage percentages.

The existing quarry (Site 21) also has closely spaced jointing and high potential wastage percentages compared with some of the potential quarry sites identified during this work. The fact that Site 21 has nonetheless been used successfully as an ornamental stone quarry (albeit operating only on a small scale) suggests good potential for those higher-ranking sites in the "best" and "moderate quality" categories.

Although they were thought promising in the field, sites 22 & 23 (which are close enough together to be considered a single potential quarry site) can be eliminated as prospective quarry sites on the basis of the jointing measurements. In retrospect this is perhaps not surprising since they are located close to Site 21 which has similarly close jointing and high potential wastage.

(6.2) Microfracture analysis
Microfracture intensities were measured on microscope thin sections prepared from oriented samples according to the method described in Appendix Three. This method provides a direct comparison of the amount of microfracturing found in the granite at each site.

Microfracture intensities were measured in this fashion for the six sites initially considered promising on field criteria (sites 22/23, 24, 26, 30, 33/34 & 35), and for comparison two samples were taken from the existing quarry (Site 21).

Site 21 is significant for comparison purposes as stone from this site is considered to have too high a microfracture intensity for high-stress applications such as external veneer slabs, but is acceptable for applications such as bench tops and other interior uses (J.Dunn, *pers. comm*).

At Site 21, a surface sample and a subsurface sample from 1.2 metres below the surface of the same excavated block, were taken. This allows determination of the degree of variation in microfracture intensity which may result from surface weathering. Since all samples from the other sites were taken from the surface, the site 21 data can be used to give a suggestion of the subsurface variation in microfracture intensity which can be expected at other sites.

The detailed microfracture measurements obtained are given in Appendix Three, and summarised in Table (2) below:

Site No.	**21**	**21**	**22**	**23**	**24**	**26**	**30**	**33**	**34**	**35**
Sample No.	1	2	3	4	5	6	7	8	9	10
Subsurface depth (m)	0.05	1.2	0.05	0.05	0.07	0.1	0.07	0.2	0.05	0.1
Total Micro - fracture Count	120	95	103	116	136	71	105	33	47	56

Table 2: Total microfracture count (microfracture intensity) obtained from thin sectioned samples using standard 400mm total traverse lengths for all samples.

See also Figures (3) & (4) for a graphical comparison of this microfracture data with the joint spacing and wastage data at each site.

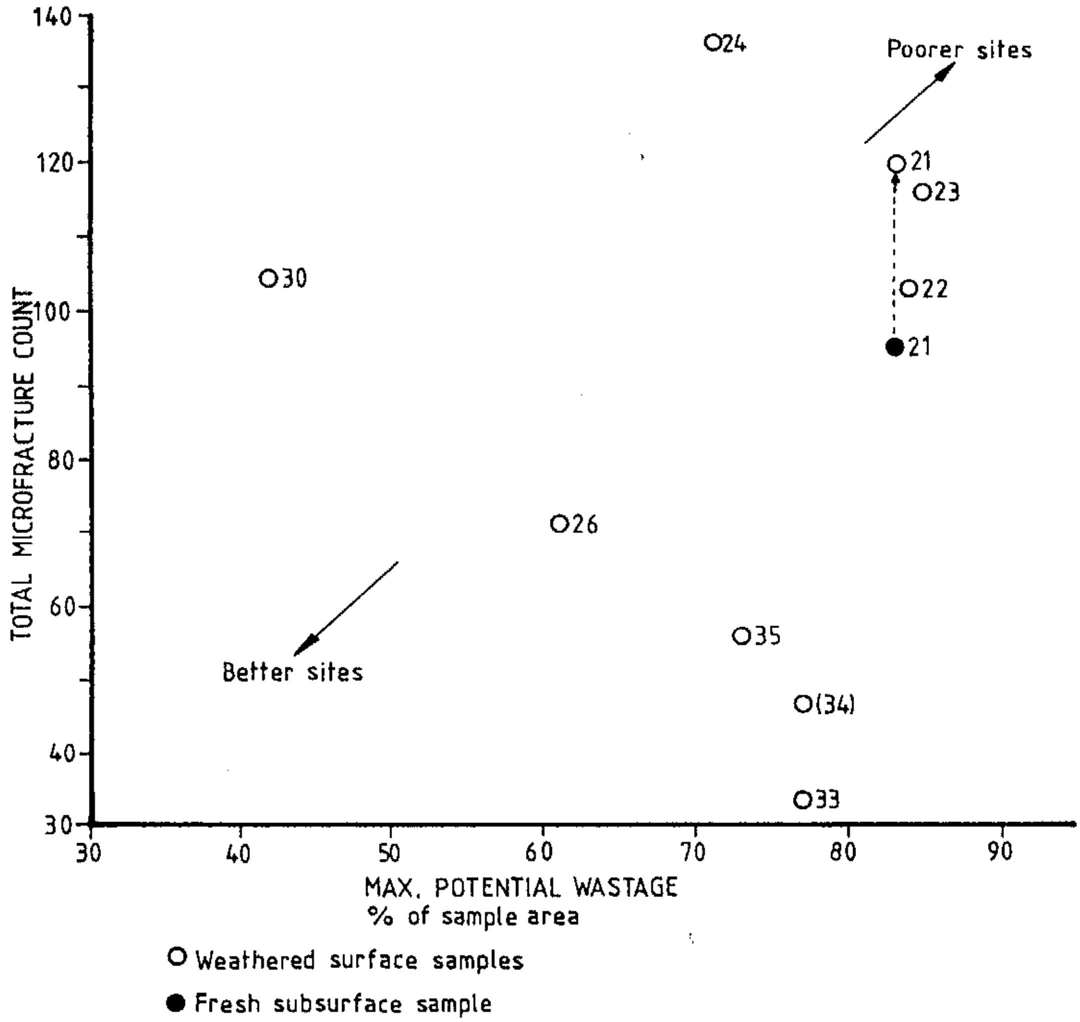


Figure 3: Comparison between total microfracture count and maximum potential wastage at existing and potential quarry sites. Maximum potential wastage is a comparitive figure only, based on using only unflawed blocks of dimensions 3 x 2 metres in the horizontal dimensions.

Based on the existing assessment that stone from Site 21 is too intensely microfractured for high-stress applications (but acceptable for low stress uses), a microfracture count of 120 for surface stone (95 for fresh subsurface stone) can be taken as a benchmark figure indicating high microfracture intensity.

On this basis, many of the potential quarry sites identified during this project contain stone of significantly better quality in terms of microfracturing.

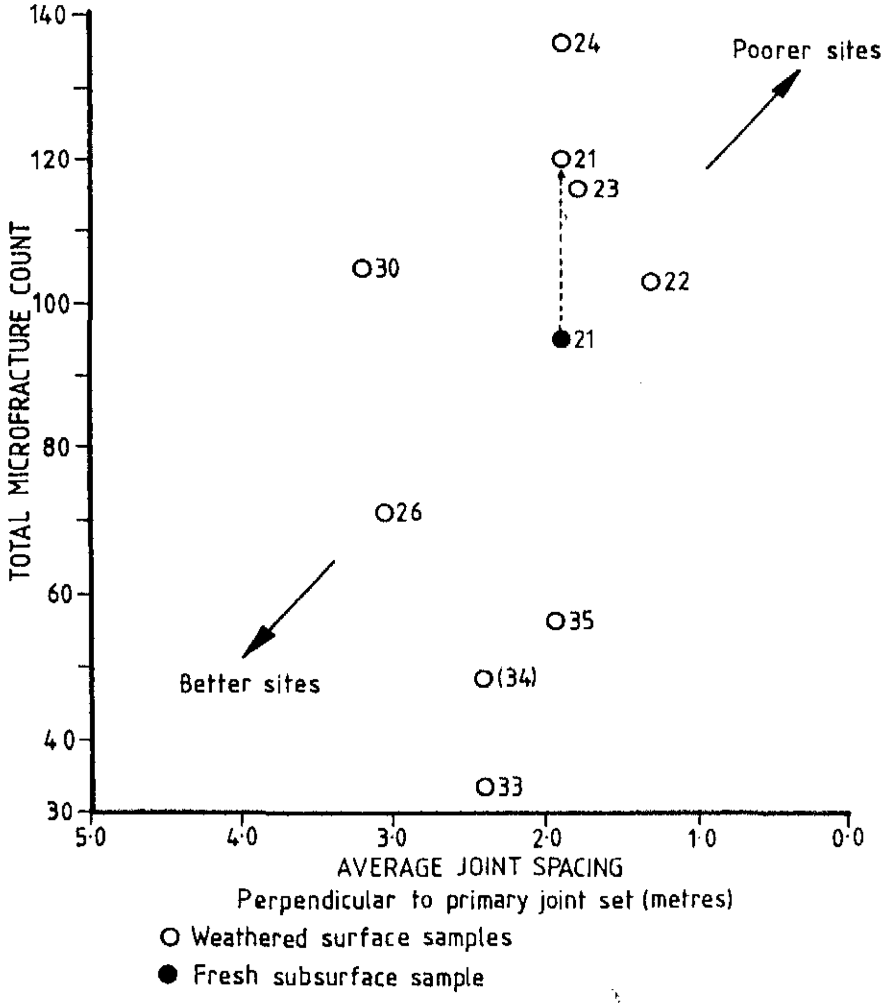


Figure 4: Relationship between total microfracture count and average spacing of joints belonging to the primary joint set at each site. Primary joint set data is used since field observations indicate that microfracturing (expressed as a "grain" in weathered outcrops) is generally parallel to, and thus likely to be genetically related to, the primary joint set.

The sites can be ranked in terms of microfracture intensity as below:

	Rank	Site No.	Microfracture Count (surface sample)
Best sites:	1	33-34	33 - 47
	2	35	56
	3	26	71
Moderate quality sites:	4	22	103
	5	30	105
Worst sites:	6	23	116
	7	21	120
	8	24	136

The adjacent sites 22/23 have been eliminated as promising quarry sites on the basis of joint spacing (Section 6.1 above), and this judgement is confirmed by their moderate to high microfracture intensities. Again, this is not surprising in view of their close proximity to Site 21.

Stone from Site 21 is now seen to be one of the most intensely microfractured samples obtained, with better sites having as little as only 25 - 50% as much microfracture intensity (Sites 33/ 34, 35). Site 26 has only 60% as much microfracturing, and can also be considered to be a much better quality site in these terms.

Although Site 24 was considered acceptable in terms of joint spacings, it has a very high microfracture intensity, and must be eliminated as a potential quarry site for that reason.

Site 30 has a surprisingly high microfracture intensity in consideration of the fact that it has the widest (best) average joint spacings. Since it's microfracture intensity is still below that of Site 21, and it's wide jointing is a major advantage, the site should still be considered a potential quarry site at this stage.

The eastern-most sites tested (33, 34, 35) have, both individually and as a group, distinctly lower microfracture intensities than all the other sites in the southern Heemskirk Red granite. These eastern sites also have moderately widely spaced jointing, suggesting that, in general, the eastern area is one which has been less affected by stresses leading to jointing and fracturing, and is thus more suitable in general for stone quarrying.

A significant observation is the fact that the microfracture count in the Site 21 samples shows a reduction from 120 microfractures in the surface sample to only 95 microfractures in the subsurface (fresh) sample. It can be anticipated that similarly reduced counts will occur in fresh subsurface granite from other sites.

It is probable that microfracture counts increase in surface (weathered) samples due to the opening of tight, incipient microfractures in response to weathering processes.

As with jointing calculations, the microfracture data has a number of limitations which should be kept in mind. In the first place, as noted above, the samples measured were obtained from surface outcrops; lower microfracture intensities can be expected in fresh subsurface stone.

Additionally, it was noted in the field that, where microfracturing is expressed in weathered outcrops as a subtle linear "grain", the grain is generally more intense immediately adjacent to major joint fractures. It is probable, therefore, that microfracture counts will vary within a site, being more intense closer to joints or within narrower joint blocks.

Factors such as these may explain the seeming anomaly of Site 30, in which a higher microfracture count was obtained than might have been expected from the wide jointing at that site.

The microfracture data presented in this report should therefore be regarded as indicative figures which are of value in preliminary assessment of potential quarry sites; more definitive data would be obtained once trial excavations have exposed fresh stone. At that stage, several fresh subsurface samples should be taken from each site, at varying measured distances from major joints, so as to provide reliable microfracturing data.

It is expected on theoretical grounds that microfracturing would be more intense in deposits having a closer average spacing of joint fractures. This is based on the assumption that jointing and microfracturing both result from the same physical stresses in the granite body, and is supported by the field observation that the microfracture "grain" commonly evident in weathered outcrops is generally parallel to the primary joint direction.

Figure (4) plots measured microfracture intensity against average joint spacing (between primary joints) for all sites where both parameters were determined. On the above theoretical grounds a neat linear distribution of data points would be expected; however, the data points show, at best, only a very vague linear trend. Data from multiple subsurface samples, as described above, would be necessary to assess whether or not a linear relationship between microfracture intensity and joint spacing actually exists.

(6.3) Promising potential quarry sites

The combination of field observations, statistical joint spacing data and microfracture intensity measurements can now be used to select and rank the most promising quarry sites for further evaluation and development, as below (see also Map 5):

	Rank	Site No.	
Potential quarry sites	1	26	This site has the best balance between wide joint spacings and moderate microfracture count. Free of black tourmaline nodules and veins.
	2	33/34	Adjacent sites best considered as a single potential quarry site. Excellent (low) microfracture counts; joint spacings adequately wide but not as good as Sites 26 & 30. Sparse black tourmaline nodules and veins present.
	3	35	Smaller outcrop than Site 33/34, but otherwise a site of similar quality: Low microfracture count; joint spacings adequately wide but not as good as Sites 26 & 30. Sparse black tourmaline nodules and veins present.
	4	30	Excellent wide joint spacings; microfracture count moderately high but still favourable compared to Site 21, and possibly due to anomalous sample (see Section 6.2). Better microfracture counts in further samples would elevate this site to rank 1 or 2. Free of black tourmaline nodules and veins.
Unsuitable sites		22/23	Close jointing, intense microfracturing.
		24	Excessive microfracturing, marginal joint spacings.
		21	As for site 22/23; existing quarry.

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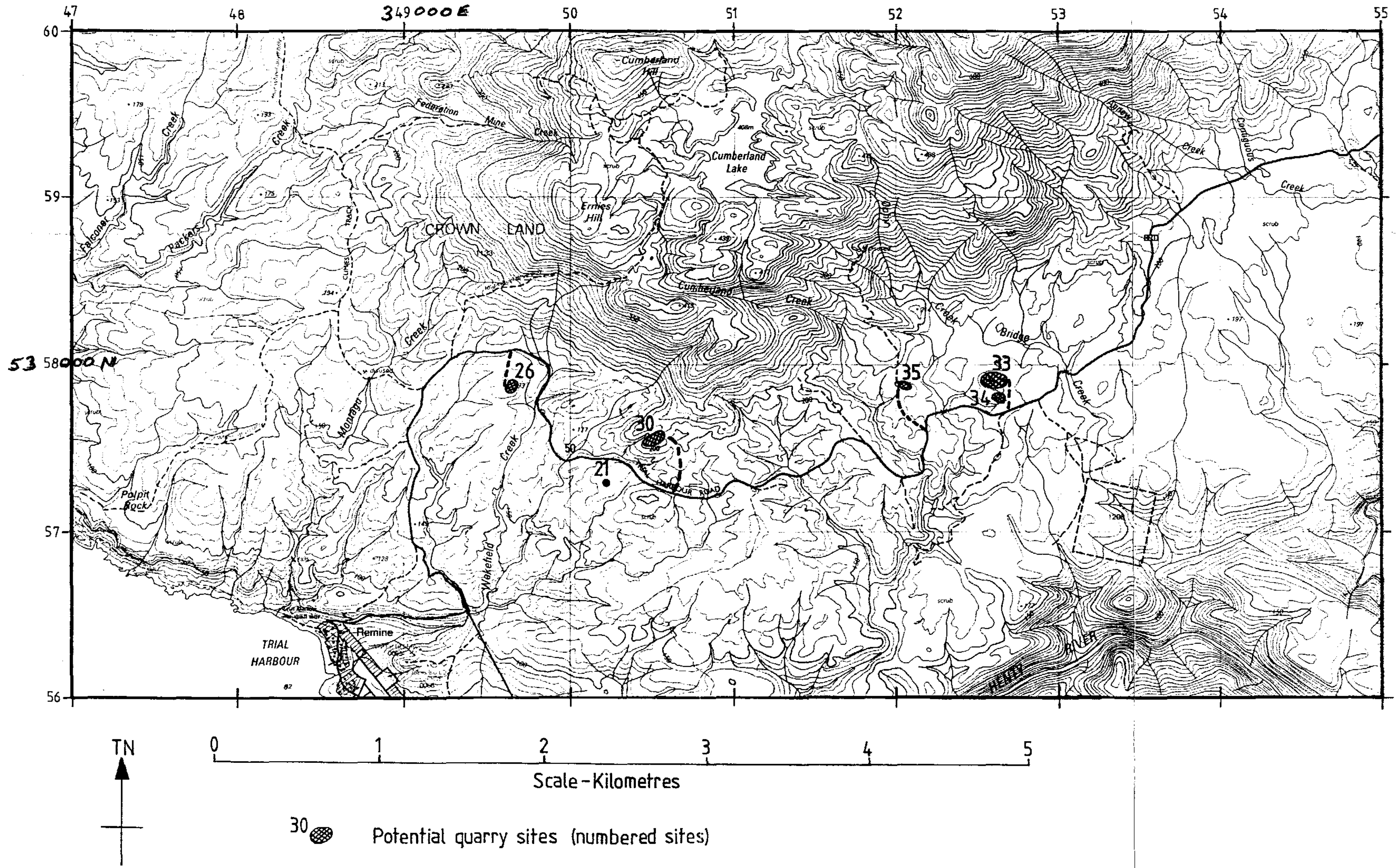

AMG REFERENCE POINTS ADDED

5 cm

Map 5: Potential red granite quarry sites in the southern Heemskirk Red Granite. The cross-hatching indicates the approximate outcrop area, but potential reserves probably cover a greater area.

The four potential quarry sites are shown on Map (5), and details of each site are given below (see also Appendices One to Three). The format for each site description is as follows:

AMG Grid Reference
Grid co-ordinates of each site are given according to the Universal Transverse Mercator Grid, Zone 55 (Australian Map Grid).

Stone character
Overall stone colour is determined on sawn and wetted sample surfaces; these give a deeper colour than dry surfaces, which is comparable to the colour of polished stone. All samples are surface samples (see Appendix One), and so may be slightly paler than fresh subsurface stone. Colours are described both verbally and by the alpha-numeric Munsell code as used on the "Rock Color Chart" available from the Geological Society of America.

The granite texture and structure is described according to the terminology below, and the presence of features such as veins, nodules, and dykes noted (see also Appendix One).

Grainsize: (refers to average diameter of individual grains or crystals)

Pegmatitic	> 30mm
Coarse	5 - 30mm
Medium	1 - 5mm
Fine	< 1mm

Equi-granular:	All grains of similar uniform size.
Porphyritic:	Large crystals (phenocrysts) set in a groundmass of smaller grains.
Massive:	Uniform colour and texture throughout granite mass, no banding or other textural variations.
Dyke:	Late stage intrusion of differing granite magma (generally aplite:- fine-grained granite).
Vein:	Mineral deposit formed by precipitation along a fracture.
Xenolith:	Fragment of country rock entrained within the granite magma.

Jointing
The strike (or trend) direction of each significant parallel linear joint fracture set is given. These directions are significant since the most efficient quarry operation will involve developing benches and faces in such a fashion as to use the natural joint fractures to assist in removal of stone blocks. Average joint spacings parallel and perpendicular to the primary joint set are given (as per Appendix Two and Table One).

Microfracturing
The total microfracture count, determined by the method described in Appendix Three, for a surface sample from each site is given. The figures, and constraints on their validity, are as discussed in Section (6.2) and Appendix Three.

Site description and workability
The topography of each site is briefly noted, and preliminary observations as to appropriate means of quarry development made.

Reserves and wastage
A preliminary reserves and wastage figure for each site is calculated as follows:

1) A nominal size for the ultimate (exhausted) quarry pit at each site is estimated using the 1:25,000 topographic map together with field observations. This pit size is purely nominal, and could theoretically be increased with a deeper or more extensive pit. A nominal ultimate reserves figure (good blocks plus wastage) is calculated from this pit size. The ultimate reserves are quoted in cubic metres (m^3) and in tonnes.

   The tonnage figure is calculated on the basis of a typical dry granite density of 2.64 tonnes per m^3 (Berkman 1989, p.316). Although the densities of samples from the Heemskirk Granite have not been measured during the present work, this typical figure is adequate for these preliminary calculations.

   On this figure, a nominal 3 x 2 x 1 metre (6 m^3) granite block will weigh 15.84 tonnes.

2) The maximum potential wastage for each site given in Table (1) is then used to calculate the maximum wastage, yielding a figure for the minimum reserves of unflawed 3 x 2 x 1 metre blocks obtainable (ultimate reserves minus maximum potential wastage).

   This figure is then used to calculate the potential lifetime of the quarry on the nominal basis of extracting 30,000 m^3 per annum of unflawed 3 x 2 x 1 m blocks.

   Quarry lifetime would be extended by planning for a larger or deeper pit than the nominal size used for this calculation, by extracting smaller annual quantities of stone, or alternatively by planning for concurrent working of all four quarry sites for a combined annual output of 30,000 m^3. In the latter case, the lifetime of each quarry would be approximately four times the figure quoted.

   It is important to note, as is discussed in Section (6.1) and Appendix Two, that the potential wastage and consequent minimum reserves quoted are extreme figures based on only preliminary joint measurements and the assumption that only 3 x 2 x 1 m blocks can be used. With more detailed joint traverses (as described in Section 8.0), and with the utilisation of smaller blocks, smaller wastages and greater minimum reserves can be anticipated.

Access
The most appropriate access route to each potential quarry site is discussed.

Environmental considerations
A preliminary discussion of potential environmental problems for each site, and means of dealing with them, is given.

Prior to full quarry development it will be necessary to survey and sample sites in detail, as described in Section (8.0), so as to obtain more reliable data than is available at the present initial stage of potential quarry site exploration and identification.

Site 26

AMG Grid Reference
CP49625787

Stone character
Moderate Red (5 R 5/4)
Medium to coarse grained, equi-granular, massive.
No tourmaline nodules or veins, no xenoliths.
Linear white quartz veins 5-15mm wide present, striking 110° T and spaced 1.0 - 8.0 metres apart are present, as are very minor aplite dykes up to 0.5m wide. Both will result in minor additional wastage.

Jointing
Primary Joint set: Strikes 65°T, subvertical.
Set 2: Strikes 165°T, subvertical.

Av. Joint spacings:
Perpendicular to Primary Joint Set: 3.05 metres
Parallel to Primary Joint Set: 3.62 metres

Microfracturing
Sample 6 total count: 71

No microfracturing "grain" evident in outcrops.

Site description and workability
Large low slabs on and near crest of an easy-angled ridge. Quarry faces can easily be commenced on the western side of the ridge crest, and can be developed into long broad benches due to the low angle of the ridge slopes.

Reserves and wastage
Nominal ultimate pit size: 100m x 200m x 20m deep
Thus, Volume = 400,000 m^3
Tonnage = 1,056,000 tonnes

Maximum Potential Wastage (Table 1): 61%

Thus, = 244,000 m^3 wastage (max.)

= 156,000 m^3 (411,840 tonnes) of good unflawed 3 x 2 x 1 m blocks (min.)

At 30,000 m^3 per annum extraction of good blocks:

156,000/30,000

= 5.2 year quarry lifetime (min.)

At 30,000 m^3 per annum extraction of total stone (good blocks + wastage):

400,000/30,000

= 13.3 years quarry lifetime (min.)

Access

Good dry solid-based access route available by approaching site directly up ridge from Trial Harbour Road 200 metres to the north.

Environmental considerations

Vegetation is low buttongrass moorland species; the presence of rare or endangered plant or animal species is not expected, although this should be checked.

Soils are shallow and disturbance should be avoided except where necessary for quarrying operations. Stripped soil and waste stone should be separately stockpiled up or along slope from workings in suitable locations to facilitate progressive rehabilitation of worked out sections of the quarry, in accordance with a long term quarry management plan.

Suitable drainage and sediment traps (small dams) should be planned as part of a long term quarry management plan, and constructed to control soil erosion, runoff, and siltation of adjacent creeks.

The site is exposed and highly visible, particularly from the Trial Harbour Road to the west. Careful siting of grassed over soil stockpiles, and some planting of local tree and shrub species may mitigate visual impact, but some aesthetic impact is unavoidable.

Noise and dust emissions are unlikely to be a significant problem in this relatively remote location.

Site 30

AMG Grid Reference
CP50525757

Stone character

Moderate red, similar to Site 26 or possibly very slightly darker red (5 R 5/4 to 5 R 4/6). Medium to coarse grained, equi-granular, massive.
No tourmaline nodules or veins, no other veins or xenoliths, minor aplite dykes < 0.5m wide only sparsely present.

Jointing

Primary Joint set: Strikes 155°T, subvertical.
Set 2: Strikes 70°T, subvertical.

Av. Joint spacings:
Perpendicular to Primary Joint Set: 3.20 metres
Parallel to Primary Joint Set: 4.70 metres

Microfracturing

Sample 7 total count: 105

As discussed in Section (6.2) above, this microfracture count seems anomalously high considering the wide jointing at this site, and further sampling may yield lower figures. Microfracturing "grain" is evident in outcrops parallel to primary joint set close to some joints, but is not evident in the middle part of large joint blocks.

Site description and workability

Large low slabs on and near crest of an easy-angled north-east trending ridge. Quarry faces can easily be commenced at the north-eastern side of the ridge crest, and can be developed into long broad benches due to the long, fairly flat, nature of the ridge top.

Reserves and wastage

Nominal ultimate pit size: 100m x 250m x 20m deep

Thus, Volume = 500,000 m^3
Tonnage = 1,320,000 tonnes

Maximum Potential Wastage (Table 1): 42 %

Thus, = 210,000 m^3 wastage (max.)
= 290,000 m^3 (765,600 tonnes) of good unflawed 3 x 2 x 1 m blocks (min.)

At 30,000 m^3 per annum extraction of good blocks:
290,000/30,000
= 9.7 year quarry lifetime (min.)

At 30,000 m^3 per annum extraction of total stone (good blocks + wastage):
500,000/30,000
= 16.7 years quarry lifetime (min.)

<u>Access</u>
As shown on Map 5, the best access appears to be a 350 metre route following a dry easy-angled ridge northwards from the Trial Harbour Road, and then crossing a small gully to reach the quarry site. Some work would be required to stabilise the gully crossing, and to provide drainage under the access track at this point.

<u>Environmental considerations</u>
Vegetation is low buttongrass moorland species; the presence of rare or endangered plant or animal species is not expected, although this should be checked.

Soils are shallow and disturbance should be avoided except where necessary for quarrying operations. Stripped soil and waste stone should be separately stockpiled up or along slope from workings in suitable locations to facilitate progressive rehabilitation of worked out sections of the quarry, in accordance with a long term quarry management plan.

Soil stockpiles planted with grasses and local shrubs on the southern side of the ridge crest may be the most effective means of both screening the workings from view and facilitating eventual rehabilitation.

Suitable drainage and sediment traps (small dams) should be planned as part of a long term quarry management plan, and constructed to control soil erosion, runoff, and siltation of adjacent creeks.

If quarry development commences at the north-east end of the ridge, and the larger faces are designed to face north and north-east (ie, working into the ridge from the northern or north-eastern side), then the quarry workings will be largely hidden from the Trial Harbour Road and most other major vantage points. Careful siting of grassed over soil stockpiles, and some planting of local tree and shrub species may be appropriate along the southern side of the ridge crest to mitigate visual impact from the Trial Harbour Road to the south.

Noise and dust emissions are unlikely to be a significant problem in this relatively remote location.

Site 33/34
These two adjacent sites are sufficiently close to be considered a single quarry site.

AMG Grid Reference
Site 33: CP52615791
Site 34: CP52625779

Stone character
Moderate red (5 R 5/4) at Site 33, to a distinctly darker moderate red (5 R 4/6) at Site 34. Medium to coarse grained, equi-granular, massive.
Quartz/black tourmaline nodules 10 - 25mm diameter sparsely present in over 50% of site (absent in some patches up to 10 x 10 metres size). Parallel linear quartz/black tourmaline veins 5 - 10mm thick are present, spaced from 0.1 to 10.0 metres or more apart, striking 55°T and dipping about 80° towards the NW.
The tourmaline nodules do not affect the technical quality of the stone, but are an aesthetic consideration. They will be acceptable for some uses or to some clients, but possibly not to others.
Minor aplite dykes up to 2.0 metres wide and containing abundant tourmaline nodules are sparsely present, and will constitute minor additional wastage. Xenoliths are absent.

Jointing

Primary Joint set:	Strikes 95°T, subvertical.
Set 2:	Strikes 55°T, subvertical. (commonly infilled by tourmaline veins)

Av. Joint spacings:

Perpendicular to Primary Joint Set:	2.4 metres
Parallel to Primary Joint Set:	3.3 metres

Microfracturing
Sample 8 total count: 33
Sample 9 total count: 47

Microfracturing "grain" is not evident in outcrops.

Site description and workability
Site 33 consists of abundant bold slabby outcrops on a small isolated hill approximately 120 metres diameter. The entire hill could be worked, starting with easy benches on easy angled ground near the top of the hill. By starting on the northern side of the hill, visibility from the Trial Harbour Road will be minimised.

Site 34 is a small isolated outcrop on easy-angled ground close to the Trial Harbour Road. A face and bench could easily be commenced on the outcrop, and worked northwards for a considerable distance.

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Reserves and wastage

Nominal ultimate pit size: 120 m x 220m x 20m deep

Thus, Volume = 528,000 m^3
Tonnage = 1,393,920 tonnes

Maximum Potential Wastage (Table 1): 77 %

Thus, = 406,560 m^3 wastage (max.)
= 121,440 m^3 (320,601 tonnes) of good unflawed 3 x 2 x 1 m blocks (min.)

At 30,000 m^3 per annum extraction of good blocks:
121,440/30,000
= 4.0 year quarry lifetime (min.)

At 30,000 m^3 per annum extraction of total stone (good blocks + wastage):
528,000/30,000
= 17.6 years quarry lifetime (min.)

Access

Access to Site 33 can easily be obtained by a 150 metre dry route extending directly north off the Trial Harbour Road along the crest of a slight rise.

Environmental considerations

Vegetation is low buttongrass moorland species; the presence of rare or endangered plant or animal species is not expected, although this should be checked.

Soils are shallow and disturbance should be avoided except where necessary for quarrying operations. Stripped soil and waste stone should be separately stockpiled in suitable locations to facilitate progressive rehabilitation of worked out sections of the quarry, in accordance with a long term quarry management plan.

Soil stockpiles planted with grasses and local shrubs may be the most effective means of both screening the workings from view and facilitating eventual rehabilitation.

Suitable drainage and sediment traps (small dams) should be planned as part of a long term quarry management plan, and constructed to control soil erosion, runoff, and siltation of adjacent creeks. Particular attention should be paid to the small creek draining off the northern side of Site 33.

If quarry development commences on the northern side of the hill, and the faces are worked southwards into the hill, then the quarry workings will be largely hidden from the Trial Harbour Road and most other major vantage points. Careful siting of grassed over soil stockpiles, and some planting of local tree and shrub species may be appropriate to mitigate visual impact from the Trial Harbour Road to the south and east.

Noise and dust emissions are unlikely to be a significant problem in this relatively remote location.

Site 35

AMG Grid Reference

CP52305787

Stone character

Moderate red (5 R 5/4), similar to Site 33.

Medium to coarse grained, equi-granular, massive

Quartz/black tourmaline nodules av. 10mm diameter sparsely present (less abundant than at Site 33). The tourmaline nodules do not affect the technical quality of the stone, but are an aesthetic consideration. They will be acceptable for some uses or to some clients, but possibly not to others.

No tourmaline veins, other veins, or xenoliths. No aplite dykes evident.

Jointing

Primary Joint set: Strikes 140°T, subvertical.

Set 2: Strikes 60°T, subvertical.

Av. Joint spacings:

Perpendicular to Primary Joint Set: 1.97 metres

Parallel to Primary Joint Set: 3.3 metres

Microfracturing

Sample 10 total count: 56

No microfracturing "grain" evident in outcrops, except in a few narrow zones.

Site description and workability

Large knobs and slabs on a low easy-angled knoll and ridgetop. Wide benches can easily be worked westwards along and into this ridge.

Reserves and wastage

Nominal ultimate pit size: 100m x 200m x 20m deep

Thus, Volume = 400,000 m^3

Tonnage = 1,056,000 tonnes

Maximum Potential Wastage (Table 1): 73 %

Thus, = 292,000 m^3 wastage (max.)

= 108,000 m^3 (285,120 tonnes) of good unflawed 3 x 2 x 1 m blocks (min.)

At 30,000 m^3 per annum extraction of good blocks:

108,000/30,000

= 3.6 year quarry lifetime (min.)

At 30,000 m^3 per annum extraction of total stone (good blocks + wastage):

400,000/30,000

= 13.3 years quarry lifetime (min.)

Access
An existing 400 metre 4wd track provides access to the site from the Trial Harbour Road to the south. Two or three boggy patches will require stabilising and drainage, but most of the track is dry and follows the crest of a low rise.

Environmental considerations
Vegetation is low buttongrass moorland species; the presence of rare or endangered plant or animal species is not expected, although this should be checked.

Soils are shallow and disturbance should be avoided except where necessary for quarrying operations. Stripped soil and waste stone should be separately stockpiled in suitable locations to facilitate progressive rehabilitation of worked out sections of the quarry, in accordance with a long term quarry management plan.

Suitable drainage and sediment traps (small dams) should be planned as part of a long term quarry management plan, and constructed to control soil erosion, runoff, and siltation of adjacent creeks.

The quarry site is easily visible from the Trial Harbour Road to the south and east, and it will not be possible to entirely conceal quarry operations from view. However, careful siting of grassed over soil stockpiles, and some planting of local tree and shrub species may mitigate visual impact.

Noise and dust emissions are unlikely to be a significant problem in this relatively remote location.

(7.0) CONCLUSIONS AND RECOMMENDATIONS

Field investigations have established that a large area of aesthetically attractive dark red, uniformly structured and evenly textured granite of medium to coarse grainsize exists in the Heemskirk Red granite.

However, feasible access is currently only available to relatively small proportions of the total granite area, specifically the northern and southern parts of the red granite. Within these areas, granite quality in terms of joint fracture spacing and microfracturing intensity varies considerably, with stone of both better and worse quality than the existing Trial Harbour Granite Quarry (Site 21) being present at various locations. There is also some evidence that micro-fracture intensities are somewhat variable within sites as well as between them. Access and site workability also varies considerably, from very difficult sites to easily accessible and workable sites.

The entire northern area of the red granite has been rejected as a potential ornamental granite resource due to generally close joint fracture spacings over most of the area, and poor access and site workability at the best (albeit still marginal) sites identified.

In contrast, significant resources of widely jointed red granite having moderate to low micro-fracture intensities have been identified in the southern area. From these promising granite areas, four sites having good access and easily workable topography have been selected as promising potential red granite quarry sites.

These sites are those numbered 26 and 30, which have a uniformly textured and structured red granite, and sites 33/34 and 35, which have a similar stone with the addition of a minor content of quartz/black tourmaline nodules. The tourmaline nodules are not considered detrimental to technical stone quality, but are a feature which may or may not be considered aesthetically acceptable in particular applications or by particular clients.

The work conducted has been sufficiently detailed to establish these sites as being the best available in the relatively limited area to which reasonable access is possible. On the basis of technical data available to date, all four of these sites are of considerably better quality, in terms of joint fracture spacing and microfracture intensity, than the existing quarry (Site 21).

It is recommended that further development and evaluation work, as described in Section (8.0) below, be concentrated on these four sites.

(8.0) FURTHER WORK

In addition to legal requirements including the pegging of stone leases, the detailed evaluation and development of each potential quarry site requires the following works to be undertaken:

Access preparation
Access routes, probably those described in Section (6.3), must be prepared for heavy machinery.

Sub-surface sampling and detailed evaluation
It is necessary to obtain fresh granite samples from at least 1.0 metre below the natural outcrop surface. Cored drilling could be considered, but trial excavation is probably a more practical alternative in this case since bulk samples will be required for prospective buyers.

Excavated faces will also allow further assessment of fresh stone colour, structure, texture, and presence of other features such as veins, aplite dykes and tourmaline nodules. Insofar as natural and excavated faces allow, the distribution and concentrations of such features should be mapped to assist in quarry development planning.

In order to allow more rigorous wastage calculations to be made, joint spacing measurements should be determined along as many traverses of both natural and excavated rock surfaces as possible, in a fashion similar to that described in Appendix Two. Ideally, a grid pattern of traverse lines, with a line spacing of 5 metres, should be run over the entire area of the potential granite resource.

Bulk block samples will be required by prospective clients so that they can test-process the granite with their own facilities. Sample polished slabs will allow determination of ability to take a polish.

The following tests and determinations should be made on fresh samples obtained from subsurface excavations:

<u>Mineralogy and alteration</u>: The mineralogical composition of thin sectioned specimens should be determined by microscopic point count. Particular attention should be paid to assessing the degree of clay alteration present, and the presence of unstable minerals such as those listed in Section (2.0).

<u>Microfracture intensity determination</u>: Microfracture counts should be performed as described in Appendix Three. As noted elsewhere in this report, it is expected that subsurface counts will be less than those obtained for surface samples.

Several samples should be tested at each site, at different measured subsurface depths and distances from major joint fractures, in order to test the possibility that microfracture intensities decrease away from joints and below the natural outcrop surface.

Other laboratory tests: Granites having good mineralogies and low microfracture counts can often be marketed without further laboratory tests. However, prospective clients may require test data on the strength, porosity, abrasion resistance, dimensional stability or other technical characteristics of the stone (see Section 2.0).

The facilities to perform some of these tests are not available in Tasmania, so that if they are required it may be necessary to submit subsurface samples to a specialist mainland laboratory. One suitable laboratory which specialises in building stone testing is:

AMDEL Limited
P.O. Box 114
Eastwood
South Australia 5063
Phone (08) 372 2700
Telex AA82520
Fax (08) 79 6623

Based on information obtained from trial excavations, combined with market research and the collection of buyers technical specifications of granite quality required (particularly in respect of acceptable microfracturing intensities), it will be possible to assess potential markets and suitable applications for the available stone.

Quarry development planning

Prior to full quarry development each site should be surveyed and a detailed quarry development plan drawn up which takes into account topography, jointing directions, any variations in stone quality determined in the detailed assessments outlined above, and environmental considerations.

At Sites 33/34 and 35, mapping the concentration of quartz/black tourmaline nodules, including defining areas free of them, will allow planning of quarry development for the extraction of quantities of both nodule-free and nodule-bearing stone.

The location and orientation of quarry faces and benches should be planned to make maximum use of natural joint fracture sets in the extraction of stone blocks.

Alternative quarry development plans should be considered to determine which are the most efficient and have the least environmental impact.

More accurate reserve and wastage calculations will be possible using detailed data obtained during the grid traverses proposed above. Long term planning using detailed jointing data will enable planning for the most efficient quarry development so that both widely and closer jointed zones in the quarry can be utilised in the most efficient sequence to maintain desired production levels

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Environmental Impact Assessment and Management Planning

Prior to full quarry development a detailed Environmental Impact Statement should be drawn up, and a management plan incorporated into the quarry development plan in order to cope with potential impacts.

Such management will need to include drainage and sediment traps (dams) to control erosion, runoff and siltation of local watercourses.

Planning for eventual rehabilitation of progressively worked out parts of the quarry should be made, and soil and waste rock stockpiles sited to allow easy backfilling during rehabilitation.

A visual impact survey should be made to determine vantage points from which each quarry would be visible. Careful siting of grassed over soil stockpiles, and some planting of local tree and shrub species may mitigate visual impact if suitably located to obscure the quarry from these identified vantage points.

Noise and dust emissions will probably not be a major problem, but should be assessed.

A brief consultation with a suitably qualified biologist should be made to ascertain whether any rare or endangered plant or animal species are present at the potential quarry sites; this seems unlikely, but if it were the case action to protect them would need to be taken. The same biologist should also determine whether any plant diseases (eg. *Phytopthora cinnamoni*) are present or at risk of being introduced. Buttongrass areas are known to be susceptible to the spread of *Phytopthora*.

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REFERENCES

Baker, R.T., 1915: Building and Ornamental Stones of Australia. Technical Education Series, No. 20, Technological Museum, Sydney.

Berkman, D.A., 1989: Field Geologists Manual. Aust. Inst. Min. Met., 3rd Edition.

Blissett, A.H., 1962: Zeehan. Geol. Atlas Sheet No. 50, 1:63,360, Geol. Surv., Tas. Dept. Mines.

Burrett, C.F., & Martin, E.L., (*Eds*), 1989: Geology and Mineral Resources of Tasmania. Special Publication 15, Geol. Soc. Aust. Inc.

Klominsky, J., 1972: The Heemskirk Granite massif, Western Tasmania - a study of chemical variability in plutonic rocks. Ph. D. Thesis, Uni. of Tas. (Unpubl.).

Ray, H.N., 1988: Dimension Stone in New South Wales. Geol. Surv. N.S.W., Dept. Miner. Resour., Rept. No. GS 1988/102, Dec. 1986 with minor updating May 1988

Sharples, C., 1990: The Building and Ornamental Stone Resources of Tasmania. Report Prep. for the Tasmanian Development Authority and the Tasmanian Department of Resources and Energy, April 1990, 271 p.

Spry, A.H. 1988: Building Stone Seminar (papers presented). Alan H. Spry & Associates, Adelaide, South Australia, April 18-21, 1988.

APPENDIX ONE -

FIELD SITES; BASIC DATA

Northern Area

Site 1
AMG Grid Ref.: CP48276675
Site & Outcrop description: Base of steep slope.
Site workability: Moderately easy workability.
Access: Good; close to end of good 4WD track.
Colour: Red
Texture: Fine-grained, quartz-porphyritic (phenocrysts 8-10 mm dia.)
Features/imperfections: Common quartz / black tourmaline nodules av. 50 mm dia. Joints commonly quartz-lined (ie, veins), av. 10mm wide.
Jointing: Closely jointed:
Primary Set: Strike 90° T, subvertical, Spacing: 50-200mm
Several sets of secondary joints.
Assessment: Unsuitable: closely jointed, abundant qtz/tour. nodules

Site 2 (Database Site No. G/Rb/2/1)
AMG Grid Ref.: CP48186657
Site & Outcrop description: On steep slope, fairly bold slabs.
Site workability: Difficult: steep slope.
Access: 600m from end of good 4WD track, up steep slope (difficult access).
Colour: Medium red
Texture: Medium to coarse grained, uniform equi-granular.
Features/imperfections: No nodules; one aplite dyke 100 mm wide.
Jointing: Marginal; generally moderately wide spacing but with some fine joint fractures inbetween. Outcrops within 100 metres have generally moderately wide joint spacings, but with some close joints (av. 1.0 m spacings).
Primary Set: Strike 345° T, subvertical, Spacing: av. 2.0 m
Set 2: Strike 300° T, subvertical, Spacing: 0.1 - 2.0m
Micro-fracturing: Not evident.
Environmental Aspects: Highly visible site; steep slope might create problems.
Assessment: Unsuitable: jointing marginal, access and site workability difficult.

Site 3
AMG Grid Ref.: CP48116651
Site & Outcrop description: On steep slope, close to Site 2.
Site workability: Difficult: steep slope.
Access: Difficult: 600m from end of 4WD track, up steep slope.
Colour: Medium red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline.
Jointing: Closely jointed.
Primary Set: Strike 330° T, subvertical, Spacing: 0.1-0.3m
Assessment: Unsuitable: difficult site and access, closely jointed.

Site 4
AMG Grid Ref.: CP48076637
Site & Outcrop description: Moderate-sized outcrops below crest of steep ridge.
Site workability: Poor; steep site.
Access: Difficult: one kilometre from end of 4WD track, 150 m vertically up steep slope.
Colour: Red
Texture: Fine grained, quartz porphyritic (phenocrysts 5-10mm dia.)
Features/imperfections: Many joints are lined with quartz/black toumaline veins; sparse tourmaline nodules present.
Jointing: Very closely jointed.
Primary Set: Strike 350° T, subvertical, Spacing: < 100mm
Variable secondary joint directions.
Assessment: Unsuitable; closely jointed, difficult access and workability.

Site 5
AMG Grid Ref.: CP48256630
Site & Outcrop description: Abundant outcrops on crest of steep ridge.
Site workability: Moderately workable.
Access: Difficult: one kilometre from end of 4WD track, 150 m vertically up steep slope.
Colour: Red
Texture: Fine to medium grained, quartz-porphyritic (phenocrysts 5-10mm dia) to equi-granular in coarser parts.
Features/imperfections: Common to sparse quartz/black tourmaline nodules, and joints often filled by quartz/black tourmaline veins.
Jointing: Closely jointed.
Primary Set: Strike 360° T, subvertical, Spacing: 0.1 - 0.8m
Set 2: Strike 70° T (variable), subvertical, Spacing: 0.2 - 1.0 m+
Assessment: Unsuitable: closely jointed, difficult access.

Site 6
AMG Grid Ref.: CP48456617
Site & Outcrop description: Outcrops on crest of steep ridge.
Site workability: Moderately workable.
Access: Difficult: one kilometre from end of 4WD track, 150 m vertically up steep slope.
Colour: Red.
Texture: Fine grained quartz-porphyritic (abundant phenocrysts 5-10mm dia.) varying to medium grained equigranular.
Features/imperfections: Sparse to common quartz/black tourmaline nodules, joints commonly filled with quartz/tourmaline veins.
Jointing: Closely jointed.
Primary Set: Strike 340° T, subvertical, Spacing: 0.1-0.5m
Set 2: Strike 80° T (variable 10-20°), subvertical, Spacing: 0.2 - 1.0 m+
Assessment: Unsuitable: closely jointed, difficult access.

Site 7
AMG Grid Ref.: CP48706580
Site & Outcrop description: 100 - 200 metre diameter area of big slabs surrounded by closely jointed outcrops. On moderate slope.
Site workability: Probably workable.
Access: Difficult: 1.5 km from end of 4WD track, via 200 m vertical climb, steep in places.
Colour: Red.
Texture: Not examined on site.
Features/imperfections: Not examined on site.
Jointing: Viewed from Site 6 only, but jointing appears moderately widely spaced.
Assessment: Unsuitable: Jointing may be marginal to adequately wide-spaced, but access is difficult.

Site 8
AMG Grid Ref.: CP47886630
Site & Outcrop description: In saddle behind top of a ridge.
Site workability: Workable.
Access: Difficult: one kilometre from end of 4WD track, 150 m vertically up steep slope.
Colour: Dark Red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No nodules or veins.
Jointing: Moderately closely jointed.

Primary Set:	Strike 320° T, subvertical, Spacing: 1.0 - 1.5m
Set 2:	Strike 70° T, subvertical, Spacing: 0.2 - 1.0m

Micro-fracturing: Faint "grain" visible parallel to primary joint set.
Assessment: Unsuitable; difficult access and close jointing.

Site 9
AMG Grid Ref.: CP47756622
Site & Outcrop description: Big 10m diameter slab on moderate slope.
Site workability: Workable
Access: Difficult: one kilometre from end of 4WD track, 150 m vertically up steep slope.
Colour: Dark Red
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No nodules, but some quartz veins with black tourmaline.
Jointing: Moderately widely spaced jointing in big slab, but surrounded by closer jointing (av. 0.5m spacing).

Primary Set:	Strike 315° T, subvertical, Spacing: 1.0 - 1.5m
Set 2:	Strike 70° T, subvertical, Spacing: 0.1 - 2.0m

Micro-fracturing: Intense parallel "grain" evident between closer joints, less evident between wider joints.
Assessment: Unsuitable; difficult access, generally close jointing.

Site 10
AMG Grid Ref.: CP47786646
Site & Outcrop description: Bold outcrop surrounded by closer jointing.
Site workability: Workable
Access: Difficult: 800 metres from end of 4WD track, 120 m vertically up steep slope.
Colour: Dark Red
Texture: Medium to coarse grained, equi-granular
Features/Imperfections: No nodules
Jointing: Moderately widely jointed outcrop surrounded by closer jointing.
Primary Set: Strike 330° T, subvertical, Spacing: 0.2 - 2.0m
Set 2: Strike 70° T, subvertical, Spacing: 0.1 - 2.0m
Micro-fracturing: "Grain" clearly evident parallel to primary joint set.
Assessment: Unsuitable; difficult access, predominantly close jointing.

Site 11
AMG Grid Ref.: CP47926667
Site & Outcrop description: Outcrops at end of minor spur on moderate slope.
Site workability: Workable.
Access: Difficult: 500 metres from end of 4WD track, 50 metres vertically up moderate slope.
Colour: Dark red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules, but common quartz/black tourmaline veins line joints.
Jointing: Generally closely jointed with some wider spacings.
Primary Set: Strike 90° T, subvertical, Spacing: 0.1 - 1.0m
Set 2: Strike 310° T, subvertical, Spacing: 0.1 - 1.0m
Micro-fracturing: Not evident
Assessment: Unsuitable; difficult access, closely jointed.

Site 12
AMG Grid Ref.: CP49076668
Site & Outcrop description: Good outcrop on low spur.
Site workability: Easily workable.
Access: Moderately difficult: 1 kilometre around side of slope from end of good 4WD track, involving crossing forested gully. Alternative 1 km access route involves crossing low boggy river flats.
Colour: Red
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No nodules.
Jointing: Closely jointed.
Primary Set: Strike 335° T, subvertical, Spacing: 0.1 - 0.5m
Set 2: Strike 90° T, subvertical, Spacing: 0.1 - 1.0m
Several other minor joint directions evident.
Micro-fracturing: Not evident.
Assessment: Unsuitable: closely jointed, difficult access.

Site 13
AMG Grid Ref.: CP49046655
Site & Outcrop description: Bold slabs at base of steep slope.
Site workability: Reasonably easy to start working, but steep slope above would create difficulties.
Access: Moderately difficult: 1 kilometre around side of slope from end of good 4WD track, involving crossing forested gully. Alternative 1 km access route involves crossing low boggy river flats.
Colour: Red.
Texture: Medium to coarse grained, equi-granular
Features/imperfections: No nodules.
Jointing: Closely jointed (despite bold appearance of slabs).

Primary Set:	Strike 340° T, subvertical, Spacing:0.1 - 1.0m+
Set 2:	Strike 100° T, subvertical, Spacing: 0.1 - 2.0m

Micro-fracturing: Possible parallel "grain" parallel to joint Set 2.
Assessment: Unsuitable; difficult access, poort site workablility, closely jointed.

Site 14
AMG Grid Ref.: CP49926720
Site & Outcrop description: Deeply weathered low-relief outcrops in 4WD track surface, on large flattish plain.
Site workability: Poor.
Access: Difficult; on very rough 4WD track, involves major crossing of Heemskirk River.
Colour: Red.
Texture: Medium grained, equi-granular.
Features/imperfections: No nodules, but quartz/black tourmaline present along some joints.
Jointing: Closely jointed.

Primary Set:	Strike 300° T, subvertical, Spacing: 0.1 - 0.3m
Set 2:	Strike 45° T, subvertical, Spacing: 0.2 - 1.0m+

Assessment: Unsuitable; difficult access, very close jointing.

Site 15
AMG Grid Ref.: CP49686670
Site & Outcrop description: Abundant outcrop on low spur above Heemskirk River.
Site workability: Workable.
Access: Difficult access via very rough 4WD track involving major crossing of Heemskirk River, then across country approx 500 metres.
Colour: Strong Red.
Texture: Medium grained, equi-granular to somewhat quartz porphyritic (quartz phenocrysts 5 - 10mm diameter in 1 - 5 mm feldspar groundmass).
Features/imperfections: Rare quartz/black tourmaline nodules (< 1 per square metre surface).
Jointing: Closely jointed.

Primary Set:	Strike 205° T, subvertical, Spacing: 0.1 - 0.4m
Set 2:	Strike 325° T, subvertical, Spacing: 0.5 - 1.0m+

Assessment: Unsuitable; difficult access and close jointing.

Site 16
AMG Grid Ref.: CP49976670
Site & Outcrop description: Good bold outcrops on small 20m high hillock above plain at end of a spur.
Site workability: Workable.
Access: Difficult access via very rough 4WD track involving major crossing of Heemskirk River, then across country approx 500 metres.
Colour: Strong red.
Texture: Medium grained, equi-granular to somewhat quartz porphyritic (quartz phenocrysts 5 - 10mm diameter in 1 - 5 mm feldspar groundmass).
Features/imperfections: Common quartz/black tourmaline nodules, and some quartz/black tourmaline veins filling some joints.
Jointing: Closely jointed.

Primary Set:	Strike 90° T, subvertical, Spacing: 0.1 - 1.0m
Set 2:	Strike 330° T, subvertical, Spacing: 1.0 - 1.5m

Several other minor joint directions.
Assessment: Unsuitable; difficult access, closely jointed.

Site 17 (Database Site No. G/Rb/2/2)
AMG Grid Ref.: CP50086658
Site & Outcrop description: Steep bold outcrops about 30m high on north side of a small spur ridge.
Site workability: Steep site but probably workable.
Access: Difficult access via very rough 4WD track involving major crossing of Heemskirk River, then across country approx 500 metres and up slope about 30 metres.
Colour: Red.
Texture: Medium - coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules, but quartz/black tourmaline veins fill some joints.
Jointing: Widely jointed in patches (2 - 3m dia. joint blocks), but mostly close jointed, and predominantly close jointed outcrops surround site within 50 metres, including on south side of spur.

Primary Set:	Strike 315° T, subvertical, Spacing: 0.1 - 3.0m+
Set 2:	Strike 70° T, subvertical, Spacing: 1.0 - 2.0m

Several other minor joint directions.
Micro-fracturing: Some "grain" indicating micro-fracturing close to joints, but not apparent within big joint blocks away from joints.
Assessment: Marginally interesting, but difficult access and wastage probably very high due to large proportion of close jointing.

From Site 17 to Site 18 (traversing up (south-east) along spur crest):
Same stone as Site 17, nodules absent to sparsely present, quartz/black tourmaline veins (in joints) present. A few minor aplite dykes 0.2 - 0.5m wide present.

Jointing variable, as at Site 17: common widely-jointed zones with 2 - 3 metre joint spacings, interspersed with common zones of 0.5 - 1.0 metre joint spacings

Site 18
AMG Grid Ref.: CP50316623
Site & Outcrop description: Good outcrops on crest of a spur ridge.
Site workability: Workable.
Access: Difficult access via very rough 4WD track involving major crossing of Heemskirk River, then across country approx 1 kilometre and up slope about 50 metres vertically.
Colour: Red (dark red feldspars and some pale green feldspars).
Texture: Medium - coarse grained, equi-granular.
Features/imperfections: Quartz/black tourmaline nodules very rare, but quartz/black tourmaline veins commonly fill joint fractures.
Jointing: Widely spaced (2 - 3 metres) joints common, but closer jointed zones also common.
Primary Set: Strike 80° T, subvertical, Spacing: 0.3 - 3.0m
Set 2: Strike 315° T, subvertical, Spacing: 0.3 - 3.0m
Assessment: Marginally interesting, but difficult access and wastage probably very high due to large proportion of close jointing.

Site 19
AMG Grid Ref.: CP50556623
Site & Outcrop description: Large outcrops on crest of spur ridge.
Site workability: Workable.
Access: Difficult access via very rough 4WD track involving major crossing of Heemskirk River, then across country approx 1 kilometre and up slope about 80 metres vertically.
Colour: Red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules, but common quartz/black tourmaline veins filling joints.
Jointing: Close jointing predominates - no big blocks as lower down spur.
Primary Set: Strike 330° T, subvertical, Spacing: 0.1 - 2.0m
Set 2: Strike 70° T, subvertical, Spacing: 0.5 - 3.0m
Other minor joint directions present.
Assessment: Unsuitable: Difficult access, close jointing.

Site 20 (Database Site No. G/Rb/2/3)
AMG Grid Ref.: CP50306530
Site & Outcrop description: Large bold slabs and cliffs 10 - 20 metres high on middle-upper north-facing slopes of a 100 metre high hill immediately above and south of Heemskirk Falls and Heemskirk River.

About 200 metres west of Site 20 across a small gully, more outcrops on a gentler slope also look widely jointed.

Site workability: Very difficult: high on steep to vertical slope, and upper 30 metres or so thick cap of closely jointed stone would first have to be removed from top of hill to allow benching to proceed.
Access: Difficult: Necessary to cross Heemskirk River (major crossing), followed by 2 kilometre traverse across rough ground.
Colour: Red.
Texture: Medium to coarse, equi-granular.
Features/imperfections: Sparse tourmaline nodules, but quartz/black tourmaline veins commonly fill joints. Aplite dykes up to ten metres or so wide are present, and some of these contain abundant quartz/black tourmaline nodules (and are very closely jointed).
Jointing: Variable - Joints spaced up to 4 metres apart produce a moderate proportion of large joint blocks, but closely jointed zones (< 1.0m spacing) are common. Top 30 metres or so of hill above bold outcrops is closely jointed.
Primary Set: Strike 90° T, subvertical, Spacing:0.1 - 3.0m
Set 2: Strike 310° T, subvertical, Spacing:0.1 - 3.0m+
Numerous other minor joint directions apparent.
Micro-fracturing: Not apparent.
Environmental Aspects: Any quarrying of this site would have major aesthetic impact on viewfield of the Heemskirk Falls viewed from the north (their best viewing direction), and would also be highly visible from the Heemskirk Road to the north. Removal of overburden from hill top, and high wastage from quarry, would create major waste-rock disposal problem.
Assessment: Marginally interesting, but definitely unsuitable due to difficult access, difficult site workability, high proportion of closely jointed stone, and major environmental impact.

__Southern area:__

Site 21 (Database Site No. G/Rb/1/1)
Existing quarry (Dunn Monumental Masons Pty. Ltd.)
AMG Grid Ref.: CP50225725
Site & Outcrop description: Low slabs on top of broad ridge
Site workability: Workable
Access: 200 metre 4WD track off Trial Harbour Rd.
Colour: Dark Red (red feldspars & minor green feldspars.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules or veins; no xenoliths. Two 0.4m wide aplite dykes. Rare galena grains noted in granite.
Jointing: Moderate joint spacing.

Primary Set:	Strike 130° T, subvertical, Spacing: 1.0 - 3.0m
Set 2:	Strike 40° T, subvertical, Spacing: 2.0 - >3.0m
Set 3:	Strike 90° T, subvertical, Spacing: 1.0 - >5.0m

Other minor joint directions present.
Micro-fracturing: Parallel micro-fracturing evident in polished slabs (excessive for external veneers) but not apparent in most natural outcrops on the site.
Samples: **Field No.:** 1 (Database Spec. No. G/Rb/1/1/2/c)
From natural weathered surface of a quarried block.
2 (Database Spec. No. G/Rb/1/1/3/a)
From 1.2m below natural surface of same quarried block.
Environmental Aspects: Quarry will not constitute an aesthetic intrusion unless it becomes much larger than at present. Minimal effect on vegetation or watercourses likely.
Assessment: Existing quarry operation.

Site 22 (Database Site No. G/Rb/1/2)
AMG Grid Ref.: CP50215710
Site & Outcrop description: Large slabs on low ridge just above (and in) small creek.
Site workability: Easy workability; wide benches could easily be worked back into low ridge.
Access: Easy access from Trial Harbour Rd.; 400 metre track could be constructed along side of low ridge.
Colour: Dark Red, as at Site 21.
Texture: Medium to coarse grained, equi-granular
Features/imperfections: No tourmaline nodules or veins, no xenoliths. A few aplite dykes present, max. 0.5m wide.
Jointing: Moderate to wide joint spacings. Within 100 m radius, many large joint blocks interspersed with zones of close jointing.

Primary Set:	Strike 110° T, subvertical, Spacing: <0.5 - 4.0m+
Set 2:	Strike 15° T, subvertical, Spacing: 2.0 - 10.0m+

Micro-fracturing: "Grain" parallel to primary joint set apparent in some narrow joint blocks, not visible in wider blocks.
Samples: **Field No.:** 3 (Database Spec. No. G/Rb/1/2/1/c)
Surface sample from thick exfoliation flake in middle of 3.2m wide joint block. Sample splits parallel to primary joint set easier than perpendicular to it (due to

micro-fracturing?)
Environmental Aspects: Quarrying on south side of ridge would be largely hidden from road. Need to avoid runoff silting up adjacent creeks.
Assessment: Potential quarry site.

Site 23 (Database Site No. G/Rb/1/3)
AMG Grid Ref.: CP50405722
Site & Outcrop description: Large slabs higher on same broad ridge as Site 22.
Site workability: Easily workable; broad benches can be worked into ridge.
Access: Easy access; 150 metre track from Trial Harbour Rd. would be needed.
Colour: Dark red, as at Sites 21 & 22.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules or veins, no xenoliths. A few very minor aplite dykes.
Jointing: Moderate to wide joint spacings.
Primary Set: Strike 95° T, subvertical, Spacing: 0.5 - 4.0m+
Set 2: Strike 175° T, subvertical, Spacing: 1.0 - 4.0m+
Micro-fracturing: "Grain" visible in narrow joint blocks, not visible in wide joint blocks.
Samples: **Field No.:** 4 (Database Spec. No. G/Rb/1/3/1/c)
Surface sample from 100mm thick exfoliation flake on 1.5 x 2.0m joint block.
Environmental Aspects: Quarrying on southern side of this ridge would be out of sight of road and most vantage points. Vegetation is not particularly sensitive (grasses), but would need to avoid siltation of watercourses.
Assessment: Potential quarry site.

Site 24 (Database Site No. G/Rb/1/4)
AMG Grid Ref.: CP49195750
Site & Outcrop description: Bold outcrops on low broad ridge.
Site workability: Easily workable site; wide benches could be worked into low angle ridge.
Access: Close to Trial Harbour Rd., but need to cross deep gully to approach from closest point. Easier(?) alternative is to build 800 metre track approaching site from north-east along easy ridge via Site 26.
Colour: Dark red
Texture: Medium to coarse grained, equi-granular
Features/imperfections: No tourmaline nodules or veins, no xenoliths. Minor 0.05 - 0.5m wide aplite dykes present.
Jointing: Moderate to wide joint spacings.
Primary Set: Strike 130° T, subvertical, Spacing: 1.0 - 4.0m+
Set 2: Strike 30° T, subvertical, Spacing: 1.5 - 6.0m+
Set 3: Strike 170° T, subvertical, Spacing: < 1.0 - 10.0m+
Micro-fracturing: Not apparent.
Samples: **Field No.:** 5 (Database Spec. No. G/Rb/1/4/1/c)
Surface sample: 150mm thick exfoliation flake on 3 x 4m joint block.
Environmental Aspects: Site visible from nearby road to the west, but would be less visible if east side of ridge quarried. Vegetation is grasses only; would be necessary to avoid siltation of nearby creeks.
Assessment: Potential quarry site.

Site 25
AMG Grid Ref.: CP49435692
Site & Outcrop description: Outcrops on top of moderate angled ridge.
Site workability: Workable.
Access: Would require 600 metre track from Trial Harbour road over easy ridges.
Colour: Dark red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules or veins, no xenoliths
Jointing: Generally closely jointed.

Primary Set:	Strike 95° T, subvertical, Spacing: 0.5 - 3.0m
Set 2:	Strike 185° T, subvertical, Spacing: 1.5 - 4.0m

Micro-fracturing: "Grain" apparent parallel to primary joint set in thinner joint blocks.
Assessment: Unsuitable; close jointing.

Site 26 (Database Site No. G/Rb/1/5)
AMG Grid Ref.: CP49625787
Site & Outcrop description: Large slabs on top of small low-angle ridge.
Site workability: Easily workable; broad benches can be cut into low-angle sides of ridge.
Access: Easy access from north; would require 200 metre track from Trial Harbour Rd to north, crossing easy-angled well-drained side of ridge.
Colour: Dark red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules or veins. No xenoliths. A feature of this site is the presence of linear white quartz veins 5-15mm wide, subvertical (?), striking 110° T and spaced 1.0 - 8.0m+ apart (these represent an early, annealled, phase of jointing). Very minor aplite dykes up to 0.5m wide.
Jointing: Wide joint spacings typical.

Primary Set:	Strike 65° T, subvertical, Spacing: 0.5 - 5.0m+
Set 2:	Strike 165° T, subvertical, Spacing: 1.0 - 10.0m+

Micro-fracturing: Not apparent.
Samples: **Field No.:** 6 (Database Spec. No. G/Rb/1/5/1/c)
Two pieces, surface samples from 0.5m thick block flaked off the side of an 8 x 5m joint block.
Environmental Aspects: Site would be visible from road to the west, but hidden from the road to the north and east. Vegetation is grasses only. No major watercourses in immediate proximity, but still necessary to control silty runoff.
Assessment: Potential quarry site.

Site 27
AMG Grid Ref.: CP49345797
Site & Outcrop description: Steep slabs on either side of small flowing creek. Relatively poor outcrop.
Site workability: Workable, but steepness of slope would limit size of benches.
Access: Easy access from Trial Harbour Rd. 100 metres to the north.
Colour: Red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules, veins or xenoliths.
Jointing: Moderate to wide joint spacings (typically 2.0 - 4.0m+ spacings)
Micro-fracturing: Slight suggestion of microfracturing "grain"
Environmental Aspects: Site straddling flowing creek not desirable.
Assessment: Unsuitable; jointing probably OK, but topography not ideal for workability and proximity to flowing creek undesirable.

Site 28
AMG Grid Ref.: CP49735738
Site & Outcrop description: Outcrops on top of broad low ridge.
Site workability: Workable.
Access: Easy access from Trial Harbour rd. via 300m route along easy ridgetop.
Colour: Dark red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules or veins, no xenoliths.
Jointing: Moderate to close joint spacings (mostly <3m, commonly <2m spacings).

Primary Set:	Strike 140° T, subvertical, Spacing: 0.5 - 3.0m
Set 2:	Strike 60° T, subvertical, Spacing: 0.5 - 5.0m+

Micro-fracturing: Microfracturing "grain" clearly evident parallel to primary joint set.
Assessment: Unsuitable; joint spacing generally too close.

Site 29
AMG Grid Ref.: CP50025776
Site & Outcrop description: Low outcrops on top of small ridge.
Site workability: Good workability; could work wide benches into low-angled ridgetop.
Access: Easy access: 200 metres up easy ridge crest from Trial Harbour Rd.
Colour: Dark red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules or veins, no xenoliths. Minor aplite dykes up to 0.5m wide.
Jointing: Close to marginal joint spacing (very close spacing (av. 50-100mm) in aplite, parallel to primary joint set).

Primary Set:	Strike 135° T, subvertical, Spacing: 0.5 - 3.0m
Set 2:	Strike 30° T, subvertical, Spacing: 1.0 - 5.0m
Set 3:	Strike 55° T, subvertical, Spacing: > 4.0m

Micro-fracturing: "Grain" evident parallel to primary joint set.
Assessment: Unsuitable; joint spacing generally <2.0 metres.

Site 30 (Database Site No. G/Rb/1/6)
AMG Grid Ref.: CP50525757
Site & Outcrop description: Large low slabs on broad ridgetop.
Site workability: Easily workable; very wide benches can easily be worked into sides of broad ridgetop.
Access: Reasonable: best route is a 500 metre ridgetop route from Trial Harbour Rd. to the south, only difficulty is crossing a low gully just east of site.
Colour: Dark red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No tourmaline nodules or veins, no xenoliths, minor aplite dykes < 0.5m wide sparsely present.
Jointing: Predominantly widely spaced; 4.0 - 6.0m is common spacing, some joint blocks over 13.0 metres wide are present. Widely spaced jointing (with a few zones of marginally close jointing) is predominant over an area at least 150m SW-NE x 100m SE-NW. The SW-NE ridge 100m north-west of this site also has wide-jointed outcrops on its NW side.

Primary Set: Strike 155° T, subvertical, Spacing: 0.2 - 13.0m+
Set 2: Strike 70° T, subvertical, Spacing: 1.0 - 7.0m

Micro-fracturing: "Grain" evident parallel to primary joint set close to some joints, but is not evident in the middle parts of joint blocks.
Samples: **Field No.:** 7 (Database Spec. No. G/Rb/1/6/1/c)
From 150mm thick exfoliation flake from centre of a 2.5 x 2.5m joint block.
Environmental Aspects: By working on north side of ridge quarry would be largely out of sight of road. Vegetation is grass only. Need to avoid silt runoff into nearby creeks.
Assessment: Potential quarry site.

Site 31
AMG Grid Ref.: CP52385800
Site & Outcrop description: Outcrops on small hillock in middle of boggy plain.
Site workability: Workable.
Access: Difficult; only 250 metres from Trial Harbour Rd., but necessary to cross low boggy plains.
Colour: Red
Texture: Medium to coarse-grained, equi-granular.
Features/imperfections: Sparse quartz/black tourmaline nodules and veins.
Jointing: Some big joint blocks (joints spaced 5m+ apart), but over 50% of hillock is joint blocks 2.0m wide or less.
Assessment: Unsuitable: closely jointed in general.

Site 32
AMG Grid Ref.: CP52655801
Site & Outcrop description: Reasonable outcrops on small ridge just north of (promising) Site 33.
Site workability: Workable.
Access: Good (as for Site 33).
Colour: Red.
Texture: Medium to coarse grained, equigranular
Features/imperfections: Sparse quartz/black tourmaline nodules and veins.
Jointing: Marginal/close: joint spacing generally 2.0 - 3.0 m apart or less.
Assessment: Unsuitable: jointing generally too close, despite proximity to much better jointing at Site 33.

Site 33 (Database Site No. G/Rb/1/7)
AMG Grid Ref.: CP52615791
Site & Outcrop description: Abundant bold slabby outcrops on small hill approx. 120 metres diameter and 15-20 metres high.
Site workability: Good; entire hill could ultimately be worked, starting with easy benches on easy angled ground at the top.
Access: Very easy ridgetop route, about 200 metres from Trial Harbour Rd. to the south.
Colour: Dark red, green feldspars a little more dominant than at Site 21.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No xenoliths; quartz/black tourmaline nodules 10 - 25mm diameter sparsely present to absent over areas 10 x 10m or so (present over >50% of site). Parallel linear quartz/black tourmaline veins 5-10mm thick, spaced 0.1 - 10m+ apart, striking 55°T and dipping about 80° towards NW. Minor aplite dykes up to 2.0m wide but only sparsely present (contain abundant tourmaline nodules).
Jointing: Widely spaced jointing predominates, with joint blocks up to 14 metres or more wide.

Primary Set: Strike 95° T, subvertical, Spacing: 0.3 - 5.0m+
Set 2: (=tour. veins) Strike 55° T, subvertical, Spacing: 0.1 - 10m+
Other minor joint directions present.

Micro-fracturing: Not evident.
Samples: **Field No.:** 8 (Database Spec. No. G/Rb/1/7/1/c)
Sample from 0.2m below natural surface, 0.7m from a small blast hole (small joint inbetween blast hole and sample stopped blast fractures). Sample 1.0m in from edge of 14m x 5m joint block.
Environmental Aspects: Quarrying can commence on north side of hill, out of sight of road. Vegetation is grasses only. Small creek gully on north side of hill - drains and a small dam can be constructed here as sediment trap to catch all silty runoff.
Assessment: Potential quarry site.

Site 34 (Database Site No. G/Rb/1/8)
AMG Grid Ref.: CP52625779
Site & Outcrop description: Small outcrop with fresh (blasted) exposure, on broad ridge leading from Trial Harbour Rd. to Site 33.
Site workability: Easily Workable.
Access: Easy access; 100m from road on access route to Site 33.
Colour: Dark Red - distinctly darker than Site 33 stone.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: Very sparse quartz/black tourmaline nodules.
Jointing: Wide joint spacing.
Primary Set: Strike 95° T, subvertical, Spacing: 2.0 - 4.0m
No other joint sets apparent on this small outcrop.
Micro-fracturing: Not evident.
Samples: **Field No.:** 9 (Database Spec. No. G/Rb/1/8/1/c)
From small blasted exposure, 50mm below natural surface and 0.8m from blast hole. No apparent blast fractures in sample, but note that direction of radial blast fractures would be parallel to primary joint direction at the sample point.
Environmental Aspects: Quarrying at this point would be visible from road. Vegetation is grasses only.
Assessment: Potential quarry site, could be operated in conjunction with Site 33.

Site 35 (Database Site No. G/Rb/1/9)
AMG Grid Ref.: CP52305787
Site & Outcrop description: Large bold outcrops on small ridgetop.
Site workability: Workable: wide benches can easily be worked into this ridge.
Access: Existing 400m 4WD track provides access to site (one or two boggy patches need stabilising).
Colour: Dark red.
Texture: Medium to coarse grained, equi-granular.
Features/imperfections: No xenoliths or aplite dykes evident. No tourmaline veins; quartz/black tourmaline nodules 10mm diameter sparsely present (less abundant than at Site 33)
Jointing: Generally widely spaced: mostly spacings > 3m, with one joint block 18m x 5m noted. Less than 50% of area has closer (2 - 3m spacing) jointing zones.
Primary Set: Strike 140° T, subvertical, Spacing: 0.5 - 5.0m
Set 2: Strike 60° T, subvertical, Spacing: 3.0 - 18.0m+
No other consistent joint sets evident.
Micro-fracturing: Not evident except in a few narrow zones.
Samples: **Field No.:** 10 (Database Spec. No. G/Rb/1/9/1/c)
Surface sample from 200mm thick exfoliation flake on the side of a 3.0 x 3.0m joint block.
Environmental Aspects: Site easily visible from Trial Harbour Rd.; vegetation grasses only.
Assessment: Potential quarry site.

060061

APPENDIX TWO -

FIELD JOINT DATA AND ANALYSIS

This appendix presents the field data, and the data collection and analysis techniques, which were used in the preparation of Table (1).

Data collection and analysis

Primary Joint Direction:
The primary joint set at any particular site is considered to be that set of parallel linear joint fractures which:

a) Has the closest average spacing between parallel joints, and:
b) Has the most persistent (continuous) joint fractures.

The primary joint direction was identified visually in the field, and this identification is confirmed by the fact that the average joint spacing of that joint set (ie, spacing between joints measured perpendicular to the strike direction of the identified primary joint set) is closer than the average spacing of other joints intersecting the primary joint sets (ie, spacing between joints measured parallel to the identified primary joint set). Average joint spacings are given as **(B)** and **(F)** in Table (1).

The only exception to this is Site 21, and this result is probably biased due to the fact that soil cover only allowed measurement of an unusually short joint traverse parallel to the identified primary joint set.

Sample traverses:
For the purpose of making this statistical analysis of joint spacings and wastage, the spacings between joints was measured along two random traverses at each site, aligned perpendicular and parallel to the identified primary joint direction. Each traverse was intended to be approximately 20 metres long; however each traverse is considered to end at the last joint fracture encountered before 20 metres, so that most traverses are a little less than 20 metres long. Where a 20 metre traverse could not be achieved due to soil cover, two shorter traverses in the same direction have been combined to yield one longer traverse. The sample traverse lengths in each direction are given as **(A)** and **(E)** in Table (1).

Wastage calculations:
For the purposes of making a statistical comparision between potential quarry sites, it is assumed that only unflawed blocks measuring 3 x 2 x 1 metres can be used. In reality, some slightly smaller blocks will be usable, which will reduce the actual wastage obtained at all sites.

The vertical dimension (one metre block depths) is not considered in these calculations; rather, only the horizontal surface area of 2 x 3 metre blocks are considered. Since horizontally-oriented fractures are rare at all sites, wastage in the vertical dimension will be minimal.

Since the primary joint set constitutes the most closely spaced persistent joint fractures, the minimum wastage at any site will be obtained by cutting blocks with their 2 metre sides perpendicular to the primary joint set, and their 3 metre sides parallel to it. The wastage calculations are based on cutting blocks in this way.

(C) and **(G)** Block widths and lengths:
The percentage of each sample traverse which is made up by blocks of stone having their bounding joints spaced 2 and 3 metres or more apart is given as an indicator of wastage. However this figure may be somewhat deceptive. For instance, a 2.5 metre joint spacing will not yield 2.5 unflawed blocks 2 metres wide; rather it will yield one 2 metre wide block plus 0.5 metres of wastage.

(D) and **(H)** Actual numbers of unflawed blocks:
A more accurate indication of wastage is obtained by using the traverse data to count the actual number of unflawed blocks which could be obtained. For instance, a joint block 3.6 metres wide would yield one 2 metre wide block, whereas a joint block 4.1 metres wide would yield two such blocks.

(I) Unflawed blocks obtainable from area of sample traverses:
The actual number of unflawed 2 metre wide blocks which can be cut perpendicular to the primary joint set is multiplied by the number of unflawed 3 metre long blocks which could be cut parallel to the primary joint set to yield the total number of unflawed 2 x 3 metre blocks which could be obtained from the area encompassed by the sample traverses.

(J) Wastage calculations:
These calculations can be considered the best measure of the suitability of potential quarry sites in terms of joint spacings. It must be noted that these figures are based on a quarrying scenario in which only unflawed blocks of horizontal dimensions 2 x 3 metres can be used. However, in reality somewhat smaller blocks could also be used for at least some purposes.

The figures provide a useful and consistent comparision between sites, but should not be considered to represent actual wastages which should be expected; rather they represent maximum potential wastage figures.

More realistic actual wastage figures would be calculated utilising longer joint traverses and taking into account the actual minimum block sizes which could realistically be used.

The total surface area represented by the sample traverses is calculated by multiplying the lengths of the two perpendicular traverses together **(A x E)**. The total area of unflawed blocks obtainable from within that area is calculated by multiplying the number of unflawed blocks obtainable **(I)** by the surface area of a single standard block ($2 \times 3 = 6\ m^2$). The wastage is then the total surface area represented by the sample traverses minus the total surface area of the unflawed blocks obtained. The wastage area is quoted as a percentage of the total surface area.

Site 21 (*):
In the case of Site 21 only (Dunns Quarry), examination of the data shows that the least wastage would be obtained by quarrying blocks with their longer (3m) dimension perpendicular to the primary joint set rather than parallel to it. This anomaly may be an artifact resulting from a shorter than normal sample traverse due to soil cover.

The wastage figure indicated with an asterisk (*) has been calculated on the basis of this modification of the normal procedure.

Field data
The actual field data obtained for this analysis is listed below.

Due to the clear lack of promising sites, no traverses were made in the northern area. In the southern area, traverses were made at sites considered to be promising potential quarry sites. For comparison, a few traverses were also made at sites considered less promising.

At each site where joint data was measured, two sample traverses were measured, one perpendicular to the strike direction of the primary joint set, and one parallel to it.

In effect, the traverse perpendicular to the strike of the primary joint set measures the spacing of joints belonging to that primary set, while the traverse parallel to the primary set measures the spacing of joints belonging to secondary joint sets.

The traverses were made as close to 20 metres long as possible; in a few cases soil cover precluded a 20 metre traverse, in which case two shorter traverses in the same direction were made. In the case of Site 21, only one 11 metre traverse could be made parallel to the primary joint set, due to soil cover.

Starting from an initial joint, the data consists of the distance (in metres) from the origin at which each successive joint was encountered on the traverse.

SITE 21 (Dunns Quarry)
Primary Joint Set: Strike 130° True

Perpendicular to Primary Joint Set:
0.0 0.5 3.3 4.0 5.0 7.4 [10.4 - 10.9: aplite dyke, not joint] 12.0 15.0 18.1 19.3

Parallel to Primary Joint Set:
0.0 1.4 2.1 4.3 6.0 7.4 9.6 11.0 [no outcrop past this joint]

SITE 22
Primary Joint Set: Strike 110° True

Perpendicular to Primary Joint Set:
0.0 3.2 5.2 7.4 8.5 8.9 10.6 11.7 12.4 13.5 14.4 15.0 15.7 17.2 18.1 19.7

Parallel to Primary Joint Set:
0.0 5.8 7.2 9.3 13.4 15.2 23.3

SITE 23
Primary Joint Set: Strike 95° True

Perpendicular to Primary Joint Set:
0.0 3.4 6.1 7.2 7.6 10.8 12.5 13.5 15.7 17.0 17.9 19.9

Parallel to Primary Joint Set:
0.0 2.6 4.2 5.3 7.9 8.8 11.9 14.0 15.8 19.6

SITE 24
Primary Joint Set: Strike 130° True

Perpendicular to Primary Joint Set (two shorter traverses):
0.0 1.6 2.9 6.2 8.0 9.1 9.9 12.0
0.0 2.3 3.3 5.6 7.3 10.3 13.0

Parallel to Primary Joint Set:
0.0 1.5 2.7 4.3 11.1 17.7 20.0

SITE 25
Primary Joint Set: Strike 95° True

Perpendicular to Primary Joint Set:
0.0 0.5 2.2 2.6 3.3 4.5 6.6 9.7 10.0 10.6 11.3 12.3 14.2 15.7 18.0 20.0

Parallel to Primary Joint Set:
0.0 1.1 1.9 6.2 10.9 12.2 14.2 17.3 18.6 20.0

SITE 26
Primary Joint Set: Strike 65° True

Perpendicular to Primary Joint Set (two shorter traverses):
0.0 3.1 6.3 12.1 13.1 16.0
0.0 3.0 6.5 7.8 11.4 14.5

Parallel to Primary Joint Set:
0.0 1.8 5.7 7.0 8.7 18.1

SITE 29
Primary Joint Set: Strike 135° True

Perpendicular to Primary Joint Set:
0.0 1.8 6.5 7.3 8.1 9.0 9.9 10.5 11.7 12.6 14.6 15.1 15.4 17.1 19.2 19.9

Parallel to Primary Joint Set:
0.0 1.8 2.9 4.0 4.3 5.3 6.4 10.7 14.4 15.0 20.0(+)

SITE 30
Primary Joint Set: Strike 155° True

Perpendicular to Primary Joint Set:
0.0 2.0 7.4 9.1 11.4 14.8 19.2

Parallel to Primary Joint Set:
0.0 3.6 9.6 13.8 18.8

SITE 33
Primary Joint Set: Strike 95° True

Perpendicular to Primary Joint Set:
0.0 1.4 4.9 7.9 9.1 9.7 11.2 15.9 19.4

Parallel to Primary Joint Set:
0.0 2.6 3.7 7.9 11.6 14.4 19.9

SITE 35
Primary Joint Set: Strike 140° True

Perpendicular to Primary Joint Set:
0.0 2.6 5.0 7.2 8.3 9.9 11.9 15.5 16.9 19.0 19.7

Parallel to Primary Joint Set:
0.0 8.3 11.0 13.5 15.1 17.0 20.0(+)

060067

APPENDIX THREE -

MICROFRACTURE DATA AND ANALYSIS

060068

In view of the significance of micro-fracturing in the Heemskirk Granite, it was considered essential to quantify the amount of micro-fracturing present at the various sites considered on other criteria to be promising quarry sites.

The aim was to determine whether any variability in degree of micro-fracturing existed between the various sites, and if so, which sites had the least micro-fracturing. A secondary aim was to attempt to determine whether the degree of micro-fracturing at a site could be correlated with other characteristics of the site, such as jointing density.

Field observations at a number of sites where intense micro-fracturing was macroscopically visible as a distinct linear "grain" in weathered outcrops showed that the most intense micro-fracturing occurs as linear fractures oriented parallel to the strike of the primary joint direction, as defined in Appendix Two above.

Data collection:
Hand samples were collected at each site considered to be a promising potential quarry site, and for comparision several samples were also collected from sites whose jointing was too intense to be considered a possible quarry site. Of necessity, the samples collected were from the surface of natural weathered outcrops, but the freshest obtainable samples were selected.

For additional comparision, both a surface sample and a sample from approximately a metre below the natural surface were collected from Site 21 (Dunns Quarry). These samples are significant as they allow:

1) Comparision of stone quality at other sites with the stone of known quality at Site 21.

2) Comparision of micro-fracturing in surface stone with that in subsurface stone from the same site (and in fact, from the same block of stone).

The primary joint direction was marked on each sample. Large microscope thin sections were then cut from each sample in an orientation perpendicular to the marked primary joint direction. The thin section slides were prepared with a stain to enhance the visibility of micro-fractures, although it was found that this is not strictly essential as the micro-fractures are quite visible under the microscope without staining.

A set of parallel line traverses totalling 200 millimetres long were marked in ink in each of two perpendicular directions on the surface of each thin section (ie, yielding a grid totalling 400 mm of traverses per slide). The traverses were marked perpendicular and parallel to the long side of the slides.

The microscope was then used at low power to count the number of fractures which intersected the traverses. Since microfractures can range in size down to sub-microscopic, it was necessary to reduce the subjective element in deciding which fractures were significant enough to be counted. This was done by only counting fractures which were distinct and large enough to extend all the way across at least one crystal grain of the granite.

Micro-fracture types counted were classified as follows:

Intra-crystalline fractures
Fractures which cut across one or more crystals. Sub-divided as:

Parallel: Linear fractures which form part of an obvious set of parallel fractures across the slide.

Random: Fractures having no apparent common orientation.

Grain boundary fractures
Distinct fractures which have formed along crystal boundaries. It is sometimes difficult to tell whether a grain boundary is fractured or not; therefore these fractures are only counted where they are quite distinctly fractured. Sub-divided as:

Parallel: Linear grain boundary fractures which are parallel to an obvious set of parallel fractures (including intra-crystalline fractures) across a slide. Generally follow part only of a grain boundary.

Random: Fractures having no apparent common orientation; generally follow all or most of the grain boundary.

Data analysis

Although the microfractures were categorised as above during the data collection phase, they were simply totalled to give a single figure representing the total microfracture count for each specimen.

These figures were then used in the manner outlined in Section (6.2).

Data obtained:

Traverse (a) = Parallel to long side of slide; 200mm total length.

Traverse (b) = Perpendicular to traverse (a); 200mm total length.

Site No.	Spec. No.	TRAVERSE (a) Intra-Crystalline		TRAVERSE (a) Grain Boundary		TRAVERSE (b) Intra-Crystalline		TRAVERSE (b) Grain Boundary		TOTAL
		Par.	Rand.	Par.	Rand.	Par.	Rand.	Par.	Rand.	
21	1	12	23	0	3	62	15	1	4	120
21	2	3	20	0	6	37	28	0	1	95
22	3	9	22	1	12	22	27	3	7	103
23	4	17	45	0	10	8	29	0	7	116
24	5	10	36	1	14	12	52	0	11	136
26	6	9	22	2	10	5	18	0	5	71
30	7	29	35	2	4	8	20	0	7	105
33	8	0	13	1	4	1	11	1	2	33
34	9	5	5	0	7	9	11	0	10	47
35	10	15	13	0	9	2	12	0	5	56