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GEOLOGICAL MAPPING AND INVESTIGATIONS
Environmental Studies

BUILDING AND ORNAMENTAL STONE
Exploration and Evaluation

AMG REFERENCE POINTS ADDED

RED GRANITE EXPLORATION IN THE NORTHERN HEEMSKIRK GRANITE, WESTERN TASMANIA EL 23/90

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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 northern part of the Heemskirk Granite, in Exploration Licence 23/90, 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).

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, outside EL 23/90).

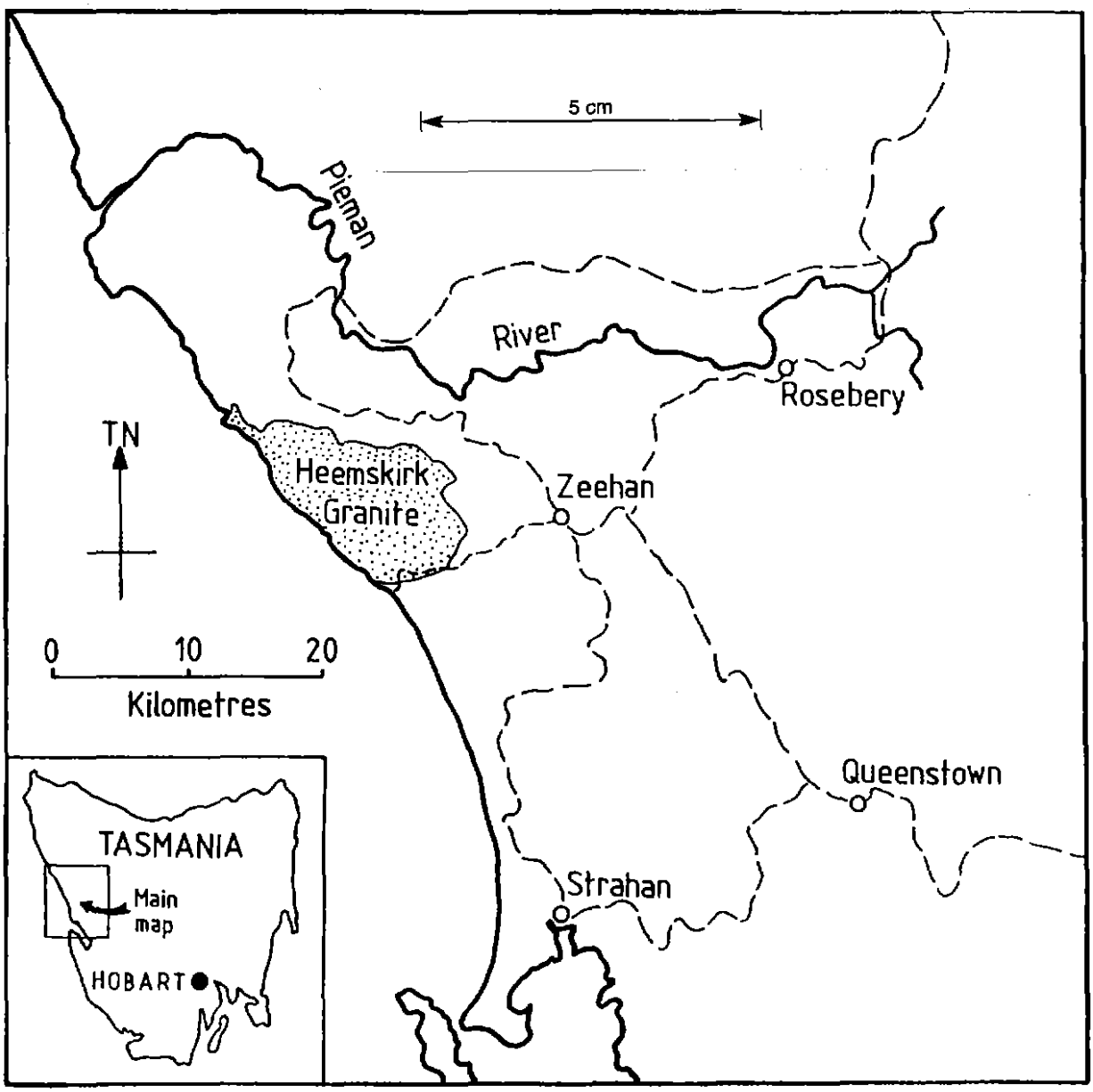
All possible quarry sites in the northern part of the red granite were found to be unsuitable due to excessively close joint fracturing, difficult site topographies, and difficult access.

It is recommended that further exploration work for high quality red granite be concentrated on the southern part of the Heemskirk Granite, the most accessible parts of which lie outside EL 23/90.

(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 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 (outside EL 23/90) 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).

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 bocks 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.

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.

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. 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 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 lies within EL 23/90, and 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. The southern area lies outside EL 23/90, and is not described in this report.

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 for 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 initial field investigations in the northern area; no potential good quality quarry sites were located, hence more advanced stages of evaluation have not been

proceeded with in that area.

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

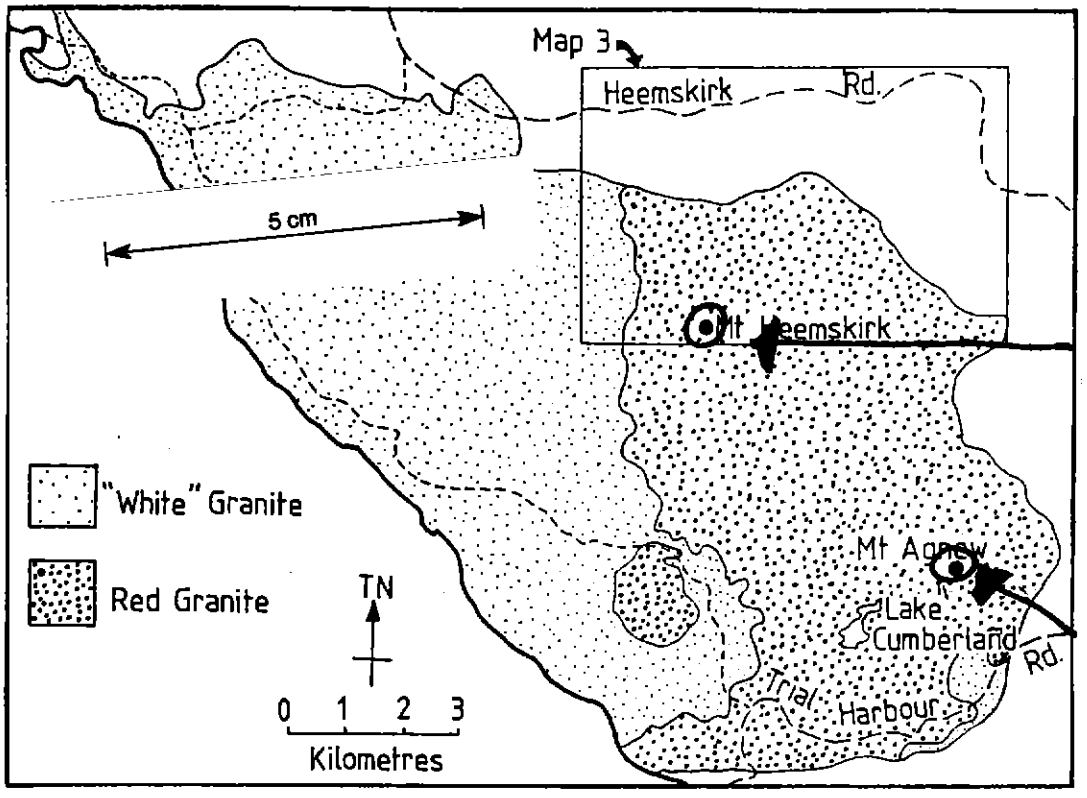
Outcrops were evaluated in the field in terms of the following criteria:

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

The field data obtained is recorded in the Appendix and Map (3), and discussed in Section (5.0).

(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.



Map 2: The Heemskirk Granite - Regional Geology (from Klominsky 1972) showing the northern red granite area which was explored during this project. Outline of detailed map (3) indicated

AMG REFERENCE POINTS ADDED

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) (M.P. McClenaghan *pers. comm.*).

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 equi-granular 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.

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

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.

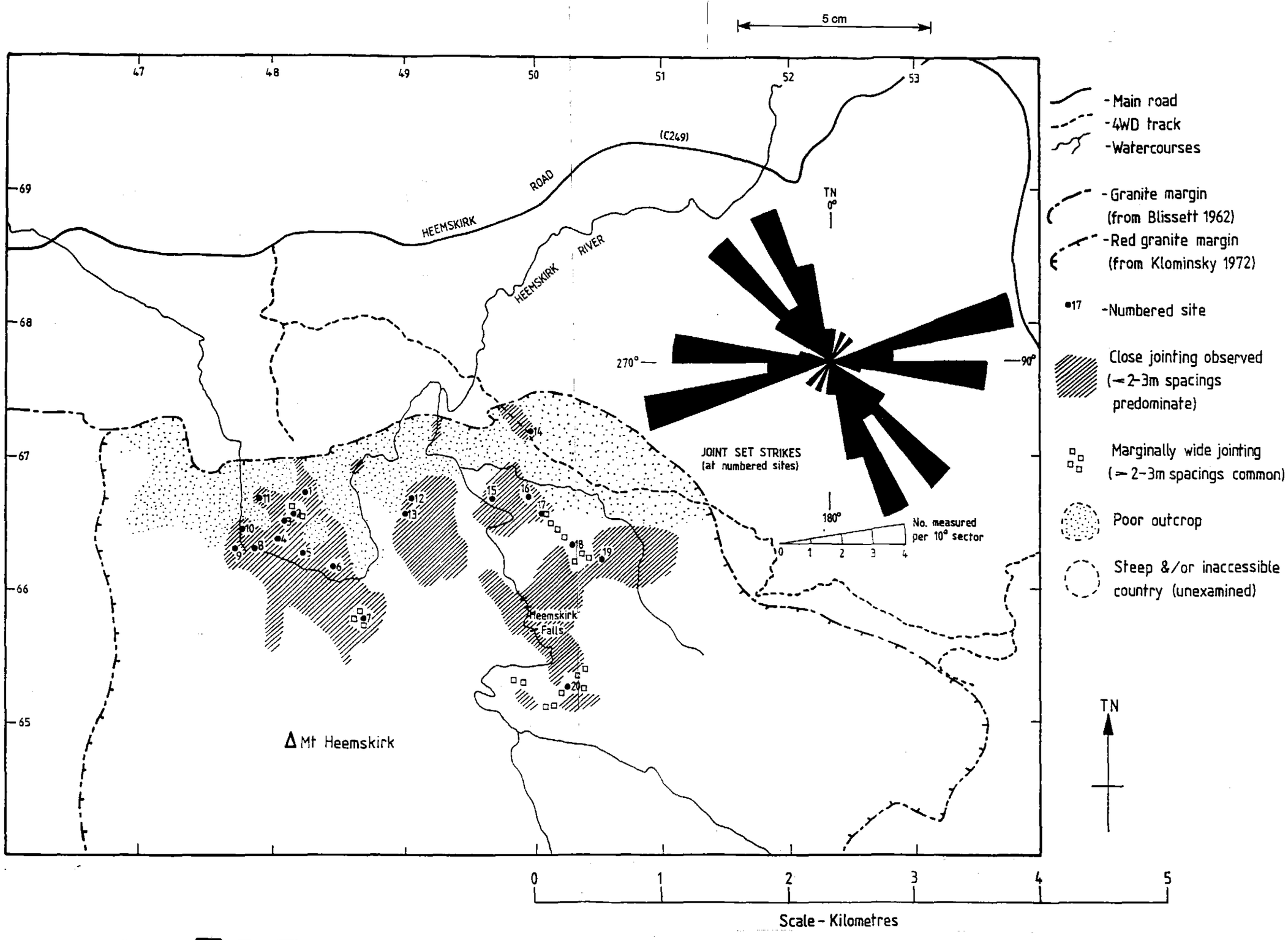
As noted in Section (4.0), these rapid alternations appear to result from the red granite having intruded in a succession of pulses, each producing a thin sheet which differentiated during cooling to produce a gradation in grainsize and quartz/tourmaline content over short distances.

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.

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



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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.

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).

(6.0) CONCLUSIONS AND RECOMMENDATIONS

The northern area of the Heemskirk Red Granite within EL 23/90 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.

It is recommended that exploration for high quality red granite be concentrated on the southern portion of the red granite, where considerable potential for good quarry sites is considered to exist. The most accessible parts of the southern area lie outside EL 23/90.

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APPENDIX -

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 tourmaline 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 equigranular 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