Reconnaissance geology of the Norfolk Range–Sandy Cape area, northwest Tasmania

A report for the Western Tasmanian Regional Minerals Program

Tasmanian Geological Survey Record 2005/02

Tasmania

MINERAL RESOURCES TASMANIA

DEPARTMENT *of* INFRASTRUCTURE, ENERGY *and* RESOURCES

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***Cover:** View looking southwest from the summit of Mt Vero to Mt Sunday (left) and coast*

Abstract

Recent detailed aeromagnetic and radiometric surveys were used, in conjunction with existing ground information, to interpret the geology of the Norfolk Range–Sandy Cape area in western Tasmania. This was followed up with ground traverses in selected key areas.

The entire area is underlain by Proterozoic Rocky Cape Group shelf sequences, which are intruded by Devonian granite in western coastal areas and by NNE-trending Precambrian dolerite dykes, mainly in the east. In the west, radiometrics clearly distinguish between quartzarenite (mainly orthoquartzite) and Cainozoic coastal sand on the one hand, and pelitic siltstone and Devonian granite on the other, although the extent of outcropping granite is less than previously thought. In the Norfolk Range and further east, the radiometric image is strongly modulated by topographic effects, and Rocky Cape Group units are less easily discriminated because of a significant micaceous component in the matrix of the arenites. The stratigraphy of the Rocky Cape Group, which is disrupted by the extension of the Balfour Shear Zone and other NNW-trending faults further east, is not simple. Near the coast, the Pedder River Siltstone underlies the Lagoon River Quartzite, which appears to thin and grade to micaceous sandstone eastward. East of the Norfolk Range, the Balfour Subgroup correlate may have a transitional to overlying relationship with the Lagoon River Quartzite, contains major lenses of micaceous sandstone, and is in turn probably a partial facies equivalent of the Cowrie Siltstone.

The Rocky Cape Group predominantly dips and youngs eastward throughout the region. West of the Balfour Shear Zone, dominant folds are gentle to open, west verging and NNW/SSE-trending with usually weak cleavage development. To the east of the zone, folds are typically tighter and NNE/SSW-trending with well-developed cleavage.

Localised metamorphism of siltstone (chlorite porphyroblasts, biotite and tourmaline in matrix) provides limited field evidence for shallow granite, but the localities do not correspond closely to known gravity lows. A large granite intrusion beneath the Norfolk Range remains possible but no clear surface evidence was found.

Numerous aeromagnetic anomalies in the area mainly occur in siltstone units, and some delineate major faults, although virtually no rocks with moderate to high magnetic susceptibility, capable of generating the anomalies, were located. Because of the poor exposure in much of the area, it is possible that the sources are concealed, or are narrow and/or poorly outcropping veins and alteration zones. Limited previous work suggests that the magnetic anomalies may be due to siltstone with significant pyrrhotite and/or magnetite, possessing strong remanent magnetisation with Koenigsberger ratios up to 20–24. If so, quantitative models of the magnetic anomalies are difficult or impossible to adequately constrain.

Introduction

Detailed (200 m line spacing) airborne geophysical surveys were flown over much of western and northwestern Tasmania (fig. 1) to aid in assessing the mineral resource potential for the Regional Forest Agreement (RFA; in April 1996) and Western Tasmanian Regional Minerals Program (WTRMP; in 2001–2002). During qualitative interpretation and quantitative modelling (e.g. Webster, 2002) of the magnetic, radiometric and electromagnetic data it became apparent that, for a large tract of the western Rocky Cape Region, the virtual absence of regional geological maps and the extreme paucity of reliable ground information were serious obstacles to an improved understanding. This geologically poorly known and under-explored area (fig. 2) extends from the Norfolk Range westward to the coast around Sandy Cape and eastward into the equally poorly known central Arthur Lineament area. Field work, focussing on areas containing geophysical anomalies, was carried out from January to March 2003, as part of the WTRMP program, in attempt to partly remedy this deficiency.

The boundary of the study area (about 420 km^2, fig. 2) is defined by the limit of previously published geological mapping to the south, and partly to the north. It extends westward to the coast, and whilst largely for logistical reasons easting 340 000 mE arbitrarily and approximately defines the eastern boundary. The area lies almost entirely on the Lily, Lagoon and Venables (Johnsons Bay and Kenneth Bay) 1:25 000 scale map sheets. Whilst not intended as a regional mapping project, the new information obtained has enabled existing Mineral Resources Tasmania 1:250 000 scale digital geological maps and databases for the area to be substantially upgraded.

In this report, 'quartzite' is used as a field term for rocks that include both orthoquartzite (well sorted quartzarenite with >90–95 % quartz grains and no muddy matrix), and micaceous quartz sandstone with a significant amount of micaceous or chloritic matrix.

Figure 1

Extent of WTRMP/RFA geophysical surveys and area discussed in this report. Yellow shaded areas show WTRMP and RFA aeromagnetic and radiometric surveys, 200 m line spacing, 1996–2002.

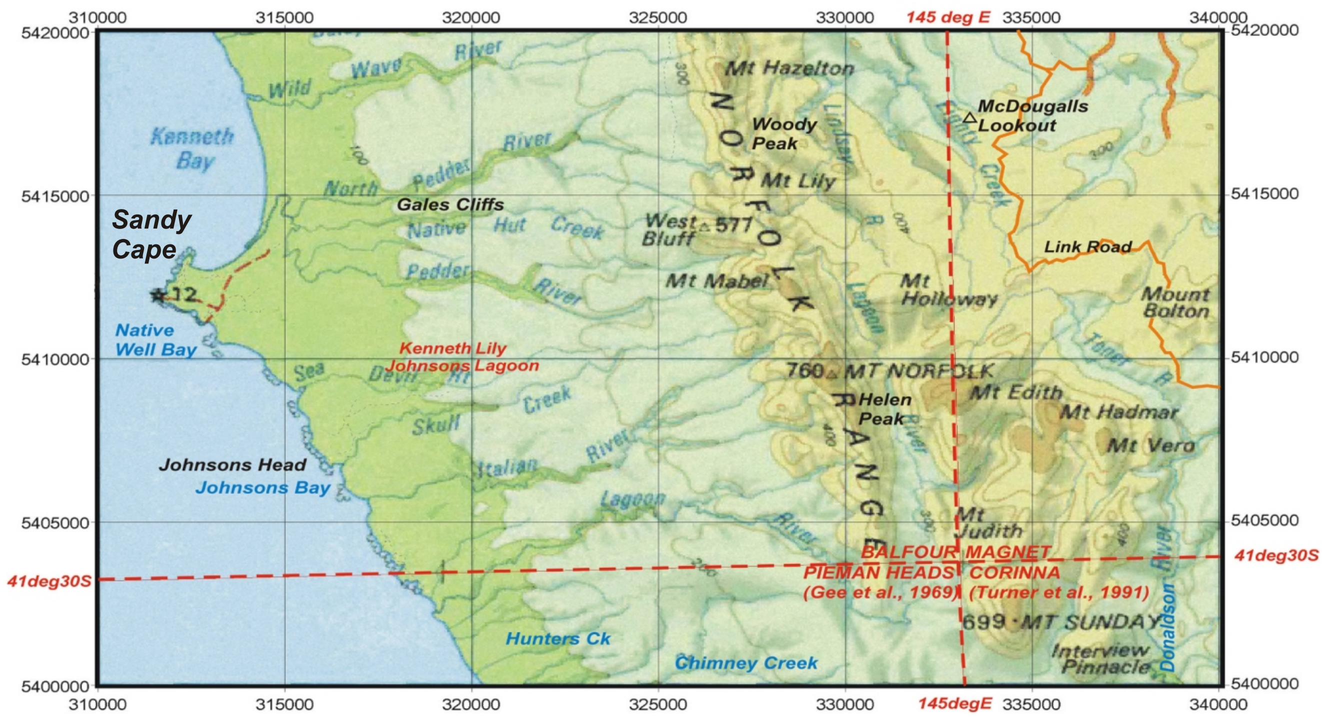


Figure 2

Geographic map of study area with 5 km grid, showing place names mentioned in text and 1:25 000 and 1:50 000 scale map sheet boundaries.

Physiography

The major physiographic features of the region are clearly evident on an image derived the statewide digital terrain model (fig. 3). The relatively straight NNW-trend of the coast, parallel to the continental margin, is interrupted by the low granite promontory of Sandy Cape. To the north, wave refraction of the dominant southwesterly swell around Sandy Cape accounts for the long curved beach of Kenneth Bay, but to the south, shorter sandy beaches and small rocky headlands face directly into the swell. Windblown sand, including stabilised and mobile dunes up to 40 m high, lies immediately behind the coast.

Between one and three kilometres inland (increasing to about 6 km behind Sandy Cape) and parallel to the modern coast is a small but prominent escarpment, 40–50 m high, which probably represents an old coast line formed at a time of higher relative sea level. Behind it, a flat relatively featureless heathy peneplain about eight kilometres wide rises very gradually eastward from about 100 m above sea level to 250 m at the base of the Norfolk Range (plate 1). The peneplain is dissected by narrow (mostly 250 m wide), deeply incised to gorge-like valleys of west-flowing streams originating in the range. The larger streams, particularly the Lagoon and Italian rivers, display entrenched meanders and their course probably originally developed on the peneplain surface. Later, they may have been rejuvenated by relative sea level regression, which lowered their base level.

The main Norfolk Range (extending from Mt Hazelton to the spur south of Helen Peak) is an 18 km long NNW-trending strike ridge which rises abruptly from the coastal peneplain and appears to be structurally controlled. To its east, a long narrow, funnel-shaped valley, containing the headwaters of the Lagoon River, separates it from the more irregularly shaped outlying peaks of Mt Edith, Mt Hadmar and Mt Vero. In the far east of the study area, the Donaldson and Toner rivers, and part of the upper Lindsay River, are also deeply incised, but not the upper Leigh River.

Topographic lineaments

A visual compilation of topographic lineaments apparent in the digital terrain model image was made (fig. 4). Although some subjectivity is probably involved in this method, the overall impression is probably correct.

In the western coastal areas, topographic lineaments are subdued, but the main set trends NNW/SSE subparallel to the overall trend of the coast, at a high angle to a subordinate E/W to ENE/WSW set which may partly control the direction of some streams.

The NNW trend of the Norfolk Range and the upper Lagoon River valley are the strongest topographic lineaments in the whole area. To their east, the dominant grain of the topography is defined by numerous, closely-spaced NNE-trending lineaments, although there are also a few lineaments with this trend west of the valley around Mt Norfolk. East of the upper Lagoon River valley, the weak ENE set is still present, particularly in the north of the area, but there are few NNW-trending lineaments.

As discussed below, the upper Lagoon River valley corresponds to an extension of the Balfour Shear Zone. The contrast between dominant NNW-trending and NNE-trending lineaments on either side is comparable to a similar change further north across the Smithton Synclinorium between Marrawah and the Rapid River area, which reflects different fold trends in the Rocky Cape Group.

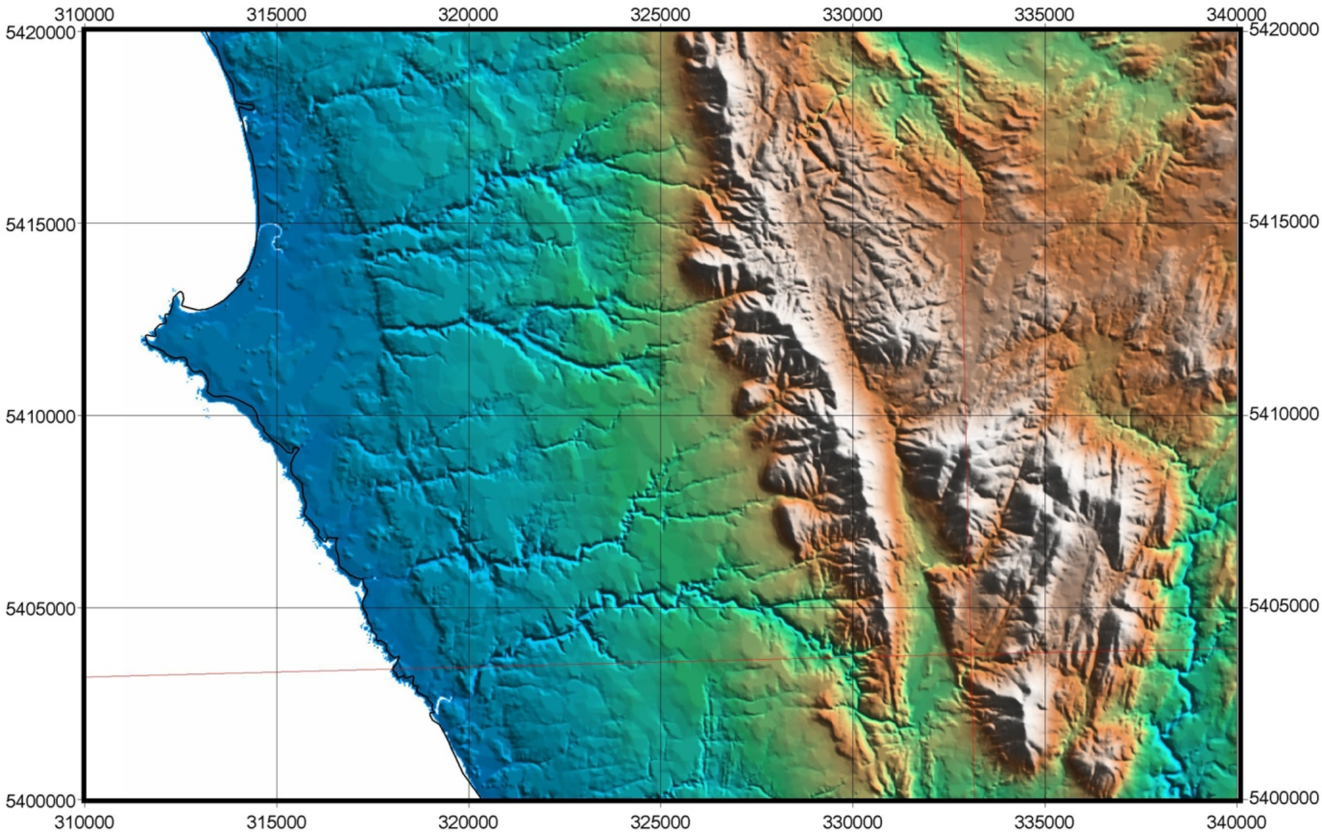


Figure 3

Digital terrain model of study area, derived from DPIWE data, with NE illumination.

Plate 1

Mt Norfolk and coastal peneplain, looking east from Skull Creek campsite.

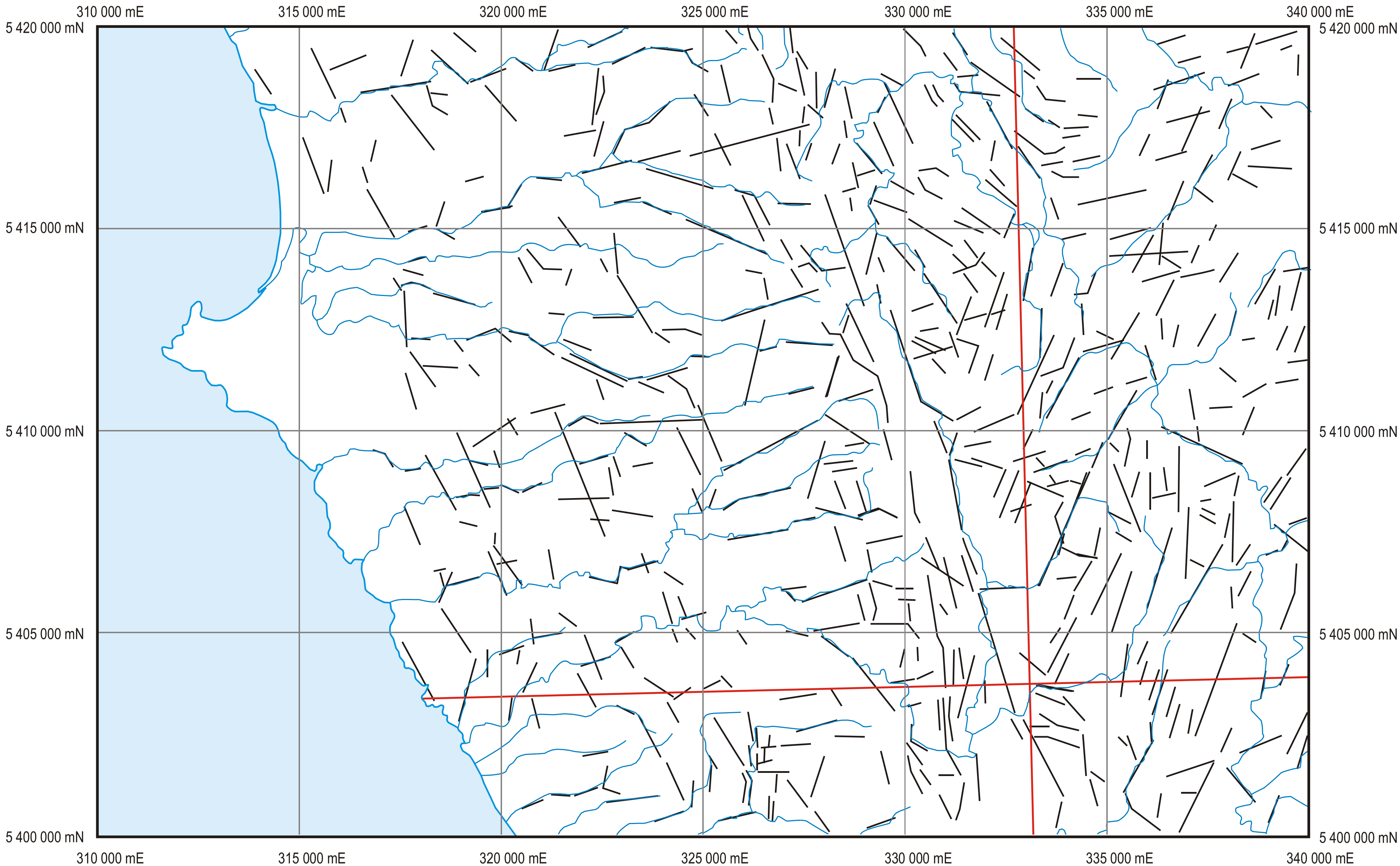


Figure 4. *Topographic lineaments in the study area, interpreted from the Digital Terrain Model (fig. 3).*

Previous Work

Historical

Johnson's (1888) geological sketch map of Tasmania showed granite in the Interview River area (but not at Sandy Cape), whilst the remainder of the area, like much of western Tasmania, was loosely described as crystalline metamorphic rocks of "Archaean" to Silurian age.

Late in the nineteenth century, the coast south of Marrawah was used as a route to the gold mining settlement of Corinna and beyond. Tungsten, copper and lead-zinc prospects were discovered near the Interview River, south of the area under discussion. Prospectors working south from Balfour located and prospected small lodes, mainly for copper, as far south as the Toner River. Subsequently T. B. Moore, working for the Mt Lyell Mining and Railway Company between 1907 and 1911, examined copper occurrences in the Toner River, Mt Hadmar, Norfolk Range and Balfour areas. Although contemporary records are sketchy, high grade (sometimes over 20% Cu) but small deposits in shear zones, consisting of pyrite, chalcopyrite with minor bornite, chalcocite, tenorite and native copper, were reported (Hutton, 1981). These prospects were also described by Ward (1911, see below).

Geological Survey work

Geology

Virtually the only previous Geological Survey report containing ground information for the immediate area is that of Ward (1911). His geological sketch map shows the Norfolk Range area underlain by the "Balfour slates and sandstones", which on the basis of sparse bedding readings are variably (15–75°) east-dipping. Sedimentary structures noted, particularly in the sandstone, include cross bedding, ripple marks and possible worm trails or sun cracks (notably on the summit of Mt Hazelton). A Cambro-Ordovician age was assigned both to these rocks and to a number of mostly NNE-trending amphibolite dykes. Granite at Sandy Cape is shown extending southward, parallel to the coast but largely concealed by sand dunes, to the Pieman River. Prospects in the region are described in detail, including some south of Mt Hazelton and near the Toner River in the present study area.

The first 1:250 000 scale geological map that covered the area was the compilation of Williams and Turner (1973). Most of the region is shown, mainly after Ward (1911), as otherwise undifferentiated Precambrian "comparatively unmetamorphosed sequences" intruded by granite near the coast and a few dolerite dykes near Mt Edith and Mt Bolton. Further coastal outcrops of granite were inferred (incorrectly) south of Sandy Cape, near Johnsons Bay.

A reconnaissance geological map of the Leigh River area, including a small part in the extreme northwest of the Lily sheet and just within the current study area, was produced by Everard (1994).

Adjacent areas to the south have been mapped on the Pieman Heads 1:63 360 (Gee *et al.*, 1969) and Corinna 1:50 000 (Turner *et al.*, 1991) scale geological map sheets, whilst the Balfour 1:25 000 scale digital geological map (Everard *et al.*, 2003) abuts part of the northern boundary of the study area.

In the absence of new information, the original 1:250 000 scale digital geology map of northwest Tasmania (Calver *et al.*, 1995) largely followed Williams and Turner (1973) in this area (fig. 5). Although new geophysical (especially radiometric) data acquired by MRT enabled differentiation of the Rocky Cape Group quartzite and siltstone to be inferred north of 5 420 000 mN, their distribution was highly speculative southward as far as the Pieman Heads map sheet. Tentatively, the high country of the Norfolk Range (including mounts Edith, Hadmar and Vero) were depicted as largely fault-bound blocks of quartzite, flanked by siltstone to the east and north, and more quartzite to the west.

Geophysics

A fixed-wing aeromagnetic survey, with a line spacing of 500 m and a nominal height of 135 m, was flown by the Tasmania Department of Mines in 1981 over the West Coast, including the entire study area. A brief qualitative interpretation by Corbett *et al*. (1982) noted "irregular and linear anomalies scattered over a large area" in the Interview River–Norfolk Range area. It was noted that, at least where the surface geology was known, the anomalies were mainly in siltstone sequences, and that the adjacent quartzite was relatively quiet. Some linear anomalies in the area were thought to correspond to dolerite dykes.

A similar aeromagnetic survey (500 m line spacing, 150 m nominal terrain clearance) of the adjoining area in far northwest Tasmania (north of 5 421 000 mN) was flown by the Bureau of Mineral Resources in 1984. This survey also collected radiometric data.

Brief, mainly qualitative, interpretations of these surveys were made by Bishop (1986) and Richardson (1994). Both authors attributed the SSE-trending chain of magnetic anomalies parallel to the 'Balfour trend' to disseminated pyrrhotite in siltstone, the former author also invoking strong remanence (after T. Dickson, pers. comm.) and the latter suggesting a very steep easterly dip.

The aeromagnetic and radiometric survey of April 1996, flown for the Regional Forest Agreement with a line spacing of 200 m, included the entire Norfolk Range–Sandy Cape study area and largely supersedes previous geophysical surveys. A brief qualitative interpretation was made by McClenaghan and Seymour (1996). The magnetically noisy character and NNW-trending structural grain of the 'Sundown

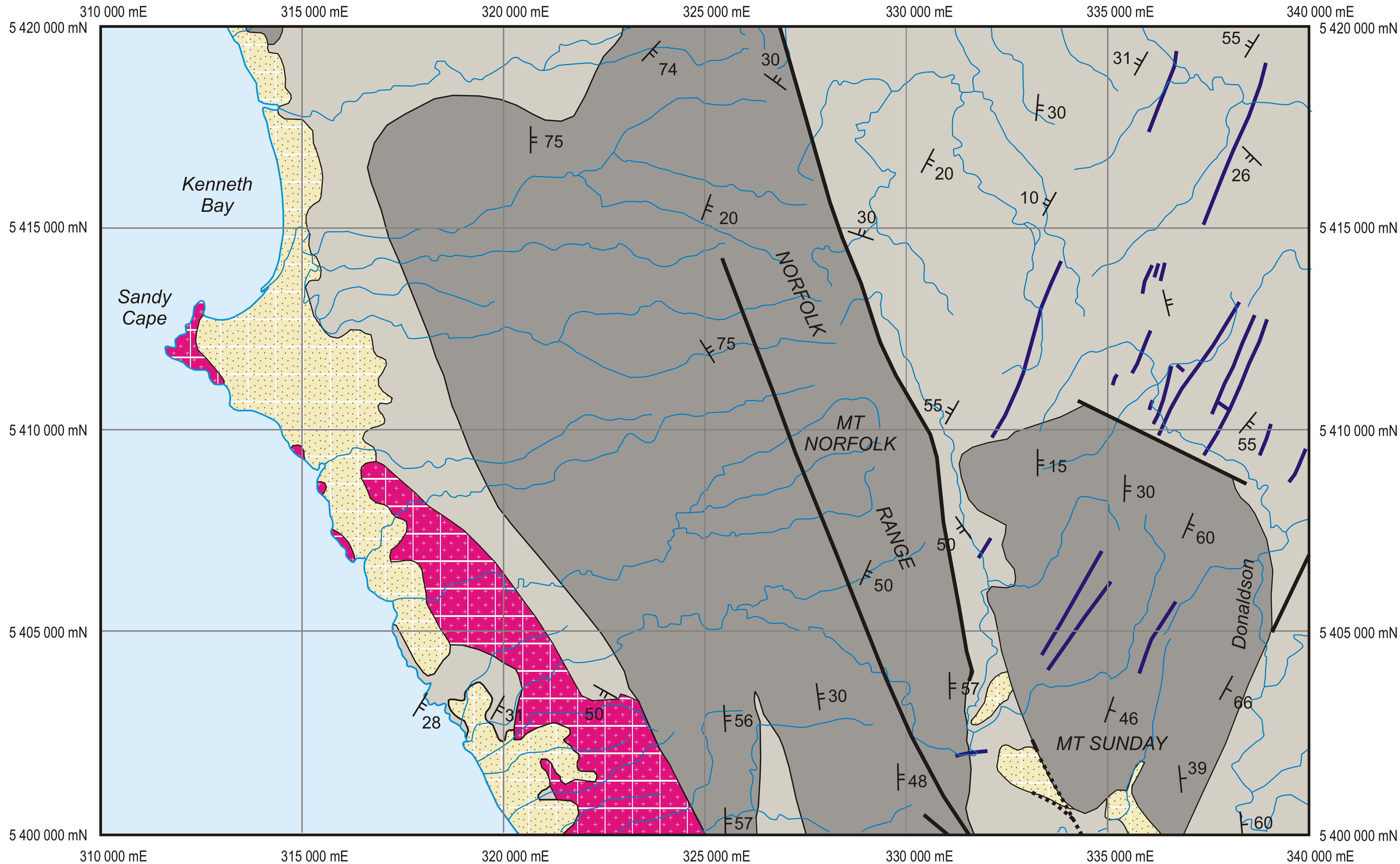


Figure 5. *Pre-WTRMP interpreted geology (from original 1:250 000 scale compilation, Calver et al., 1995). Grey = Rocky Cape Group (light – mudstone and siltstone, dark – orthoquartzite); blue lines = dolerite dykes; pink = Devonian granite; yellow = coastal sand, talus.*

Point–Norfolk Range' domain, lying along the coast between the Pieman River and Sundown Point, was noted. It was thought to be fault-bounded immediately east of the Norfolk Range against the 'Balfour–Mt Sunday domain' with a similarly magnetically noisy signature but intersecting NNE-trending and WNW-trending structural grains. In both domains, the magnetic anomalies were speculatively attributed to possible fault-related mineralisation above shallow granite, although the possibility of a pyrrhotite source was also acknowledged.

Gravity data were used to interpret the subsurface form of the 'Pieman Granite' by Leaman *et al*. (1980) and Leaman and Richardson (1989). This interpretation was revised after the collection of further data (see below).

Modern exploration

Parts of the Norfolk Range–Sandy Cape area have been held under exploration licence at various times but, perhaps deterred by difficulty of access, only a few companies have undertaken significant 'grass roots' fieldwork. This work, which is summarised in Appendix 2, includes a useful attempt at a synthesis of the regional geology and stratigraphy for the ACI/Renison syndicate (Bell, 1972). The only diamond drilling in the area, over a magnetic anomaly behind Sandy Cape, was done by Electrolytic Zinc (Morland, 1982; McDonald, 1983, 1984).

Granite geochemistry

Previous work on the geochemistry of the Sandy Cape and Interview granites (e.g. Sawka *et al*., 1990; Wyborn and Chappell, 1998) is discussed, in connection with further data collected during this study, below.

Soils

Nicolls (1955), on the basis of limited field observations and air photo interpretation, produced a soil map of those coastal areas lying west of the Norfolk Range and between the Lagoon and Arthur rivers. On the coastal peneplain, soils are shallow, strongly acid, rich in organic material but also related to rock type. Soils developed over quartzite are transitional to moor podzols, whilst those over "slates and schists" are yellow podsolic soils containing more clay. Both were considered unsuitable for agricultural development. Nearer the coast, deep sandy soils, some moderately alkaline, are developed on coastal flats and several generations of calcareous sand dunes. Some of these were thought to have some potential for sown pasture.

Geophysics — General Comments

Prior to the commencement of field work, a qualitative interpretation of the new WTRMP geophysical data was made for the area, using 1:25 000 scale colour images derived from radiometrics, total magnetic intensity (TMI) and EM conductivity. Unexplained anomalies and features inconsistent with the existing 1:250 000 scale geological map were identified as priority targets for ground checking. The following paragraphs briefly review these datasets. Specific features are discussed in more detail in the later sections.

Radiometrics

The radiometric data, which reflect lithology within about one metre or less from the surface, were viewed mainly in the form of a total count image (fig. 6), as this provides the sharpest spatial definition of possible lithological boundaries. Separate images for potassium, thorium and uranium are also available, but these show similar features to the total count image. Potassium (fig. 7) is particularly similar, whilst thorium (fig. 8) and uranium (fig. 9), although showing the same broad pattern of highs and lows, are more 'grainy' due to the lower concentrations of these elements. A composite RGB (red = K, green = Th, blue = U) colour image (fig. 10) is not particularly useful in this area, as it is dominated by large contrasts between strongly and very weakly radioactive lithologies, as K, Th and U vary approximately in proportion. Thus areas of high total counts are essentially white on the RGB image, and areas of low total counts are very dark to almost black. Subtle contrasts in K:Th:U ratios are best seen on a normalised RGB image (fig. 11), although this does not show the variation in total counts.

Much of the region from the coast to the western foot of the Norfolk Range is one of low total counts (blue on fig. 6) consistent with highly siliceous units such as orthoquartzite or, near the coast, dune sand. On RGB and normalised RGB images, these units mostly appear blue to dark blue-green, possibly due to some U and Th contained in accessory detrital minerals (zircon, monazite, etc.), whilst K is very low. West of the Norfolk Range, thick peaty acid soils may also further suppress K and Th, whereas the low solubility of uranium in reducing conditions (e.g. Krauskopf, 1967, p. 526–531) may have caused the absorption of small amounts of U. This may account for the blue areas on the normalised RGB image (fig. 11).

In this area there are also large strongly contrasting radiometric highs (red to yellow on fig. 6) attributable to either pelitic units (such as siltstone within the Rocky Cape Group) or granite (as at Sandy Cape and near the lower Lagoon River). Both these rock types are much higher in K, but cannot be easily distinguished from each other on the RGB image (fig. 10), on which they are bright and white to pink. On the normalised RGB image (fig. 11), counts over the Interview Granite are relatively high in Th (green), whilst the pelitic units are relatively more potassic (pink to yellow).

On topographic maps the radiometric highs over inferred siltstone mostly correspond to areas of forest or dense scrub, whilst radiometric lows over inferred orthoquartzite are generally heath and buttongrass. A variety of vegetation types have developed on granite.

Inland, total counts increase eastward across an irregular line (c. 326 000–327 000 mE) closely corresponding to the foot of the Norfolk Range, which rises abruptly from flat buttongrass plains, 10–12 km from and subparallel to the coast. The radiometric effect may be purely topographic in origin, a function of better outcrop on the range slopes. However it must also indicate that significant K, Th and U are present in the inferred quartzite bedrock. It is shown below that this is due to detrital minerals (e.g. muscovite) rather than interbedded pelite or metasomatism related to underlying granite. It is speculated that the range may be a horst-like roof block, uplifted by intrusion of granite.

The radiometric image over the Norfolk Range itself and the undulating country to its east is rather 'grainy', with few well-defined features. There is a general increase in total counts from west to east, suggesting a greater pelitic component, but there are few clear boundaries that might define sharp pelite-quartzite contacts similar to those seen near the coast. This implies a lack of strong compositional contrast between dominantly pelitic and dominantly quartzitic units. There is also an eastward change, seen on the normalised RGB image (fig. 11), from K-dominant (pink) over the Norfolk Range, to Th-dominant (green) over more pelitic units in the Leigh and Donaldson river areas.

Overall, the radiometric image is modulated by topographic and outcrop effects. Weak sinuous anomalies of slightly elevated counts coincide with incised gorges of the Lagoon, Italian, North Pedder and Wild Wave rivers, and to a lesser extent the Pedder River, particularly where they flow over inferred pelite.

Magnetics

In contrast to areas of Rocky Cape Group rocks east of the Smithton Synclinorium, much of this area is magnetically noisy, despite the apparent paucity of outcropping strongly magnetic rock units (such as mafic or ultramafic rocks).

The most prominent feature on the TMI image (fig. 12) is a discontinuous series of strong north to NNW-trending elongate anomalies occupying much of the upper Lagoon River valley. These define a broad linear (Balfour Shear Zone) which extends both to the north and south, beyond the study area. Immediately to its west, the Norfolk Range itself is magnetically quiet, but a complex series of anomalies occupies much of the coastal peneplain. These, which also have a crude NNW/SSE grain parallel to the coast and major structures, are discussed in more detail below.

East of the Lagoon River valley are two large, crudely elliptical, magnetically quiet zones, in the Mt Holloway and Mt Edith–Mt Sunday areas, which Webster (2002) tentatively attributed to outcropping or shallow S-type granite (fig. 13). Between and east of them is another large area of complex anomalies, which Webster (2002) attributed to I-type granite (fig. 13). The current fieldwork does not support this (see below). The anomalies lack any obvious source and have no consistent grain, apart from weaker superimposed NNE-trending linear anomalies readily attributed to a swarm of narrow dolerite dykes.

Electromagnetics (conductivity)

An airborne electromagnetic survey covering about 55% of the study area was flown in April 2002 as part of the WTRMP project. The survey covers the entire Norfolk Range and extends east to the vicinity of the Heemskirk Road and Donaldson River, but to the west does not reach the coast except north of about 5 415 700 mN, in the northwest of the study area.

Although the response was recorded for five frequencies (coplanar 6 kHz, 34 kHz and 880 kHz; coaxial 980 Hz and 7 kHz), only brief qualitative comments on a colour image (fig. 14) derived from the most penetrating channel (cp880 kHz) are made here.

In the lower Wild Wave River area, where the survey extended to the coast, conductivity is almost uniformly high, regardless of lithology (siltstone, quartzite or Cainozoic sand). The high conductivity extends about nine kilometres inland and is possibly due to salt contamination of groundwater by sea spray in this area of generally subdued topography. There are a few negative (more resistive) point anomalies, the most pronounced of which at about 317 100 mE, 5 416 400 mN corresponds to the northern part of 'anomaly 6' of Morland (1982) (see Appendix 2). A fault, inferred from radiometrics, which extends SSE from 320 000 mE, 5 418 700 mN is also apparent as a linear EM anomaly with parallel trough and crest.

Conductivity drops markedly east of about 322 000 mE. The boundary corresponds to the western limit, inferred from radiometrics, of the quartzite of the Norfolk Range. The effect may be partly a direct response to lithology, but other quartzite tracts further west are not distinguishable from siltstone on this image. The lower conductivity is probably mainly due to reduced salt spray at increasing distances from the coast and better drainage on the slightly more elevated topography developed on quartzite.

Conductivity drops further at the western foot of the Norfolk Range (c. 326 000 mE), the high country of which generally has very low conductivity. Limited field work suggests that quartzite cropping out on the peaks (e.g. Mt Hazelton, Mt Norfolk, south of Mt Helen) is similar to that on the plains to the west (e.g. North Pedder River headwaters at 322 900 mE, 5 417 100 mN; below West Bluff at 325 000 mE, 5 413 900 mN). Again, the lower conductivity is probably largely the effect of better drainage on steeper topography. There is no clear evidence on this image for a major fault bounding the Norfolk Range to the west. Weak NW to NNW-trending lineaments west of the 'big bend' of the Lagoon River (327 800 mE, 5 404 800 mN to 330 000 mE, 5 402 200 mN; 330 000 mE, 5 402 200 mN to 330 700 mE, 5 400 200 mN) may indicate faults, on which some magnetic anomalies lie (see above).

East of the Norfolk Range the conductivity image is broadly similar to the magnetic image, although locally a crude NW–SE grain is also developed parallel to topographic lineaments (e.g. in the McDougalls Lookout area). In particular, the inferred extension of the Balfour Shear Zone is a very strong lineament (333 600 mE, 5 410 000 mN to 328 200 mE; 5 415 500 mN) defined by sharp contrasts in conductivity which field work suggests occur between quartzite and sheared siltstone. The magnetic anomalies east of Woody Peak (327 800 mE, 5 417 600 mN) and Mt Hazelton (327 500 mE, 5 418 600 mN) are also conductivity highs, whilst the large areas of low quiet magnetics are also conductivity lows. The dolerite dykes are not obvious on the conductivity image. Near the western margin of the survey, a 500 m wide ovoid conductivity low (centred on 335 700 mE, 5 416 600 mN in the upper Leigh River area) has no obvious magnetic expression or geological explanation.

Conductivity is highly variable in the southeast of the area. The image there has a strong NNE grain parallel to structural trends and topographic lineaments. Conductivity highs south of Mt Hadmar (e.g. 336 100 mE, 5 407 100 mN to 355 000 mE, 5 405 000 mN) and a trough-like low south of Mt Vero (337 500 mE, 5 406 500 mN to 336 300 mE, 5 402 800 mN) broadly correspond to similar magnetic features (see above).

Gravity

Good gravity coverage is available over most of the area, with typical station spacing of the order of one kilometre (fig. 15). Stations south of 5 410 000 mN were acquired as part of the Mt Read Volcanics Project in the mid 1980s, whilst those to the north were partly funded by Soloriens Mining NL in 1989. The main remaining 'hole' with few stations is in the eastern half of the Lily sheet, south of the Sumac Road in the Mt Holloway–Mt Bolton–McDougalls Lookout area.

These data were reduced by Leaman (*in* Hofto and Morrison, 1989) by using a density of 2.67 t/m^3 to calculate the raw Bouguer values, and subtracting a deep crustal model 'MANTLE-88' to remove effects related to coastal thinning of the continental crust (fig. 15). Interpretation has been made by Leaman (1988) and other authors, and only brief comments mainly in relation to the current field work are made here. A colour image of the Bouguer anomaly, with superimposed depth-to-granite contours after Leaman and Richardson (2003), is also shown (fig. 16).

The entire region south of Balfour and Ordnance Point, extending inland for at least 20 km from the coast and including all the area under discussion, has negative residual Bouguer values.

A strong northwest-trending negative gravity anomaly (-9 to -10 mGal) coinciding with the Interview Granite abruptly terminates to the north at about 5 406 000 mN. This is in accord with current field work, which showed that there are only limited granite outcrops in the Italian River at 318 400 mE, 5 405 800 mN, close to the end of the gravity anomaly. To the south in the Lagoon River, granite outcrop (320 160 mE, 5 403 150 mN to 320 930 mE, 5 403 750 mN) is further east than previously thought, and more closely corresponds to the trough of the gravity anomaly. The interpolated -8.5 mGal contour approximately coincides with the limit of outcropping granite in this area.

Leaman (1988) suggested that the granite-related anomaly was offset about 2 km eastward north of the Italian River, to a slightly less negative (-7 to -8 mGal) anomaly extending from behind Sandy Cape (c. 310 800 mE, 5 409 000 mN) to Kenneth Bay (c. 314 500 mE, 5 416 500 mN). Although outcrop in the area appears to be limited, EZ Exploration reported an interval of 'altered rhyolite' in a drill hole at 316 030 mE, 5 412 850 mN, more or less directly over the gravity low (McDonald, 1984; see Appendix 2). This locality was not visited during current field work.

The absence of outcropping granite around Johnsons Bay, contrary to previous maps, is in accord with the modest Bouguer anomaly (c. -6 mGal) there. Rather oddly, there is no strongly negative anomaly over outcropping granite at Sandy Cape, perhaps suggesting a vertically limited, possibly sill-like intrusion. The Bouguer anomaly decreases northward over outcropping granite from more than -3 mGal at Native Well Bay (313 000 mE; 5 410 400 mN) to about -6 mGal at Venables Corner (312 200 mE, 5 412 800 mN).

The second strongly negative (-8 to -9 mGal) anomalous zone extends from approximately Mt Norfolk to Mt Hazelton. As noted by Leaman (1988) and Webster (2002) this roughly coincides with the elevated terrain of the Norfolk Range, and is difficult to explain unless an underlying spine of granite is postulated. A weaker (-5 to -3 mGal) extension continues northward (outside the study area) to Mt Balfour, and the Sn mineralisation at Specimen Hill, near Balfour, lies on the eastern flank of this anomaly. The present field work has confirmed that uniformly east-dipping 'quartzite' (mainly micaceous quartz sandstone) crops out on the crest of the Norfolk Range. There is no obvious indication of exposed or shallow granite, although the quartzite is unlikely to show contact metamorphic effects strongly. There is no obvious change in surface geology south of Mt Norfolk, where the anomaly weakens; Mt Helen and its southern spur appear to be merely a strike continuation of the rest of the range.

South of Mt Helen, a strong (-10 mGal) negative anomaly at 330 800 mE, 5 405 200 mN is largely due to a single station, although Leaman (1988) noted that it lies on an east–trending negative trend extending from the lower Lagoon River towards the Savage River mine. At this locality similar and unremarkable east-dipping quartzite crops out on a prominent knoll on the crest of the range.

A relative gravity high (-3.94 mGal compared to about -7 mGal in nearby stations) is present in the upper Lagoon River valley, southeast of Helen Peak, and is also largely due to a single station (station 8851.1808 at 331 430 mE, 5 407 980 mN). Outcrop in the river is of locally sheared and typically wavy laminated siltstone, intruded by a NNE-trending dolerite dyke (sample LJ106), probably about 60 m wide. The gravity station is probably within about 70 m of the extrapolation of the dyke. Assuming a density contrast between the dolerite and country rock of 600 kg/m^3, and a vertical dyke of indefinite depth extending to the surface, standard equations (e.g. Dobrin, 1976) suggest a relative anomaly of +1.11 mGal at 70 m from the dyke, or +2.2 mGal even if the station was directly over the centre of the dyke. This compares to an observed relative anomaly of about +3 mGal, so it is unclear if the dyke can fully account for the anomaly.

Anomalies over the quartz sandstone peaks of the Mt Edith–Mt Hadmar area are slightly less negative (c. -6 to -7 mGal) than over the main part of the Norfolk Range, suggesting that any underlying granite is more deeply buried. Residual Bouguer values rise eastward towards Mt Vero (where outcrop is less siliceous) and become positive roughly east of the Donaldson River.

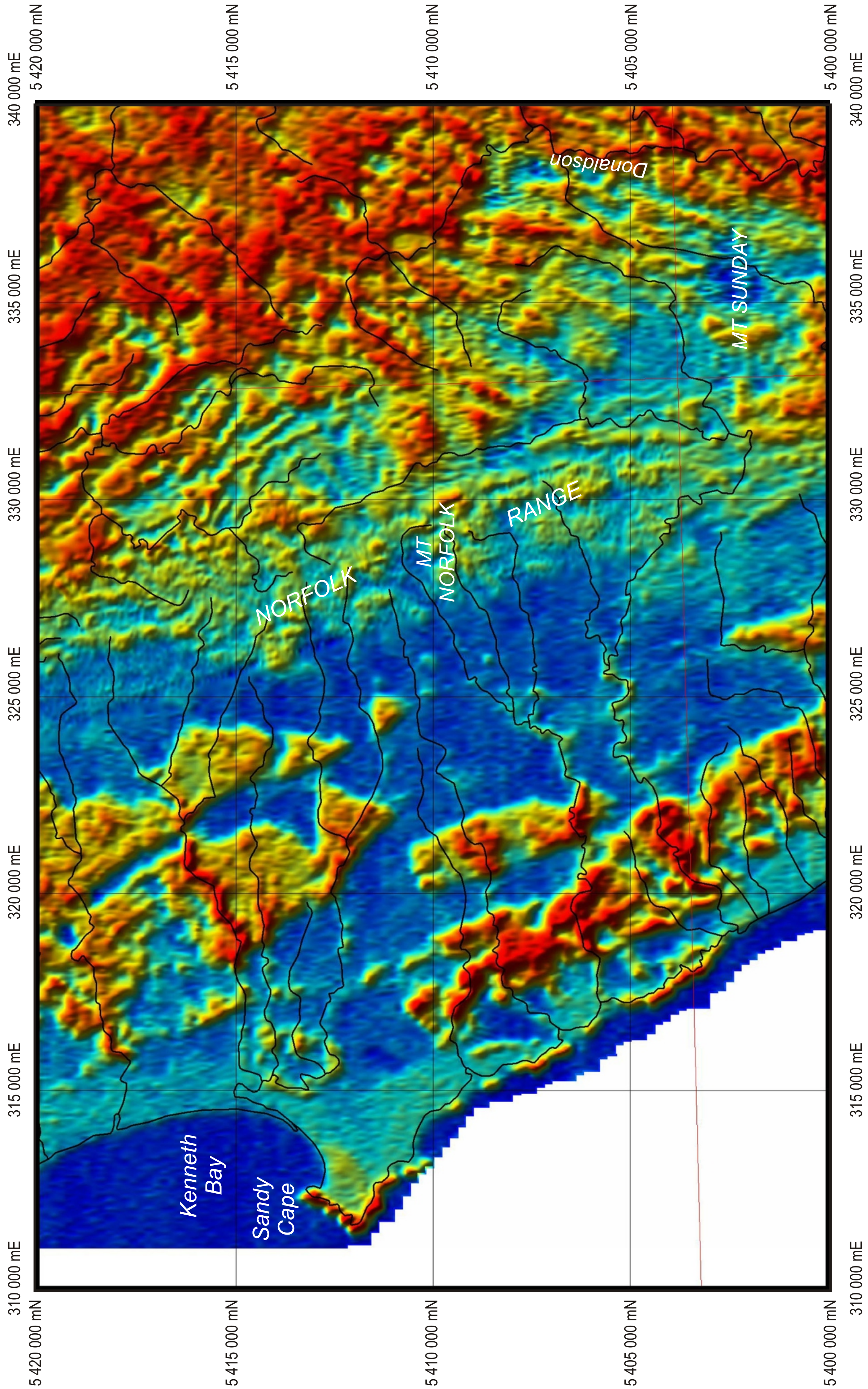


Figure 6. *Radiometric (total counts) image.*

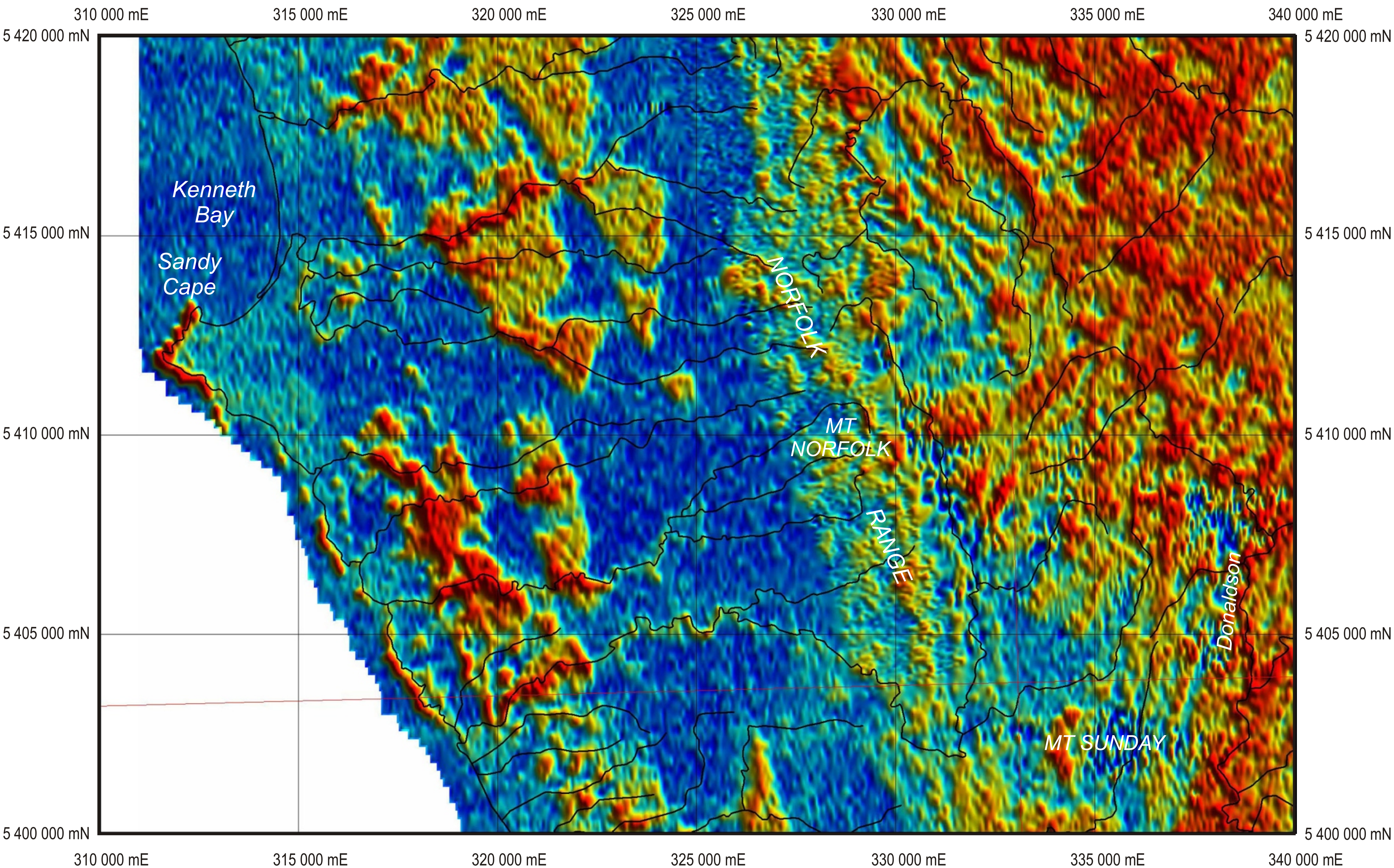


Figure 7. *Radiometric (K counts) image.*

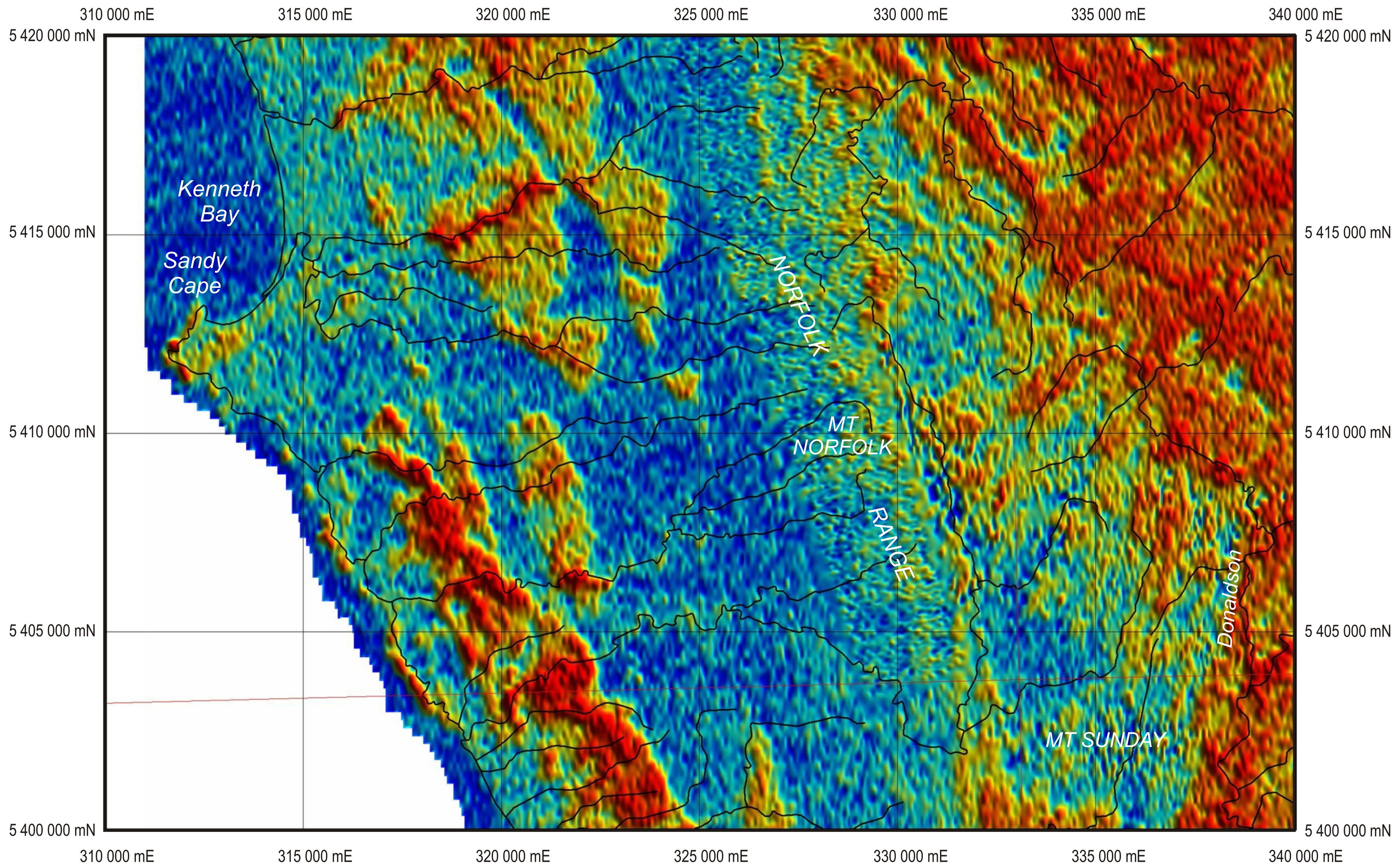


Figure 8. *Radiometric (Th counts) image.*

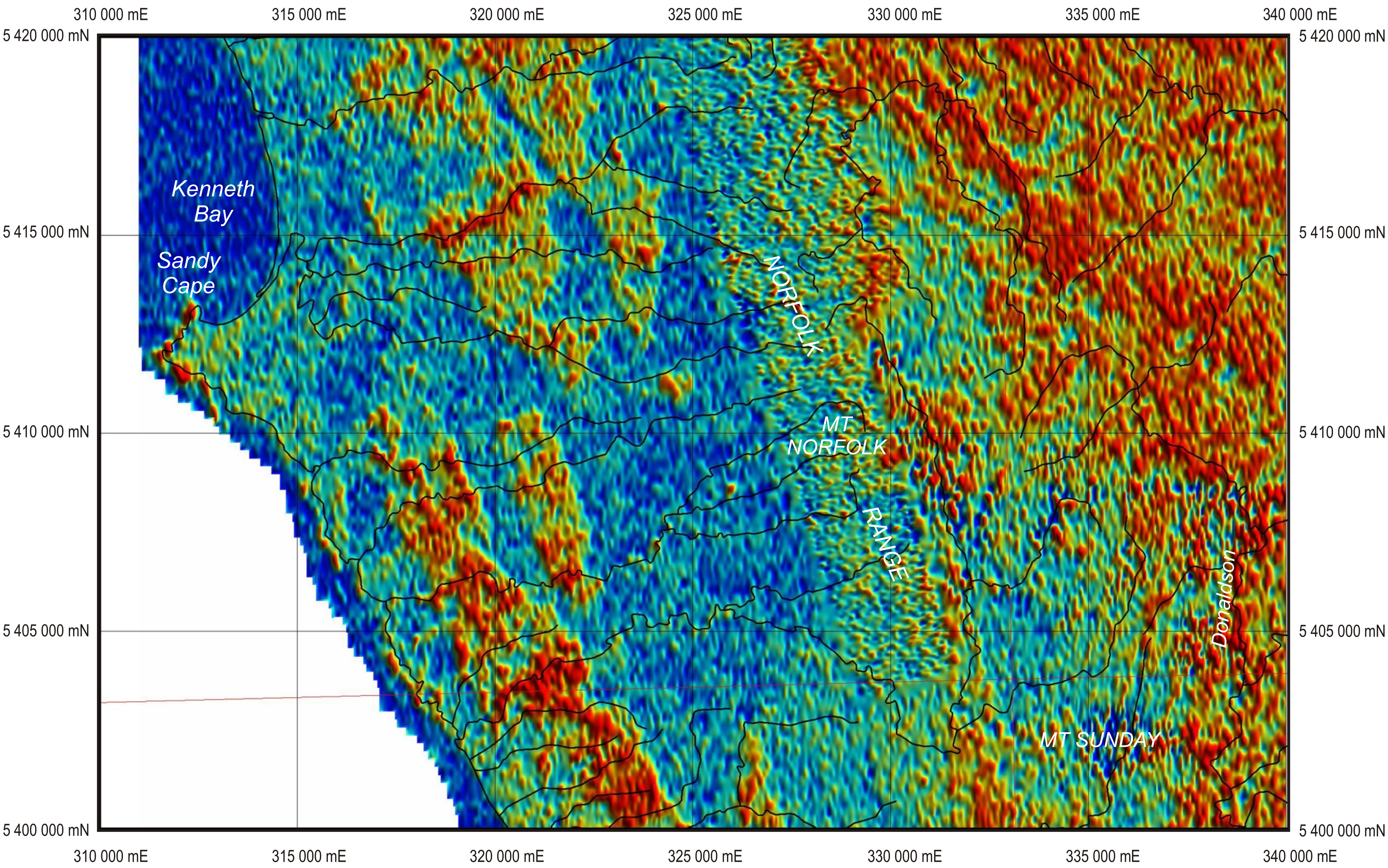


Figure 9. *Radiometric (U counts) image.*

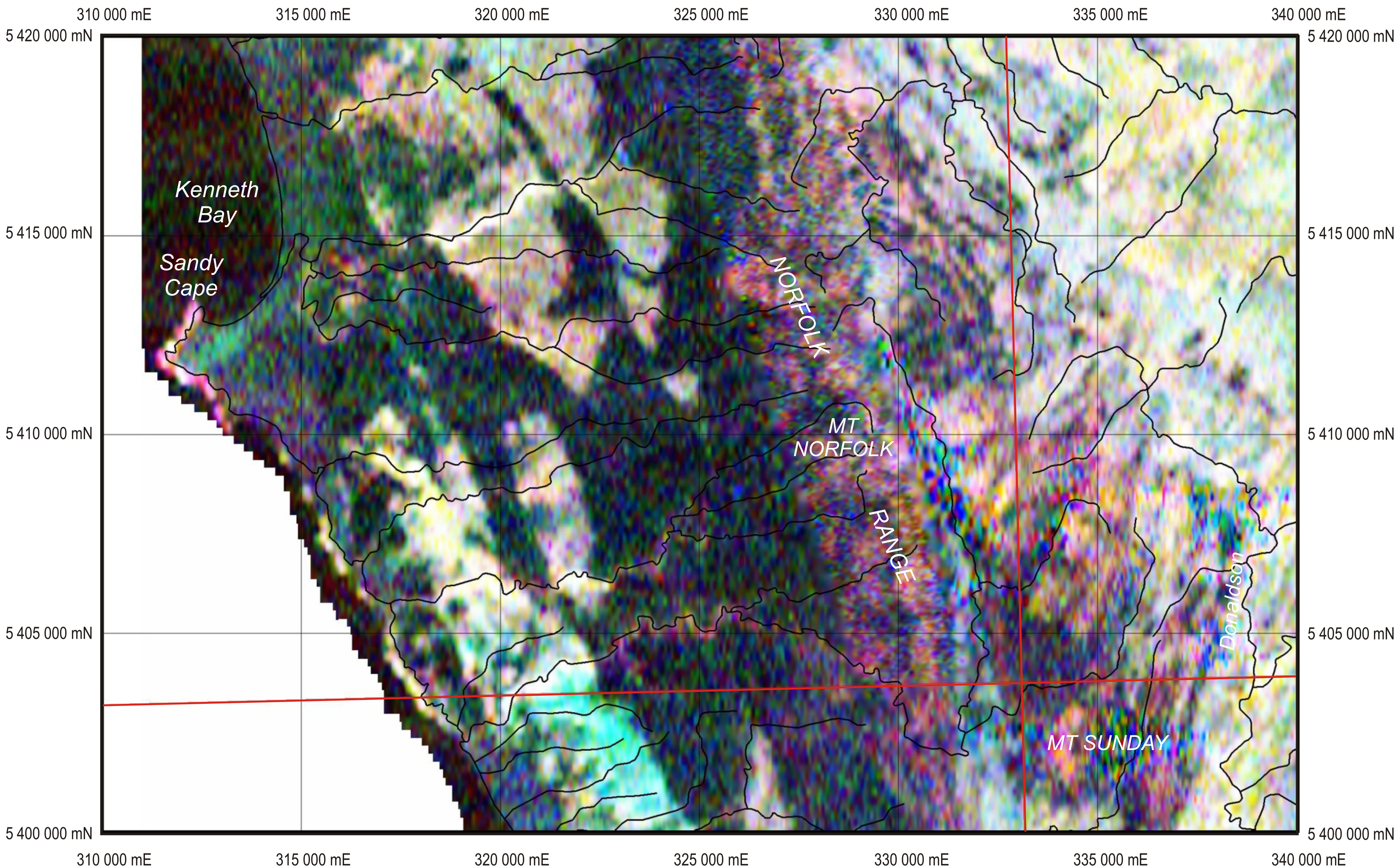


Figure 10. *Radiometric (RGB) image (red-K; green-Th, blue-U).*

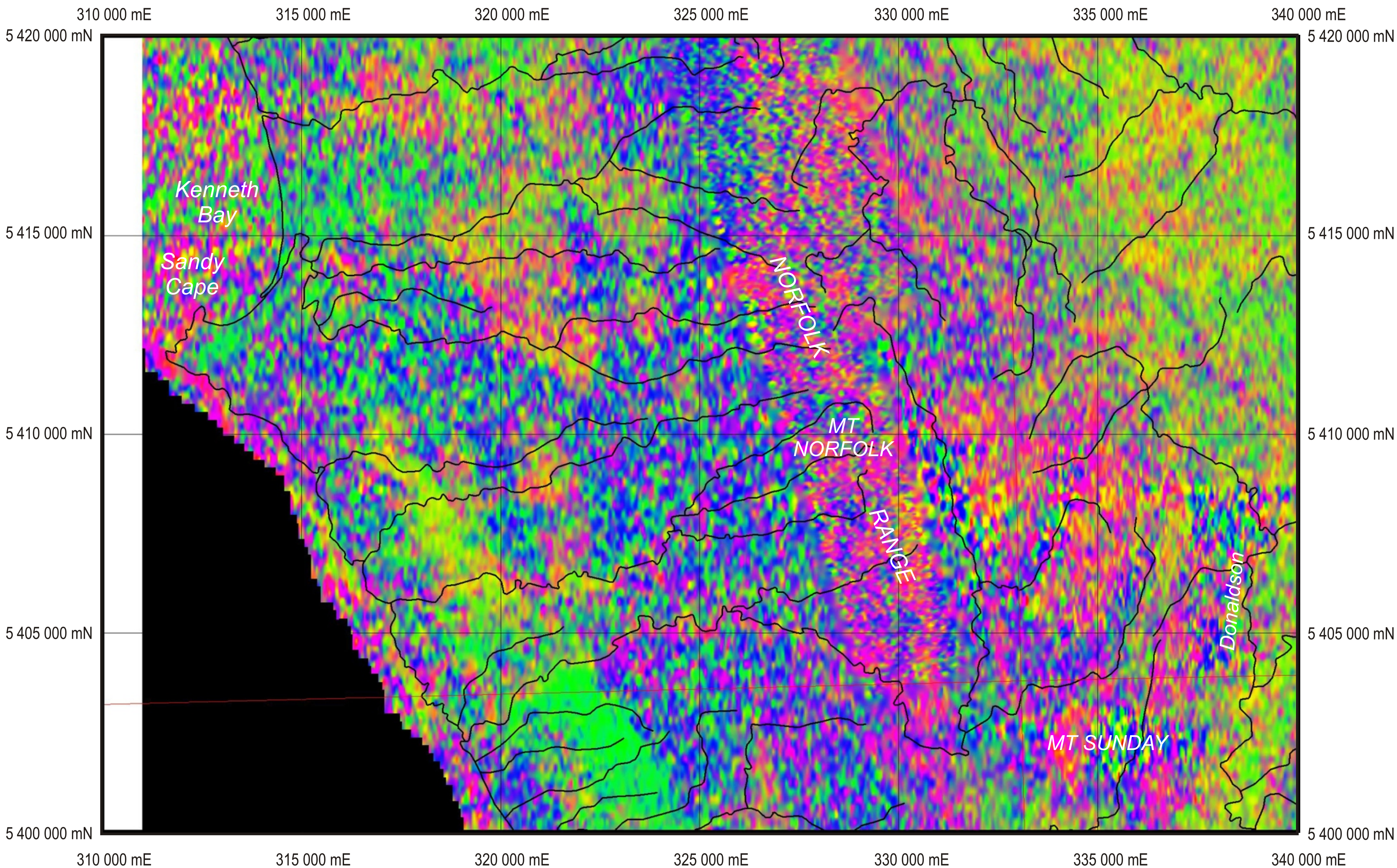


Figure 11. *Radiometric (normalised RGB) image (red-K; green-Th, blue-U).*

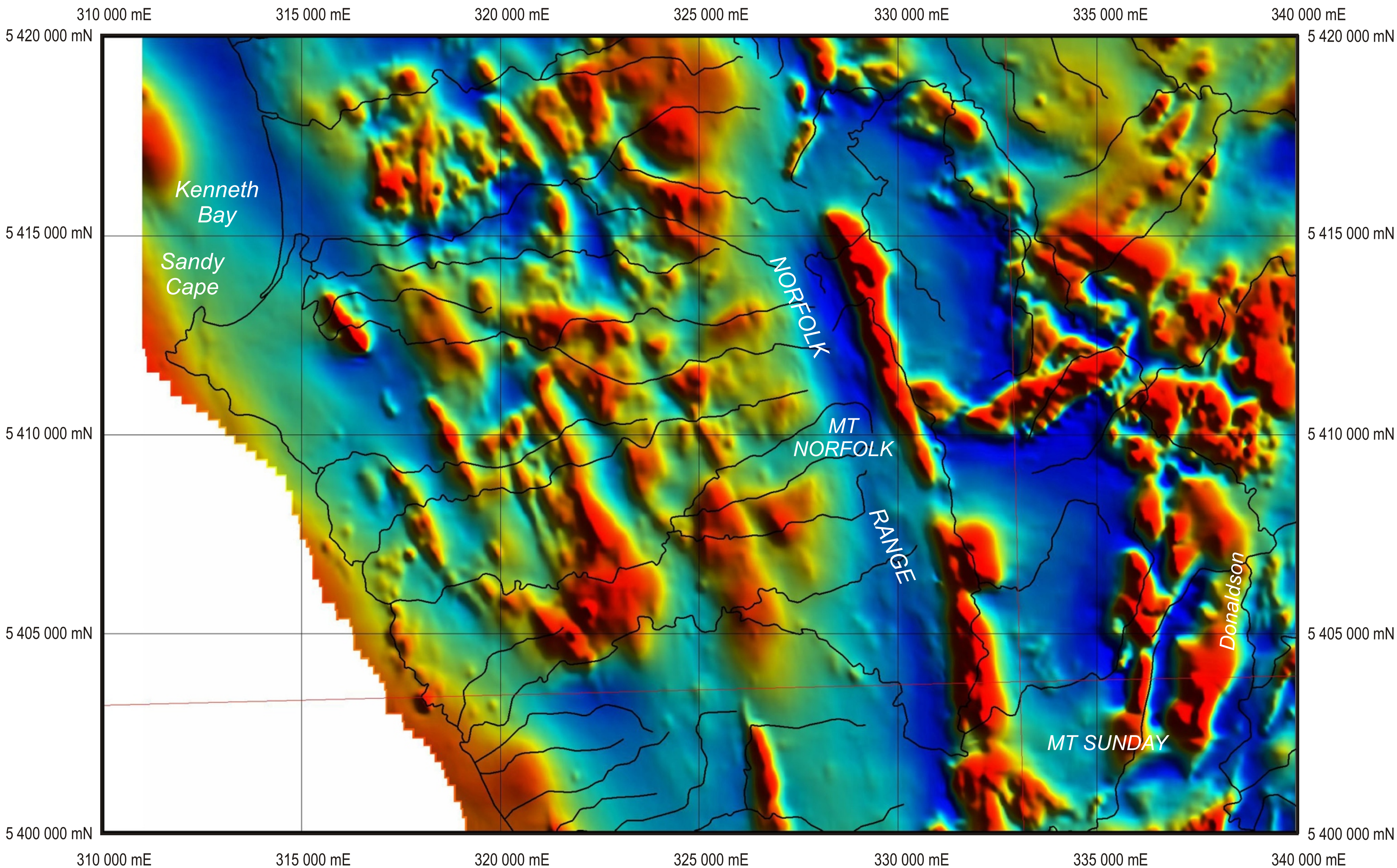


Figure 12. *Total magnetic intensity (TMI) image.*

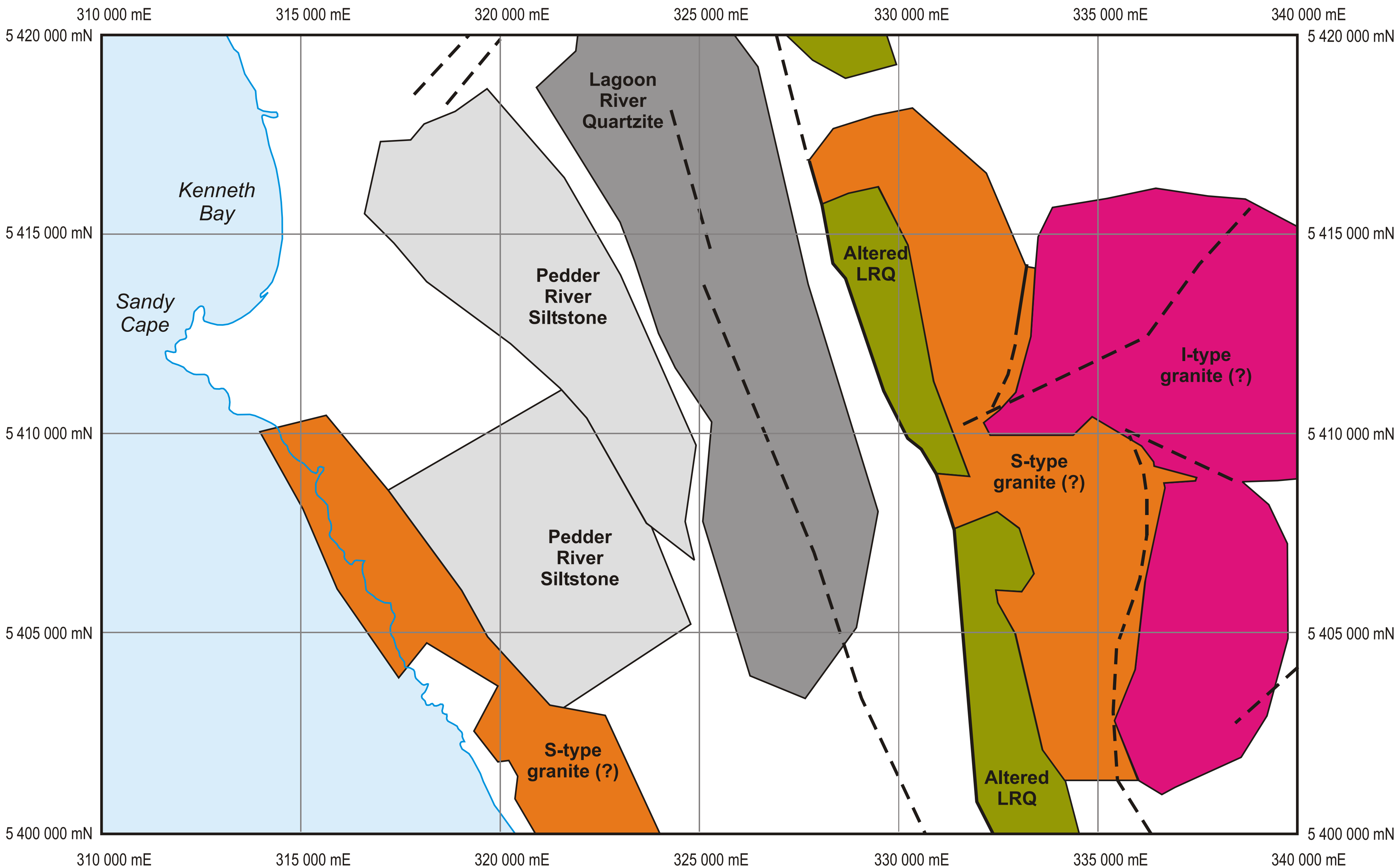


Figure 13. *Geophysical interpretation redrawn from Webster (2002).*

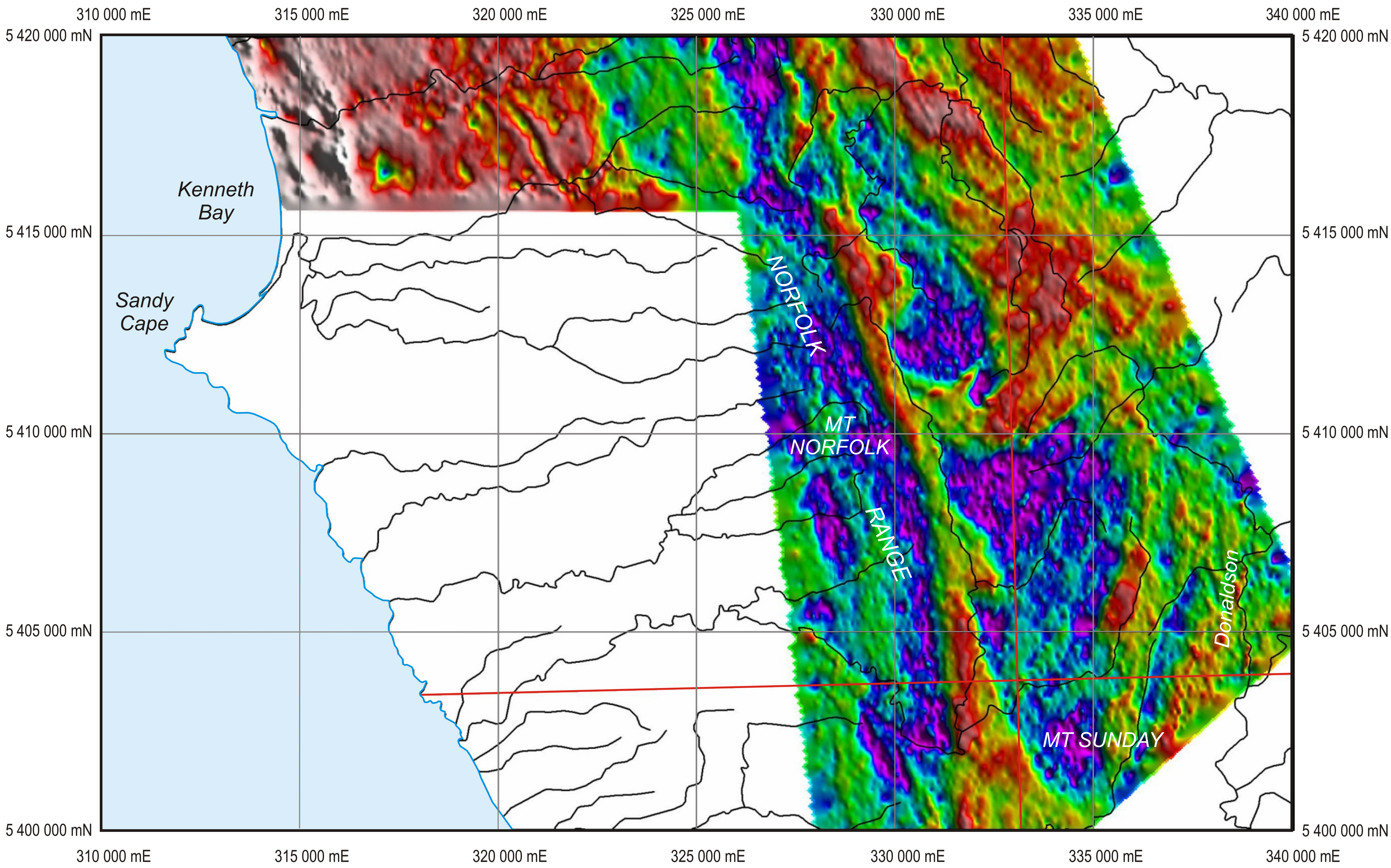


Figure 14. *Conductivity (coaxial planar 880 kHz) image.*

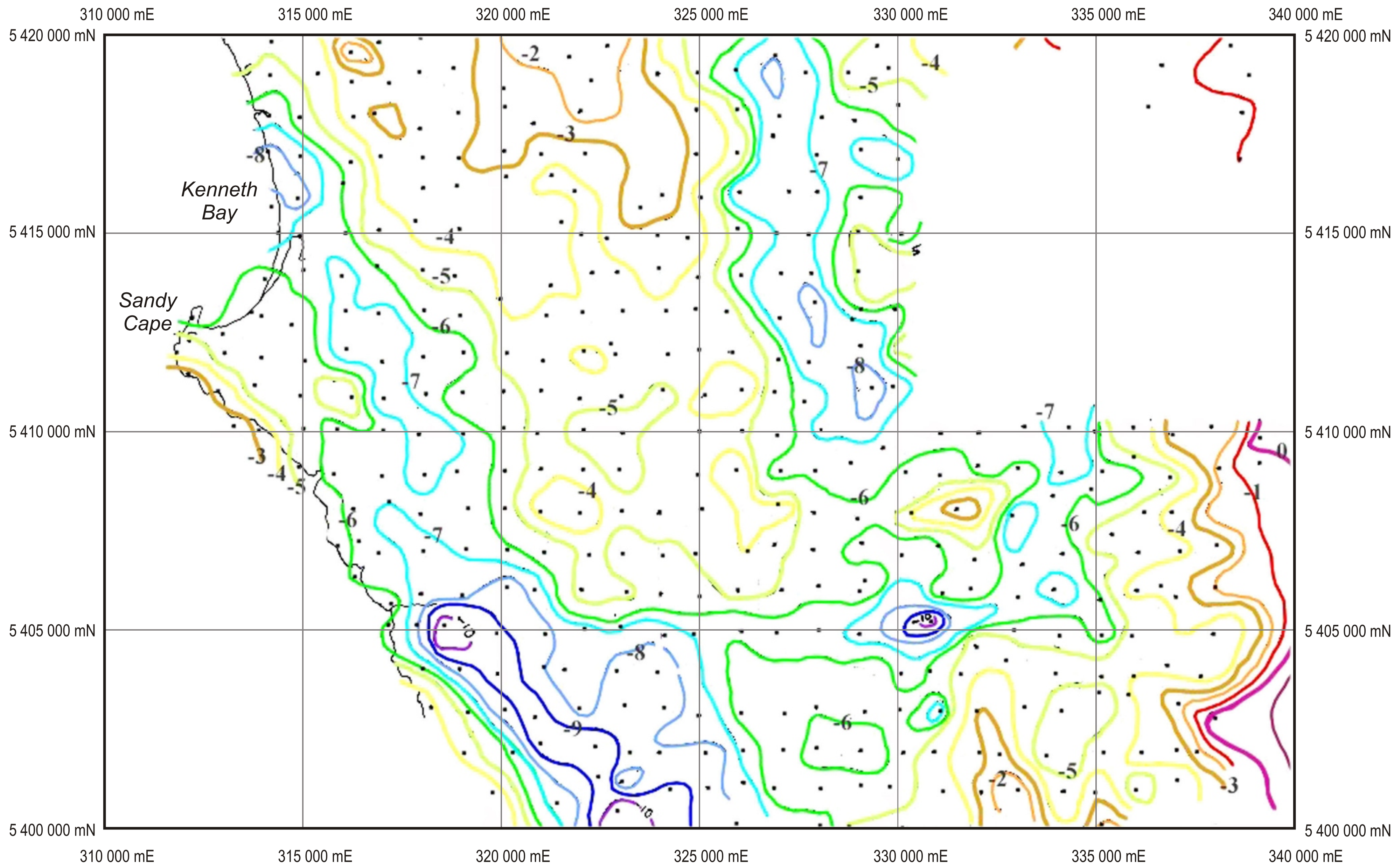


Figure 15. *Gravity stations (dots) and Bouguer anomaly contours (-10 to +1 mGal, coloured) (after Leaman* in *Hofto and Morrison, 1989).*

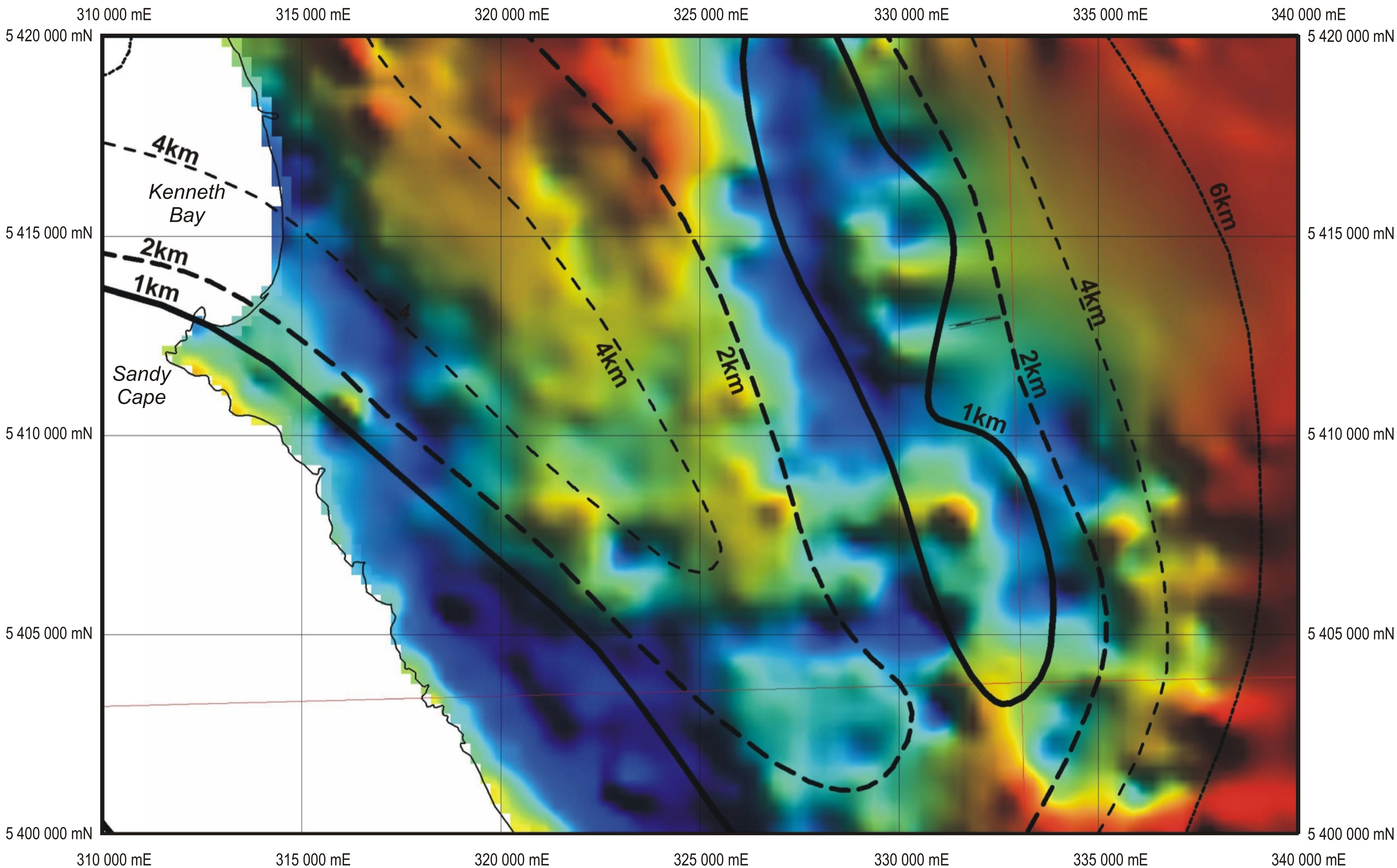


Figure 16. *Gravity (Bouguer anomaly) image with depth to granite contours (after Leaman and Richardson, 2003).*

Field Observations and Detailed Comments

Ground investigations were carried out over a period of twenty-nine field days in selected areas chosen for their geophysical interest. Five field camps were established, using helicopter access, at:

- Upper Lagoon River east of Mt Norfolk (330 140 mE, 5 410 140 mN);
- Lagoon River near Mt Judith (331 860 mE, 5 404 730 mN);
- North Pedder River (321 340 mE, 5 416 710 mN);
- Skull Creek (321 050 mE; 5 408 390 mN);
- Dago Plains near the Lagoon River mouth (318 600 mE; 5 403 070 mN).

The cost of this program included $12,487 in helicopter charter. In addition, using vehicular access, the Heemskirk Road was traversed from the limit of previous mapping (5 420 000 mN, the edge of the Balfour 1:25 000 scale geological map sheet) southward to the Donaldson River, and day traverses were made from the road to adjacent areas of geophysical interest in the vicinity of Mt Bolton, the Toner River, Mt Holloway and Mt Vero.

Much of the area is a mosaic of heath (buttongrass) interspersed with patches of scrub and eucalypt forest with a low dense understorey.

Although progress by foot is relatively quick on heath, it soon became apparent that, due to a thick peaty regolith, rock exposure (both outcrop and float) is very poor in many areas. This applies not only to the buttongrass plains but also to some elevated areas (e.g. Mt Holloway, Mt Judith and, probably, Mt Lily). Natural outcrop is largely confined to major streams, the coast and a few of the higher peaks. Accordingly, most effort was put into stream traverses, including key sections of geophysical interest in Skull Creek and the Toner, Lagoon, Italian, Pedder and North Pedder rivers. The previously virtually unknown section of the coast between Sandy Cape and the mouth of the Lagoon River was also traversed, and some major peaks of the Norfolk Range visited.

A revised, provisional 1:50 000 scale geological map of the area was compiled; a simplified version (fig. 17) is provided with this report. Field stations are shown in Figure 18, and sample locations are listed in Table 1 and depicted in Figure 19. Magnetic susceptibility data, collected in the field, are given in Table 2, and chemical analyses of selected samples in Table 3.

The Sandy Cape area

A very strong radiometric anomaly corresponds to a narrow coastal strip of outcropping granite at Sandy Cape. The hinterland immediately behind both Sandy Cape and Kenneth Bay is an area of generally low total counts, probably due to sand cover, including active dunes indicated on topographic maps. Counts over sand are very slightly higher than over inferred quartzite further inland. It seems unlikely that there are any substantial granite outcrops away from the coast.

Sawka *et al*. (1990) distinguished five textural varieties of the Sandy Cape Granite. In this study, only the southernmost accessible outcrop, on the southern headland of Native Well Bay (313 030 mE, 5 410 410 mN), was examined. It is obvious that offshore rocks to the south to about 313 200 mE, 5 409 900 mN) are also granite. These outcrops, which were not shown on the previous 1:250 000 scale map, also coincide with radiometric highs.

At Native Well Bay the granite is unfoliated, fine to medium-grained (2–4 mm) and leucocratic with abundant muscovite. Mostly it is almost equigranular, but locally there are sparse to rare tabular white feldspar phenocrysts (30 mm). In thin section (see below) small amounts of biotite and accessory tourmaline, but no opaque phase, are seen. Aplite veins are locally present.

The granite is non-magnetic (susceptibility ~0.06 10^{-3} SI) and on the TMI image a magnetically quiet zone extends for several kilometres inland. Initially this was thought to suggest a greater inland extent of granite, concealed beneath Cainozoic deposits. However immediately southeast of Native Well Bay, the location of the contact is tightly constrained by beach outcrops of black hornfels (313 830 mE, 5 410 260 mN; 313 490 mE, 5 410 350 mN; 313 270 mE, 5 410 290 mN). A slight gradient on the TMI image (seen as a weak shadow with NE illumination) extends northward to Venables Corner (312 500 mE, 5 412 800 mN) and may delineate the surface trace of the contact.

A strong long wavelength positive magnetic anomaly lies offshore north of Sandy Cape (near 311 000 mE, 5 417 000 mN) and is probably deep seated.

An intense 1.5 km long NW-trending positive magnetic anomaly about four kilometres east of Sandy Cape (around 316 000 mE, 5 413 000 mN) was investigated by EZ Exploration using gridding, mapping, ground magnetics and pulse electromagnetics (PEM). The area is mainly dune sand, but outcrops of massive white recrystallised quartzite (315 900 mE, 5 412 800 mN) and thinly laminated pyritic siltstone and shale with quartz veining (315 900 mE, 5 413 100 mN) were located (Morland, 1982; McDonald, 1983). Subsequently, a diamond-drill hole (at 316 100 mE, 5 412 920 mN) over a nearly coincident EM anomaly enabled the anomaly to be attributed to conductive, pyritic and graphitic black mudstone, interbedded with siltstone and quartz sandstone. A second hole (at 316 030 mE, 5 412 850 mN) targeted the magnetic anomaly and encountered "white and green brecciated altered rhyolite", overlying a similar but more sheared sedimentary sequence. The source of the magnetic anomaly

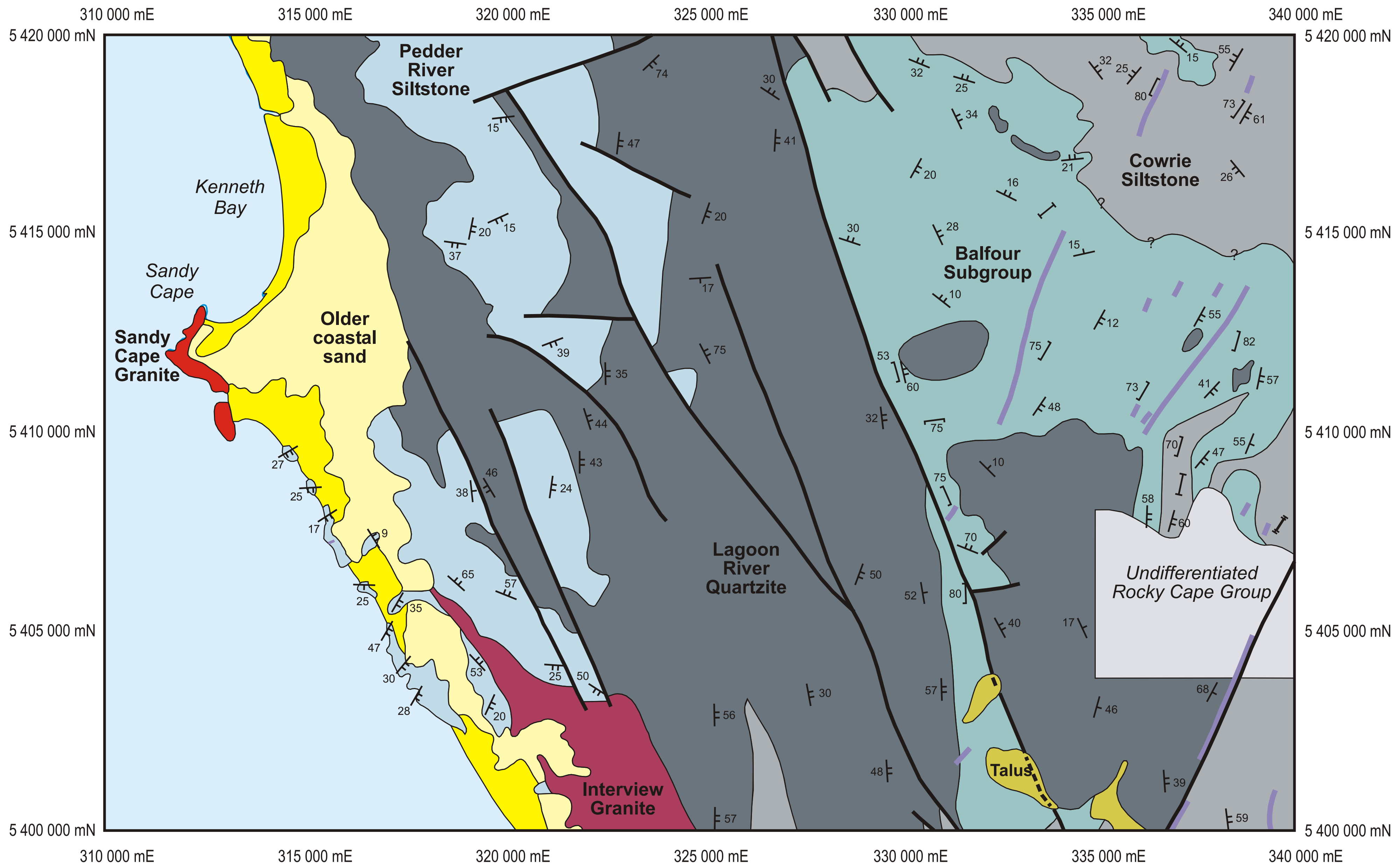


Figure 17. *Re-interpreted geology with selected structural readings. Information from this study and Gee* et al. *(1969), with some additional structural information from company reports (mainly Weir, 1985b).*

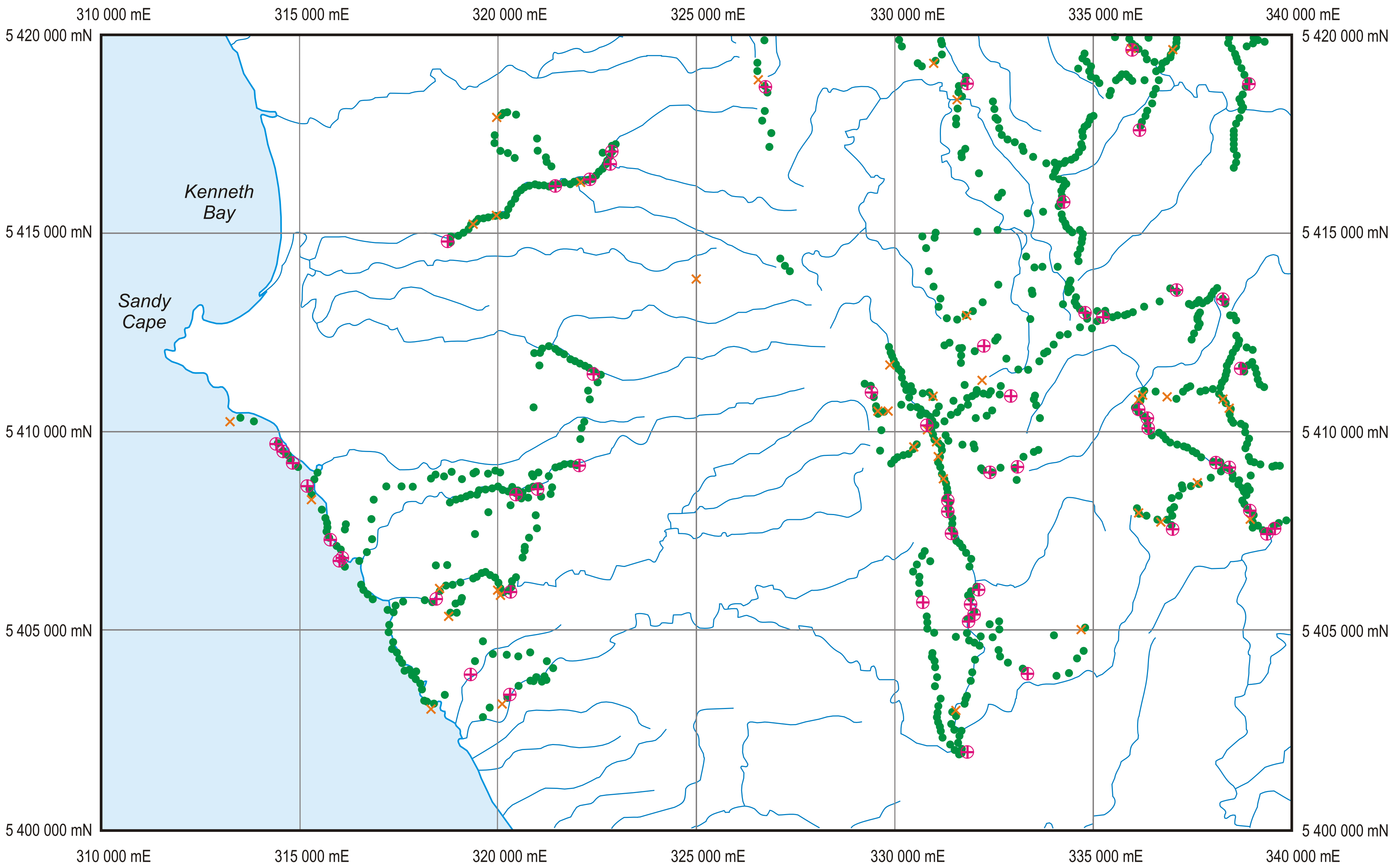


Figure 18. *Field stations (dots), locations of analysed samples (circled crosses) and other samples (diagonal crosses).*

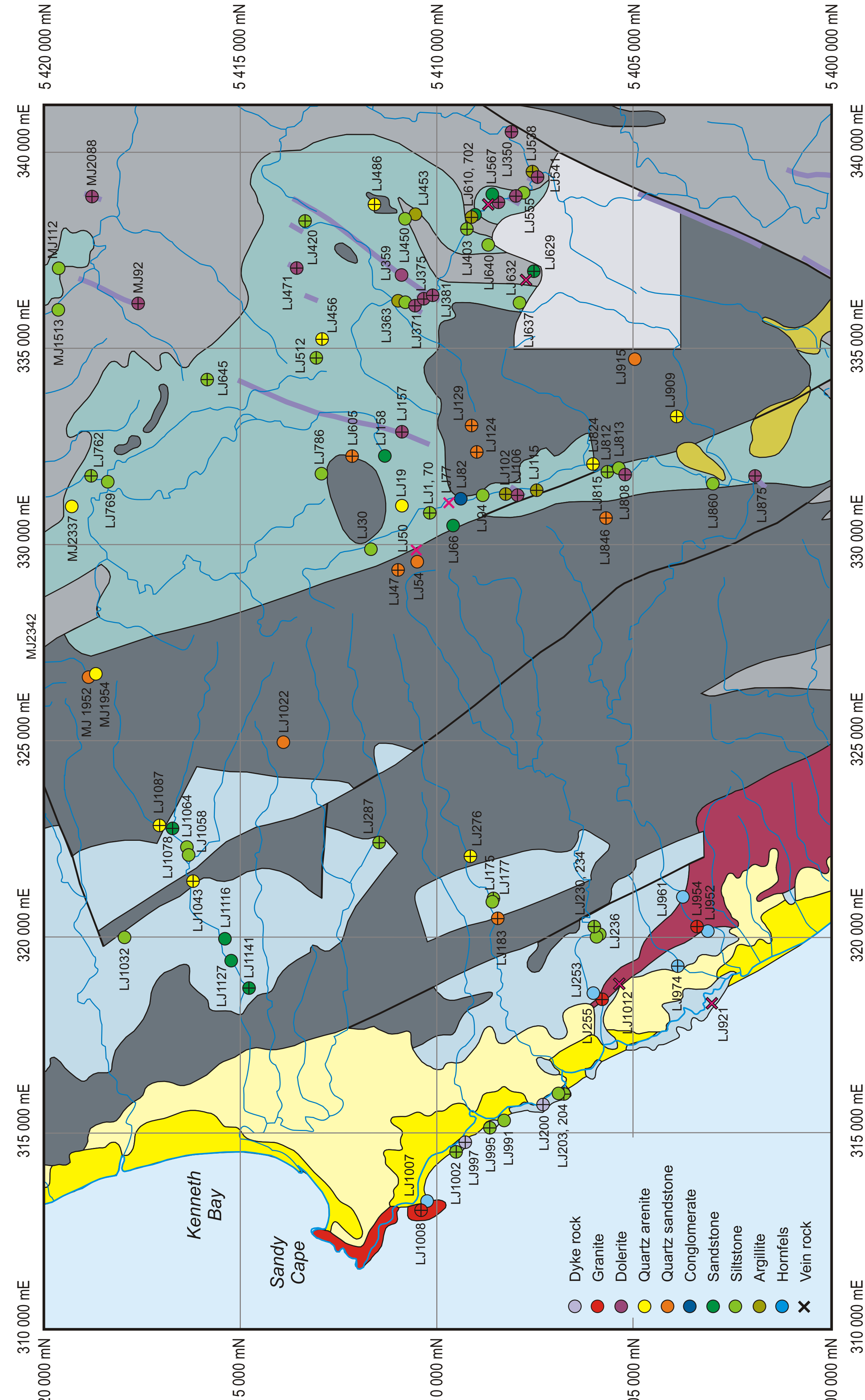


Figure 19. *Sample localities with field numbers, sorted by rock type, superimposed on 1:250 000 scale geology.*

Table 1

Sample list and treatment, Norfolk Range–Sandy Cape area

Reg. No.	Field No.	mE	mN	Locality	Unit	Rock type	Qualifiers	Comments	TS	CA
R011665	LJ1	330810	5410180	upper Lagoon River	Balfour Subgroup	siltstone	wavy lam		Y	Y
R011666	LJ19	330980	5410910	small knoll east of Lagoon River	Balfour Subgroup	orthoquartzite	medium grained		Y	
R011667	LJ30	329890	5411710	upper Lagoon River	Balfour Subgroup	siltstone	wavy lam		Y	
R011668	LJ47	329860	5410530	east flank of Mt Norfolk	within Balfour Subgroup	quartz-hematite vein			Y	
R011669	LJ50	329560	5410530	north of Mt Norfolk	Lagoon River Quartzite	quartz sandstone	fine grained		Y	
R011670	LJ54	329370	5410990	Mt Norfolk-Mt Mabel saddle	Lagoon River Quartzite	quartz sandstone	fine grained		Y	Y
R011671	LJ66	330480	5409630	creek east of Mt Norfolk	Balfour Subgroup	sandstone	vf-gr to sltst; phyllitic	weathered	Y	
R011672	LJ70	330870	5410080	upper Lagoon River	within Balfour Subgroup	quartz-sulphide vein			Y	
R011673	LJ77	331070	5409720	upper Lagoon River	within Balfour Subgroup	quartz-sulphide vein			Y	
R011674	LJ82	331130	5409420	upper Lagoon River	Balfour Subgroup	conglomerate	pebble-sized clasts		Y	
R011675	LJ94	331240	5408840	upper Lagoon River	Balfour Subgroup	siltstone	wavy lam	biotite	Y	
R011676	LJ102	331280	5408250	upper Lagoon River	Balfour Subgroup	argillite	well cleaved		Y	Y
R011677	LJ106	331290	5407980	upper Lagoon River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011678	LJ115	331370	5407450	upper Lagoon River	Balfour Subgroup	argillite			Y	Y
R011679	LJ124	332340	5408980	Mt Edith, west peak	Lagoon River Quartzite	quartz sandstone	medium grained		Y	Y
R011680	LJ129	333040	5409110	Mt Edith, main summit	Lagoon River Quartzite	quartz sandstone	very fine grained	detrital magnetite	Y	Y
R011681	LJ157	332870	5410890	2 km SE of Mt Holloway	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011682	LJ158	332230	5411330	1.3 km SE of Mt Holloway	Balfour Subgroup	sandstone	weathered			
R011683	LJ175	320940	5408590	Skull Creek	Pedder River Siltstone	siltstone	planar lam	chlorite porphyroblasts	Y	Y
R011684	LJ177	320870	5408620	Skull Creek	Pedder River Siltstone	siltstone				
R011685	LJ183	320440	5408450	Skull Creek	Lagoon River Quartzite	quartz sandstone	coarse-grained		Y	Y
R011686	LJ200	315720	5407310	north of Johnsons Head		andesite?			Y	Y
R011687	LJ203	316010	5406920	Johnsons Head	Pedder River Siltstone	siltstone	wavy lam		Y	
R011688	LJ204	315980	5406810	Johnsons Head	Pedder River Siltstone	siltstone	wavy lam	minor tourmaline	Y	Y
R011689	LJ230	320270	5406000	lower Italian River	Pedder River Siltstone	shaly siltstone			Y	Y
R011690	LJ234	320050	5405910	lower Italian River	Pedder River Siltstone	siltstone	wavy lam		Y	
R011691	LJ236	320030	5405990	lower Italian River	Pedder River Siltstone	shale			Y	
R011692	LJ253	318580	5406050	lower Italian River	Pedder River Siltstone	hornfels		tourmaline	Y	
R011693	LJ255	318410	5405800	lower Italian River	Interview Granite	granite	fine grained		Y	Y
R011694	LJ276	322030	5409150	Skull Creek	Lagoon River Quartzite	orthoquartzite	coarse grained		Y	Y
R011695	LJ287	322400	5411470	Pedder River	Pedder River Siltstone	siltstone	planar lam	chlorite p'blasts; tm	Y	Y
R011696	LJ350	340500	5408130	Donaldson River near bridge	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011697	LJ359	336860	5410900	west of Toner River	Rocky Cape Dyke Swarm	dolerite			Y	
R011698	LJ363	336220	5411000	Toner River	Balfour Subgroup	argillite	planar lam	sltst laminae	Y	
R011699	LJ366	336160	5410830	Toner River	Balfour Subgroup	siltstone	wavy lam		Y	
R011700	LJ371	336080	5410570	Toner River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011701	LJ375	336290	5410350	Toner River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011702	LJ381	336330	5410100	Toner River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011703	LJ403	338040	5409250	Toner River	Balfour Subgroup?	siltstone	planar lam		Y	Y

Table 1 *(continued)*

Reg. No.	Field No.	mE	mN	Locality	Unit	Rock type	Qualifiers	Comments	TS	CA
R011704	LJ420	338220	5413340	Heemskirk Rd 1.9 km N of Mt Bolton	Balfour Subgroup	siltstone	wavy lam		Y	Y
R011705	LJ450	338290	5410830	Heemskirk Road near Mt Bolton	Balfour Subgroup?	siltstone	planar lam		Y	
R011706	LJ453	338410	5410590	Heemskirk Road near Mt Bolton	Balfour Subgroup?	argillite	planar lam	siltstone laminae	Y	
R011707	LJ456	335200	5412920	Heemskirk Road	Balfour Subgroup	orthoquartzite	fine grained			Y
R011708	LJ471	337040	5413590	Heemskirk Road	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011709	LJ486	338670	5411590	Mt Bolton, summit	Balfour Subgroup	orthoquartzite	fine grained		Y	Y
R011710	LJ512	334740	5413040	Heemskirk Road	Balfour Subgroup	siltstone	wavy lam	biotite	Y	Y
R011711	LJ538	339490	5407560	Donaldson R near Toner R mouth	interview Siltstone correlate?	argillite	planar lam		Y	Y
R011712	LJ541	339360	5407470	Toner River near mouth	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011713	LJ555	338970	5407830	lower Toner River	Balfour Subgroup	siltstone	wavy lam		Y	
R011714	LJ560	338860	5408040	lower Toner River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011715	LJ567	338920	5408610	lower Toner River	Balfour Subgroup	sandstone	v fine grained, impure		Y	
R011716	LJ605	332230	5412150	creek 1 km east of Mt Holloway	Balfour Subgroup	quartz sandstone	medium grained	biotite, tourmaline	Y	Y
R011717	LJ610	338340	5409110	Toner River	Balfour Subgroup?	argillite	planar lam	siltstone laminae	Y	Y
R011718	LJ629	336960	5407560	Mt Vero, summit	Balfour Subgroup	sandstone	f grained, impure	biotite, tourmaline	Y	Y
R011719	LJ632	336730	5407750	NW flank of Mt Vero	within Balfour Subgroup	vein quartz		diss sulphide		
R011720	LJ637	336140	5407940	peak 0.5 km ESE of Mt Hadmar	Balfour Subgroup	siltstone	wavy lam	weathered; bte, tm	Y	
R011721	LJ640	337620	5408720	1.3 km NNE of Mt Vero	Balfour Subgroup	siltstone	pyritic	oxidized	Y	
R011722	LJ645	334200	5415820	Heemskirk Rd near McDougalls LO	Balfour Subgroup	siltstone	wavy lam	rare biotite	Y	Y
R011723	LJ702	338390	5409040	lower Toner River	Balfour Subgroup?	sandstone	f grained, impure		Y	
R011724	LJ712	338660	5408720	lower Toner River	within Balfour Subgroup	vein quartz				
R011725	LJ718	338740	5408470	lower Toner River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011726	LJ762	331750	5418780	Lindsay River	Balfour Subgroup	siltstone	wavy lam		Y	Y
R011727	LJ769	331600	5418380	Lindsay R near Eighty Creek mouth	Balfour Subgroup	siltstone	wavy lam		Y	
R011728	LJ786	331820	5412970	1 km NE of Mt Holloway	Balfour Subgroup	siltstone	wavy lam	weathered	Y	
R011729	LJ786B	331820	5412970	1 km NE of Mt Holloway	Balfour Subgroup	siltstone	wavy lam		Y	
R011730	LJ808	331780	5405260	upper Lagoon River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011731	LJ812	331950	5405410	upper Lagoon River	Balfour Subgroup	siltstone	planar lam		Y	
R011732	LJ813	331960	5405420	upper Lagoon River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011733	LJ815	331850	5405680	upper Lagoon River	Balfour Subgroup	siltstone	wavy lam		Y	Y
R011734	LJ824	332040	5406050	upper Lagoon River	Lagoon River Quartzite	orthoquartzite	v fine grained		Y	Y
R011735	LJ846	330650	5405710	ridge 3 km south of Helen Peak	Lagoon River Quartzite	quartz sandstone	medium grained		Y	Y
R011736	LJ860	331550	5402990	Lagoon R 1 km north of big bend	Balfour Subgroup	siltstone	planar lam	weathered	Y	
R011737	LJ875	331740	5401950	big bend on Lagoon River	Rocky Cape Dyke Swarm	dolerite			Y	Y
R011738	LJ909	333260	5403930	creek 1.5 km SSE of Mt Judith	Lagoon River Quartzite	orthoquartzite	f-m grained, impure	biotite	Y	Y
R011739	LJ915	334710	5405030	peak 2 km east of Mt Judith	Lagoon River Quartzite	quartz sandstone	fine-v fine grained		Y	
R011740	LJ921	318310	5403030	coast 1 km north of Lagoon R mouth	within Pedder River Siltstone	mineralized-quartz vein		atacamite		
R011741	LJ952	320160	5403160	lower Lagoon River		granite-hornfels contact			Y	
R011742	LJ954	320260	5403390	lower Lagoon River	Interview Granite	granite	f-medium grained	biotite, muscovite	Y	Y
R011743	LJ961	321020	5403750	lower Lagoon River	Pedder River Siltstone	hornfels		biotite	Y	
R011744	LJ974	319260	5403890	scarp 1 km north of Lagoon R mouth	Pedder River Siltstone	hornfels		biotite	Y	Y

Table 1 *(continued)*

Reg. No.	Field No.	mE	mN	Locality	Unit	Rock type	Qualifiers	Comments	TS	CA
R011745	LJ991	315320	5408310	coast just south of Sea Devil Rivulet	Pedder River Siltstone	siltstone	black wavy lam		Y	
R011746	LJ995	315140	5408670	coast 2.7 km north of Johnsons Head	Pedder River Siltstone	siltstone	black wavy lam		Y	Y
R011747	LJ997A	314780	5409280	coast 2.8 km north of Johnsons Head		lamprophyre?		altered	Y	Y
R011748	LJ997B	314780	5409280	coast 2.8 km north of Johnsons Head		lamprophyre?		altered	Y	
R011749	LJ1002	314540	5409530	coast 3.5 km north of Johnsons Head	Pedder River Siltstone	siltstone	wavy lam	tourmaline	Y	Y
R011750	LJ1008	314410	5409700	south headland of Native Well Bay	Sandy Cape Granite	granite			Y	Y
R011751	LJ1007	313270	5410290	coast south of Native Well Bay	Pedder River Siltstone	hornfels		biotite, tourmaline	Y	
R011752	LJ1012	318800	5405370	coastal scarp south of Italian River		tourmaline-quartz rock			Y	
R011753	LJ1022	325000	5413900	plains 1 km WNW of West Bluff	Lagoon River Quartzite	quartz sandstone	coarse grained		Y	
R011754	LJ1032	320000	5417950	creek south of Wild Wave River	Pedder River Siltstone	siltstone	planar lam	tourmaline	Y	
R011755	LJ1043	321430	5416190	North Pedder River	Lagoon River Quartzite	orthoquartzite	medium grained		Y	Y
R011756	LJ1058	322070	5416320	North Pedder River	Pedder River Siltstone	siltstone	planar lam	biotite	Y	
R011757	LJ1064	322280	5416370	North Pedder River	Pedder River Siltstone	siltstone	planar lam	chlorite p'blasts; bte, tm	Y	Y
R011758	LJ1064A	322280	5416370	North Pedder River	Pedder River Siltstone	siltstone	planar lam	biotite	Y	
R011759	LJ1078	322770	5416760	North Pedder River	Pedder River Siltstone	siltstone	to f-gr sst; planar lam	tourmaline	Y	Y
R011760	LJ1087	322830	5417050	North Pedder River	Lagoon River Quartzite	orthoquartzite	fine-grained		Y	Y
R011761	LJ1116	319970	5415430	North Pedder River	Lagoon River Quartzite	siltstone	to f gr sst; planar lam	tourmaline	Y	
R011762	LJ1127	319390	5415240	North Pedder River	Lagoon River Quartzite	siltstone	to f gr sst; planar lam	tourmaline, biotite	Y	
R011763	LJ1141	318700	5414800	North Pedder River near Gales Cliffs	Pedder River Siltstone	siltstone	to f gr sst; planar lam	tourmaline, biotite	Y	Y
R006773	MJ92	336130	5417620	End of Sumac 15 Road	Rocky Cape Dyke Swarm	dolerite			Y	Y
R006576	MJ112	337020	5419640	Sumac 15 Road	Balfour Subgroup	siltstone	wavy lam		Y	
R006620	MJ1513	335970	5419650	Leigh River	Cowrie Siltstone	siltstone	planar lam		Y	
R006641	MJ1952	326600	5418880	north peak, Mt Hazelton	Lagoon River Quartzite	quartz sandstone	fine grained, impure		Y	
R006642	MJ1954	326700	5418680	Mt Hazelton, summit	Lagoon River Quartzite	orthoquartzite	medium grained, impure			Y
R006786	MJ2088	338860	5418780	Sumac Road (1.5 km S of Sumac 15)	Rocky Cape Dyke Swarm	dolerite			Y	Y
R006652	MJ2337	330980	5419310	2 km SE of Dohertys Pimple	Balfour Subgroup	orthoquartzite	fine grained, wavy lam		Y	
R006653	MJ2342	330000	5420000	1 km SE of Dohertys Pimple	within Balfour Subgroup	gossan			Y	Y
R011511	-	326620	5420120	north of Mt Hazelton	Lagoon River Quartzite	quartz sandstone	medium grained		Y	Y

Grid co-ordinates AMG (GDA66).

TS = thin section; CA = chemical analysis

Table 2

Outcrop magnetic susceptibility data, Norfolk Range–Sandy Cape area

Field stn	mE	mN	Rock type	N	Magnetic susc. (10^{-3} SI) mean	min	max	Comments
LJ129	333040	5409110	quartz sandstone	30	1.50	0.09	6.26	detrital magnetite present
LJ997	314780	5409280	lamprophyre (?)	5	0.86	0.54	1.23	narrow dyke
LJ560	338860	5408040	dolerite	10	0.71	0.60	0.77	
LJ875	331740	5401950	dolerite	20	0.61	0.39	0.78	
LJ107	331320	5407950	dolerite	10	0.57	0.49	0.66	
LJ157	332870	5410890	dolerite	5	0.57	0.53	0.59	
LJ541	339360	5407470	dolerite	5	0.55	0.51	0.59	
LJ718	338740	5408470	dolerite	10	0.52	0.43	0.58	
LJ200	315720	5407310	dolerite	5	0.48	0.49	0.45	
LJ813	331960	5405420	dolerite	10	0.48	0.41	0.59	
LJ640	337620	5408720	pyritic siltstone	10	0.46	0.26	0.72	
LJ334	319420	5408430	siltstone	10	0.39	0.07	0.69	
LJ522	340370	5408150	siltstone	10	0.36	0.28	0.47	
LJ538	339490	5407560	argillite	10	0.35	0.31	0.39	
LJ529	340050	5407810	siltstone	10	0.32	0.27	0.39	
LJ915	334710	5405030	quartz sandstone	15	0.31	0.06	1.99	also 1.20; rest <0.29
LJ113	331350	5407600	siltstone	3	0.30	0.29	0.31	
LJ1109	320290	5415710	siltstone	20	0.30	0.18	0.43	
LJ610	338340	5409110	argillite	20	0.29	0.20	0.64	
LJ1017	318710	5406630	siltstone	5	0.28	0.22	0.34	
LJ132	333480	5409470	'quartzite'	10	0.27	0.21	0.62	
LJ1138	318810	5414910	siltstone	10	0.27	0.14	0.47	
LJ1116	319970	5415430	sandstone/siltstone	10	0.26	0.20	0.39	
LJ453	338410	5410590	argillite	10	0.25	0.22	0.31	
LJ754	332680	5417500	siltstone	10	0.25	0.13	0.36	
LJ115	331370	5407450	argillite	3	0.24	0.17	0.34	
LJ294	321910	5411770	siltstone	10	0.24	0.16	0.31	
LJ961	321020	5403750	hornfels	20	0.23	0.12	0.72	also 0.52, rest <0.23
LJ555	338970	5407830	siltstone	5	0.22	0.19	0.25	
LJ930	317890	5403710	siltstone	20	0.22	0.19	0.28	
LJ977	316790	5405830	siltstone	20	0.22	0.11	0.31	
LJ1058	322070	5416320	siltstone	20	0.22	0.10	0.34	
LJ762	331750	5418780	siltstone	10	0.21	0.17	0.27	
LJ815	331850	5405680	siltstone	10	0.21	0.20	0.24	
LJ1078	322770	5416760	siltstone	10	0.21	0.16	0.26	
LJ919	332160	5404840	siltstone	5	0.20	0.16	0.26	
LJ1038	321090	5416210	siltstone	20	0.20	0.10	0.32	
LJ443	338270	5411300	siltstone	10	0.19	0.17	0.24	
LJ645	334200	5415820	siltstone	5	0.19	0.14	0.24	
LJ767	331590	5418510	siltstone	5	0.19	0.16	0.21	
LJ812	331950	5405410	siltstone	10	0.19	0.14	0.25	
LJ853	332130	5404600	siltstone	10	0.19	0.15	0.23	
LJ1	330810	5410180	siltstone	10	0.18	0.09	0.26	
LJ21	330250	5411130	phyllite	5	0.18	0.13	0.25	
LJ114	331330	5407550	siltstone	3	0.18	0.16	0.21	
LJ641	334170	5415480	siltstone	10	0.18	0.13	0.20	
LJ702	338390	5409040	sandstone	10	0.18	0.04	0.29	
LJ1131	319190	5415090	siltstone	10	0.18	0.12	0.28	
LJ25	330140	5411450	siltstone	3	0.17	0.15	0.19	
LJ490B	339070	5411500	siltstone	4	0.17	0.11	0.22	
LJ803	334090	5414160	siltstone	10	0.17	0.12	0.23	
LJ954	320260	5403390	granite	20	0.17	0.13	0.21	Interview Granite
LJ30	329890	5411710	siltstone	3	0.16	0.15	0.17	
LJ199	315710	5407290	siltstone	10	0.16	0.12	0.20	

Table 2 *(continued)*

Field stn	mE	mN	Rock type	N	Magnetic susc. (10^{-3} SI) mean	min	max	Comments
LJ412	337750	5413230	siltstone	5	0.16	0.10	0.19	
LJ860	331550	5402990	siltstone	10	0.16	0.06	0.25	
LJ920	318360	5403070	siltstone	20	0.16	0.12	0.22	
LJ951	319770	5403020	hornfels	5	0.16	0.10	0.20	
LJ407	337540	5413230	siltstone	10	0.15	0.05	0.23	
LJ419	338240	5413390	siltstone	5	0.15	0.11	0.19	
LJ433	338470	5411930	siltstone	10	0.15	0.13	0.18	
LJ598	333760	5411990	siltstone	5	0.15	0.13	0.17	
LJ668	334180	5416780	siltstone	10	0.15	0.09	0.21	
LJ832	331580	5407120	siltstone	10	0.15	0.11	0.20	
LJ66	330480	5409630	phyllite sandstone	3	0.14	0.11	0.18	
LJ608	333380	5412860	sandstone	5	0.14	0.11	0.17	
LJ823	332010	5406020	siltstone	10	0.14	0.11	0.17	
LJ863	331540	5402840	siltstone	5	0.14	0.13	0.16	
LJ956	320800	5403710	granite	20	0.14	0.09	0.17	Interview Granite
LJ991	315320	5408310	siltstone	10	0.14	0.07	0.20	
LJ449	338250	5410840	siltstone	5	0.13	0.06	0.21	
LJ602	333090	5411530	sandstone	5	0.13	0.09	0.16	
LJ628	336980	5407580	siltstone	5	0.13	0.10	0.22	
LJ786	331820	5412970	siltstone	5	0.13	0.11	0.16	
LJ851	331510	5404790	siltstone	10	0.13	0.08	0.17	
LJ924	318040	5403410	siltstone	5	0.13	0.08	0.15	
LJ974	319260	5403890	hornfels	20	0.13	0.05	0.22	
LJ5	330870	5410330	siltstone	3	0.12	0.10	0.13	
LJ415	337980	5413500	siltstone	5	0.12	0.11	0.14	
LJ806	332000	5404680	siltstone	10	0.12	0.07	0.19	
LJ923	318110	5403200	siltstone	10	0.12	0.04	0.24	
LJ406	337490	5413180	siltstone	4	0.11	0.07	0.15	
LJ1032	320000	5417950	siltstone	3	0.11	0.07	0.18	
LJ319	320080	5408530	quartzite	10	0.10	0.04	0.20	
LJ850	330960	5404900	quartzite	5	0.10	0.07	0.13	
LJ950	319590	5402800	siltstone	3	0.10	0.09	0.12	
LJ846	330650	5405710	quartz sandstone	10	0.09	0.04	0.12	
LJ160	331680	5412080	'quartzite'	5	0.07	0.04	0.10	
LJ843	330580	5406340	'quartzite'	3	0.07	0.06	0.08	
LJ488	338830	5411640	'quartzite'	4	0.06	0.01	0.06	
LJ486	338670	5411590	orthoquartzite	5	0.05	0.03	0.10	
LJ1008	313030	5410410	granite	5	0.05	0.04	0.06	Sandy Cape Granite
LJ47	329860	5410530	vein rock?				0.58	limonitic float

Instrument: 'Exploranium' KT-5 hand held susceptibility meter, operating frequency 10 kHz measured on flattest available surfaces on natural outcrops. Sorted by decreasing mean susceptibility.

remained unresolved, although magnetite within fault zones was thought most likely. Assays were uniformly low in both holes (McDonald, 1984). The report of 'rhyolite' is intriguing, as no felsic volcanic rocks are otherwise known from the Rocky Cape Group. Alternatively, it may be a hypabyssal phase related to the Sandy Cape Granite, particularly as there is a moderate gravity low in the area. The black shale (also reported about one kilometre to the north by Neale, 1973) may account for nearby radiometric anomalies (316 100 mE, 5 431 300 mN; 316 300 mE, 5 414 100 mN) which are associated with patches of medium forest surrounded by buttongrass.

A similar but smaller and weaker magnetic anomaly occurs about two kilometres to the southeast (near 317 100 mE, 5 410 700 mN). Neither of these anomalies was visited during current field work.

There are weak positive radiometric anomalies over a small NNW-trending coastal scarp behind Kenneth Bay (around 317 600 mE, 5 413 400 mN and 316 900 mE, 5 415 500 mN). Similar weak radiometric anomalies at 318 200 mE, 5 410 500 mN and 317 800 mE, 5 411 600 mN both appear to lie on a southerly continuation of this feature. These localities were not field checked, but some outcrop is likely.

The coast between Lagoon River and Sandy Cape

The poorly known section of coast from the northern edge of the Pieman Heads map sheet to Sandy Cape was examined in some detail. All outcrops south of Sandy Cape are of Rocky Cape Group siltstone, apart from a few narrow dykes of possible andesite and lamprophyre. This is in agreement with the map of Bell (1972), whereas Williams and Turner (1973) incorrectly depicted Devonian granite at and north of Johnsons Bay (314 500 mE, 5 409 400 mN; 315 200 mE, 5 408 500 mN; around 315 500 mE, 5 407 400 mN).

Exposure is nearly continuous south of Italian River and around Johnsons Head. Elsewhere, and especially in the north towards Sandy Cape, outcrop is interrupted by long sandy beaches. Radiometric highs closely correspond to major areas of siltstone outcrop, and lows to major beaches. Numerous small siltstone outcrops project through a large expanse of outwash and beach sand at the mouth of Italian River (near 317 400 mE, 5 405 600 mN) (plate 2) and through coastal sands behind the mouth of Skull Creek (316 490 mE, 5 406 720 mN; 316 680 mE, 5 406 960 mN; 316 810 mE, 5 407 290 mN).

Typical outcrops are composed of thinly (0.5–5 mm) interlaminated medium to dark grey or greenish-grey siltstone and paler, cream-coloured fine-grained sandstone. The lamination is parallel but usually wavy rather than planar, often anastomosing and sometimes convolute (plate 3). Locally there are thin interbeds (typically about 50 mm but rarely up to 250 mm thick) of impure quartzite. The darker siltstone laminae are sometimes slightly pyritic. Sedimentary features noted include scouring, graded bedding, load casts, small-scale cross bedding and centimetre-scale syn-depositional reverse faults. Bell (1972) introduced the term Pedder River Siltstone for this sequence.

The sequence is poorly cleaved and fairly consistently dips and faces south to east. Although mesoscopic folds were observed at several localities, they do not appear to have a consistent trend. Gentle dome-like non-cylindrical folding is well exposed on the shore platform about one kilometre south of Italian River (317 290 mE, 5 404 460 mN) and may be related to a large (3 m) quartz vein immediately to the west. Complex non-cylindrical folding was noted in an isolated 30 × 30 m beach outcrop of black siltstone south of Sea Devil Rivulet (315 320 mE, 5 408 310 mN). On the north side of the outcrop the folding is tight and associated with quartz veins and an axial planar foliation (165W75). Similar irregular contorted, locally steeply dipping black siltstone occurs in the next outcrop to the north (315 250 mE, 5 408 410 mN).

Outcrop-scale faults (e.g. 318 050 mE, 5 403 430 mN; 315 660 mE, 5 407 600 mN) are associated with quartz veins and strong drag folding and, in places, fault-parallel cleavage development in adjacent siltstone.

Three small weathered dykes were noted on a rocky headland north of Sea Devil Rivulet (314 780 mE, 5 409 280 mN). These are subparallel at about 020W65, about one metre apart and typically 40–60 mm wide, with an isolated eroded 350 mm wide remnant a few metres away. Intrusion is dilational and discordant to the bedding in the enclosing wavy laminated siltstone (172E39). They crosscut quartz veins (20–100 mm wide) in the siltstone (plate 4) and a relatively young, possibly post-Devonian, age seems likely. The dyke rock is pale grey, weathering reddish-brown, fine grained, aphyric and aphanitic. In thin section (see below), the rock is extremely weathered and only a relict igneous texture remains. The dykes are weakly magnetic (mean susceptibility 0.86 × 10^{-3}) but their narrowness probably accounts for the lack of any associated aeromagnetic anomaly.

Attempts were made to field check point magnetic anomalies on non-adjacent flight lines near Johnsons Head (315 600 mE, 5 407 200 mN; 316 100 mE, 5 407 600 mN), but at the latter locality bedrock is concealed by dune sand, and the former is just offshore. At least two dykes of purplish to greenish-grey 'dolerite' intrude siltstone on the foreshore (315 720 mE, 5 407 310 mN) between the anomalies. The main dyke is about 10 m wide and trends out to sea at 050°. On the shore platform about 30 m away, a narrow (5 m) dyke trending at 110° may be an offshoot. The dykes have slightly higher magnetic susceptibility (0.48 × 10^{-3} SI) than the country rock (0.16 × 10^{-3} SI), but it is doubtful whether this is sufficient to explain the anomalies, or the absence of any anomaly on the intermediate flight line (5 407 400 mN) unless the dykes locally pinch out. Petrography and geochemistry (see below) indicate a broadly andesitic composition.

Plate 2

Coast looking south near the mouth of Italian River. Note the large expanse of beach, dune and outwash sand with southeasterly dipping outcrops of Pedder River Siltstone in foreground.

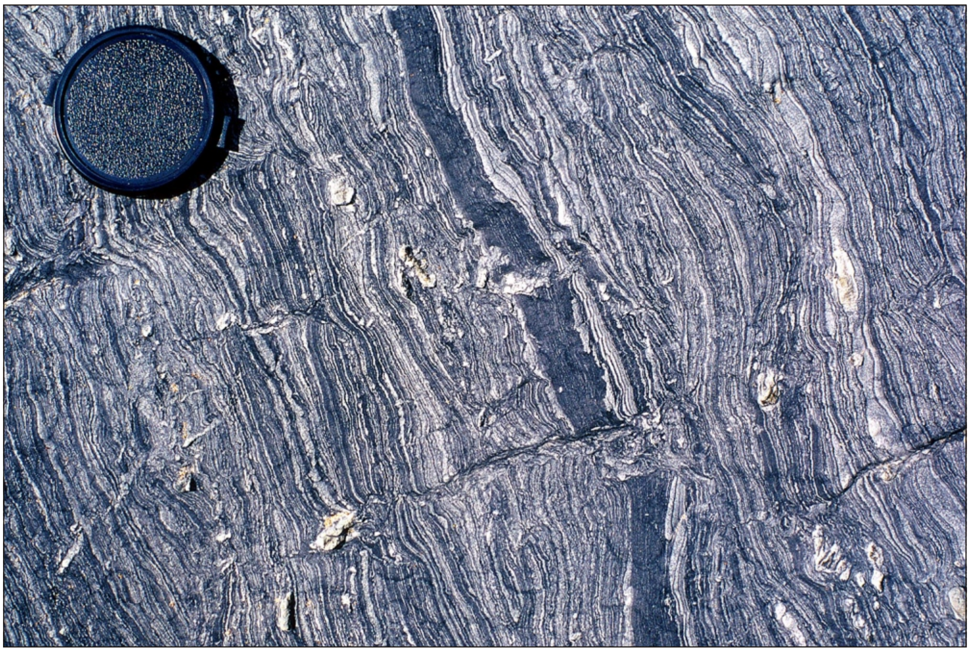


Plate 3

Close-up of typical sedimentary structures in Pedder River Siltstone, Johnsons Bay (316 100 mE, 5 406 570 mN).

Plate 4

Lamprophyre dykes in Pedder River Siltstone south of Sandy Cape (sample LJ997, 314 780 mE, 5 409 280 mN). Note dilational emplacement indicated by offset of quartz veinlets.

A belt of short wavelength magnetic anomalies along the coast further south (317 200 mE, 5 406 800 mN to 318 100 mE, 5 403 200 mN) also lie within siltstone. Copper mineralisation was noted nearby on the foreshore about one kilometre northwest of the mouth of Lagoon River (318 310 mE, 5 403 030 mN). Encrustations of bright copper-green atacamite ($Cu_2(OH)_3Cl$; identified by x-ray diffraction) and possible azurite are associated with quartz veins, up to 600 mm wide, also containing minor sulphides and angular slivers of copper-stained siltstone. The veins occupy a shear zone, about two metres wide, flanked by steeply-dipping siltstone (plates 5, 6). The zone strikes roughly north-south and disappears offshore to the south. It seems possible that the magnetic anomalies are related to associated alteration, although no strongly magnetic rocks were found.

Immediately inland, between the shore and the coastal scarp, predominantly low total counts are due to extensive sand cover (e.g. around 317 000 mE, 5 408 500 mN, where previous maps incorrectly show granite). The sand conceals the source of a short NNW-trending linear magnetic anomaly (316 400 mE, 5 409 100 mN to 316 900 mE, 5 408 300 mN) nearby.

Two small point magnetic anomalies lie on the coastal scarp (319 200 mE, 5 404 000 mN; 319 800 mE, 5 403 200 mN), but at the former only essentially non-magnetic (0.10–0.13 10^{-3} SI) hornfelsed siltstone crops out. Access to the latter is difficult because of the small deep estuary of the Lagoon River and surrounding low dense coastal scrub. Outcrop of thinly wavy laminated grey siltstone was noted at 319 590 mE, 5 402 800 mN and hornfelsed siltstone at 319 770 mE, 5 403 020 mN. Both outcrops are also essentially non-magnetic.

There is another small positive point magnetic anomaly north of Hunters Creek (321 850 mE, 5 401 350 mN). This locality was not visited, but dune sand over granite was mapped on the Pieman Heads map sheet (Gee *et al*., 1969).

The extent of outcropping Interview Granite

On the Pieman Heads geological map sheet (Gee *et al*., 1969) the Interview Granite has been mapped as a NNW-trending body, 3–4 km wide, subparallel to the coast. Previous compilers (e.g. Williams and Turner, 1973) have assumed that it extends northward, although locally obscured by coastal sands, to Sandy Cape.

South of the lower Lagoon River and 1–3 km from the coast, a large NNW-trending belt of high total counts (roughly 323 500 mE, 5 440 000 mN to 321 000 mE, 5 403 500 mN) corresponds well to the Interview Granite as mapped on the Pieman Heads map sheet. The country rock, here the Lagoon River Quartzite, contrasts with markedly lower total counts. The northward continuation of this radiometric anomaly extends east of the supposed eastern contact of the granite on the previous 1:250 000 scale geological map.

A traverse of the lower Lagoon River showed that there the granite is a dyke-like body about one kilometre wide. Outcrop is locally nearly continuous in large platforms and cliffs, as in a small gorge at 320 800 mE, 5 403 710 mN. The rock is a massive, equigranular, unfoliated, fine to medium-grained granite with abundant biotite and minor muscovite.

The western contact is exposed at 320 160 mE, 5 403 150 mN, where gently east-dipping hornfels on the left (locally the southeastern) bank is intruded by thin dykes of fine-grained granite. Massive fine to medium granite crops out a few metres upstream, but small cliffs immediately above the bank are composed of hornfels. This locality lies about 500 m downstream of the position mapped at the northern edge of the Pieman Heads map sheet, even though these authors showed a bedding reading in hornfels nearby, east of the river. It seems possible that the contact dips shallowly west or southwest and the hornfels forms a roof above the granite.

The eastern contact also lies about 500 m further southwest than previously thought, probably by extrapolation from the Pieman Heads geological map sheet. The contact crosses the river at about 320 930 mE, 5 403 750 mN, where outcrops of granite and bedded, moderately south-dipping, spotted hornfels occur on the left bank, about 30 m apart. Further upstream, the eastern contact grazes the river on a bend at 321 100 mE, 5 403 690 mN. At the latter locality the contact is sharp, irregular and angular, and follows joints in the hornfels, although the local overall trend is about 110°. Aplite and pegmatite dykes occur in adjacent hornfels immediately downstream. Spotted hornfels, probably pelitic in composition, is sporadically exposed further upstream, at least as far as 321 350 mE, 5 404 050 mN, and probably to an inferred contact with Lagoon River Quartzite near 322 300 mE, 5 404 200 mN. This accounts for the eastern part of the radiometric anomaly.

The radiometric high extends northward across the mainly buttongrass plains between the Lagoon and Italian rivers. It is consistent with either pelitic siltstone or granite, but outcrop is very poor, float and even mineral soil is sparse, and contacts could not be mapped on the ground. Small 'holes' of low total counts (e.g. 320 500 mE, 5 404 200 mN; 320 800 mE, 5 405 000 mN) probably represent superficial cover; field checking near the former locality failed to find either outcrop or float. A granite cobble was found in a small creek (319 850 mE, 5 404 390 mN), and micaceous wavy-laminated to spotted hornfels sporadically crops out at the top of the coastal scarp (319 400 mE, 5 404 210mN; 319 260 mE, 5 403 890 mN). A small granite outcrop (318 789 mE, 5 405 450 mN) and quartz-tourmaline float (318 800 mE, 5 405 370 mN) were located just south of Italian River, during spot checking by helicopter.

In the Italian River, granite outcrop, although inferred to be about two kilometres wide by Williams and Turner (1973), is limited to a 70 m wide section on the

Plate 5

Quartz-atacamite vein in sheared Pedder River Siltstone, Johnsons Bay (sample LJ921, 318 310 mE, 5 403 030 mN)

Plate 6

Close-up of quartz-atacamite vein

left (south) bank between 318 440 mE, 5 405 860 mN and 318 410 mE, 5 405 800 mN. It is a fine-grained, unfoliated, nearly equigranular biotite granite with sparse small (15 mm) feldspar phenocrysts. Hornfelsed wavy laminated siltstone crops out in the river west of the granite, downstream from 318 320 mE, 5 405 690 mN. Spotting was noted as far west as a siltstone outcrop in the outwash plain at 317 350 mE, 5 405 450 mN, about one kilometre from the eastern contact.

A small spur of the coastal scarp (317 700 mE, 5 406 900 mN) behind Johnsons Bay, one kilometre north of Italian River and along strike of granite, coincides with a weak radiometric anomaly, but has not been field checked. Although the lower part of Skull Creek was not fully traversed, it is worth noting that stream cobbles of siltstone and quartzite, but no granite, are present near its mouth at 316 610 mE, 5 406 890 mN.

In summary, the northward extent of outcropping Interview Granite is much less than previously thought. North of the Lagoon River it rapidly tapers to a narrow northwest-trending spine-like body which probably plunges beneath Rocky Cape Group siltstone just north of Italian River. The body trends towards Sandy Cape, which may be a more fractionated cupola developed from it. On radiometric images, the granite contrasts with the Lagoon River Quartzite but is difficult to distinguish from the Pedder River Siltstone.

The coastal peneplain

The geology of this area was very poorly known, but contrasting areas of low and high radiometric counts suggest some lithological diversity. It is also magnetically noisy, in contrast to some areas of Rocky Cape Group further east (e.g. Rapid River area). A subparallel series of strong but ragged NNW-trending linear magnetic anomalies extends roughly from lower Lagoon River (321 000 mE, 5 403 800 mN–324 000 mE, 5 405 500 mN) to the Wild Wave River (315 000 mE, 5 418 300 mN–322 500 mE, 5 419 500 mN) and beyond. The trend is parallel to regional structural trends and topographic grains (including both the coast and the Norfolk Range). Several of these large linear anomalies were investigated by ground traverses. As outcrop is poor, most effort was put into stream traverses.

Chimney Creek area

Near upper Chimney Creek in the south of the study area, nearly coincident north-trending magnetic (327 000 mE, 5 400 000 mN to 326 100 mE, 5 403 400 mN) and radiometric (327 000 mE, 5 400 000 mN to 326 300 mE, 5 402 600 mN) anomalies closely correspond to a wedge-shaped tract of Interview Siltstone shown on the Pieman Heads geological map sheet. Although not depicted as such, the eastern or both of its contacts with the Lagoon River Quartzite may be faulted. Similar magnetic anomalies further north (326 700 mE, 5 403 400 mN to 325 300 mE, 5 408 700 mN), apparently within Lagoon River Quartzite, may represent alteration along an *en echelon* series of similar trending faults. These anomalies were not checked during current field work.

Lower Italian River

Southwest-dipping quartzite crops out in the Italian River gorge (at 320 430 mE, 5 406 240 mN) and sporadically on the buttongrass plains to the north. There are large bluff-like outcrops, probably also of quartzite (not visited) on the south side of the gorge a short distance upstream (near 320 500 mE, 5 406 000 mN). A short distance downstream (320 360 mE, 5 406 240 mN), pale brown to cream-coloured siltstone with interbeds of thin (5–20 mm) quartzite has a similar southwest dip, apparently conformably and transitionally overlying the quartzite.

The rest of the siltstone in the river section (downstream to 318 460 mE, 5 405 970 mN) consistently dips and faces steeply northeast, towards the quartzite unit. Geometrically it seems a fault is implied at or near the contact with the quartzite. The fault may be in the vicinity of small outcrops of fractured pale brown siltstone (320 330 mE, 5 406 240 mN), and pale brown to greenish siltstone with minor southeasterly-plunging folds with associated strong cleavage (320 340 mE, 5 406 180 mN).

The change from quartzite to predominantly siltstone is consistent with a NW-striking boundary between tracts of low and high total counts on the radiometric image (intersecting the river near 320 400 mE, 5 406 200 mN).

In the remainder of the river section, much of the sequence is typically thinly planar laminated and sometimes fissile, medium to dark grey siltstone, weathering pale brown or greenish. Locally fine-grained paler grey to cream-coloured sandstone is present, with thin darker wavy laminae (e.g. 320 050 mE, 5 405 960 mN; 320 010 mE, 5 406 020 mN). Facings in the sandstone units are obtainable from scouring and flame structures. In the lower part of the river section (below about 319 420 mE, 5 406 300 mN) pale fine-grained sandstone with dark thin wavy siltstone laminae predominates.

The sequence is generally weakly cleaved. Most observed mesoscopic folds are gentle to open, although tight dextrally verging, southeast-plunging kink folds occur at 319 600 mE, 5 406 420 mN. No obvious contact metamorphism was noted until about 318 580 mE, 5 406 050 mN, where very wavy laminated siltstone and sandstone is hard, brittle and spotted.

A large NNW-trending linear magnetic anomaly (about 317 000 mE, 5 409 200 mN to 321 100 mE, 5 403 900 mN) lies within the siltstone sequence, east of the Interview Granite (which is magnetically quiet) and its northward extrapolation. No obvious source crops out where it intersects the Italian River near 318 900 mE, 5 406 100 mN. A broader and more complex series of magnetic anomalies lie to the southeast. Part of this area (around 322 000 mE, 5 405 000 mN) was gridded as "anomaly 4" by EZ, but ground magnetic profiles were subdued. Massive quartzite, dark grey laminated siltstone and possibly Cainozoic quartzitic conglomerate were noted in the area. Although the weak ground magnetic anomalies correlated with the siltstone, the main anomaly was attributed to a deeper source (Morland, 1982), possibly related to underlying granite.

Further east near the base of the Norfolk Range, a three kilometre long, NNW-striking positive anomaly (326 700 mE, 5 408 200 mN to 327 800 mE, 5 406 300 mN) lies in a radiometrically low area. It may indicate a fault within quartzite, possibly extending to small anomalies near 329 100 mE, 5 405 000 mN. Moderate, NW-aligned anomalies just south of Lagoon River (328 300 mE, 5 404 400 mN; 328 800 mE, 5 404 000 mN) may have a similar source. These areas were not visited.

Lower to middle Skull Creek area

Skull Creek flows generally west across several sharply contrasting tracts of low and high total counts in the radiometric data. A traverse between 318 500 mE, 5 408 400 mN and 322 100 mE, 5 409 200 mN showed that the radiometric highs lie over siltstone (not granite), and the lows over orthoquartzite.

In Skull Creek, between 319 460 mE, 5 408 480 mN to 318 780 mE, 5 408 200 mN (below which outcrop is poor), the dominant lithology is a thinly wavy laminated dark to pale grey siltstone, locally grading to cream-coloured fine-grained sandstone. Facing is obtainable from flame structures, scouring and truncations. The sequence mostly dips and faces east, but there are several reversals of dips indicating gentle to moderate, upright megascopic folds. Cleavage is usually poorly developed, but at 319 460 mE, 5 408 480 mN, near the eastern contact, east-dipping strongly cleaved siltstone grades to phyllite. The adjacent quartzite dips generally southwest, also towards the contact (319 460 mE, 5 408 480 mN), which therefore may be faulted, as in the Italian River (see above).

A NNW-trending linear magnetic anomaly (about 318 100 mE, 5 410 900 mN to 320 000 mE, 5 407 000 mN) lies close to the inferred fault, but no potentially magnetic rocks were encountered in Skull Creek. The anomaly partly corresponds to 'anomaly 2' (north of Sea Devil Rivulet around 318 500 mE, 5 410 000 mN) which was briefly investigated by EZ Exploration by gridding, soil sampling, and ground magnetics and electromagnetics. No geological observations appear to have been recorded (possibly due to lack of outcrop) and the source of the magnetic anomaly was unresolved (McDonald, 1983).

The quartzite tract is about one kilometre wide in a deeply incised to gorge-like creek section (319 500 mE, 5 408 520 mN to 320 480 mE, 5 408 470 mN). The usual rock type is a tough white, thickly planar-bedded to cross-bedded quartzarenite with occasional ripple marks, similar to other Rocky Cape Group quartzites. Interbeds of pale brown weathering siltstone are locally present (319 790 mE, 5 408 530 mN; 320 120 mE, 5 408 510 mN; 320 220 mE, 5 408 460 mN). Dips are mostly moderate to rather steep with numerous reversals in direction. Gentle to open mesoscopic folding, usually south plunging, was noted at several localities. The nature of the eastern contact (about 320 610 mE, 5 408 470 mN) is uncertain, but the radiometric image suggests that it is also a fault, and is apparently also associated with a linear magnetic anomaly (320 100 mE, 5 410 000 mN to 321 200 mE, 5 407 000 mN).

Further east, another NNW-trending belt of high total counts (roughly 320 800 mE, 5 410 400 mN to 322 300 mE, 5 405 500 mN) was shown to be due to siltstone by a traverse along Skull Creek. The contacts with cross-bedded quartzarenite (320 510 mE, 5 408 470 mN and 321 850 mE, 5 409 160 mN) closely correspond to the radiometric image. Although initially a broad anticlinal structure was thought possible, the sequence fairly consistently dips and faces east throughout, and the western contact of the siltstone (320 510 mE, 5 408 470 mN) may be a NNW-trending fault downthrown to the west. The tract is about 1.5 km wide in Skull Creek and may have a true stratigraphic thickness of about 750 metres. The rock is dark grey to paler weathering, and typically thinly and mostly planar laminated. Locally (e.g. 321 630 mE, 5 409 150 mN) it is interbedded with pale fine-grained sandstone, and graded bedding, scouring, flame structures and slightly wavy lamination provide facings, but it lacks the very wavy to convolute lamination seen in some other siltstone tracts. Chlorite porphyroblasts (2 mm) were noted at 320 870 mE, 5 408 600 mN. In a few places (e.g. 320 980 mE, 5 408 600 mN) a steep SSE-striking cleavage is the dominant fabric.

At about 321 890 mE, 5 409 140 mN, about where Skull Creek exits a small gorge, the siltstone passes, apparently conformably upward, into tough well-jointed white quartzite, locally with thin dark grey siltstone and micaceous sandstone laminae. Although there is no field evidence for a faulted contact here, there is an associated magnetic anomaly. Rare small low outcrops of quartzite are scattered across buttongrass plains from Skull Creek (near 322 000 mE, 5 409 100 mN) to the Pedder River (322 600 mE, 5 411 400 mN). Dips are consistently and moderately to the east.

The radiometric image suggests that this quartzite tract extends eastward to the Norfolk Range.

The NNW-trending magnetic anomalies that cross Skull Creek have not been linked to any outcropping magnetic rocks, but generally either lie within siltstone (e.g. 317 000 mE, 5 409 200 mN to 321 100 mE, 5 403 900 mN) or at possibly faulted contacts with quartzite (e.g. 318 100 mE, 5 410 900 mN to 320 000 mE, 5 407 000 mN; 320 100 mE, 5 410 000 mN to 321 200 mE, 5 407 000 mN), whereas the adjacent quartzite tracts are mostly magnetically quiet.

There are a few magnetic anomalies over inferred quartzite further east (e.g. 322 500 mE, 5 410 500 mN; 323 200 mE, 5 410 000 mN to 324 700 mE, 5 407 300 mN). Although these were not visited, they may also be associated with faulting.

Sea Devil Rivulet area

Near Sea Devil Rivulet (318 000 mE, 5 409 400 mN; 318 500 mE, 5 408 500 mN; 319 500 mE, 5 407 200 mN) the siltstone-quartzite contact, previously only vaguely sketched, has been redrawn from the radiometric image, but field checking in this area has been inconclusive because of poor outcrop. On an overgrown four-wheel drive track at 318 350 mE, 5 408 890 mN there is a large outcrop of poorly-sorted pebble-cobble conglomerate, consisting of mostly well-rounded quartzite clasts (50–150 mm) grading down to a tough siliceous matrix. There is a smaller outcrop at 318 260 mE, 5 408 820 mN. Float of rounded quartzite pebbles and small cobbles was noted at several localities (318 810 mE, 5 408 980 mN; 318 600 mE, 5 408 860 mN; 317 830 mE, 5 408 610 mN) in the area. These may be of Tertiary age, possibly strand-line deposits formed at a time of higher sea level. North of the track, nearer Sea Devil Rivulet (318 400 mE, 5 408 910 mN), there is a large very silicified outcrop of tough massive white quartz or quartzite. No sign of granite was encountered in this area although windblown and dune sand obscures bedrock from about 317 200 mE, 5 408 600 mN west to the coast. Further work in this area should include a traverse along Sea Devil Rivulet.

Pedder River area

In the northwest of the study area, two large crudely NNW-trending tracts of high total counts (321 900 mE, 5 411 100 mN to 317 800 mE, 5 419 600 mN; 323 700 mE, 5 412 200 mN to 320 000 mE, 5 420 000 mN and beyond) are separated by a narrow NNW-trending corridor, from about one kilometre to 400 m wide, of low total counts. The surrounding areas are also radiometrically low. The eastern boundary of the corridor (and western boundary of the eastern tract) is linear and probably a 10 km long major fault (324 500 mE, 5 410 800 mN to 320 000 mE, 5 418 700 mN). The western tract may be truncated at its southern end by one or more cross faults (NNE, 322 000 mE, 5 411 000 mN to 322 900 mE, 5 412 900 mN and/or E-W, roughly 321 000 mE, 5 413 000 mN to 323 000 mE, 5 413 000 mN).

Prior to field work, these were interpreted as tracts of pelitic siltstone, surrounded by quartzite. The suggested structure was repetition of Pedder River Siltstone in two anticlinal cores, disrupted by faults. Traverses along sections of Pedder River (322 600 mE, 5 411 400 mN to 321 000 mE, 5 412 000 mN) and North Pedder River (322 800 mE, 5 417 200 mN to 318 700 mE, 5 414 800 mN) confirmed the interpreted lithologies, but showed that the overall dip is consistently east, southeast or south.

In the Pedder River, immediately downstream (west) of 322 600 mE, 5 411 400 mN, well bedded off-white quartzite conformably overlies siltstone. The contact appears to be transitional over a few tens of metres, as thin dark grey silty laminae appear in quartzite and become thicker and more numerous stratigraphically downward.

Generally moderately east to southeast-dipping and facing 'banded' siltstone crops out well in the Pedder River gorge, at least to 321 000 mE, 5 412 000 mN. It consists typically of variably wavy laminae (5–50 mm) of alternating dark grey siltstone and paler grey to cream fine-grained sandstone. Sedimentary structures include scouring, graded bedding, cross bedding and soft-sediment deformation. Although this area is 'noisy' on TMI images, no obvious sources were encountered in the river section.

A large bluff-like outcrop of massive white quartzite, possibly also dipping southeast, occurs in dense scrub on the southern side of the gorge (320 990 mE, 5 408 980 mN). The radiometric image suggests that the quartzite-siltstone contact here strikes (120–135°) at a high angle to regional bedding, and is probably a fault. It may have controlled the course of a section of the river downstream (321 000 mE, 5 412 000 mN to 320 000 mE, 5 415 000 mN).

A limited area of high total counts around 324 500 mE, 5 411 200 mN may likewise represent a small inlier of siltstone, but this was not field checked.

Middle and upper North Pedder River area

Further north, a longer traverse along the North Pedder River gorge, from near Gales Cliffs (318 700 mE, 5 414 800 mN) to four kilometres ESE of Mt Hazelton (322 930 mE, 5 417 220 mN), provides a five kilometre long profile roughly orthogonal to regional strike. It crosses the two tracts of high total counts noted above, and several magnetic features.

As in the Pedder River (see above), most of the section is a pale to dark grey 'banded' siltstone, grading to cream-coloured fine-grained sandstone (plate 8*a*, *b*). Planar to slightly undulose laminae are 2–50 mm (typically 5–20 mm) thick. Facings are obtainable from scouring and occasional small-scale cross bedding, but wavy to convolute lamination is absent. Chlorite porphyroblasts (2 mm) were noted in two localities (321 090 mE, 5 416 210 mN; 322 280 mE, 5 416 370 mN). Samples collected from the latter locality contain a micaceous matrix with abundant red-brown biotite and minor tourmaline. Traces of sulphide are locally present (e.g. 322 070 mE, 5 416 320 mN, pyrrhotite?).

The westernmost contact of the siltstone was not observed, but the radiometric image suggests that quartzite occurs west of Gales Cliffs (near 318 100 mE, 5 415 000 mN). Near here the siltstone dips south or SSW towards the inferred contact, suggesting that it occupies the core of a broad anticline, underlying the inferred quartzite, but more structural data are needed. Further upstream, the sequence dominantly dips and faces east or southeast. Occasional mesoscopic folds mostly plunge south or southeast, but cleavage is poorly developed. The siltstone tract is about three kilometres wide, and assuming an average dip of 30° east with little repetition by folding, the unit may be about 1500 m thick.

The siltstone appears to be overlain (at 321 430 mE, 5 416 190 mN) by a massive to well-bedded, well-jointed, white to medium-grey saccharoidal orthoquartzite. In the river, the quartzite crops out for only about 150 m (to 321 540 mE, 5 416 290 mN) and may be only 80–90 m thick, as more banded siltstone occurs upstream. The radiometric image suggests that the quartzite tract extends NNW as a narrow sliver along a slight ridge towards the Wild Wave River (319 800 mE, 5 418 800 mN). To some extent this was confirmed by a ground traverse (e.g. east-dipping quartzite outcrop in a small creek at 321 170 mE, 5 416 890 mN, quartzite float at 320 110 mE, 5 418 060 mN) but outcrop on the buttongrass plains is very poor. There is a large outcrop of white vein quartz at 320 400 mE, 5 416 910 mN.

Neither the eastern nor western contacts of the quartzite were directly observed, but in the river the bedding on each side and immediately adjacent to each contact dips east, and conformable relationships are possible from the field evidence. The NNW trends of the contacts are discordant to bedding, in particular, the eastern contact appears sharp and linear, and is almost certainly a fault. Just upstream of the eastern contact (321 640 mE, 5 416 290 mN to 322 160 mE, 5 416 310 mN), bedding is generally reversed, dipping and facing west towards the contact, for about 500 m of river section. The inferred fault (325 600 mE, 5 409 200 mN to 320 000 mE, 5 418 700 mN, see above) corresponds to a major magnetic linear. There are quieter zones to its west (over inferred quartzite) and more noisy zones to its east (over inferred pelite). No magnetic rocks were identified at 322 100 mE, 5 416 300 mN, where it crosses the North Pedder River.

In the upper North Pedder River (upstream of 322 820 mE, 5 416 980 mN), further well jointed, pale grey, generally thinly bedded quartzite appears in the sequence. Large quartzite bluffs, particularly on the south side of the gorge, and a series of small waterfalls, have developed from the quartzite. In places (e.g. 322 850 mE, 5 417 130 mN to 322 920 mE, 5 417 240 mN) the quartzite is interbedded with laminated grey siltstone. The nature of the contact is again uncertain, but is possibly faulted. Shearing in interbedded siltstone (at 322 850 mE, 5 417 130 mN) may indicate an outcrop scale fault (orientation 050NW27). However the regional easterly dip suggests that, overall, the quartzite probably overlies the banded siltstone. The contact roughly corresponds, on the radiometric image, to the edge of a large tract of low total counts which extends east to the Norfolk Range.

The traverse crosses several strong, mostly NNW-trending magnetic anomalies but, as in the Pedder River, no obviously magnetic rocks were located.

Little work was done on the surrounding buttongrass plains, but a prominent outcrop of cross-bedded south-dipping 'quartzite', on the plains just west of West Bluff (approximately 325 000 mE, 5 413 900 mN) was visited by helicopter. Thin section study (see Appendix 1) shows that this rock is a micaceous quartz sandstone.

A zone of short wavelength magnetic anomalies, confused and without obvious grain, lies between the North Pedder and Wild Wave rivers, behind Kenneth Bay (near 317 000 mE, 5 416 500 mN to 319 000 mE, 5 417 000 mN). Although pelite is inferred from radiometrics, total counts are lower than usual, possibly due to surficial cover. Gridding and ground magnetics by EZ Exploration confirmed the anomaly ('anomaly 6' around 317 000 mE, 5 416 200 mN) but augering failed to find any possible source. The local geology was reported as intensely recrystallised quartzite and thinly laminated siltstone, possibly folded along north-trending fold axes (Morland, 1982). No further investigation was made during the current field program.

A longer wavelength, presumably deeper seated positive magnetic anomaly, about two kilometres across, is centred over inferred quartzite on the plains two kilometres WSW of Mt Hazelton (324 500 mE, 5 417 500 mN). Near the northern margin of the area, very low total counts around 319 000 mE, 5 419 300 mN (over buttongrass) may indicate a small area of orthoquartzite outcrop. These areas were also not visited.

Norfolk Range (Mt Hazelton to south of Helen Peak)

On radiometric images, total counts over the high country of the Norfolk Range are slightly higher relative to the plains to the west. This may be simply a topographic effect due to better exposure, rather than lithological differences. Most of the range is magnetically quiet.

Although only segments were visited, because of the difficulty of access and some low dense scrub, the Norfolk Range is essentially a strike ridge of moderately to steeply east-dipping, cross-bedded micaceous quartz sandstone ('quartzite'). No other rock types were encountered, although in many places outcrop is surprisingly poor.

Previously (in 1999) Mt Hazelton was ascended via the walking track up the northern spur and the crest of the range followed as far south as Woody Peak. Platy to massive, locally cross-bedded, coarse-grained quartz sandstone dips and faces east at 30–55°. In forest just north of Mt Hazelton (326 600 mE, 5 418 880 mN), a large overhanging, joint-bounded outcrop is composed of very fine-grained (~100 m) but mineralogically similar sandstone.

A helicopter landing was made on the range crest east of West Bluff (327 100 mE, 5 414 360 mN) but no definite outcrop is present in the immediate area. There are sporadic boulders of silicified quartzite, and boulders and probable outcrop suggest a quartz vein striking at about 145° for at least 400 m (327 070 mE, 5 414 340 mN to 327 300 mE, 5 414 050 mN).

Seen from here, the broad heathy dome-like summit of Mt Lily, about 1.5 km to the northeast, lacks obvious outcrop. The lower northern slopes of West Bluff (not visited) appear to be composed of 'quartzite' dipping east at about 30°, but there is no obvious outcrop on the scrubby summit or on Mt Mabel (not visited).

On the heathy saddle between Mt Mabel and Mt Norfolk, cross-bedded fine-grained quartz sandstone has a typical easterly dip of about 30°. A weakly developed southwest-dipping fracture cleavage was noted at a few localities. Mt Norfolk was ascended from the north by a rough bushwalker's pad, but only 'quartzite' float is present on the summit. Low dense sub-alpine scrub prevented progress towards Helen Peak.

The long southern spur of Helen Peak was followed from near the big bend of Lagoon River (331 500 mE, 5 402 000 mN) to an un-named peak (330 700 mE, 5 407 000 mN). Again all outcrops are east-dipping cross-bedded 'quartzite', although the dip is steeper (50–80°) than further north.

All samples of 'quartzite' from the Norfolk Range are coarse to fine-grained impure quartz sandstone with appreciable amounts of interstitial white mica and chlorite (see Appendix 1).

A weak NNW-trending positive radiometric linear passing just east of Helen Peak (330 000 mE, 5 409 400 mN to 330 900 mE, 5 406 600 mN) coincides with steep slopes immediately east of the ridge crest and may be caused by better exposure. There is little apparent outcrop in the area, although access was not achieved due to low dense scrub.

Upper Lagoon River valley

This valley, between the main Norfolk Range and mounts Holloway, Edith and Judith, trends slightly west of north and roughly coincides with a series of strong broad magnetic anomalies with a similar trend. These extend from the Lindsay River headwaters immediately east of Mt Lily (328 300 mE, 5 415 500 mN), across a low saddle and SSE down the upper Lagoon River valley, to the southern margin of the study area (332 100 mE, 5 400 000 mN) and beyond. The magnetic anomalies represent the southern continuation of the mineralised Balfour Shear Zone (see Webster, 2002). Copper vein prospects occur at the northern end of the anomalies (Poseidon prospect at 328 500 mE, 5 414 500 mN; 328 400 mE, 5 415 300 mN; 328 100 mE, 5 413 900 mN) but none have been recorded in the upper Lagoon River valley, where the geology was very poorly known.

The river was traversed from the 'big bend' (331 600 mE, 5 401 800 mN) northward to the headwaters west of Mt Holloway (329 800 mE, 5 412 100 mN). Outcrop is good in the upper parts, but sporadic south of about 5 407 000 mN where the river meanders over a small flood plain. The sides of the valley are scrubby in many places and outcrop is poor.

The dominant lithology is a thinly, usually wavy to convolute-laminated siltstone consisting of alternating medium-dark grey or bluish-green and cream to off-white laminae, typically 0.5–3 mm thick. The paler laminae are coarser-grained and grade into fine-grained sandstone and occasional thin beds (usually 0.5 m) of quartzite. Sedimentary structures include cross lamination, scouring and flame structures. Locally (e.g. southwest of Mt Edith between 331 380 mE, 5 407 810 mN and 331 570 mE, 5 407 200 mN; 331 530 mE, 5 402 470 mN) the lamination is almost planar. Small amounts of diagenetic pyrite may be present, although not to the extent often seen in the more planar-laminated Cowrie Siltstone. Overall it closely resembles the 'pyjama siltstone' characteristic of the Balfour Subgroup, notably the Skinners Flat Siltstone of Reed (*in* Everard *et al.*, 2001).

Less deformed outcrops of siltstone often dip and face north or east, but frequently bedding is transposed subparallel to a strong cleavage which generally strikes NNW-SSE and dips steeply west. At 331 770 mE, 5 405 870 mN, the cleavage appears to be parallel to the axial planes of tight to isoclinal folds. These more deformed outcrops have a phyllitic appearance.

The radiometric response of the siltstone is surprisingly subdued, possibly due to poor exposure and, particularly in the south of the valley, alluvial cover. In the northern part of the valley, a weak diffuse north to NNW-trending radiometric linear (slightly higher total counts than local background) between about 330 000 mE, 5 411 000 mN and at least 329 300 mE, 5 413 800 mN, lies up to 700 m east of the crest of the main magnetic anomaly. It possibly extends northward across a low watershed to the Lindsay River headwaters (328 800 mE, 5 417 200 mN). Further south, a similar weak radiometric linear near or just west of the river (331 300 mE, 5 407 300 mN to 331 500 mE, 5 403 600 mN) roughly coincides with the magnetic anomaly. Although the siltstone is flanked by quartz sandstone both to the east (e.g. Mt Judith, 332 700 mE, 5 405 200 mN) and west (ridge south of Helen Peak, 331 200 mE, 5 402 200 mN to 330 700 mE, 5 407 000 mN), there seems to be relatively little compositional difference and therefore radiometric contrast between the units. This may reflect the pelitic matrix of many of the sandstones (see Appendix 1).

An unusual pebble conglomerate crops out on the left (east) bank at 331 130 mE, 5 409 420 mN. This is clast-supported with poorly-sorted angular clasts

(25 mm) of off-white siltstone in a very sparse interstitial sandy matrix. The outcrop is crudely jointed but there is no obvious bedding or cleavage.

The NNW trend is roughly parallel to topographic lineaments and the trend of magnetic anomalies, and suggests that a large fault, or series of faults, runs through the valley. West of Mt Judith, a fault is probably expressed as a prominent topographic scarp (332 700 mE, 5 403 000 mN to 331 900 mE, 5 405 900 mN), and appears to have thrown quartzite, which crops out on the left (east) bank of the Lagoon River near 331 900 mE, 5 405 800 mN, against strongly sheared siltstone to the west. Immediately to the north, a cross-fault may have displaced the main fault one kilometre east (to about 332 800 mE, 5 406 200 mN). Further north, the fault probably crosses the river (near 331 300 mE, 5 408 400 mN), where bedding and cleavage are subparallel in phyllitic siltstone. It may pass close to a small outcrop of similar blue-green sheared phyllitic siltstone noted in a small creek east of Mt Norfolk (330 480 mE, 5 409 630 mN).

Dolerite dykes belonging to the Rocky Cape Dyke Swarm crop out in the lower part of the river traverse. Tough massive pale blue-green dolerite is sporadically exposed for about 50 m downstream from 331 290 mE, 5 407 980 mN. The mean magnetic susceptibility, although higher than the enclosing siltstone, is low (0.57 10^{-3} SI), and no associated anomaly is visible on aeromagnetic images. There are smaller, largely submerged outcrops of similar dolerite west of Mt Judith at 331 790 mE, 5 405 270 mN and 331 960 mE, 5 405 420 mN.

A large dyke of well jointed (0.5 m spacing), although otherwise massive, dolerite crops out sporadically on both sides of Lagoon River at the big bend, between 331 740 mE, 5 401 950 mN and 331 680 mE, 5 401 880 mN. The dyke contains septa of thermally metamorphosed siltstone and appears to strike NE/SW, not east–west as depicted on the Pieman Heads geological map (Gee *et al*., 1969). It is roughly in line with a strong NE/SW topographic lineament east of Mt Judith where dolerite stream boulders were found (see below), but again there is no discernible aeromagnetic anomaly.

Quartz veins are common in the siltstone. Most are apparently unmineralised, but in the river west of Mt Edith (330 870 mE, 5 410 080 mN), a four metre wide vein, trending about 060°, contains disseminated to almost massive pyrite in a quartz boxwork. About 400 m downstream (331 070 mE, 5 409 720 mN) is an irregular five metre wide outcrop of vein quartz with chlorite and pyrite. Further quartz veins, trending about 150°, crop out downstream. Quartz-hematite veinlets, and associated ferruginous alteration, were noted on the flank of the Norfolk Range at 329 860 mE, 5 410 530 mN.

The sources of the large magnetic anomalies in the upper Lagoon River valley remain unknown. Quartz-hematite veinlets and associated ferruginous alteration, resembling the Balfour Shear Zone, were noted on the flank of the Norfolk Range at 329 860 mE, 5 410 530 mN, close to the axis of the anomaly, but no strongly magnetic rocks were found anywhere in the valley (Table 2). A clue may exist in work done by CRA Exploration on core from earlier (1965) BHP drilling just south of Balfour (hole DDB5, 323 980 mE, 5 428 660 mN). Although outside the area under review, this hole tested a strong magnetic anomaly lying near the northern end of the Balfour Shear Zone. The hole "intersected disseminated pyrrhotite (usually <5 vol. %) in a sequence of interbedded shales and quartzites with minor white quartz veining". Seven samples submitted to the CSIRO had magnetic susceptibilities of 1.6–10.6 10^{-3} but high natural remanent magnetisation (NRM) with Koenigsberger ratios of 20–24. The remanence was thought likely to be parallel to the Earth's present field and adequate to explain the positive anomaly (McKay and Flis, 1980). If similar strong remanence is widespread in the Rocky Cape Group, it may explain the apparent lack of rocks with sufficient magnetic susceptibility sources to explain many magnetic anomalies, and greatly complicate attempts to quantitatively model their sources.

A less intense but sharp NNE-trending linear magnetic anomaly is located east of Woody Peak (327 300 mE, 5 416 400 mN to 327 800 mE, 5 417 800 mN) and a small positive magnetic anomaly east of Mt Hazelton (327 500 mE, 5 418 600 mN). These lie broadly along the Balfour Shear Zone but were not ground checked during current field work.

Mt Judith–Mt Edith–Mt Hadmar area

East of the anomalies in the Lagoon River valley, a large (10 4 km) magnetically low and quiet tract occupies the high country from Mt Edith and Mt Hadmar and extends southward to Mt Sunday, where Lagoon River Quartzite is mapped on the Corinna geological map sheet. Total counts are somewhat higher than the surrounding plains and foothills, and higher than expected for orthoquartzite. Webster (2002) tentatively suggested that S-type granite may crop out in this area.

Much of the area is difficult to access, but near Mt Judith is mainly relatively open heath and buttongrass. The sporadic outcrops are all east or northeast-dipping, well-bedded, cross-bedded to flaggy quartzite. Dips decrease eastward from up to 54° south of Mt Judith to about 15° at an un-named peak (334 800 mE, 5 405 100 mN).

Boulders of dolerite, resembling Precambrian dolerite of the Rocky Cape Dyke Swarm, were noted in a strongly incised creek southeast of Mt Judith at 333 360 mE, 5 403 930 mN, although no outcropping dolerite was found. This and several other nearby creeks have a strong NNE/SSW trend, parallel to the usual trend of the dolerite dykes elsewhere in the region. It seems possible that the dykes are less physically and chemically resistant than the surrounding quartzite, and have controlled drainage development in this area and south of Mt Hadmar. Several NNE-trending belts of trees, evident in air photos and topographic maps, do not always coincide with creeks or topographic lineaments and may delineate more fertile soil developed on dolerite. Alternatively, some of the NNE-trending lineaments may indicate faults or major joints in the quartzite, rather than dykes. There is a two kilometre long zone of rather weak short wavelength magnetic anomalies in this area (around 333 500 mE, 5 404 500 mN), although its fabric has a different, northwesterly trend.

Mt Edith was ascended from the northwest from the Lagoon River valley (encountering some dense scrub immediately below the western summit). Descent was made via the northeast spur onto the plains south of Mt Holloway. The southern slopes are densely vegetated and were not visited. Although outcrop is poor on its flanks, Mt Edith is composed of shallowly and mostly north-dipping cross-bedded micaceous quartz sandstone. Herringbone (chevron) cross bedding was noted at 332 370 mE, 5 409 000 mN. Although described in the field as quartzite, a thin section of a sample from Mt Edith West (332 340 mE, 5 408 980 mN) revealed that the rock is a more-or-less matrix-supported fine to medium-grained sandstone, consisting of rather poorly sorted and angular grains (150–500 m) of quartz and minor feldspar with substantial amounts of interstitial fine-grained sericite and quartz. The sericitic matrix explains the moderate to high total counts, unlike those observed over true orthoquartzite, on radiometric images. Good exposure of sandstone talus accounts for a particularly strong radiometric anomaly to the west (around 332 100 mE, 5 408 800 mN).

A sample from the main summit of Mt Edith (333 040 mE, 5 409 110 mN) is finer-grained (mostly 150 m) and particularly rich in detrital heavy minerals, including magnetite (100 m) and zircon. The magnetite content explains the high but erratic magnetic susceptibility (average of 30 measurements 1.5 10^{-3}, maximum 6.26 10^{-3} SI) observed at this locality, but does not appear to be widespread enough to produce a discernible anomaly on aeromagnetic data.

Mt Hadmar was not reached but, viewed from Mt Edith, is fairly obviously composed of similar quartz sandstone.

Mt Holloway area

Another large (8 3 km) area magnetically quiet area extends from the Lindsay River headwaters to near Mt Holloway (332 000 mE, 5 411 000 mN to 328 500 mE, 5 418 500 mN; 330 000 mE, 5 414 000 mN to 332 500 mE, 5 415 500 mN) and was also tentatively attributed to S-type granite by Webster (2002). A small anomaly with a WNW trend lies near the eastern margin (331 000 mE, 5 461 000 mN).

Access to Mt Holloway is fairly easy across gently undulating, relatively open heathy country north of Mt Edith, between the Heemskirk Road and upper Lagoon River. There is locally abundant float, mainly of vein quartz and weathered off-white fine-grained quartzite or leached sandstone. Most of the few definite outcrops are of soft weathered wavy laminated 'pyjama siltstone' and less commonly pale brown to off-white, sometimes micaceous, fine-grained sandstone. A steep northeast-striking cleavage is conspicuous on a few etched, bladed siltstone outcrops (e.g. 331 980 mE, 5 410 940 mN; 332 420 mE, 5 410 550 mN; 333 760 mE, 5 411 990 mN), and sparse bedding readings suggest folding in this direction.

It seems likely that siltstone is the main bedrock lithology in the relatively low-lying area between Mt Edith and Mt Holloway, but that volumetrically subordinate but more resistant sandstone or quartzite interbeds, together with vein quartz, preferentially persist as float and lag.

Abundant quartzite float is present on the eastern flank of Mt Holloway (e.g. 331 680 mE, 5 412 080 mN) although the rounded summit is devoid of any rock. Outcrop of thinly-bedded, cross-bedded, gently northeast-dipping quartzite occurs at 332 000 mE, 5 412 030 mN and is well exposed in falls in a small creek nearby (332 230 mE, 5 412 150 mN). Small sporadic outcrops of quartzite, also dipping gently northeast, are present on the northern spurs (e.g. 331 920 mE, 5 413 040 mN; 331300 mE, 5 412 860 mN; 331 000 mE, 5 415 020 mN), although wavy laminated siltstone is present at 331 820 mE, 5 412 970 mN. Given the poor outcrop it is difficult to get an accurate picture of the bedrock, but it seems likely that Mt Holloway, like Mt Edith, is composed mainly of relatively resistant quartz sandstone or quartzite, perhaps with minor interbedded siltstone.

Float of tough, well-jointed blue-grey dolerite was located within a conspicuous NNE-trending line of trees at 332 870 mE, 5 410 890 mN, strongly suggesting more fertile soils developed on one of the dykes of the Rocky Cape Dyke Swarm. The belt extends from roughly 332 600 mE, 5 410300 mN to the Heemskirk Road at 334 300 mE, 5 415 300 mN, although nothing more than small patches of reddish soil were found in road cuttings. Other tree belts with similar trend (e.g. 332 600 mE, 5 412 400 mN to 333 300 mE, 5 414 700 mN) suggest dykes, but were not proven by finding associated dolerite float.

A quartz vein, trending about 060°, can be traced from outcrop for about 500 m along the crest of a slight rise south of Mt Holloway (331 400 mE, 5 410 410 mN to 331 810 mE, 5 410 720 mN).

Mt Vero area

A crudely elliptical (7.5 3.5 km) magnetically noisy zone lies west of the Donaldson River, extending from the vicinity of Mt Vero to just north of Interview Pinnacle. Webster (2002) suggested the presence of outcropping or shallow, relatively magnetic I-type granite in this area, which was very poorly known. Within this zone there is a large strong north-trending magnetic high extending from southwest of Mt Vero (336 000 mE, 5 407 000 mN) south towards Interview Pinnacle (336 000 mE, 5 402 000 mN), flanked to the east by a trough-like magnetic low (337 300 mE, 5 406 300 mN to 336 300 mE, 5 402 700 mN) and another high further east (338 000 mE, 5 405 000 mN to 337 500 mE, 5 402 500 mN). Other notable strong magnetic highs occur between Mt Hadmar and Mt Vero (336 200 mE, 5 408 000 mN), east of Mt Vero (around 338 100 mE, 5 407 400 mN), around Mt Vero (337 000 mE, 5 407 600 mN) and on the ridge to its south (around 337 000 mE, 5 406 700 mN). Most of these have a fairly long wavelength and may be deep seated.

Moderately high total counts predominate on radiometric images, suggesting potassium-rich (mainly pelitic?) rocks. A NNE-trending linear of lower total counts is present north of Interview Pinnacle (337 100 mE, 5 402 200 mN to 338 000 mE, 5 405 000 mN), where quartzite and dolerite dykes are indicated on the Corinna geological map sheet. The linear is parallel to strike and could conceivably be due to a bed of relatively pure quartzite, but this area is of very difficult access. There are also less elongate radiometric lows east of Mt Vero (338 200 mE, 5 406 000 mN; 338 300 mE, 5 407 500 mN; 337 500 mE, 5 408 400 mN).

The area is still relatively inaccessible and only the northern part was field checked. A rough flagged route from the Heemskirk Road (338 900 mE, 5 409 300 mN) crosses the Toner River (338 340 mE, 5 409 110 mN) and leads to Mt Vero, a prominent blade-shaped peak. This is a north-trending strike ridge of east-dipping siltstone, not quartzite as previously thought, coinciding with a rather strong positive north to NNE-trending radiometric anomaly. The siltstone is typically pale to dark grey or greenish-grey, thinly planar laminated, and resembles outcrops in the Toner River. Magnetic susceptibility measurements on outcrops and samples collected are again low and the source of the magnetic anomalies remains obscure. Float of oxidised, orange to red pyritic siltstone was noted on the lower slopes at 337 620 mE, 5 408 720 mN.

Sporadic float boulders of quartzite occur on the northern flank of Mt Vero (337 420 mE, 5 408 650 mN; 337 230 mE, 5 408 570 mN) and, although no outcrop was encountered, a lens of quartzite may account for the radiometric lows in the immediate area. The radiometric image does not show any sharp discontinuity that might correspond to a sharp siltstone-quartzite contact between Mt Vero and Mt Hadmar (the southern and eastern slopes of which are very scrubby). A ground traverse from Mt Vero towards Mt Hadmar showed that siltstone becomes more wavy laminated in the saddle (336 580 mE, 5 407 780 mN) and extends westward at least as far as the knoll (336 070 mE, 5 407 940 mN) 500 m east of Mt Hadmar. In this area the siltstone is interlaminated with off-white fine-grained sandstone, suggesting a gradational contact. A large (3 m wide) and prominent north-trending (005°) quartz vein, containing traces of sulphide, was also noted just east of the saddle (336 730 mE, 5 407 750 mN).

Toner River–Mt Bolton area

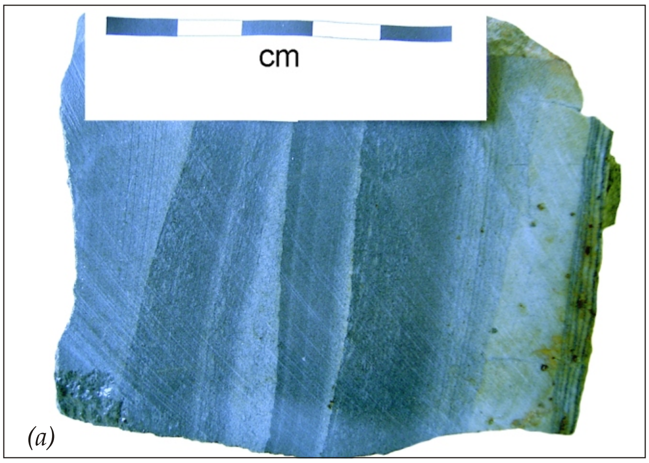
This area is again magnetically noisy with numerous fairly short wavelength anomalies, and radiometrically high. Webster (2002) suggested either a large (c. 10 7 km) outcropping body of magnetic I-type granite (an extension of that inferred in the Mt Vero area) or contact metamorphic effects around similar granite.

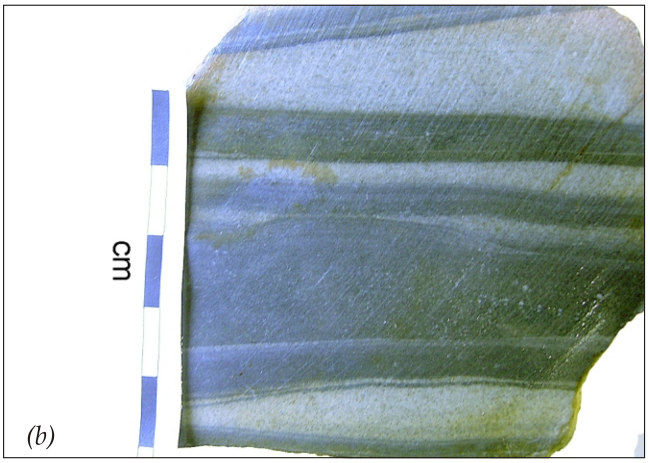
Traverses along and near the Heemskirk Road and Toner River demonstrated that the area is dominated by mostly thinly wavy-laminated Rocky Cape Group siltstone, fairly consistently dipping and facing east or southeast. This alternates with a finer-grained more planar laminated facies which becomes more common up-section, towards the Donaldson River. No strongly magnetic rocks capable of explaining the main large, strong, irregular, magnetic anomalies were found, although there are a few weakly magnetic dolerite dykes associated with weaker NE to NNE-trending linear anomalies.

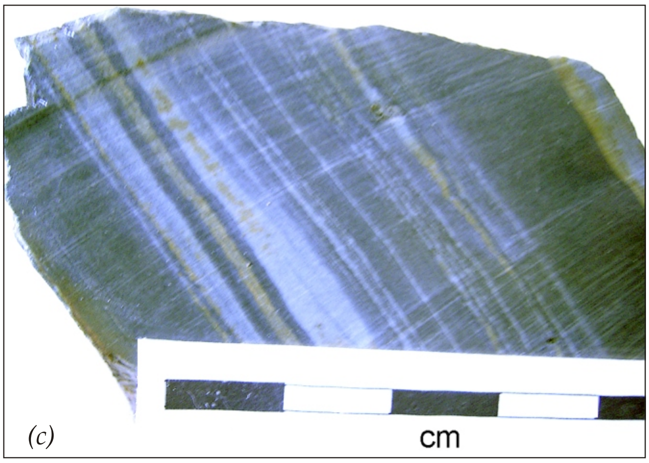
The wavy laminated facies (plate 8*e*, *f*) is perhaps best and most accessibly exposed in road cuttings near 337 500 mE, 5 413 200 mN. Here, thinly (0.5–2 mm) and variably wavy laminated, dark to pale grey siltstone is interbedded with beds of off-white fine-grained sandstone (100 mm thick) and white orthoquartzite (0.3–1 m) (plate 7). Lithologically it closely resembles units within the Balfour Subgroup, particularly the Skinners Flat Siltstone. The cuttings are overlain by a

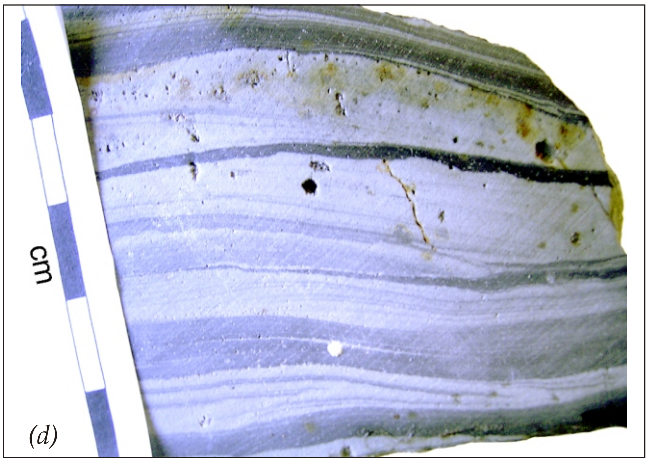
Plate 7

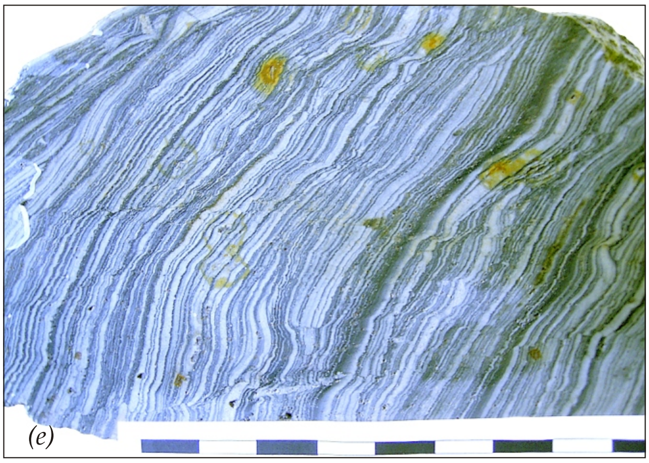
Orthoquartzite beds in Balfour Subgroup, Heemskirk Road near Mt Bolton (337 540 mE, 5 413 230 mN).

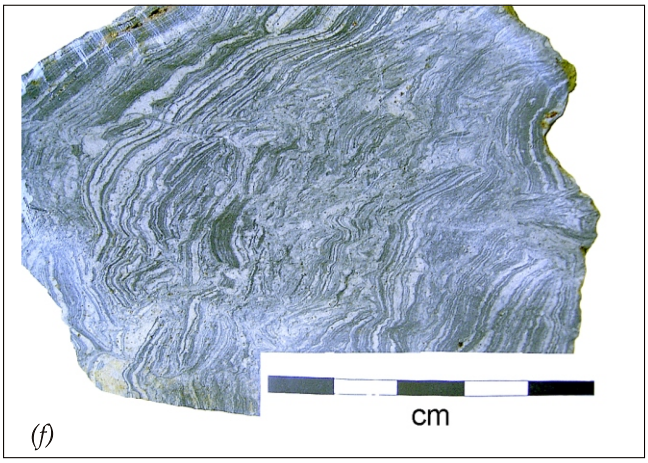












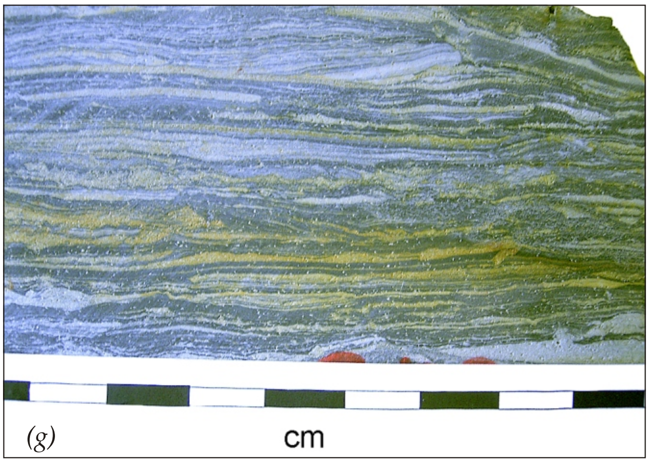


Plate 8

Cut hand specimens of Rocky Cape Group siltstone samples showing bedding styles.
(a) Pedder River Siltstone, sample LJ1032, creek south of Wild Wave River;
(b) Pedder River Siltstone, sample LJ1141, Gales Cliffs;
(c) Balfour Subgroup, sample LJ403, Toner River;
(d) Balfour Subgroup, sample LJ450, Mt Bolton;
(e) Balfour Subgroup, sample LJ420, Heemskirk Road;
(f) Balfour Subgroup, sample LJ512, Heemskirk Road;
(g) Balfour Subgroup, LJ645, McDougalls Lookout.

thick blanket of vein quartz lag, locally up to 1.5 m thick. Away from the road, outcrops are mostly small, sparse and severely weathered.

The westernmost unit of grey-green, essentially planar-laminated siltstone in the Toner River (336 780 mE, 5 409 880 mN to 337 400 mE, 5 409 550 mN) (plate 8*c*) is probably a northward continuation of the unit that forms Mt Vero (see above). Eastward facings are obtainable from truncations and graded bedding. It may strike northeastward to a section of similar siltstone on the Heemskirk Road (338 290 mE, 5 410 830 mN to 338 410 mE, 5 410 590 mN), but apparently lenses out south of Mt Bolton. Other intervals of planar-laminated siltstone are present in the Toner River further downstream (338 040 mE, 5 409 250 mN to 338 340 mE, 5 409 070 mN; around 339 000 mE, 5 407 900 mN) but it is difficult to confidently correlate them with exposures on the Heemskirk Road, only 1–2 km away. Lateral facies variation seems likely.

Cross-bedded, moderately east-dipping and facing off-white orthoquartzite occurs on and around the summit of Mt Bolton (338 670 mE, 5 411 590 mN), explaining a small area of reduced total counts on the radiometric image. The orthoquartzite is probably a laterally and vertically restricted lens within the sequence, as to the east it appears to be conformably overlain by dark grey to off-white wavy laminated 'pyjama siltstone'. Another similar but poorly outcropping lens of quartzite occurs on a small ridge 1.5 km to the northwest (c. 337 500 mE, 5 412 500 mN) and also coincides with an area of low total counts.

Dykes of typically well-jointed but otherwise massive, coarse-grained green or greenish-grey dolerite, apparently usually about 20 m wide, crop out at several places in the Toner River. At 336 290 mE, 5 410 350 mN, pyritic quartz veins were noted at the contact with siltstone. On the Heemskirk Road, the dykes are usually deeply weathered to greenish clay with a relict igneous texture (e.g. 338 070 mE, 5 413 620 mN) or, more commonly, oxidised to orange-red soil. In the Donaldson River area, narrow NNE-trending linear magnetic anomalies are resolvable, some of which correspond to dolerite dykes mapped on the Corinna geological map sheet (339 400 mE, 5 400 600 mN; 338 600 mE, 5 402 600 mN probably extending SSW to 338 100 mE, 5 400 500 mN). Other dykes are likely in unmapped country to the north, at 338 300 mE, 5 405 600 mN and 340 000 mE, 5 407 800 mN.

On the Heemskirk Road, rather poorly outcropping, pale grey-green to off-white weathering planar-laminated siltstone (plate 8*d*) predominates southeast of about 338 900 mE, 5 409 300 mN. Immediately north of the Donaldson River bridge (340 410 mE, 5 408 330 mN) a 30 m interval of strongly sheared siltstone may mark the Donaldson Fault, a major NNE-trending regional structure. Dolerite has intruded along the fault, and there are fresh outcrops in the river immediately below the bridge (340 500 mE, 5 408 130 mN). The fault and the dolerite dyke are not particularly obvious on either the magnetic or radiometric image, although both display a crude NNE/SSW grain in this area.

Similar thinly planar-laminated greenish-grey siltstone crops out in the Donaldson River downstream from the bridge (340 500 mE, 5 408 100 mN) to at least the mouth of the Toner River. Although this accounts for the lack of radiometric expression for the Donaldson Fault, it does not match the adjoining Corinna map sheet (Turner *et al.*, 1991) on which quartz sandstone and quartzarenite are shown west of the fault and planar laminated siltstone to its east.

McDougalls Lookout–upper Leigh River area

These areas have a mainly noisy magnetic character, although a low and relatively quiet zone extends east from near the eastern margin of the study area (around 339 000 mE, 5 416 000 mN). As in much of the study area, many features of the magnetic image are difficult to relate to surface outcrop. Total counts are high almost everywhere.

This area is dominated by thinly (0.5–3 mm) variably wavy to convolute-laminated, dark grey to cream siltstone (plate 8*g*), similar to that described above. Outcrops are poor except in sporadic cuttings on the Heemskirk Road, in which subordinate interbedded off-white sandstone to quartzite (20–300 mm) is present (e.g. 334 600 mE, 5 414 500 mN). Small-scale cross bedding, scouring and graded bedding are common. Soft sediment deformation and rip-up clasts with apparent double truncations were observed at 334 200 mE, 5 416 300 mN.

Bedding is very variable in strike, but dips are fairly consistently low, and gentle mesoscopic folds can be observed in some of the larger exposures (334 400 mE, 5 413 500 mN; 334 200 mE, 5 415 300 mN; 334 100 mE, 5 416 400 mN). A steeply north-dipping shear zone with a 10–100 mm gouge was noted at 334 200 mE, 5 415 340 mN.

Around a small hill on the Heemskirk Road near 335 200 mE, 5 413 000 mN, there is a larger area of pure white orthoquartzite (mainly float), corresponding to a small (400 200 m) but discrete radiometric low. The quartzite appears to be another minor lens within the siltstone sequence, here dipping gently east.

A larger radiometric low around McDougalls Lookout (roughly 333 500 mE, 5 416 900 mN to 332 600 mE, 5 417 500 mN) coincides with a northwest-trending ridge. Quartzite (mostly float) was noted in the area, but outcrop is very poor. On the Heemskirk Road, north of about 334 700 mE, 5 417 200 mN, wavy laminated siltstone gradually gives way to thinly planar-laminated greenish-grey or blue-green, locally fissile siltstone. The latter crops out in the Leigh River downstream from the bridge on Sumac 15-1 road (336 400 mE, 5 419 100 mN). As bedding in the area is variable but with generally low to moderate dips, this may be a lateral facies change. Physiographically, low-lying flat areas near the Leigh River are underlain by the planar-laminated facies, whilst the more siliceous wavy-laminated facies occupies higher ground.

Similar variably wavy-laminated siltstone crops out in the Lindsay River around the mouth of Eighty Creek (331 800 mE, 5 418 400 mN to 331 800 mE, 5 418 900 mN) and consistently dips northeast. Ripple marks (331 750 mE, 5 418 780 mN) and some interbedded blue-grey quartzarenite (331 690 mE, 5 418 750 mN) were noted.

Small areas of khaki-green to orange soil (334 570 mE, 5 414 440 mN; 334 270 mE, 5 415 260 mN) are the only indications of dolerite dykes intersecting the Heemskirk Road in this area. Large NNE-trending dykes of fresh dolerite, accompanied by orange soil, crop out on the Sumac Road (338 600 mE, 5 418 100 mN to 338 900 mE, 5 419 000 mN) and Sumac 15 spur (336 100 mE, 5 417 600 mN to 336 700 mE, 5 419 300 mN) in the extreme northeast of the area. As in the Toner River area, these are clearly associated with narrow linear magnetic anomalies.

CRA investigated five magnetic anomalies near the Leigh River in the northwest of the current area, attributing them to either pyrrhotite and/or pyrite in siltstone or 'amphibolite' (dolerite) dykes (Weir, 1984*b*; see Appendix 2). Geopeko arrived at a similar explanation for anomalies in the Toner River–Mt Bolton area (Pemberton, 1984*a, b*; Appendix 2).

Igneous Rocks

Dolerite dykes

A swarm of mainly northeast to NNE-trending dolerite dykes intrudes the Rocky Cape Group over a large region about 20 km wide and 100 km long, lying between the north coast and the lower Pieman River, and including the eastern part of the study area.

Petrography

Fifteen relatively fresh samples, mostly from the Toner and Lagoon rivers, are essentially similar metadolerites, differing mainly in the rank (intensity) rather than grade of metamorphism. Relict igneous textures may be preserved, but seldom any primary igneous minerals.

A typical sample (LJ106 from the upper Lagoon River; plate 9*a*, *b*) displays a relict subophitic texture defined by pseudomorphs of former clinopyroxene (0.4–1 mm; now amphibole) and turbid plagioclase (now partly replaced by sericite and minor epidote). The amphibole is mostly bladed to fibrous, nearly colourless tremolite-actinolite, but there are subordinate ragged, usually anhedral grains (500 m) of pleochroic yellow-green to brown-green hornblende, sometimes forming rims around actinolite. Irregularly angular pseudomorphs of former magnetite (0.5 mm) are largely replaced by fine-grained turbid sphene, although some opaque blebs or blades (possibly originally exsolution lamellae) remain as inclusions. Sea-green chlorite and epidote are rare. A few small interstitial quartz anhedra, and micrographic intergrowths (plate 9*c*, *d*) of quartz and K-feldspar (?) up to 200 m across, are also present.

All samples contain minor quartz (although very rare in LJ375), and rare to minor chlorite and epidote are usually present in addition to tremolite-actinolite. About half of the samples contain subordinate coloured pleochroic amphibole, presumably hornblende. Micrographic quartz-K feldspar intergrowths are well developed in only two other samples (LJ157, LJ813).

Colourless grains of relict clinopyroxene (200–500 m across) were noted in only one sample (MJ92), from Sumac 15 spur road in the far northeast of the study area. Otherwise, this rock is texturally and mineralogically similar to the other samples. The clinopyroxene, which shows incipient alteration to pale yellow tremolite-actinolite, interlocks with very turbid feldspar laths (typically 500 m–1 mm; rarely 1.5 mm). Interstitial quartz anhedra, micrographic quartz-feldspar intergrowths, small ragged grains of brown hornblende, sphene (500 m) with relict cores of opaque grains, abundant chlorite, rare epidote and rare possible blue-green pumpellyite are also present.

Geochemistry

The dykes are all rather similar, mostly weakly to moderately fractionated, slightly potassic tholeiites (Table 3). They generally plot within the fields defined by previous analyses from the Rocky Cape Dyke Swarm (fig. 20*a-d*), the geochemistry of which will be discussed in more detail elsewhere.

A few of these dykes have distinctive characteristics. Six samples (LJ350, LJ375, LJ381, LJ560, LJ875 and MJ2088) have slightly higher Nb/Zr and P_2O_5/TiO_2 ratios than the remainder, suggesting weakly alkalic affinities, but petrographically these do not form a separate group, and are geographically dispersed. Sample LJ541, from near the mouth of the Toner River, is a less fractionated rock, with higher MgO, Ni and Cr, than the others, and sample LJ471 is distinctly higher in light rare earths (La, Ce and Nd).

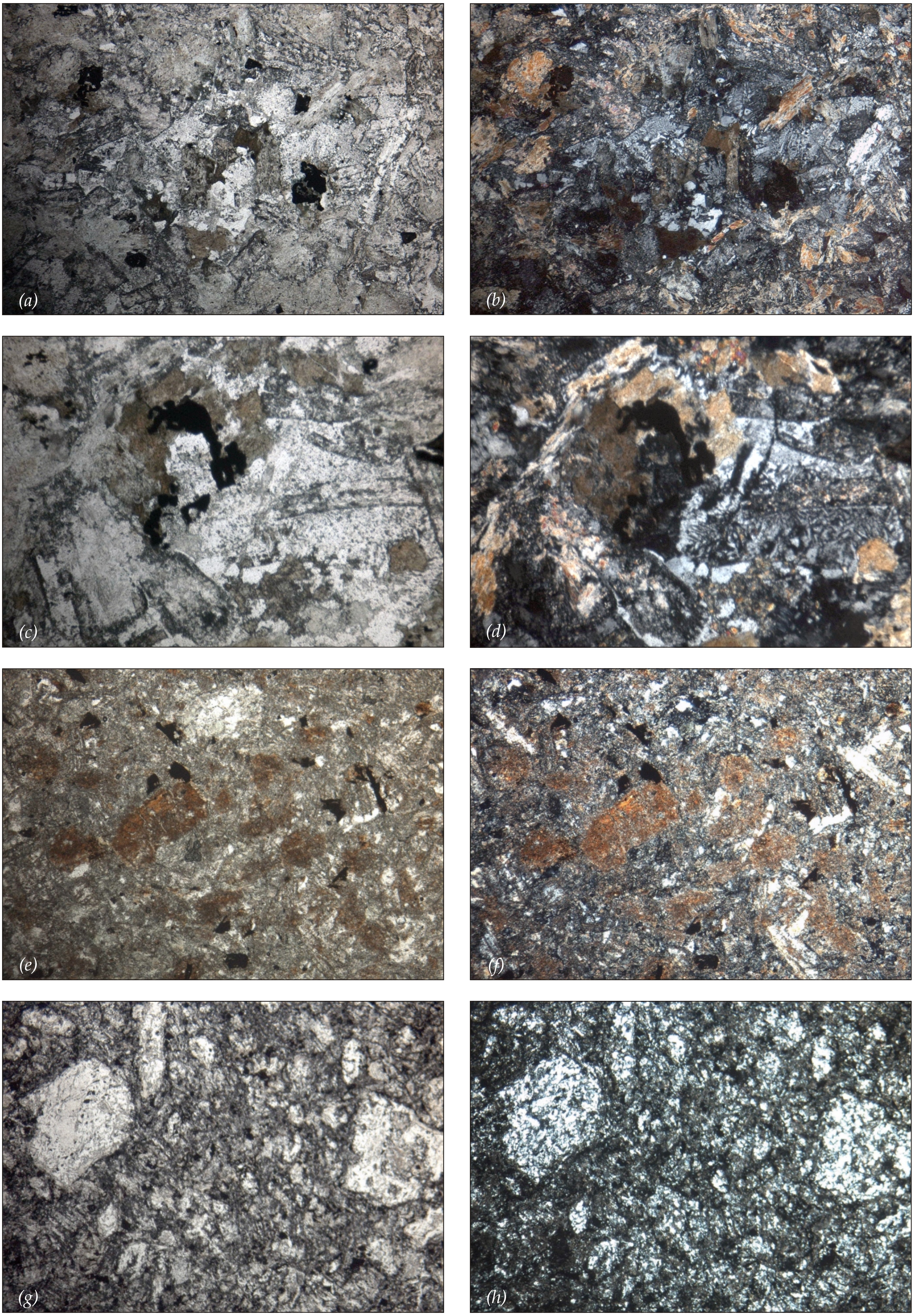


Plate 9

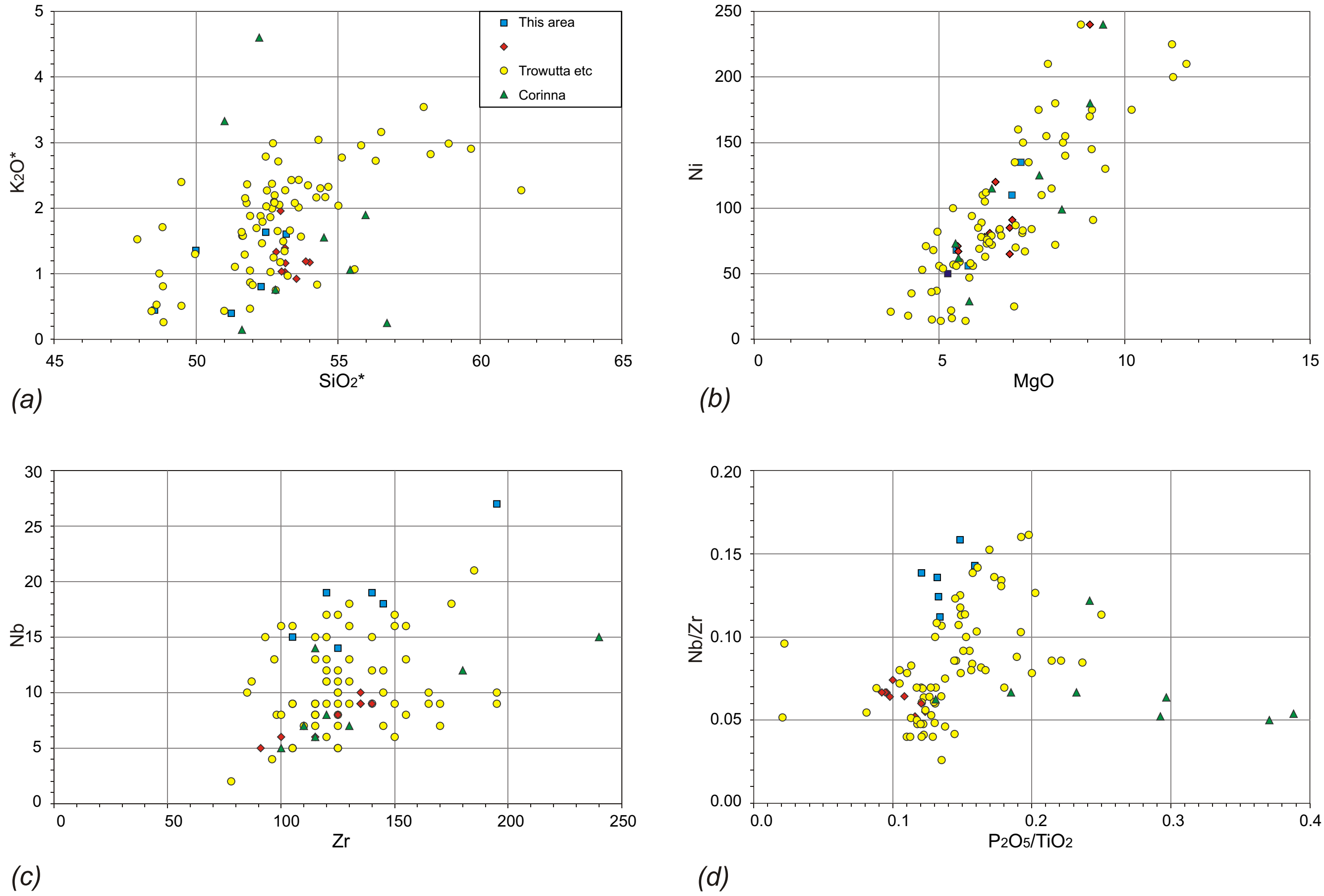


Figure 20

Geochemistry of dolerite dykes. Data for this area from Table 3; for Trowutta quadrangle and adjacent areas mainly from J. L. Everard and D. B. Seymour (unpublished); for Corinna quadrangle from Turner and Crawford (1993). (a) K_2O vs SiO_2, with major elements recalculated to 100% anhydrous; (b) Ni vs MgO; (c) Nb vs Zr; (d) Nb/Zr vs P_2O_5/TiO_2.

Dykes of unknown age

Andesite (?), Johnsons Head

A large (10 m wide) branching dyke or series of dykes intrude Pedder River Siltstone near Johnsons Head. In thin section, the rock (sample LJ200; plate 9*e*, *f*) displays an anhedral microgranular texture, and consists of plagioclase laths (500 m–1 mm), turbid alkali feldspar, abundant scaly red-brown biotite, pale yellow-green chlorite, scattered very irregular opaque grains (mostly 200 m) and minor (few %) quartz anhedra (mostly 200 m).

Plate 9

Photomicrographs of dyke rocks, plane polarised light (left) and crossed nicols (right):
(a, b) dolerite dyke, sample LJ106, upper Lagoon River, 4.5 3.4 mm;
(c, d) also sample LJ106, showing micrographic quartz-feldspar intergrowth, 730 550 m.
(e, f) andesite (?), sample LJ200, north of Johnsons Head, 4.5 3.4 mm
(g, h) altered alkaline lamprophyre (?), sample LJ997A, north of Johnsons Head, 4.5 3.4 mm.

An analysis (Table 3) shows that the rock is broadly a high-magnesium, tholeiitic basaltic andesite. It differs from typical Rocky Cape Dyke Swarm dolerites in many respects (e.g. higher SiO_2, Mg#, Ni and Cr, low Sr and very low CaO). It is also unlike the Cambrian boninites of western Tasmania, which are much lower in TiO_2, Zr, K_2O and other incompatible elements (e.g. Brown and Jenner, 1989). Its age and affinities are unknown.

Alkaline lamprophyre (?), north of Johnsons Head

A series of narrow (40–60 mm) dykes intrude a beach outcrop of Pedder River Siltstone 2.8 km north of Johnsons Head, and appear to post-date quartz veins (see above). A thin section (sample LJ997A; plate 9*g*, *h*) shows numerous equant to slightly elongate, oblong to polygonal pseudomorphs (3 mm), possibly after pyroxene, each now completely replaced by a mosaic of fine-grained quartz. The fine-grained matrix largely consists of carbonate, chlorite, quartz and irregular more-or-less equant opaque minerals.

A second sample (LJ997B) is still more altered and mainly consists of turbid brown carbonate, but a relict densely porphyritic igneous texture of closely spaced equant to slightly elongate euhedral phenocrysts (0.5-2 mm), now replaced by carbonate, is clearly discernible. The matrix consists of yellow-green chlorite, turbid formless granules of sphene, and a small amount of secondary quartz. A distinct foliation is present.

An analysis of LJ997A (Table 3) must be viewed with caution as the rock is very altered and has lost most of its alkalis. The high total FeO, Ti/Zr (192), Cr (750 ppm) and Ni (360 ppm) suggest an original mafic composition, and high P_2O_5 (1.03%), Nb (93 ppm) and rare earth elements (e.g. La 160 ppm) indicate strongly alkaline affinities. Arsenic is also strongly anomalous (300 ppm).

The rock is too altered for positive identification, but may have been an alkaline lamprophyre. It is chemically dissimilar to previously described western Tasmanian calc-alkaline lamprophyres, which are Late Devonian and predominantly minettes (e.g. Baillie and Sutherland, 1992; McClenaghan *et al*., 1994).

Granite

The granite outcrops that extend south from Sandy Cape to just beyond Pieman Heads have traditionally been termed the Pieman Granite (e.g. Leaman and Richardson, 1989). In this report, the subdivision of Chappell *et al*. (1991) is adopted, whereby the bodies at Sandy Cape, in the Interview River area (north of Pieman Heads) and at Conical Rocks (south of Pieman Heads) are recognised as separate plutons. This is justified by geochemical differences. The Sandy Cape Granite and the northern part of the Interview Granite fall into the main area discussed in this report.

Petrography

A relatively fresh sample (LJ954) of the Interview Granite, from the lower Lagoon River, is a fine to medium-grained equigranular rock consisting of anhedral quartz, zoned subhedral plagioclase and K feldspar, abundant red-brown biotite and subordinate ragged muscovite (plate 10*a, b*). Apatite and zircon (commonly as inclusions in biotite) are accessory minerals, together with sparse small, equant euhedral opaque minerals, probably ilmenite.

Another sample (LJ255) from the lower Italian River is similar but more altered. Feldspars are commonly turbid and partly sericitised, and biotite partly altered to chlorite. Accessory minerals include small apatite and monazite euhedra and yellow-brown to pale blue anhedra of tourmaline, but no opaque phase is present.

A sample (LJ1008) of the Sandy Cape Granite from the south headland of Native Well Bay is more leucocratic, and consists mainly of interlocking quartz, plagioclase (albite), microcline perthite and muscovite, together with small amounts of biotite (pleochroic from dark green to pale yellow-green) and accessory brown tourmaline (plate 10*e, f*). No opaque phase is present.

Geochemistry

For this project, two new analyses were obtained of the Interview Granite (samples LJ255, LJ954) and one of the Sandy Cape Granite (LJ1008) (Table 3). These are assessed together with previous data, mainly from the database of B.W. Chappell and co-workers, which includes five analyses from the Sandy Cape Granite, three from the Interview Granite and five from the Conical Rocks Granite. An additional six analyses (two from each body) are available, from samples collected primarily for radiometric (SHRIMP) dating by M. P. McClenaghan and L. P. Black, and for physical properties as part of the Mt Read Volcanics Project. The latter are of unknown quality and are treated with more caution in the following discussion. All these data are available on the MRT TASCHEM database.

Pseudomodes (quartz-alkali feldspar-plagioclase) calculated from the chemical analyses are plotted on the granite classification diagram of Streckeisen (1976) (fig. 21). All the samples from Sandy Cape plot in the alkali feldspar granite field, as they are low in CaO and plagioclase is essentially albite. The samples from Conical Rocks, and all but one from the Interview pluton, plot in the fields of monzogranite ('adamellite') or syenogranite ('granite *sensu stricto*').

All these bodies are felsic (SiO_2 >70 %) (fig. 22*b-d*) and fractionated (Rb >250 ppm) (fig. 22*e-p*) in the sense of Chappell *et al*. (1991). The strongly peraluminous character (Alumina Saturation Index, ASI >1.10 and mostly >1.20) (fig. 22*d*) of the Interview and Sandy Cape plutons identifies them as S-types, and they were assigned to the Interview Suite by Chappell *et al*. (1991).

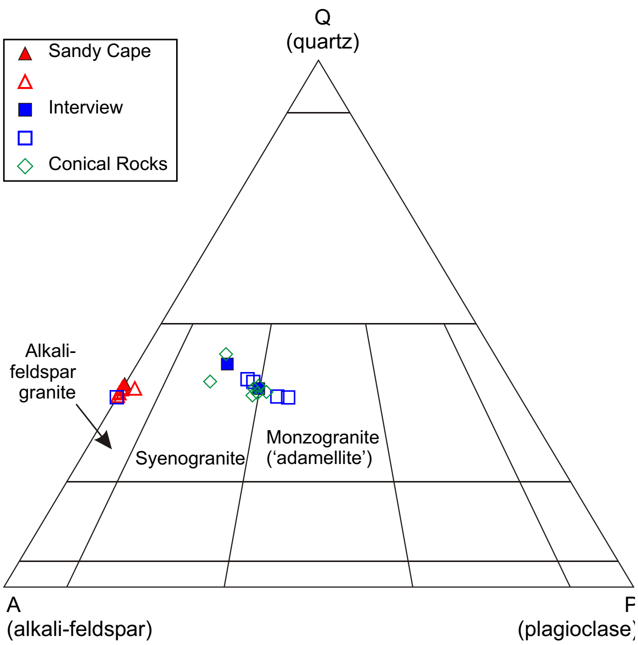


Figure 21

Q (quartz)–(A) alkali feldspar–P (plagioclase) plot of pseudomodes, calculated from chemical analyses, of Devonian granites. Granite classification of Streckeisen (1976) also shown. Solid symbols – new data from Table 3; other data from Sawka et al. *(1990) and databases of Mineral Resources Tasmania and B. W. Chappell.*

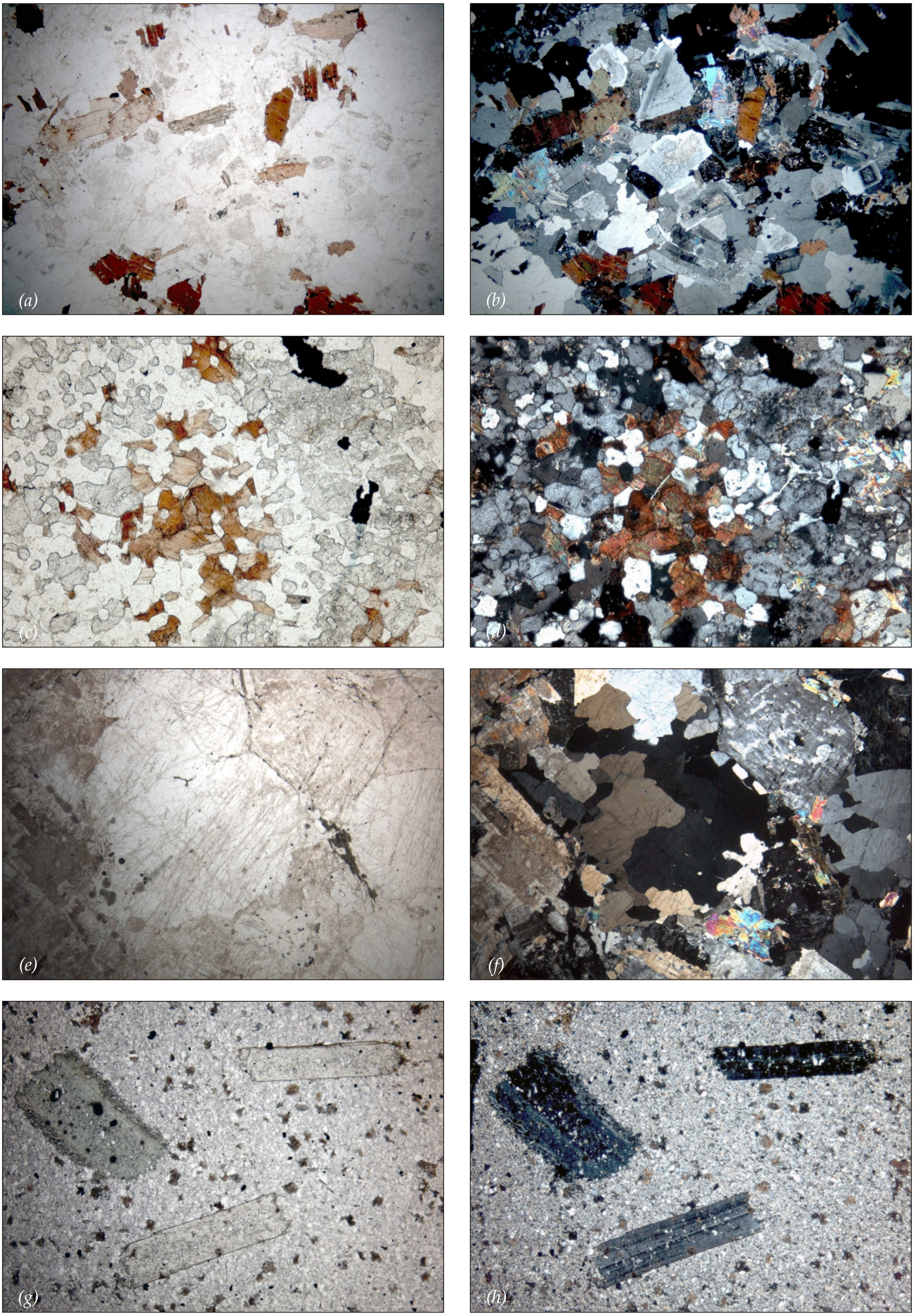


Plate 10

The Conical Rocks pluton is distinctly less peraluminous and falls within a rather ambiguous range (ASI 1.066–1.112), but is probably also an S-type. It has lower Al_2O_3 (<13.9%) than the Interview Suite samples (>14.4%) and is not simply a southern extension of the Interview Granite, dextrally offset by the Pieman Fault. It was assigned by Chappell *et al*. (1991) to the Pieman Suite.

The Fe_2O_3/FeO ratio of all these bodies is low (mostly <0.33) and the redox index [log(Fe_2O_3/FeO) + 0.03 (FeO_{tot}) + 0.3] is mostly between -0.1 and -0.8, within the range (0 to -0.8) considered to characterise moderately reduced granites (P. Blevin, *pers. comm.*). The two most oxidised samples (401390 and 401391) were collected during the Mt Read Volcanics Project and may have been slightly weathered.

The major elements TiO_2, FeO_{tot}, MgO and CaO show strong positive correlations (fig. 22*b, c*), with the Sandy Cape Granite being the most felsic and the Interview Granite the least felsic. The Conical Rocks Granite plots between them, but has slightly lower MgO and higher CaO at equivalent FeO_{tot}, providing further evidence that it belongs to a different suite.

The only moderately high Rb contents (275–340 ppm) of both the Interview and Conical Rocks granites indicate that they are only weakly fractionated, and their Sr and Ba contents are rather high for fractionated granites (normally <50 ppm and <200 ppm respectively). It was originally thought probable that the Interview pluton graded northward, towards Sandy Cape, to progressively more felsic and more fractionated compositions. However the two new analyses from the Interview Granite, from the previously unsampled northern part of that body, are both amongst the least felsic (e.g. highest FeO_{tot}) and least fractionated (e.g. highest Sr and Ba). Slight alteration or weathering of sample LJ255, noted in thin section, may account for its relatively low Na_2O and high ASI.

In contrast, the Sandy Cape Granite, which may represent a cupola rising upward from a northward subsurface continuation or spine of the Interview Granite, includes some highly fractionated rocks (e.g. Rb 423–950 ppm; Sr 20–57 ppm; Ba 2–250 ppm).

Within the Interview Suite, Na_2O, P_2O_5, Zn, Ga, Rb, Nb and Sn increase with fractionation whilst TiO_2, total iron as FeO_{tot}, MgO, CaO, K_2O, V, Y, Zr, Sr, Ba and Th decrease (e.g. fig. 22*e-p*). The trends for P_2O_5, Y, Ce and Th in particular are characteristic of fractionated S-type granites, and the reverse of those typical of I-types (Wyborn and Chappell, 1998). Sawka *et al*. (1990) used these bodies to illustrate geochemical trends (including rare earth element patterns) during the fractionation of S-type granites.

The higher Th in the Interview Granite, relative to the more fractionated Sandy Cape Granite, is evident in the radiometric images, particularly the normalised RGB image (fig. 11).

In view of their distinct geochemistry and lack of continuity in outcrop, it is suggested that the Sandy Cape, Interview and Conical Rocks granites be recognised as separate plutons as proposed by Chappell *et al*. (1991), and that the traditional term 'Pieman Granite' (or 'Pieman Heads Granite') be abandoned.

Figure 10

Photomicrographs, plane polarised light (left) and crossed nicols (right):
(a, b) Interview Granite, sample LJ954, 11.5 8.5 mm;
(c, d) contact between Interview Granite (left) and hornfels (right), sample LJ961, 730 550 m;
(e, f) Sandy Cape Granite, sample LJ1008, 11.5 8.5 mm;
(g, h) Pedder River Siltstone with chlorite porphyroblasts, sample LJ1064, 4.5 3.4 mm.

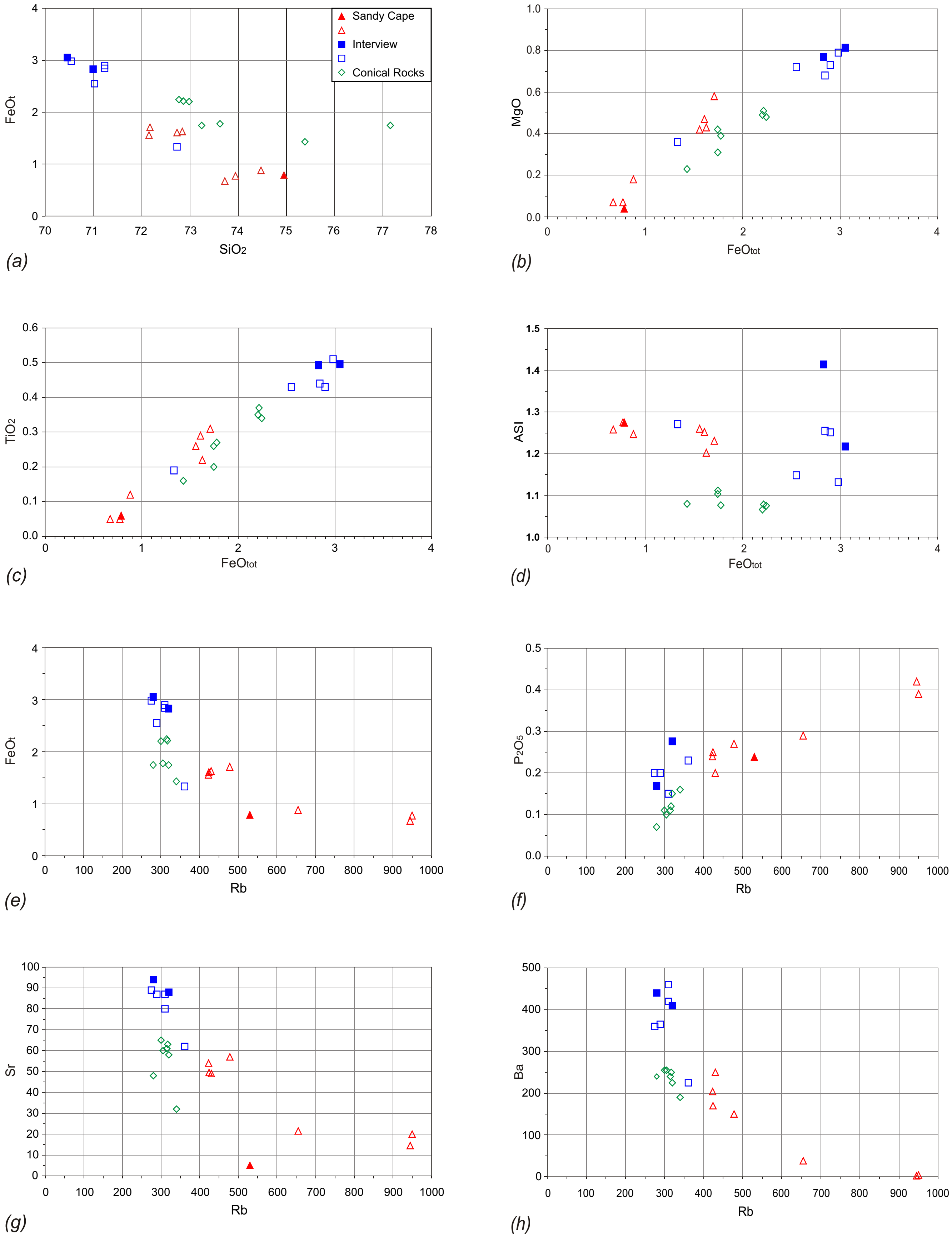


Figure 22

Geochemistry of Devonian granites. Data sources as for Figure 21.
(a) FeO_{tot} vs SiO_2; (b) MgO vs FeO_{tot};
(c) TiO_2 vs FeO_{tot}; (d) Alumina Saturation Index vs FeO_{tot};
(e)FeO_{tot} vs Rb; (f) P_2O_5 vs Rb;
(g) Sr vs Rb; (h) Ba vs Rb

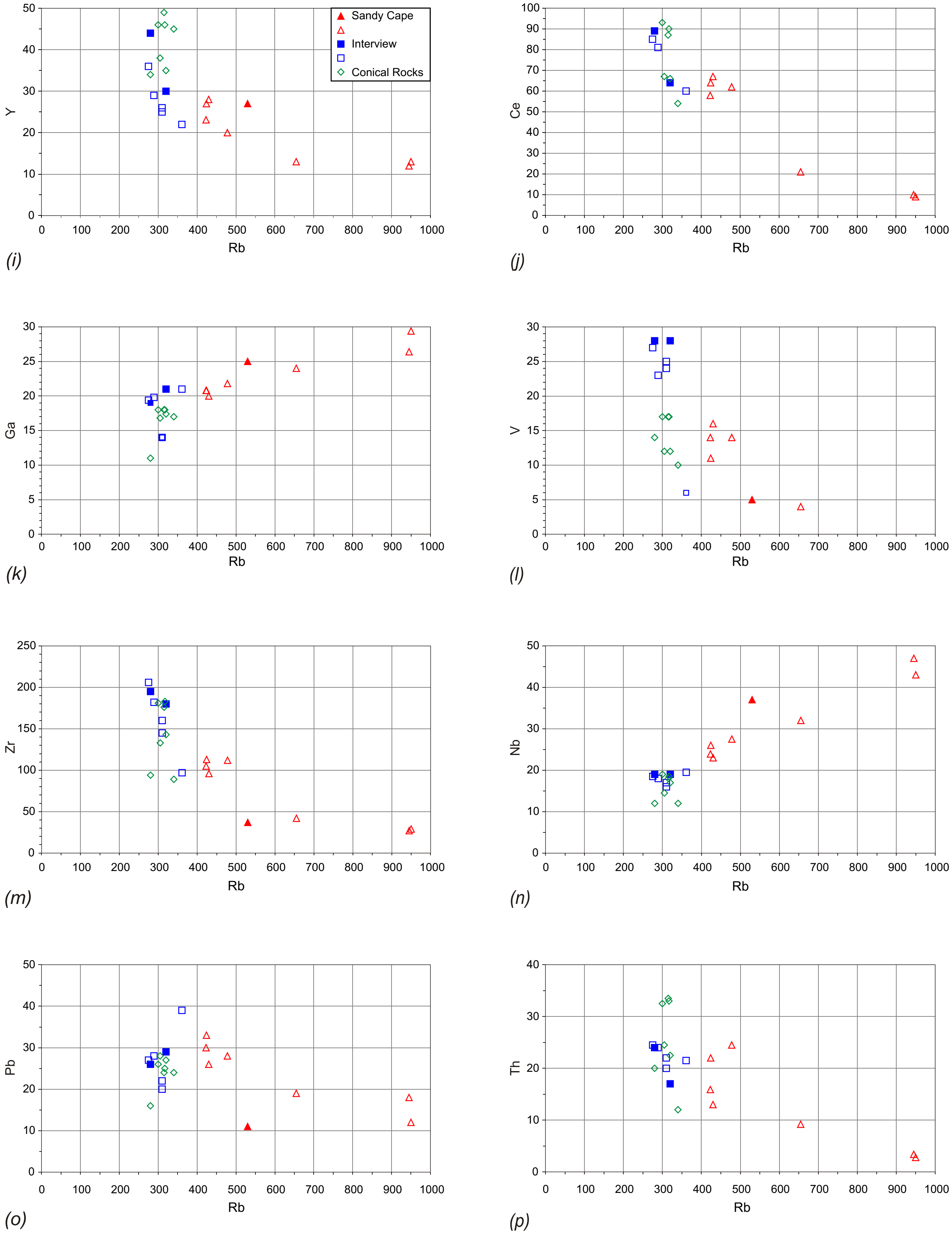


Figure 22 *(continued)*

Geochemistry of Devonian granites. Data sources as for Figure 21.
(I) Y vs Rb; (j) Ce vs Rb;
(k) Ga vs Rb; (l) V vs Rb;
(m) Zr vs Rb; (n) Nb vs Rb;
(o) Pb vs Rb; (p) Th vs Rb.

Table 3

Chemical analyses

Rocky Cape dyke swarm dolerites															
Field No.	LJ106	LJ157	LJ350	LJ371	LJ375	LJ381	LJ471	LJ541	LJ560	LJ718	LJ808	LJ813	LJ875	MJ92	MJ2088
Reg No.	R011677	R011681	R011696	R011700	R011701	R011702	R011708	R011712	R011714	R011725	R011730	R011732	R011737	R006773	R006786
Anal No.	20030194	20030198	20030207	20030208	20030209	20030210	20030214	20030218	20030219	20030224	20030226	20030227	20030231	902533	990466
Unit	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd	Pd
SiO_2 (%)	51.04	51.37	48.19	51.09	48.94	50.37	50.64	50.60	50.93	52.13	51.58	51.73	51.45	51.14	45.60
TiO_2	1.53	1.40	1.47	0.71	1.94	1.25	0.80	1.16	1.42	1.24	1.57	1.48	1.41	1.38	1.82
Al_2O_3	13.87	13.32	14.97	14.79	15.64	14.72	15.18	13.10	13.58	13.90	14.37	14.56	14.27	13.62	16.33
Fe_2O_3	2.38	2.09	3.25	2.37	1.95	2.85	3.85	2.46	3.22	3.44	2.47	2.43	2.49	1.99	5.59
FeO	8.86	9.11	7.56	7.30	10.41	8.60	7.05	7.82	8.86	7.05	8.47	8.27	9.05	8.98	6.85
MnO	0.18	0.18	0.18	0.16	0.19	0.19	0.17	0.15	0.19	0.16	0.19	0.18	0.19	0.18	0.19
MgO	6.90	6.23	6.96	6.90	5.78	5.46	6.36	9.06	5.44	6.52	5.50	5.51	5.23	6.97	7.20
CaO	7.60	9.99	10.74	10.32	6.23	9.90	8.44	7.67	9.90	8.75	8.87	7.79	9.10	8.58	8.08
Na_2O	2.18	2.08	1.86	1.88	4.01	2.34	1.76	2.19	2.12	2.43	2.54	3.04	2.07	2.72	2.15
K_2O	1.89	0.99	1.31	1.00	0.38	0.77	1.33	1.11	1.59	1.13	0.89	1.14	1.55	1.29	0.42
P_2O_5	0.15	0.14	0.23	0.09	0.23	0.17	0.10	0.13	0.19	0.12	0.16	0.14	0.19	0.16	0.27
SO_3	0.01	0.02	0.07	0.06	0.01	0.04	0.02	0.11	0.02	0.01	0.02	0.01	0.03	0.21	0.06
CO_2	0.04	0.07	0.00	0.03	0.05	0.04	0.11	0.00	0.00	0.01	0.07	0.20	0.04	0.10	0.18
H_2O^+	3.19	2.74	3.22	3.02	3.79	2.88	3.80	3.82	2.47	3.08	3.05	3.12	2.67	2.65	4.76
Total	**99.81**	**99.72**	**100.02**	**99.72**	**99.55**	**99.57**	**99.61**	**99.38**	**99.91**	**99.97**	**99.74**	**99.60**	**99.73**	**99.97**	**99.49**
FeO_{tot}	11.00	10.99	10.48	9.43	12.17	11.16	10.51	10.04	11.76	10.15	10.69	10.45	11.29	8.98	6.85
LOI	2.25	1.80	2.38	2.24	2.68	1.96	3.13	2.96	1.48	2.31	2.18	2.40	1.70	10.77	4.18
S (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0		
Sc (ppm)	38	37	41	49	54	47	49	32	45	35	39	36	45	31	43
V	320	300	270	270	350	340	290	290	350	290	340	320	340	230	350
Cr	115	120	150	190	56	105	165	720	64	330	105	98	66	125	195
Co	47	48	49	44	42	47	42	45	49	38	43	43	46	49	38
Ni	65	78	110	85	56	68	81	240	57	120	71	67	50	91	135
Cu	20	115	120	86	9	120	105	91	175	52	64	37	150	135	74
Zn	98	115	105	94	130	97	115	86	110	110	125	90	110	95	99
Ga	20	19	17	17	18	19	18	19	18	19	21	21	19	18	21
As	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Rb	83	48	48	47	13	28	57	47	77	43	38	47	74	49	18
Sr	150	160	300	135	160	195	105	145	220	190	175	200	220	155	300
Y	30	29	24	28	41	33	41	31	34	28	28	29	34	24	24
Zr	135	125	105	91	195	125	100	140	140	135	135	135	145	115	120
Nb	9	8	15	5	27	14	6	9	19	9	10	9	18	6	19
Mo	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sn	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9
Ba	280	170	410	240	165	220	220	200	240	190	185	185	360	350	130
La	<20	<20	<20	<20	<20	<20	53	<20	<20	51	23	<20	<20	20	<20
Ce	31	<28	30	<28	62	36	125	28	38	30	34	36	42	61	42
Nd	<20	<20	<20	<20	28	20	50	<20	22	21	<20	<20	21	<20	<20
W	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	19	<10
Pb	<10	11	<10	10	<10	<10	11	<10	10	13	15	10	10	<10	11
Bi	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Th	13	15	10	13	17	14	16	15	18	14	15	13	17	<10	13
U	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

Table 3 *(continued)*

	Other dykes		Devonian granites			Pedder River Siltstone									
Field No.	LJ200	LJ997A	LJ255	LJ954	LJ1008	LJ230	LJ204	LJ995	LJ175	LJ287	LJ1064	LJ1078	LJ1141	LJ974	LJ1002
Reg No.	R011686	R011747	R011693	R011742	R011750	R011689	R011688	R011746	R011683	R011695	R011757	R011759	R011763	R011744	R011749
Anal No.	20030201	20030236	20030204	20030233	20030238	20030203	20030202	20030235	20030199	20030206	20030240	20030241	20030243	20030234	20030237
Unit	Pd?	Kl?	Dg	Dg	Dg	Prp planar	Prp wavy	Prp wavy	Prp banded	Pru banded	Prp banded	Prp banded	Prp banded	Prp hornfels	Prp hornfels
SiO_2 (%)	54.63	69.86	70.99	70.46	74.95	65.03	72.49	59.46	67.57	70.02	70.86	66.82	66.70	85.64	80.82
TiO_2	1.11	2.98	0.49	0.50	0.06	0.80	0.43	0.58	0.77	0.61	0.55	0.80	0.81	0.27	0.27
Al_2O_3	13.83	5.04	14.55	14.55	14.31	18.60	13.34	22.92	17.36	15.71	15.86	18.01	17.80	7.83	7.55
Fe_2O_3	1.06	0.42	0.27	0.45	0.30	1.18	0.85	1.29	0.76	0.96	0.79	1.43	0.74	0.39	0.56
FeO	9.11	8.86	2.59	2.65	0.52	4.46	2.65	1.49	3.43	2.39	3.17	3.04	4.07	1.10	3.62
MnO	0.08	0.36	0.04	0.04	0.02	0.05	0.01	0.02	0.05	0.04	0.05	0.03	0.02	0.02	0.05
MgO	9.71	4.23	0.77	0.81	0.04	1.12	2.39	1.04	1.07	1.35	0.97	0.92	1.09	0.23	1.34
CaO	0.28	1.56	0.76	1.46	0.42	0.02	0.03	0.11	0.13	0.05	0.08	0.06	0.07	0.07	0.60
Na_2O	2.43	0.07	2.20	2.49	3.56	0.23	0.12	0.79	1.19	0.52	0.27	0.74	0.75	1.73	2.06
K_2O	1.61	0.04	4.89	4.81	4.27	5.05	4.17	7.45	4.17	4.99	4.10	4.48	4.04	1.33	0.46
P_2O_5	0.11	1.03	0.28	0.17	0.24	0.02	0.02	0.09	0.04	0.04	0.03	0.03	0.04	0.01	0.37
SO_3	0.02	0.08	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.01
CO_2	0.07	1.57	0.11	0.02	0.01	0.03	0.16	0.59	0.22	0.20	0.13	0.24	0.27	0.06	0.32
H_2O^+	5.23	3.33	1.63	1.12	0.73	3.43	3.02	4.10	3.03	2.60	2.87	3.06	3.27	0.89	1.62
TOTAL	**99.27**	**99.40**	**99.57**	**99.52**	**99.41**	**100.02**	**99.69**	**99.94**	**99.80**	**99.49**	**99.73**	**99.66**	**99.67**	**99.57**	**99.65**
FeO_{tot}	10.06	9.24	2.83	3.05	0.79	5.52	3.42	2.65	4.12	3.25	3.88	4.32	4.74	1.45	4.12
LOI	4.29	3.91	1.45	0.85	0.68	2.97	2.89	4.53	2.87	2.53	2.65	2.96	3.08	0.83	1.54
S (%)	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sc (ppm)	39	18	<9	<9	<9	17	9	9	17	13	15	18	19	<9	<9
V	320	195	28	28	5	85	43	55	74	45	46	82	92	23	17
Cr	700	750	14	17	7	66	27	26	57	42	33	67	72	23	19
Co	55	55	<8	<8	<8	8	<8	<8	8	<8	<8	<8	<8	<8	<8
Ni	210	360	6	7	5	19	8	7	13	11	7	9	10	6	6
Cu	115	6	20	6	7	7	11	<5	13	5	5	8	5	9	7
Zn	88	250	30	39	25	52	44	74	50	12	47	41	44	6	72
Ga	18	12	21	19	25	23	18	29	22	20	22	23	23	10	10
As	23	300	22	<20	<20	28	<20	<20	<20	<20	<20	<20	<20	<20	<20
Rb	130	<5	320	280	530	270	200	370	175	210	200	210	210	43	21
Sr	41	73	88	94	5	25	10	64	39	20	24	36	30	16	90
Y	24	29	30	44	27	43	36	52	35	51	54	63	48	15	37
Zr	105	250	180	195	37	220	220	260	360	320	250	350	310	240	155
Nb	5	93	19	19	37	19	11	22	19	17	14	19	21	5	5
Mo	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sn	<9	<9	<9	<9	9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9
Ba	160	25	410	440	<23	680	600	1200	700	540	910	770	710	185	96
La	<20	67	34	48	<20	38	32	53	72	45	<20	56	50	21	<20
Ce	<28	160	64	89	<28	65	58	95	135	90	<28	100	95	58	44
Nd	<20	71	29	37	<20	22	32	42	50	31	<20	43	38	21	<20
W	<10	13	18	<10	14	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pb	<10	36	29	26	11	<10	<10	32	13	<10	12	13	34	15	125
Bi	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Th	<10	14	17	24	<10	26	12	30	26	21	14	26	29	<10	<10
U	<10	13	19	13	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

Table 3 *(continued)*

Balfour Subgroup and correlates

Field No.	LJ102	LJ115	LJ538	LJ610	LJ403	LJ1	LJ420	LJ512	LJ645	LJ762	LJ815	LJ605	LJ629	LJ456	LJ486
Reg No.	R011676	R011678	R011711	R011717	R011703	R011665	R011704	R011710	R011722	R011726	R011733	R011716	R011718	R011707	R011709
Anal No.	20030193	20030195	20030217	20030221	20030211	20030191	20030212	20030216	20030223	20030225	20030228	20030220	20030222	20030213	20030215
Unit	Prb argillite	Prb argillite	Prb argillite	Prb argillite	Prb planar	Prb wavy	Prb wavy	Prb wavy	Prb wavy	Prb wavy	Prb wavy	Prb sandstone	Prb sandstone	Prb o' quartzite	Prb o' quartzite
SiO_2	65.40	64.06	65.74	67.12	67.29	64.24	73.20	67.06	65.10	72.11	67.88	78.71	72.62	99.03	99.48
TiO_2	0.71	0.79	0.79	0.70	0.80	0.96	0.60	0.78	0.82	0.60	0.77	0.32	0.59	0.02	0.02
Al_2O_3	17.88	18.92	17.81	17.08	17.65	19.54	14.10	17.91	20.52	13.00	16.87	10.36	14.42	0.23	0.02
Fe_2O_3	0.93	1.05	1.06	1.00	1.19	0.94	0.68	1.32	1.07	0.82	1.33	1.51	1.21	0.03	0.01
FeO	4.98	4.72	4.72	4.65	3.17	3.17	2.65	1.81	1.62	3.43	3.17	1.75	1.75	0.19	0.26
MnO	0.08	0.03	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.06	0.01	0.02	0.01	0.00	0.00
MgO	1.39	1.19	1.24	1.20	0.89	1.14	0.81	1.22	0.72	1.02	1.09	1.13	0.91	0.01	0.00
CaO	0.05	0.05	0.05	0.05	0.10	0.05	0.06	0.03	0.05	0.95	0.05	0.11	0.04	0.02	0.03
Na_2O	0.81	0.77	0.55	0.54	0.97	1.00	2.07	0.72	1.14	1.70	1.32	0.08	1.62	0.01	0.00
K_2O	3.75	4.44	4.28	4.18	4.46	5.26	2.77	5.75	4.63	2.69	4.07	3.85	4.20	0.11	0.08
P_2O_5	0.04	0.03	0.05	0.05	0.05	0.02	0.04	0.03	0.04	0.04	0.01	0.09	0.06	0.00	0.00
SO_3	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.14	0.01	0.01	0.01	0.00	0.00
CO_2	0.04	0.07	0.00	0.01	0.16	0.35	0.21	0.25	0.29	0.77	0.33	0.05	0.07	0.02	0.00
H_2O^+	3.65	3.76	3.55	3.34	2.94	3.20	2.28	2.92	3.74	2.18	2.83	1.99	2.02	0.05	0.05
TOTAL	**99.71**	**99.89**	**99.89**	**99.97**	**99.72**	**99.88**	**99.50**	**99.82**	**99.76**	**99.52**	**99.74**	**99.98**	**99.53**	**99.72**	**99.95**
FeO_{tot}	5.81	5.67	5.67	5.55	4.25	4.02	3.27	3.00	2.58	4.17	4.37	3.11	2.84	0.22	0.27
LOI	3.14	3.31	3.03	2.84	2.75	3.20	2.20	2.97	3.85	2.57	2.80	1.85	1.90	0.05	0.02
S%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Sc (ppm)	15	18	17	14	16	21	10	17	17	11	15	<9	11	<9	<9
V	78	92	86	87	80	105	52	93	90	58	81	48	55	7	8
Cr	55	64	70	62	61	56	33	68	38	37	55	19	47	9	11
Co	14	9	15	14	<8	<8	<8	<8	<8	8	<8	<8	<8	<8	<8
Ni	20	15	18	18	8	8	9	7	8	12	8	11	6	4	4
Cu	5	5	65	<5	11	5	10	10	10	16	7	7	9	8	8
Zn	70	58	59	56	44	39	43	32	43	91	17	5	23	<5	<5
Ga	22	24	22	21	22	24	17	24	26	16	21	14	18	5	5
As	<20	<20	23	<20	<20	<20	<20	<20	<20	<20	<20	<20	105	<20	<20
Rb	195	240	220	220	210	250	130	270	230	125	200	170	185	<5	<5
Sr	38	21	25	26	31	21	46	24	38	51	17	6	31	<5	<5
Y	38	43	43	40	38	53	34	52	37	34	35	27	70	<5	<5
Zr	210	220	230	200	210	250	220	330	300	320	300	520	550	19	21
Nb	16	17	19	17	17	19	14	19	17	12	18	10	15	<3	<3
Mo	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sn	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9
Ba	720	790	600	680	560	510	520	1050	800	410	350	390	610	45	23
La	45	46	27	46	<20	31	48	28	110	<20	<20	<20	<20	<20	<20
Ce	87	83	56	95	49	68	73	46	93	45	32	31	200	<28	<28
Nd	34	34	27	33	<20	33	27	20	36	<20	20	<20	77	<20	<20
W	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pb	<10	<10	33	<10	33	12	13	<10	29	49	<10	<10	<10	<10	<10
Bi	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Th	25	25	27	24	16	22	17	25	21	17	22	14	22	<10	<10
U	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

Table 3 *(continued)*

Lagoon River Quartzite and correlates												**gossan**
Field No.	LJ54	LJ124	LJ129	LJ183	LJ846		LJ276	LJ824	LJ1043	LJ1087	LJ909	MJ2342
Reg No.	R011670	R011679	R011680	R011685	R011735	R011511	R011694	R011734	R011755	R011760	R011738	R006653
Anal No.	20030192	20030196	20030197	20030200	20030230	20029997	20030205	20030229	20030239	20030242	20030232	990469
Unit	Prl sandstone	Prl sandstone	Prl sandstone	Prl sandstone	Prl sandstone	Prl sandstone	Prl o'quartzite	Prl o'quartzite	Prl o'quartzite	Prl o'quartzite	Prl o'quartzite	
SiO_2	87.26	88.95	80.01	93.95	92.03	91.11	98.02	95.57	97.97	93.98	88.70	84.63
TiO_2	0.14	0.18	0.34	0.07	0.08	0.17	0.02	0.04	0.01	0.05	0.16	0.01
Al_2O_3	6.65	5.63	10.17	3.07	4.07	4.83	0.28	1.98	0.85	2.22	5.49	0.22
Fe_2O_3	0.84	0.89	2.08	0.08	0.49	0.17	0.06	0.01	0.05	0.16	0.79	6.22
FeO	0.45	0.45	0.71	0.71	0.52	0.58	0.78	0.32	0.52	1.10	0.52	1.47
MnO	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.00	0.01
MgO	0.20	0.19	0.41	0.13	0.18	0.59	0.34	0.14	0.01	1.03	0.38	0.20
CaO	0.02	0.03	0.02	0.04	0.03	0.04	0.02	0.02	0.02	0.01	0.05	0.03
Na_2O	0.01	0.04	0.02	0.03	0.01	0.02	0.01	0.13	0.01	0.01	0.02	0.11
K_2O	3.03	2.43	4.37	1.05	1.82	1.57	0.04	0.95	0.21	0.41	2.46	0.10
P_2O_5	0.01	0.02	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.03
SO_3	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.08
CO_2	0.02	0.04	0.03	0.01	0.15	0.06	0.03	0.03	0.06	0.17	0.10	0.19
H_2O^+	0.95	0.83	1.52	0.61	0.51	0.83	0.29	0.28	0.27	0.80	0.81	4.55
TOTAL	**99.58**	**99.70**	**99.71**	**99.77**	**99.91**	**99.98**	**99.91**	**99.47**	**99.98**	**99.95**	**99.48**	**98.18**
FeO_{tot}	1.20	1.25	2.58	0.78	0.96	0.73	0.84	0.33	0.57	1.24	1.23	7.07
LOI	0.92	0.82	1.47	0.54	0.60	0.83	0.23	0.27	0.27	0.85	0.85	4.58
S%	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	
Sc (ppm)	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9
V	20	14	28	16	16	20	8	11	7	11	21	<5
Cr	10	19	24	30	14	25	15	12	12	15	15	<5
Co	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	20
Ni	6	6	10	8	6	5	7	4	6	7	6	16
Cu	6	6	5	8	7	6	15	8	9	9	8	12500
Zn	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	<5	<5
Ga	10	9	14	8	8	8	5	6	5	6	9	7
As	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	67
Rb	100	98	190	31	66	54	<5	26	8	20	83	<5
Sr	29	7	6	<5	25	<5	<5	<5	<5	<5	8	<5
Y	32	31	30	37	18	12	<5	7	<5	15	16	165
Zr	135	180	440	165	120	180	17	52	33	125	230	<5
Nb	<3	<3	9	<3	<3	3	<3	<3	<3	<3	<3	<3
Mo	<5	<5	<5	<5	<5	<5	6	<5	6	6	<5	<5
Sn	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9
Ba	490	500	670	110	260	180	<23	140	28	51	530	47
La	<20	30	27	<20	<20	<20	<20	<20	<20	<20	<20	<20
Ce	<28	59	42	<28	49	<28	<28	<28	<28	31	30	<28
Nd	<20	30	<20	<20	21	<20	<20	<20	<20	<20	<20	27
W	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Bi	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<6
Th	<10	<10	14	<10	<10	<10	<10	<10	<10	<10	<10	<10
U	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

Discussion

Lower Rocky Cape Group stratigraphy

The current work suggests that previous stratigraphic relationships recognised within the Rocky Cape Group stratigraphy are only locally valid. When viewed *in toto* major lateral facies changes are implied.

Previous work

The Rocky Cape Group as introduced by Spry (1957) originally comprised all 'pre-Dundas Group' rocks between Penguin and Smithton. Gee (1968) more narrowly re-defined the group along the north coast, where it was considered to consist of the Cowrie Siltstone (oldest), the Detention Subgroup, the Irby Siltstone and the Jacob Quartzite (youngest).

The term 'Balfour slates and sandstones' was originally a local name (Ward, 1911) and variants have been used by several other authors. The term Balfour Subgroup (and its constituent units) was formally defined near Balfour by Reed (*in* Everard *et al*., 2001), where it was considered to stratigraphically underlie the Cowrie Siltstone and overlie the Lagoon River Quartzite.

The Interview Beds of Spry and Ford (1957) were formally defined (as the Interview Slate and Quartzite) along the lower Pieman River by Spry (1962, 1964). Subsequently, Gee *et al*. (1969) divided it into the Interview Siltstone and an informal underlying unit, 'Quartzite of the Lagoon River'. The Interview Siltstone is thus probably the approximate equivalent of the Balfour Subgroup.

Bell (1972) tentatively subdivided the Rocky Cape Group in the Sandy Cape–Pieman Heads area into five units, comprising from top to bottom:

1. Surprise Creek 'Beds' thought to be probably laterally equivalent to the upper part of the Interview Siltstone, lying east of the granite at Pieman Head (outside the current study area).
2. Interview Siltstone, "consisting of light to medium grey finely laminated siltstones displaying original sedimentary features, particularly truncation of bedding, and containing relatively thin quartzite beds."
3. Lagoon River Quartzite, "a distinctive white massive apparently 'recrystallised' quartzite with rare shale units…"
4. Chimney Creek 'Hornfels', consisting of quartzose sandstone and siltstone with minor rhyolitic volcanic rocks, and outcropping west of the Interview Granite between the lower Lagoon and Interview rivers. The volcanic rocks were thought to indicate a depositional break tentatively correlated with a transitional boundary between the Pedder River Siltstone and Lagoon River Quartzite, and to account for the more intense contact metamorphism in this unit, seen particularly near Chimney Creek (south of the current study area). As recognised by Bell himself, the validity of this unit is questionable and further work on the reported volcanic rocks is desirable (although his interpretation was partly based on thin section study).
5. Pedder River Siltstone, "a distinctive unit of dominantly dark grey siltstones, in which slump and scour-and-fill sedimentary structures are prominent …[appearing] to conformably underlie the Lagoon River Quartzite in the Sandy Cape area…"

Reinterpretation

The present work confirms that, although the stratigraphy is disrupted and repeated by faults, the lowermost exposed unit of the Rocky Cape Group is indeed a major siltstone unit (**Pedder River Siltstone**). This unit is quite variable. Along much of the coast it is a dark grey siltstone with thin (0.5–2 mm) strongly wavy to convolute lamination, thin interbedded sandstone units, and numerous sedimentary structures including graded bedding, cross bedding and load casts. Here it resembles the Skinners Flat Siltstone ('pyjama siltstone') of the Balfour Subgroup. Inland, as seen in the lower Italian River and the middle reaches of Skull Creek and the Pedder and North Pedder rivers, the Pedder River Siltstone is typically a more thickly (5–20 mm) and undulose to essentially planar laminated, 'banded' grey and cream siltstone. Tractional sedimentary structures such as cross lamination and scouring are also present but are less well developed than on the coast. The unit is folded but mostly dips and faces east. There may be a regional anticline inland of Kenneth Bay, implying a locally west-facing sequence, but more structural data in the area are needed.

The overlying '**Lagoon River Quartzite**' consists of essentially pure orthoquartzite and micaceous quartz sandstone, with the proportion of the latter increasing eastward and up-sequence. Apparently conformable and transitional sections across the contact with the underlying Pedder River Siltstone were observed in Skull Creek (321 900 mE, 5 409 100 mN) and the Pedder (322 600 mE, 5 411 400 mN) and North Pedder (321 400 me, 5 416 200 mN) rivers. In the western part of the area the sequence is repeated by NNW-trending faults mostly downthrown to the west, and subsidiary cross faults. The lowermost part of the Lagoon River Quartzite remains poorly known, but it extends, probably also east-dipping, to the base of the Norfolk Range, which is tentatively interpreted as a major fault. The range itself may be an elongate horst, possibly uplifted by the intrusion of underlying granite, but only the east-dipping Lagoon River Quartzite is exposed at the surface.

This relatively simple stratigraphy and structure is interrupted in the upper Lagoon River valley by the

Balfour Shear Zone, which is marked by one or more major faults and strong cleavage in siltstone, which otherwise resembles both the Pedder River Siltstone and Balfour Subgroup.

East of the Balfour Shear Zone, the large massif around Mt Edith, and to a lesser degree Mt Holloway, is composed of micaceous quartz sandstone which closely resembles the Lagoon River Quartzite of the main Norfolk Range on the opposite side of the Lagoon River valley. On Mt Edith the sandstone is gently dipping to subhorizontal and, unless major faulting is invoked, appears to overlie wavy-laminated siltstone on the undulating plain to the north. These siltstones might therefore be correlated with the Pedder River Siltstone, but are very similar to, and continuous in outcrop with, the **Balfour Subgroup** to the north.

In its type area, near Balfour and east of Temma, the most abundant lithology within the Balfour Subgroup is a wavy cross-laminated siltstone, consisting of alternating thin pale siliceous and dark carbonaceous laminae, sometimes with chlorite porphyroblasts. Other rock types include dark grey carbonaceous planar-laminated siltstone and shale, green chloritic planar-laminated siltstone, micaceous quartz sandstone, and quartzite (Everard *et al*., 1999, 2003). In its type area the Balfour Subgroup is thought to overlie the Lagoon River Quartzite, while the sandstone on Mt Edith appears to have a transitional relationship with more pelitic sequences, correlated with the Balfour Subgroup, in the Mt Vero–Toner River area.

Although more field work in the area is necessary, the most simple explanation seems to be that the Lagoon River Quartzite is a westward-thinning wedge of sandstone within a predominantly wavy-laminated siltstone sequence. Both it and the underlying Pedder River Siltstone are probably partial facies equivalents of the Balfour Subgroup further east.

The Balfour Subgroup may also have a similar lateral transitional relationship to the **Cowrie Siltstone**, which forms the central part of the Rocky Cape Region. It is an almost invariably planar-laminated, frequently carbonaceous and pyritic siltstone (Gee, 1968; Everard *et al*., 1996, 2001) and resembles the carbonaceous, planar-laminated facies of the Balfour Subgroup, but the other facies are absent. Within the study area, it mainly occurs in topographically low areas in the northeast. There the contact with the Balfour Subgroup is not well constrained except on the Heemskirk Road (fig. 17). Planar-laminated siltstones in the Toner River area are possible correlates of the Cowrie Siltstone, and may have an interfingering relationship with wavy-laminated siltstone typical of the Balfour Subgroup, but more fieldwork is needed in the area.

This tentative stratigraphic reinterpretation is shown schematically in Figure 23. The suggested overall pattern is one of decreasing energy from west to east. Very shallow water environments with gentle current action in the west, possibly near the basin margin, gradually gave way, both spatially (eastward) and temporally, to quiet, stagnant, reducing environments in deeper water towards the centre of the basin.

Geochemistry of the Rocky Cape Group

To assist in the interpretation of airborne radiometrics and to provide baseline geochemical data, thirty-five representative samples of Rocky Cape Group sedimentary rocks were analysed by X-ray fluorescence for major and trace elements. FeO was determined by titration and CO_2 by gravimetric methods. H_2O+ was calculated from loss-on-ignition after adjusting for FeO, CO_2 and SO_3. An analysis of micaceous quartz sandstone (sample R011511) from the Lagoon River Quartzite at the base of Mt Hazelton, just outside the study area, is also quoted.

The results (Table 3) are broadly consistent with petrographic observations (Appendix 1).

Both the Pedder River Siltstone and the bulk of the Balfour Subgroup are compositionally pelitic, and consist of mainly SiO_2 (59–73%), Al_2O_3 (13–23%) and K_2O (2.7–7.5%). On binary plots of these elements (fig. 24*a-c*), the analyses generally lie close to a mixing line between quartz and ideal muscovite, reflecting the mineralogical dominance of these minerals observed in thin section.

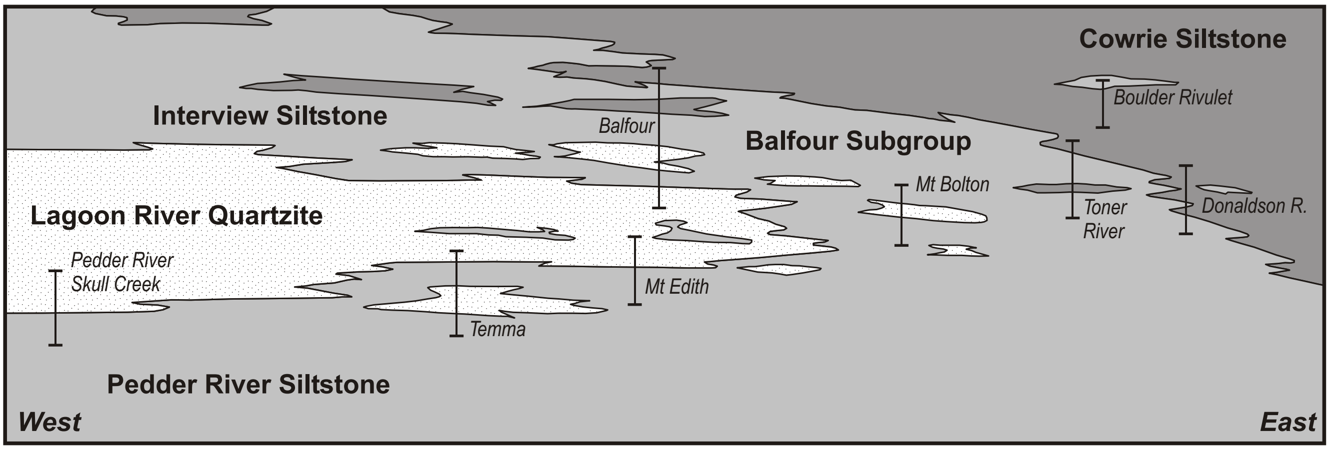


Figure 23

Schematic stratigraphic relationships of lower Rocky Cape Group (not to scale).

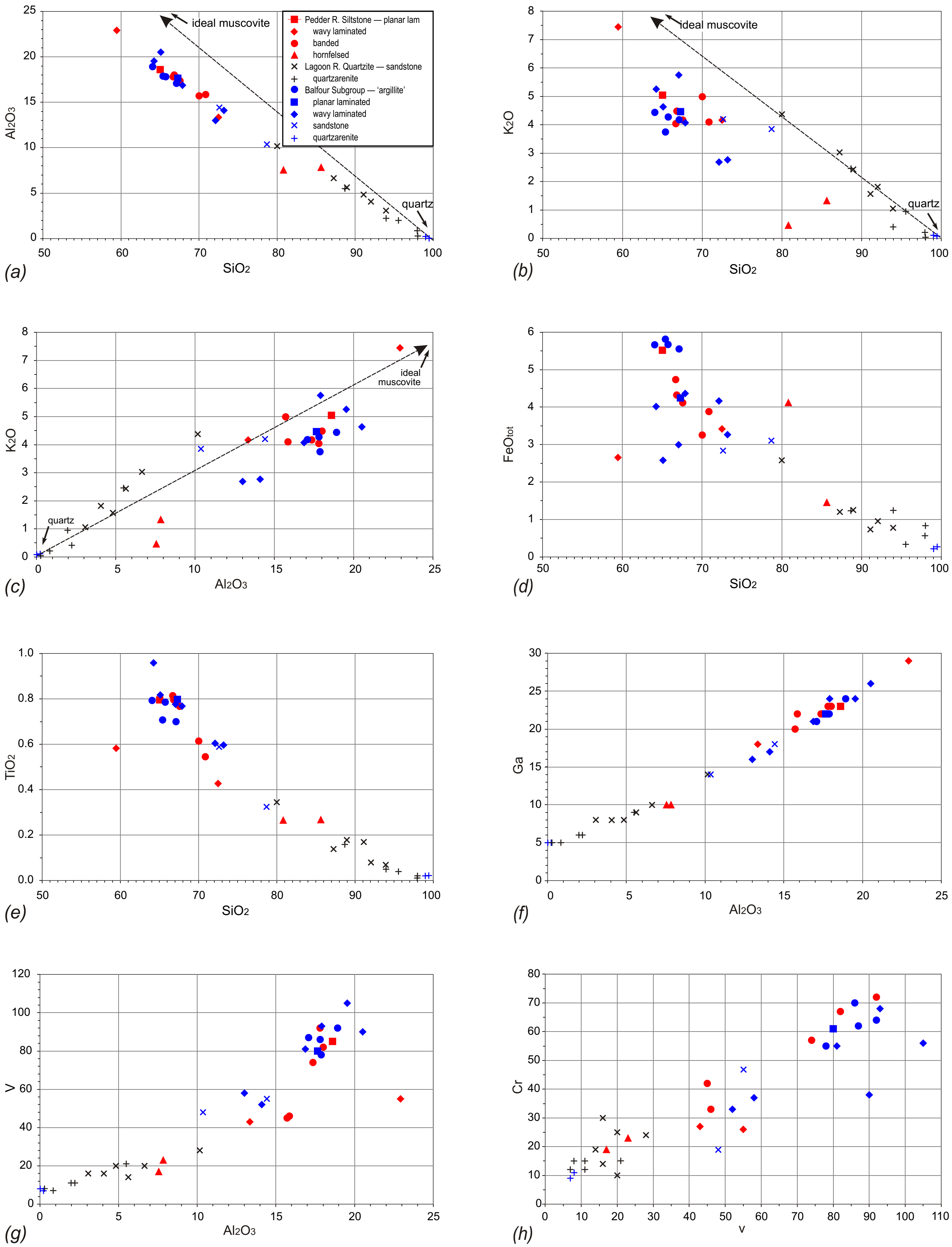


Figure 24

Lithogeochemistry of Rocky Cape Group. Data from Table 3.
(a) Al_2O_3 vs SiO_2; (b) K_2O vs SiO_2; (c) K_2O vs Al_2O_3; (d) FeO_{tot} vs SiO_2;
(e) TiO_2 vs SiO_2; (f) Ga vs Al_2O_3; (g) V vs Al_2O_3; (h) Cr vs V.

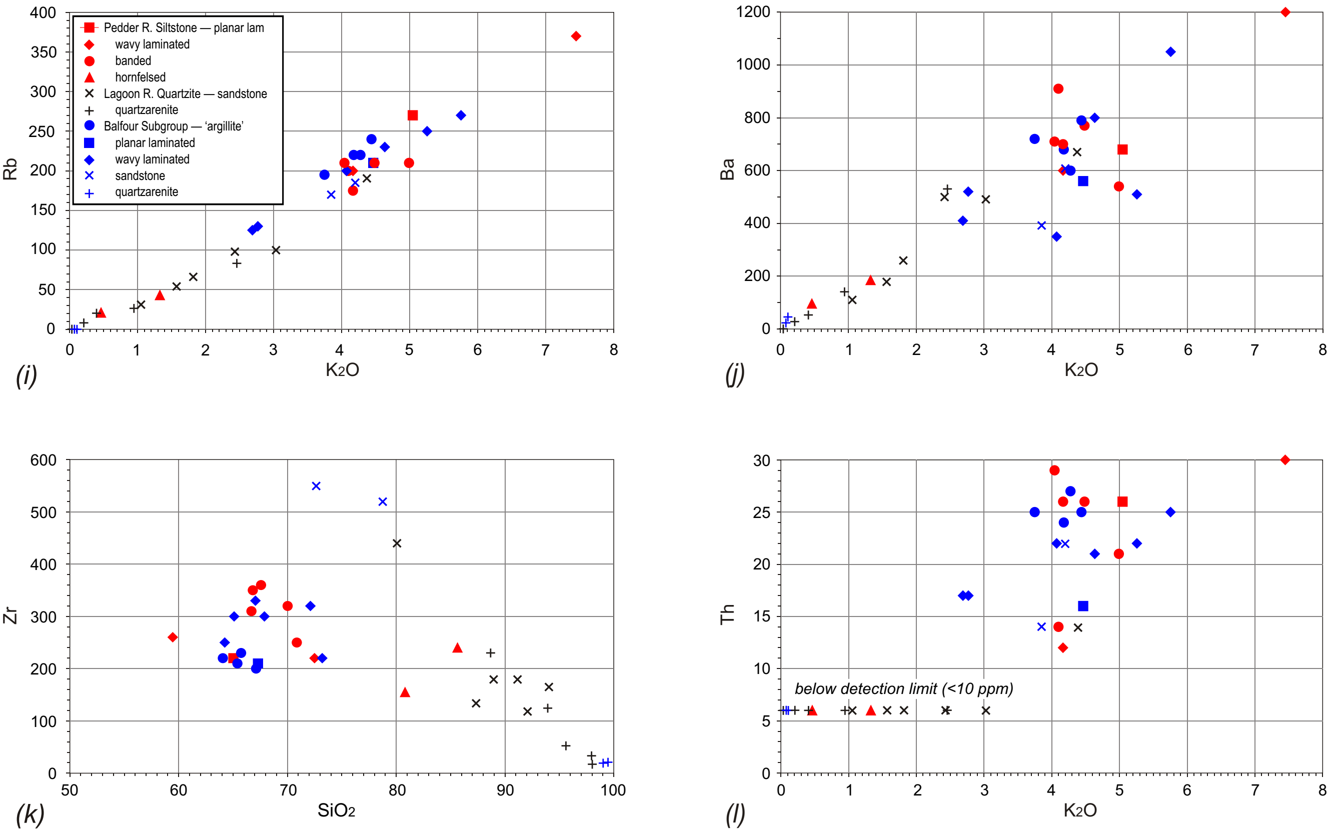


Figure 24 *(continued)*

Lithogeochemistry of Rocky Cape Group. Data from Table 3.
(I) Rb vs K_2O; (j) Ba vs K_2O; (k) Zr vs SiO_2; (l) Th vs K_2O.

The minor components iron (2.8–5.8% as FeO) and MgO (0.7–2.4%) probably reflect the additional presence of chlorite in many samples. Both total FeO and TiO_2 also correlate well with SiO_2 (fig. 24*d-e*). Na_2O is generally low (1%) except in a few samples (with 2.1%), mostly wavy-laminated siltstone from the Balfour Subgroup (LJ420, LJ762, LJ815) which contain plagioclase. Two samples (LJ974 and LJ1002) from within the aureole of Devonian granite are higher in SiO_2 and Na_2O and lower in some other elements, suggesting metasomatic alteration. Most samples have very low CaO (mostly 0.13%). A wavy-laminated siltstone (LJ762) from the Lindsay River with 0.95% CaO also contains 0.77% CO_2 and minor carbonate visible in thin section. There is no clear compositional difference between planar, 'banded' and wavy laminated facies in either unit, although 'argillites' (hard, compact, pale, faintly planar laminated fine-grained siltstone) within the Balfour Subgroup have slightly higher total FeO (5.5–5.8%), Co (15 ppm) and Ni (20 ppm) than other lithologies.

The Balfour Subgroup also contains beds and lenses of quartz sandstone and orthoquartzite. Particularly pure (>99% SiO_2) orthoquartzite lenses occur near Mt Bolton (samples LJ456, LJ486).

The Lagoon River Quartzite is composed dominantly of micaceous quartz sandstone (commonly 80–95% SiO_2, 4.4% K_2O) which are compositionally transitional to the Balfour Subgroup, with only subordinate true orthoquartzite (95% to >98% SiO_2). This accounts for the lack of strong contrast between these units on radiometric (e.g. total counts or K) images. Virtually all major and trace elements are more depleted in this unit, relative to the Balfour Subgroup and Pedder River Siltstone.

If all the Rocky Cape Group analyses are considered together, most trace elements correlate negatively with SiO_2 and positively with K_2O and Al_2O_3. To a first approximation, this probably simply reflects variable dilution of other minerals by quartz, but some elements display a distinct characteristic behaviour. Thus the trivalent elements Ga, V and Cr correlate particularly well with Al_2O_3 (fig. 24*f-h*), and Rb and Ba with K_2O (fig. 25*i-j*). Zr correlates well with SiO_2 in orthoquartzite and sandstone of the Lagoon River Quartzite and Balfour Subgroup (fig. 25*k*), but poorly in siltstone. The latter may have been deposited in lower energy environments in which heavy minerals such as zircon were less readily transported.

Although many values are below or close to detection limit, Th crudely correlates with K_2O (fig. 25*l*), consistent with the close similarity seen in radiometric images (fig. 7, 8). Uranium is below detection limit (<10 ppm) in all samples.

Few of the samples have indications of significant mineralisation (although obviously mineralised veins such as LJ70, LJ632 and LJ921 were not analysed). Arsenic is anomalous (105 ppm) in an impure fine-grained sandstone (LJ629) from the summit of Mt Vero, and weakly anomalous in two other samples (LJ230, LJ538). Lead is weakly anomalous (125 ppm) in a hornfelsed siltstone south of Sandy Cape (LJ1002), with scattered values (49 ppm) in a few other siltstones, most of which are also very weakly anomalous in zinc (91 ppm). Copper is very low (16 ppm) except in an argillite from the Donaldson River (LJ538, 65 ppm).

Extent of subsurface granite

As noted above, the entire region is one of negative Bouguer gravity anomalies (fig. 15) consistent with widespread subsurface granite. Modelling of the gravity field (Leaman and Richardson, 2003; fig. 16) suggests that the eastern contact of the Interview Granite dips northeast fairly steeply, reaching a depth of more than 4 km about 10 km east of Sandy Cape, but a NNW-trending spine of granite underlies the upper Lagoon River–upper Lindsay River area at a depth of less than one kilometre, roughly coinciding with the Balfour Shear Zone.

No obvious unequivocal surface indications of shallow granite, such as aplite dykes or hornfelsing, were encountered away from outcropping intrusions during fieldwork. Rocky Cape Group samples were collected and examined petrographically for contact metamorphic effects (see Appendix 1). Some samples, particularly siltstones, contain apparently metamorphic biotite and/or abundant metasomatic (rather than detrital) tourmaline, although their locations (fig. 25) do not show a close relationship with the form of subsurface granite inferred from gravity.

From within the one kilometre isobath in the upper Lagoon River, a wavy-laminated siltstone (LJ54) and an impure orthoquartzite (LJ909) contain biotite, but the majority of samples from this area show no evidence for proximity to granite. Further east, biotite and tourmaline were noted in quartz sandstone near Mt Holloway (LJ605) and in siltstone near Mt Vero (LJ629, LJ637). Near the Heemskirk Road, biotite is common in two wavy-laminated siltstone samples (LJ512 and LJ645). There and at Mt Vero, the inferred depth to granite is about four kilometres.

West of the Norfolk Range, chlorite porphyroblasts in siltstone were noted in Skull Creek (LJ175), Pedder River (LJ287) and the North Pedder River (LJ1064 and at 321 100 mE, 5 416 200 mN). At the Pedder River locality they are accompanied by tourmaline, and at North Pedder River, biotite and/or tourmaline are present in the matrix of several other samples (fig. 25). These observations are consistent with the influence of shallow granite, but gravity suggests depths of >2 to >4 kilometres.

Chlorite and andalusite porphyroblasts, biotite and tourmaline have been noted in Rocky Cape Group rocks in the Frankland River–Balfour area to the north (Everard *et al*., 2001). In some cases these occurrences are also well away from shallow granite inferred from gravity. It seems likely that their distribution is strongly affected by other factors, such as regional metamorphism, retrograde metamorphism, bulk rock composition, and rock permeability to hydrothermal and metasomatic fluids.

Structure

Mapping of the area remains very incomplete and there are still large areas, such as those immediately west of the Norfolk Range, in the upper Lindsay River area, and around Mt Hadmar, for which little or no structural information is available. Only preliminary conclusions can be drawn from a partial analysis of data collected during the current fieldwork (fig. 26*a*–*l*). The southern extension of the Balfour Shear Zone, which occupies the upper Lagoon River valley, appears to form the boundary between distinct structural domains.

To the west, poles to bedding (fig. 26*a*) are dispersed, but the most common dip of the Rocky Cape Group is shallowly southeast, with relatively few westerly or steep easterly dips. There is perhaps a faint suggestion of a girdle implying a shallowly-plunging southeasterly fold direction. This is consistent with a mostly steep NW/SE orientated cleavage (fig. 26*d*), although in this area cleavage is weakly developed and data are sparse and dispersed. Bedding-cleavage intersections are scattered but lie mostly in the southeast quadrant (fig. 26*g*). In addition, a majority of measured minor fold hinge-lines plunge shallowly SE or SSE (fig. 26*j*). This weak trend is also subparallel to the SSE/NNW trend of topographic lineaments (fig. 4) and inferred faults (fig. 17) in the region between the Balfour Shear Zone and the coast.

Bedding is very dispersed (fig. 26*b*) proximal to the Balfour Shear Zone, but cleavage is strongly developed, strikes mostly SSE/NNW parallel to the zone, and is usually moderately to steeply WSW-dipping (fig. 26*e*). Bedding-cleavage intersections mostly trend SSE/NNW although their plunge is variable (fig. 26*h*).

East of the Balfour Shear Zone, bedding most commonly dips moderately east or southeast (fig. 26*c*) and is dispersed around northeast-trending, shallowly plunging folds which are implied by strong maxima in plots of cleavage (fig. 26*f*), bedding-cleavage intersections (fig. 26*i*) and sometimes seen mesoscopically (fig. 26*l*). Again, this NE/SW trend is subparallel to a prominent set of topographic lineaments (fig. 4) and also to the dominant trend of the Proterozoic dolerite dyke swarm.

The contrasting structural styles and fold directions of the Rocky Cape Group to the east and west of the Balfour Shear Zone are comparable to, and an extension of, a similar contrast east and west of the Smithton Synclinorium, 20–60 km to the north.

A partly schematic cross section from Johnsons Bay, through Helen Peak, Mt Edith and Mt Vero, to the Toner River, is presented as Figure 27.

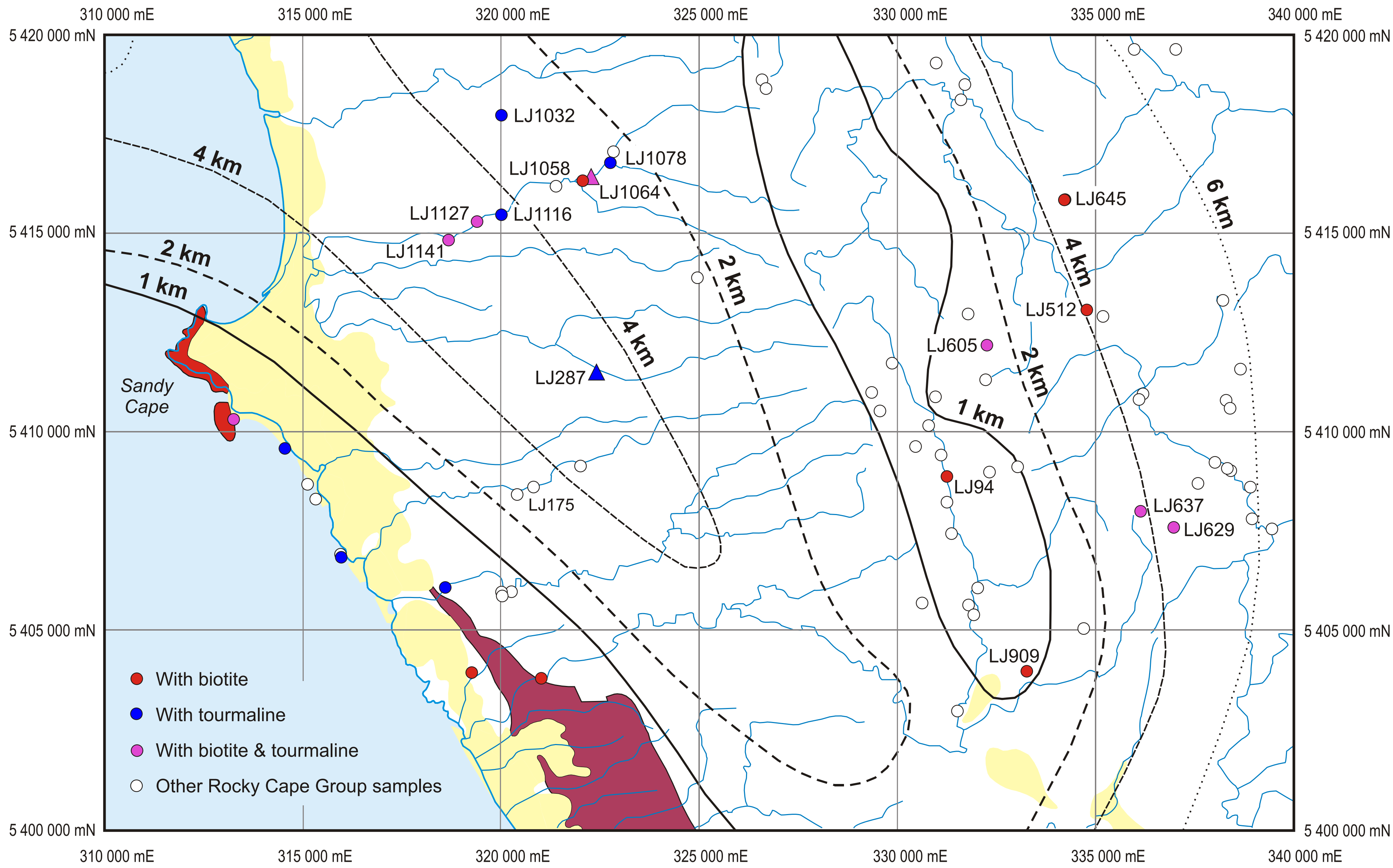


Figure 25. *Location of Rocky Cape Group samples containing metamorphic or metasomatic (not detrital) biotite or tourmaline, with outcropping granite and depth-to-granite contours superimposed. Red with biotite, blue with tourmaline, mauve with both biotite and tourmaline, triangles with chlorite porphyroblasts, open circles other samples.*

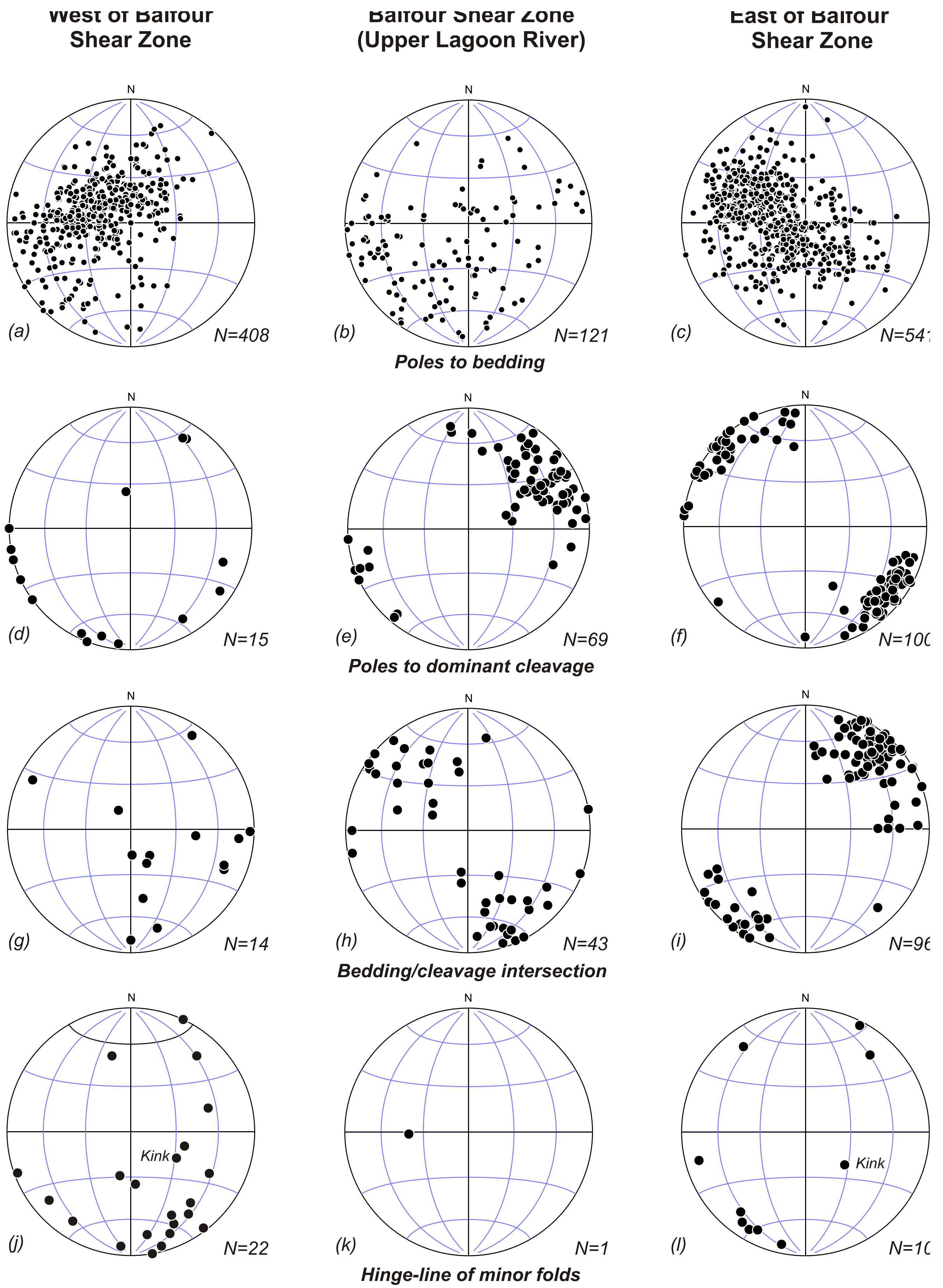


Figure 26

Schmidt equal area projections on lower hemisphere of: (a–c) poles to bedding; (d–f) poles to dominant cleavage; (g–I) calculated bedding-cleavage intersections; (j–l) hinge-lines of minor folds, from structural domains west of, proximal to, and east of the Balfour Shear Zone (upper Lagoon River valley).

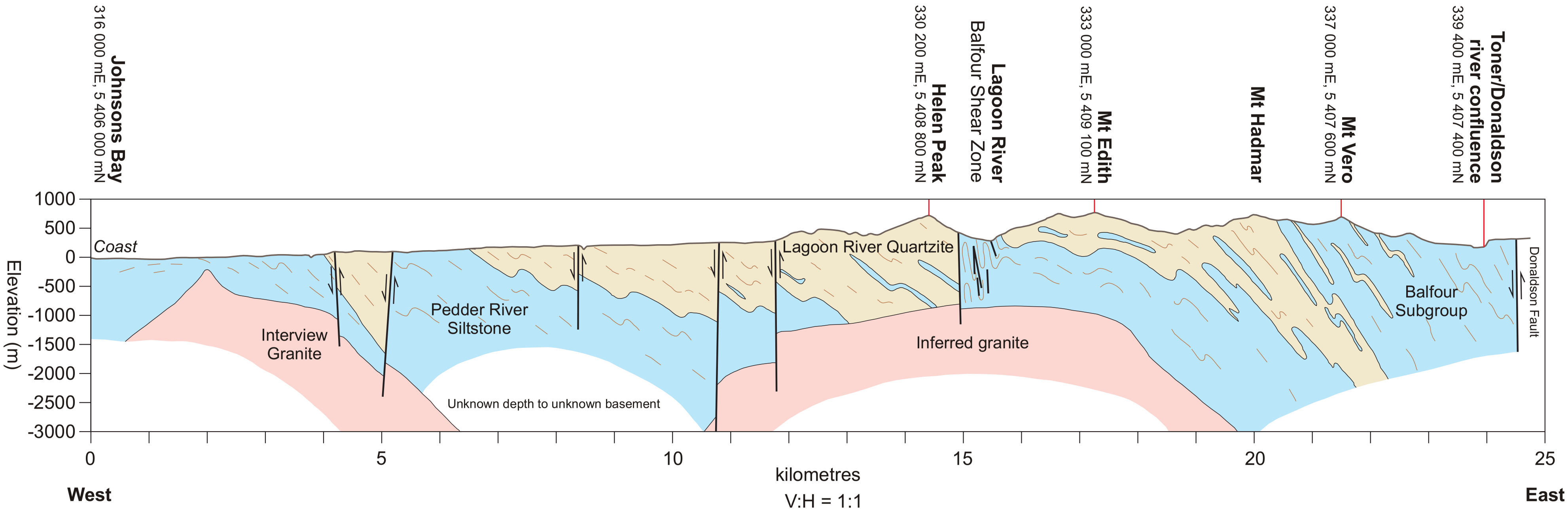


Figure 27

Cross section (partly schematic) from Johnsons Head to Toner River.

Mineralisation and related rocks

Previously known metallic mineralisation in the area is limited to a few prospects, mainly for copper, in the Toner River and upper Lindsay River areas. During this project, additional mineral occurrences were noted in the upper Lagoon River area and on the coast.

Quartz-copper (atacamite) vein

As noted above, secondary copper mineralisation is associated with a narrow north-trending shear zone on the coast one kilometre northwest of the mouth of Lagoon River (318 310 mE, 5 403 030 mN; sample LJ921). This occurrence appears not to have been previously recorded and has been added to MRT's MIRLOCH mineral occurrence database.

Quartz-sulphide veins, upper Lagoon River

Two quartz-sulphide veins were noted in the upper Lagoon River WNW of Mt Edith. Massive to boxwork quartz and disseminated to almost massive sulphide forms a bar across the river (330 870 mE, 5 410 080 mN). The contacts of the vein are not exposed, but it is at least four metres wide and probably trends at about 060° (true). In thin section a sample (LJ70) consists of a very irregular (10 m–1 mm) mosaic of interlocking quartz anhedra, some elongate to fibrous with crack-seal texture, together with pyrite euhedra (mostly 500 m–1 mm) and shreds of pale green chlorite aligned parallel to quartz fibres. Some translucent dark red hematite is also present.

About 400 m downstream (331 070 mE, 5 409 720 mN), an irregular mass of quartz, chlorite and pyrite about five metres wide crops out in the river. A sample (LJ77) displays a pseudobreccia texture consisting of patches of quartz (10 mm), anastomosing dark green chlorite veinlets and minor pyrite. In thin section the sample resembles LJ70, but is coarser-grained and chlorite is more abundant and nearly colourless with very low birefringence. Several quartz veins strike at about 150° immediately downstream.

On the northern slopes of Mt Norfolk (329 860 mE, 5 410 530 mN), float of oxidised ferruginous (originally pyritic?) siltstone contains quartz-hematite veinlets 1–2 mm wide (sample LJ47).

Toner River area

A three metre wide quartz vein, trending at 005°, crops out in the Toner River (336 730 mE, 5 407 750 mN). Further outcrops 50 m to the north contain disseminated pyrite.

Quartz veins containing pyrite were also noted adjacent to the upstream contact of a dolerite dyke (336 290 mE, 5 410 350 mN).

Further downstream (338 660 mE, 5 408 720 mN), eight narrow (5–100 mm) cleavage-parallel quartz veins crop out within a 1.5 m interval of dark grey-green siltstone (sample LJ712). Although stained yellow-brown in places, the veins are not obviously mineralised.

A large outcrop of vein quartz, with included disseminated pyrite and ferruginous alteration along irregular cracks, was noted west of Mt Vero (336 730 mE, 5 407 750 mN, sample LJ632). Another outcrop 50 m to the north suggests a vein about three metres wide trending at 005°. Weathered orange-red float on the northeast flank of Mt Vero (337 620 mE, 5 408 720 mN) appears to be derived from pyritic siltstone (sample LJ640).

These occurrences appear similar in style to the prospects in the area described by Ward (1911) and Weir (1984*b*), which were not re-located during this study.

In the Toner River (near 338 400 mE, 5 409 000 mN), pale to medium-grey fine-grained impure sandstone (sample LJ702) contains disseminated sulphides, including bornite and pale yellow (?) pyrite.

Upper Lindsay River area

Several small workings in this area were described by Ward (1911), all of which were prospected for copper, although Kingston (1965) reported traces of tin in a 'limonite-filled' adit west of the Lindsay River (near 331 100 mE, 5 419 100 mN).

This area was only briefly visited during the current project, but no remaining signs of the workings east of the Lindsay River (around 332 400 mE, 5 418 800 mN) could be located.

Workings southeast of Dohertys Pimple (330 110 mE, 5 419 890 mN) were briefly visited previously (in 1999). A quartz vein trending at about 030° has been excavated by a costean about 10 m wide, and a shaft (now flooded) was sunk at its southern end. Nearby, on the western side of the spur (at 330 000 mE, 5 420 000 mN), another costean has been dug along a sulphide-rich quartz vein trending at about 050° in coarse-grained siltstone. A grab sample of gossan from the adjacent mullock heaps assayed at 1.25% Cu but Sn was below detection limit (Table 3, sample MJ2342).

Quartz-tourmaline rock

Float (sample LJ1012) collected from an area of inferred Interview Granite consists of interlocking weakly strained quartz grains, several millimetres across, with very abundant inclusions of tourmaline as subhedral to rarely euhedral, narrowly elongate to acicular prism sections, wedge-like oblique sections and trigonal basal (sections <1 mm across). The tourmaline is pleochroic (colourless, pale blue-grey to pale brown or reddish orange) and displays colour zoning (cores blue, rims orange, or irregular). Some grains straddle quartz grain boundaries.

Conclusions

The major findings of this report are:

1. The stratigraphy of the western Rocky Cape Group requires revision because of the likelihood of lateral facies changes. Whilst the Pedder River Siltstone is abruptly overlain by the Lagoon River Quartzite, the latter unit appears to thin and taper out eastward, and may have a partly transitional relationship to the overlying Balfour Subgroup, which in turn may be a partial facies equivalent of the Cowrie Siltstone.

2. No evidence for previously unknown outcropping granite intrusions was found. In particular, the bodies tentatively suggested by Webster (2002) east of the Norfolk Range do not exist and alternative explanations are required for the magnetic and radiometric responses in this area.

3. The northern part of the Interview Granite is less extensive, in terms of surface outcrop, than previously thought. Although the more strongly fractionated, highly peraluminous S-type granite at Sandy Cape appears to be related, it may represent a cupola rising upward from a larger body at depth; it is not a lateral northwestward extension of the Interview Granite as indicated on previous maps.

4. West of the Norfolk Range, simple radiometric images clearly discriminate between outcropping tracts of predominant quartzite (Lagoon River Quartzite) and pelitic siltstone (Pedder River Siltstone), even in areas of poor surface exposure.

5. The Lagoon River Quartzite varies from pure orthoquartzite with annealed quartz grains, to impure quartz sandstone with a small amount of micaceous matrix. Whilst the orthoquartzites are radiometrically nearly 'dead', the impure sandstones contain significant potassium. This (rather than potassic alteration by underlying granite, as suggested by Webster, 2002) accounts for the slightly elevated total counts in areas of relatively better exposure or mineral soil development, such as incised stream valleys and topographic highs such as the Norfolk Range.

6. The Balfour Subgroup mainly consists of interbedded thinly wavy-laminated quartz siltstone, sandstone and orthoquartzite. It is less pelitic than the Cowrie Siltstone (of which it may be partly a facies equivalent) and the Pedder River Siltstone, and on radiometric images does not contrast as well with the Lagoon River Quartzite.

7. Precambrian dolerite dykes in the area are a southerly continuation of the 'Rocky Cape Dyke Swarm', but are more pervasively metamorphosed than dykes further north. Primary igneous minerals are completely replaced by greenschist facies assemblages (e.g. clinopyroxene by actinolite and chlorite, and calcic plagioclase by albite and epidote).

8. Of the major rock types in the area, the most magnetic are Precambrian dolerite dykes, which have typical susceptibilities (0.5–0.7 10^{-3} SI) generally only 2–3 times that of their Rocky Cape Group hosts (siltstone 0.1–0.4 10^{-3}, quartzite <0.1 $^{-3}$). They occur mostly west of the Norfolk Range, where they are expressed as weak, generally northeast-trending magnetic anomalies in otherwise magnetically quiet areas.

9. Otherwise, very few of the magnetic anomalies in the area have identifiable surface sources. There is some correlation with surface geology in that areas of outcropping granite, and most areas of outcropping quartzite or quartz sandstone, are magnetically relatively quiet. Most anomalies lie over outcropping Rocky Cape Group siltstone, but susceptibility measurements of the outcrops themselves are almost uniformly low (Table 2). Some of these anomalies parallel regional structures (including faults). The magnetic source rocks may be buried, and/or comprise a volumetrically minor, poorly outcropping component of the unit, such as narrow veins or fault-related alteration. Contact metamorphism of Rocky Cape Group units, especially siltstone, due to shallow granite and/or alteration along faults seems possible. Alternatively, the anomalies may be due to strong remanent magnetisation.

Recommendations

Geological mapping

Now that excellent geophysical data are available for almost all the area, little further progress is likely until systematic geological mapping of the area is completed. Priority should be given to completing traverses of main streams, as only in these is there good and semi-continuous rock exposure. Colour aerial photographs, preferably enlarged (1:10 000 scale) and rectified, should be obtained to identify the much more widely spaced and frequently weathered outcrops on the buttongrass plains. In similar country on the Balfour 1:25 000 scale geological map sheet (Everard *et al*., 2003), aerial photographs proved useful in defining structures (e.g. strike of bedding and mesoscopic folds), even where they are not obvious in the field due to poor outcrop.

Remanence measurements in Rocky Cape Group siltstone

The possibility of strong remanent magnetisation due to pyrrhotite or magnetite in Rocky Cape Group siltstone has been suggested by very limited previous work. As remanence has the potential to greatly modify and complicate interpretations of the aeromagnetic data, further measurements of Koenigsberger ratios should be made on samples of rocks capable of retaining significant remanence. Fresh outcrop is limited in much of the area, but initially good stream outcrops and recent cuttings on the Heemskirk Road should be sampled, especially where they lie over large high frequency aeromagnetic anomalies, together with any extant core from drilling at Sandy Cape, the Longback and near Balfour. Further drilling of magnetic anomalies may be necessary to produce suitably fresh samples.

Infill gravity survey

The main weakness remaining in geophysical coverage of the area is the almost complete absence of gravity stations in the Mt Holloway–Mt Bolton–McDougalls Lookout area. Since 1989, construction of the Heemskirk Road has made this area much more accessible and an infill survey could be done with only limited helicopter support. This would much better define the eastern limit of the negative Bouguer anomalies related to the inferred granite spine beneath the Norfolk Range. It may be worth noting that previous experience has shown remote area gravity data can be collected with helicopter support at a rate of 40 stations per day (e.g. Richardson, 1989).

In general, gravity station spacing is inadequate (5 km or more) for detailed interpretation over large parts of far northwest Tasmania, much of which is easily accessible.

Acknowledgements

At Mineral Resources Tasmania, R. S. Bottrill, C. R. Calver, G. R. Green, R. G. Richardson and D. B. Seymour are thanked for useful discussions and L. M. Hay, S. Heawood, A. Hollick, M. Jacobson, D. Shaw, J. Taheri and R. N. Woolley for technical support. G. Kowalik provided assistance in the field. Field work was funded by the Commonwealth Government as part of the Western Tasmanian Regional Minerals Program (WTRMP).

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[31 March 2005]

APPENDIX 1

Sedimentary petrography of the Rocky Cape Group

Sedimentary rocks are described as conglomerate (grain size >2 mm), sandstone (coarse-grained 500 m –2 mm, medium-grained 250–500 m, fine-grained 125–250 m, very fine-grained 62–125 m), siltstone (coarse-grained 31–62 m, medium-grained 16–31 m, fine-grained 8–16 m, very fine-grained 4–8 m) and mudstone (<4 m).

Pedder River Siltstone

Wavy laminated siltstone

Coastal outcrops of Rocky Cape Group siltstone between Sandy Cape and the Lagoon River mouth are characterised by a fine, wavy to convolute lamination, and are locally markedly carbonaceous. A typical sample (LJ204; plate 12*a, b*) is a poorly-sorted coarse to medium-grained quartzwacke siltstone composed mainly of angular quartz grains, subordinate ragged fragments (50–150 m) of pale green to nearly colourless chlorite, sparse flakes of detrital muscovite, and interstitial sericite. The lamination is defined by variations in grain size and narrow anastomosing dark seams of fine-grained sericite and carbonaceous material. Traces of detrital zircon and tourmaline are present.

Other samples may be very similar (LJ203, LJ991B) or more carbonaceous (LJ991A, LJ995). Sample LJ1002 shows signs of thermal metamorphism, with partly annealed, although very irregular, quartz grains and possible cordierite, together with detrital muscovite and ragged pale green chlorite.

Planar laminated shale

Sample LJ230 from the lower Italian River is a medium-grey planar laminated shale. In thin section it is seen to consist mainly of fine-grained sericitic siltstone laminae (typically 3–4 mm) alternating with narrower (200 m–1 mm) diffuse laminae of medium to coarse-grained poorly-sorted quartz siltstone with minor flakes of detrital muscovite. Abundant ragged grains of pale yellow-green chlorite (<200 m) and equant to irregular opaque aggregates (mostly 50–100 m) are scattered throughout the sericitic laminae. Traces of detrital muscovite and tourmaline are present. There is a weak cleavage in the sericitic laminae at about 20° to bedding.

A second sample (LJ236) from the same area is similar, but the quartzose laminae are thicker and contain more detrital muscovite. Smaller (<100 m) ragged chlorite fragments and opaque aggregates (<100 m) are dispersed throughout the rock, and partly oxidised. Narrow crooked quartz veinlets are present.

Wavy laminated but mineralogically similar siltstones occur in the same area (sample LJ234).

Planar laminated ('banded') siltstone

Many samples collected from the plain west of the Norfolk Range are banded, consisting of alternating off-white to pale grey and dark grey to olive-grey beds typically 5–20 mm thick. Individual beds are non-planar and undulose on a decimetre scale, but finely wavy to convolute lamination is absent. Graded bedding is common but scouring, flame structures and cross bedding are poorly developed.

A typical sample (LJ1141) from the North Pedder River near Gales Cliffs is graded from very fine-grained sandstone or coarse-grained siltstone (quartz typically 40–50 m) to medium-grained siltstone (more pelitic, but quartz typically about 20 m). Mineralogically the rock consists mainly of equant angular quartz anhedra and splinters of detrital muscovite, with subordinate yellow-brown tourmaline and minor pale yellow-green chlorite and biotite. Irregular aggregates, 50–200 m across, of an opaque mineral are also fairly abundant.

In this sample, tourmaline is more abundant in the more sandy and quartzose beds, and chlorite in the more silty and pelitic beds. It is distinguished from biotite, which has very similar colour and form, by its poorer cleavage, length-fast character and maximum absorption perpendicular to elongation.

Other samples from the North Pedder River area are similar but differ in the proportions of tourmaline and biotite. In sample LJ1127, both tourmaline and biotite are fairly abundant throughout, whereas LJ1032, LJ1078 and LJ1116 contain minor or trace tourmaline and little or no biotite. Biotite predominates in LJ1058.

'Banded siltstone' with chlorite porphyroblasts

Sample LJ1064, also from the North Pedder River, is unusual in containing numerous large tabular porphyroblasts of pale yellow-green chlorite, typically about 2 0.5 mm, with anomalous dark blue-grey ('berlin-blue') birefringence colours (Plate 10*g, h*). They are poikiloblastic with numerous inclusions of quartz, and some have narrow rims of brown biotite. The remainder of the rock is a very fine-grained sandstone, less well sorted than some other samples, in which biotite is fairly abundant and tourmaline rather rare. A second sample (LJ1064A) from a few metres away is similar but lacks large chlorite porphyroblasts.

Sample LJ287 (Pedder River) is a 'banded siltstone' with graded bedding. Chlorite porphyroblasts (1 mm) are common in coarse-grained siltstone beds, whereas tourmaline (50 m) is very abundant in the paler, very fine-grained sandstone beds.

Sample LJ175, from Skull Creek, is a very similar graded coarse-grained siltstone to very fine-grained sandstone with abundant chlorite porphyroblasts (mostly 1 mm). The porphyroblasts do not show any preferred orientation, are frequently at a high angle or oblique to bedding, and appear to have overgrown it. The matrix consists of quartz, detrital muscovite, finer-grained chlorite and opaque minerals and, unlike that of LJ1064, contains only traces of tourmaline.

Hornfels

Several samples of Pedder River siltstone from near the coast have been contact metamorphosed by nearby granite. The best preserved sample (LJ961; plate 10*c, d*) consists of an annealed mosaic of equant quartz (50–150   m) and subordinate potash feldspar, small laths of red-brown biotite, ragged fragments of muscovite (150–400   m) and anhedral to almost amoeboid grains of iron-rich, optically negative cordierite. Sparse irregular opaque aggregates and traces of tourmaline are also present.

Other samples (including LJ952, cut across the granite contact) are generally more altered, with cordierite partly or wholly altered to secondary white mica, but biotite has been preserved. Sample LJ974 consists of an annealed mosaic of quartz and fairly abundant feldspar (including some plagioclase) with subordinate biotite, but any cordierite is wholly altered to white mica. Samples LJ253 and LJ1007 are less metamorphosed, with a sericitic matrix, non-annealed quartz grains and a sedimentary microfabric. The latter is carbonaceous and retains some chlorite.

Lagoon River Quartzite

Orthoquartzite

Only a minority of samples from the Lagoon River Quartzite, and other samples described in the field as quartzite, are true orthoquartzites with more than 90–95% quartz.

Coarse-grained orthoquartzite

Sample LJ276 from Skull Creek consists mainly of interlocking quartz grains (0.5–1 mm) (plate 11*a, b*). Ragged anhedra (<600   m) of nearly colourless chlorite are fairly common and small irregular but more-or-less equant opaque grains (<100   m) are present, but white mica is absent.

Medium-grained orthoquartzite

Sample LJ1043 (North Pedder River) is a poorly sorted fine to medium-grained orthoquartzite (mostly 100–500   m) with traces of sericite.

Sample LJ909 (SSE of Mt Judith) is a weathered impure fine to medium-grained orthoquartzite (100–400   m) with patches of a very sparse sericitic matrix, and is transitional to quartz sandstone. Pervasive scaly deep red-brown oxidised material is probably, at least in part, an alteration of biotite. Traces of cross-twinned microcline and fresh biotite are also present.

Sample MJ1954 from the main peak of Mt Hazelton is a fairly well sorted but impure medium to fine-grained orthoquartzite, consisting of mostly annealed quartz grains (typically 200–300   m), minor detrital pale grey-green chlorite flakes (<200   m), rare detrital muscovite and traces of tourmaline. There is also some very sparse interstitial fine-grained sericite as films between some quartz grains.

Fine-grained orthoquartzite

Sample LJ1087 (North Pedder River) is an impure fine to very fine-grained orthoquartzite consisting of mainly quartz grains (<200   m) with very little interstitial sericite present. There are fairly common ragged fragments (<400   m), radiating sheaves and irregular clots of chlorite (<1 mm), and flakes of detrital muscovite. The accessory minerals include a sparse but pervasive, very fine-grained dissemination of scaly opaques and traces of zircon and tourmaline.

Very fine-grained orthoquartzite

Sample LJ824 (upper Lagoon River) consists mainly of interlocking quartz anhedra (50–100   m), together with a few feldspar grains (probably both K-feldspar and plagioclase) and traces of both detrital muscovite and interstitial very fine-grained sericite. Quartz is commonly strained and there is some cataclasis along grain boundaries.

Quartz sandstone

Most samples of the Lagoon River Quartzite are in fact impure quartz sandstone with an appreciable amount of sericitic matrix (plate 11*c-f*). The sericitic component accounts for their high total counts and potassic signature on radiometric images. Most samples are similar apart from differences in grain size.

Coarse-grained sandstone

Sample LJ1022, from the plains west of West Bluff, is poorly sorted but most quartz grains are in the 200   m–1 mm range, with the larger ones typically subrounded. Most have undulose extinction and a few are polycrystalline. The amount of sericitic matrix is quite variable, even on thin section scale, ranging between a thin intergranular film to interstitial fillings and rare small lenses. Traces of tourmaline and zircon are present, but feldspar and opaque grains are virtually absent.

Sample LJ183 (Skull Creek) is similar but is very poorly sorted. A weak tectonic fabric is defined by a preferred orientation of both sericite and quartz grain long axes. The matrix contains fine-grained comminuted quartz anhedra in addition to sericite.

Medium-grained sandstone

Sample LJ846 from the southern Norfolk Range contains angular quartz anhedra (mostly 200–500   m) and rare plagioclase in a sparse sericitic matrix.

Sample LJ124 (Mt Edith West; plate 11*c, d*) is similar, with a slightly higher proportion of sericitic matrix. Sparse scaly brown iron oxides, rare feldspar and detrital muscovite and accessory tourmaline and zircon were noted. Bedding is defined at thin section scale by small variations in grain size and proportion of matrix.

Fine-grained sandstone

Samples LJ50 and LJ54, from the crest of the range between Mt Norfolk and Mt Mabel, are poorly sorted with mostly angular quartz grains, mostly in the 100–200 m range, but some up to 500 m and commonly subrounded.

Sample LJ915 (east of Mt Judith) is also dominantly fine to very fine-grained (50–200 m), but bedding is defined by laminae with coarser-grained (250–500 m) quartz.

Sample MJ1952 (north peak of Mt Hazelton) is a poorly-sorted impure fine-grained sandstone, consisting mainly of angular, equant to irregular quartz grains (400 m but mostly 100–200 m) and much scaly fine-grained opaque material, probably derived from the oxidation of chlorite (cf. impure orthoquartzite MJ1954). There are also traces of detrital muscovite and a sparse interstitial matrix of scaly sericite.

Very fine-grained sandstone

Sample LJ129 (summit of Mt Edith; plate 11*e, f*) contains quartz grains (mostly 50–100 m) in an abundant sericitic matrix. This sample is of particular interest because of its high magnetic susceptibility, which is accounted for by abundant fresh equant opaque grains (mostly <100 m to rarely 500 m), presumably detrital magnetite. Detrital muscovite, zircon and tourmaline are also relatively common.

Balfour Subgroup

Wavy to convolute laminated siltstone ('pyjama siltstone')

Thinly, wavy to convolute laminated 'pyjama' siltstone is the most abundant and characteristic lithology of the Balfour Subgroup.

Typical samples (e.g. LJ420, plate 8*e*) consist of undulose to sometimes convolute laminae (e.g. LJ512, plate 8*f*), typically 0.5–3 mm thick, of medium grey to greenish fine-grained siltstone, alternating with cream coarser-grained siltstone or less commonly very fine-grained sandstone. Small-scale cross lamination is common.

In thin section (e.g. plate 12*c, d*) the coarser paler beds are seen to consist mainly of angular quartz and rare plagioclase grains (mostly 70 m), sparse splinters of detrital muscovite and abundant but small anhedral flakes of pale yellow-green chlorite, with sparse interstitial sericite. Graded bedding may be present. The finer darker beds are more pelitic, with sericite aligned to define the cleavage. Irregular opaque aggregates (200 m) and traces of zircon and tourmaline are commonly present.

In two samples (LJ94 and LJ512) small flakes of red-brown biotite (mostly 50 m) are common and chlorite is rare or absent (plate 12*e, f*). Biotite is also present but rare in LJ645.

In more weathered samples (LJ637, LJ786) chlorite is largely oxidised to orange-brown alteration products.

Sample LJ815 is a pale grey-green siltstone with numerous darker green wavy anastomosing laminae, 0.5–1 mm or less thick and with a spacing of 0.5–2 mm. In thin section, graded bedding from coarse to fine-grained siltstone is well developed. The coarse beds (or parts of beds) mainly consist of angular quartz and minor plagioclase (mostly <80 m), together with minor detrital muscovite and abundant interstitial chlorite and sericite; the finer beds are more sericitic. Opaque aggregates (mostly <100 m) are common, and there are traces of tourmaline and zircon. The dark anastomosing seams are composed of very fine-grained opaque material and are more common in the fine sericitic beds or parts of beds. A brown staining of parts of the section appears to be derived from oxidation of chlorite.

Planar laminated siltstone

A subordinate component of the Balfour Subgroup displays a less wavy, planar to slightly undulose lamination. Typical hand specimens (e.g. LJ403, LJ450, LJ812) are thinly banded to laminated (0.5–2 to occasionally 15 mm) alternations of pale grey to cream coarse-grained siltstone and medium to dark grey or greenish-grey siltstone. In thin section they are mineralogically similar to the more characteristic wavy-laminated siltstone (plate 12*g, h*). Chlorite is common in fresh samples, oxidising to orange-brown with weathering (e.g. LJ860). Sericite seams define cleavage, especially in more pelitic laminae.

Argillite

A few samples from within the Balfour Subgroup are hard, compact, pale greenish-grey to off-white argillaceous fine to very fine-grained siltstone with a faint, sometimes diffuse, planar lamination (1–3 mm).

In thin section typical samples (LJ115, upper Lagoon River; LJ538, Donaldson River) consist of scaly splinters of sericite (mostly 30 2–4 m), larger (50 m) subordinate but abundant ragged fragments of chlorite, and ragged anhedral quartz (20 m). There is also a sparse dissemination of equant to irregular opaque aggregates (50–100 m), rare ragged flakes of detrital muscovite (20 m) and minute traces of tourmaline and zircon. A faint but pervasive bedding fabric is defined mainly by alignment of sericite.

Sample LJ102 (upper Lagoon River) has a stronger fabric (probably cleavage close to bedding) and quartz anhedra are larger (50 m) and more abundant. Other samples (LJ363, LJ453, LJ610) from the Toner River–Mt Bolton area contain thin (0.5–1 mm) well-spaced laminae of poorly-sorted quartz siltstone, consisting mainly of quartz (50 m) and chlorite, with only minor sericite and detrital muscovite. The remainder of these rocks resemble LJ115 and LJ538, but sericite has been recrystallised to define a cleavage at a high angle to bedding. These samples are transitional to more typical Balfour Subgroup lithologies.

Impure fine-grained sandstone

Outcrops near the summit of Mt Vero were described in the field as pale grey to brown weathering, thinly planar laminated siltstone. In thin section a sample (LJ629) consists of alternating laminae 1–5 mm thick, ranging from poorly-sorted medium-grained sandstone (grains 300 m) to coarse-grained siltstone (grains mostly 30–50 m). Grains are angular and mostly of quartz with minor plagioclase, together with ragged flakes of detrital muscovite, fairly abundant irregular scaly opaque minerals, and accessory zircon. The coarser beds have a sparse sericitic matrix, but the finer beds are more pelitic with anastomosing sericitic seams defining cleavage. Fragments of orange-brown biotite (mostly 50 m) are fairly abundant, together with some pale green chlorite.

Sample LJ702 (Toner River) is texturally similar to the Mt Vero sample, but lacks biotite. Instead, ragged fragments of chlorite (mostly 100 m) are abundant in both fine to medium-grained quartz sandstone laminae and more sericitic siltstone laminae. In addition to quartz, detrital plagioclase, muscovite and traces of tourmaline and sulphide are present.

Another sample from the Toner River (LJ567) is a very fine-grained quartz sandstone (50–150 m) with minor plagioclase and relatively little sericite. Pale green chlorite is common.

Sample LJ786B (near Mt Holloway) has graded bedding at thin section scale from moderately quartz-rich very fine-grained sandstone (50–150 m) to sericite-rich pelite. Detrital muscovite and scaly oxidised ferruginous material are abundant. The latter may be altered biotite but the rock is too weathered for positive identification.

A more altered sample from the eastern side of Mt Norfolk (LJ66) ranges from poorly-sorted very fine-grained sandstone to sericitic siltstone. In less oxidised parts of the rock, pale green chlorite is abundant, but not biotite.

Medium-grained quartz sandstone

Sample LJ605 (near Mt Holloway) is a poorly-sorted medium-grained quartz sandstone, closely resembling parts of the Lagoon River Quartzite (e.g. sample LJ124, Mt Edith West). Grains (100–400 m) of mostly quartz, the larger ones subrounded, rare plagioclase and detrital muscovite and traces of zircon lie in a sericitic matrix. Orange-red biotite, partly altered to chlorite, and yellow-green tourmaline, probably of metasomatic origin, are present in the matrix. This may be evidence for shallow granite in the vicinity.

Orthoquartzite

Samples LJ456 (Heemskirk Road; plate 11*g, h*) and LJ486 (Mt Bolton) are very similar samples from small lenses within the Balfour Subgroup in the east of the study area, corresponding to radiometric lows. They are pure fine-grained orthoquartzites consisting of interlocking quartz grains with jagged grain boundaries and commonly undulose extinction, typically 100–300 m across. Only traces of white mica are present as tiny ragged anhedra. Minute grains of zircon, brown tourmaline and opaque grains are present in trace amounts.

Sample MJ2337 (southeast of Dohertys Pimple) is another well-sorted pure fine-grained orthoquartzite. Traces of detrital tourmaline, dark red-brown hematite and opaque grains were noted.

Sample LJ19, from a small knoll east of the upper Lagoon River, is a nearly pure medium-grained orthoquartzite, probably from a small lens within the Balfour Subgroup.

Clast-supported pebble conglomerate

The angular clasts (25 mm) are seen in thin section (sample LJ82) to be composed of fine-grained quartz sandstone (typical grain size 100–300 m) with subordinate feldspar (plagioclase and possible microcline) and detrital muscovite, with a small amount of fine-grained interstitial sericite. They are similar to local quartz sandstones within the Rocky Cape Group (e.g. on Mt Edith). Clast margins are mostly sharp, but in a few places the clasts appear to be partly disaggregated and grade into a finer-grained matrix of similar mineralogy. A crude outcrop-scale foliation is not apparent in thin section. The conglomerate is probably a very minor lens within and derived from the Rocky Cape Group.

Plate 11

Photomicrographs of Rocky Cape Group sandstones and orthoquartzites, plane polarised light (left) and crossed nicols (right), all 4.5 3.4 mm: (a, b) coarse-grained orthoquartzite, sample LJ276, Skull Creek; (c, d) medium-grained quartz sandstone, sample LJ124, west peak of Mt Edith; (e, f) very fine-grained quartz sandstone with detrital magnetite, sample LJ129, summit of Mt Edith; (g, h) fine-grained orthoquartzite, sample LJ456, Heemskirk Road near Mt Bolton.

Plate 12

Photomicrographs of Rocky Cape Group siltstone samples, plane polarised light (left) and crossed nicols (right):
(a, b) Pedder River Siltstone, sample LJ204, Johnsons Head, 4.5 3.4 mm;
(c, d) Balfour Subgroup, sample LJ762, Lindsay River, 4.5 3.4 mm;
(e, f) Balfour Subgroup, with biotite, sample LJ94, upper Lagoon River, 730 550 m;
(g, h) Balfour Subgroup, sample LJ403, Toner River, 4.5 3.4 mm.

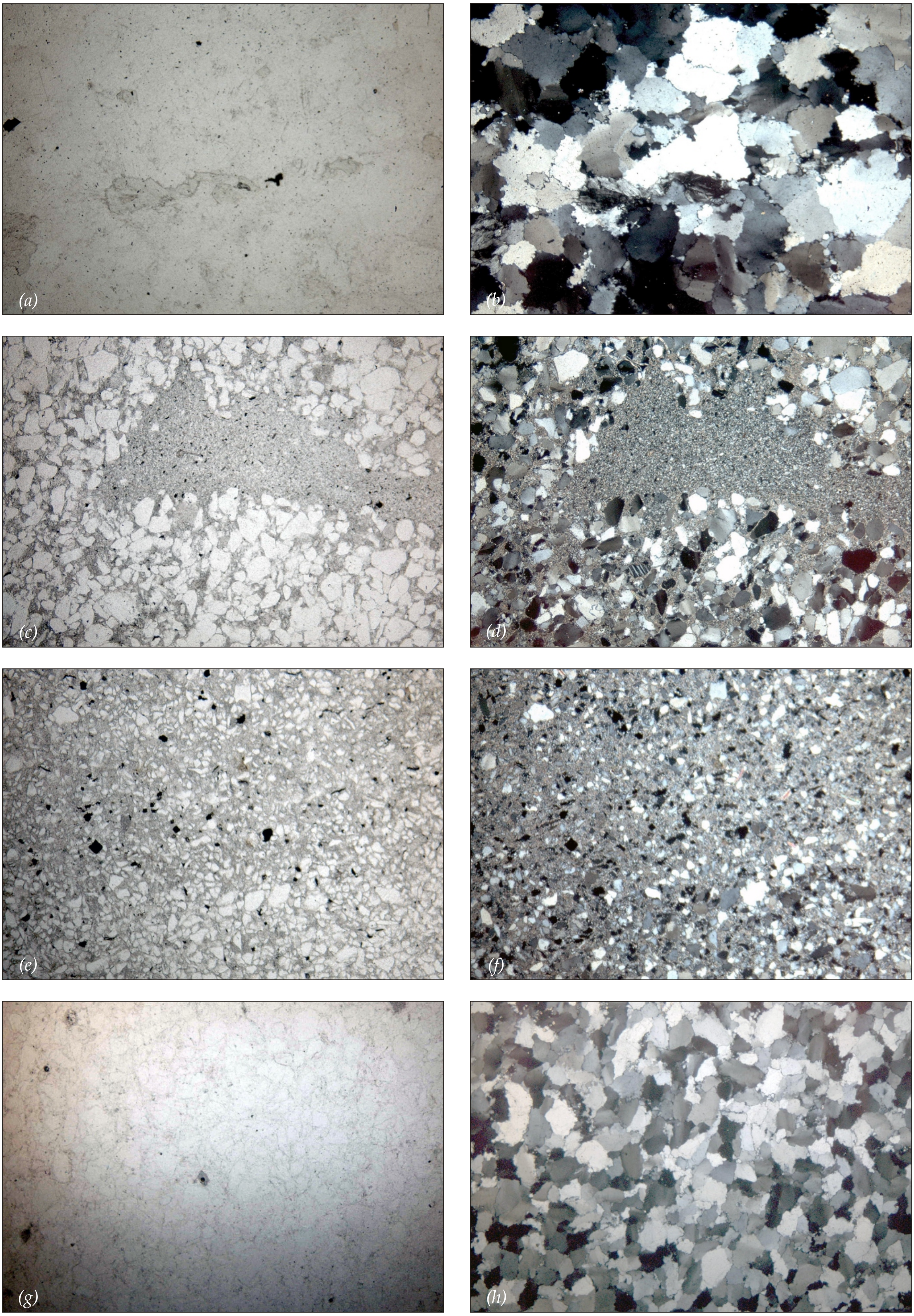

Plate 11

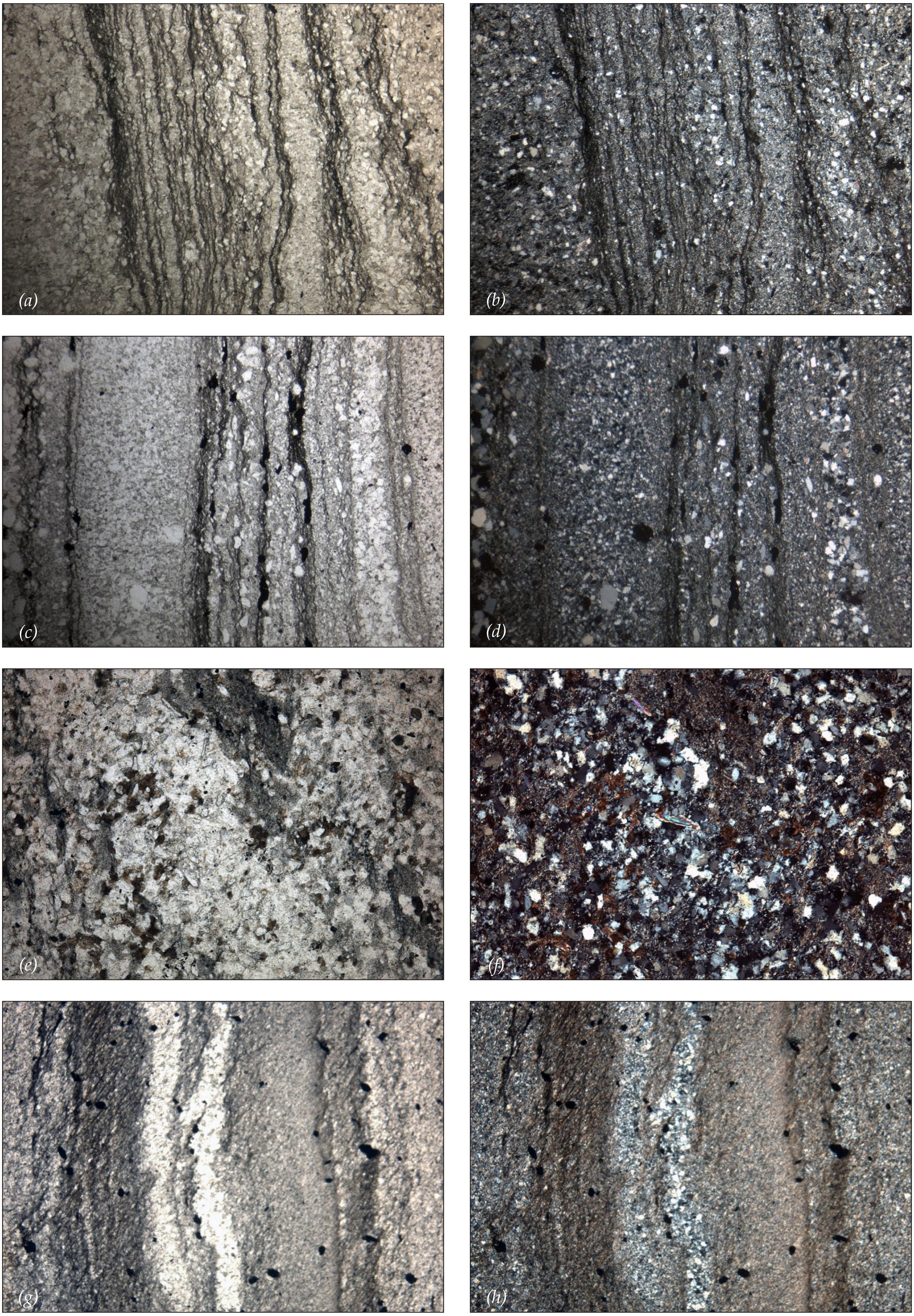

Plate 12

APPENDIX 2

Summary of modern mineral exploration

The following summary, in approximate chronological order, is derived from open file company reports available in the MRT library. Virtually no exploration in the area has been conducted since the late 1980s.

Rio Tinto Australian Exploration (SPL302)

A pioneering aeromagnetic survey, with a line spacing of a half mile (800 m) and a nominal height of 500 feet (150 m), was flown over much of northwestern Tasmania, although it appears that no follow-up work was done in the Norfolk Range–Sandy Cape area (McCarthy, 1957, 1958).

Pickands Mather (EL12/65)

Exploration over a large area of northwest Tasmania included a stream sediment survey in 1967. Some anomalous base metal values were obtained in this area (100 ppm Sn and 1500 ppm Zn in Lagoon River, 410 ppm Pb in the middle reaches of Sea Devil Rivulet) but apparently not followed up. Records are poor, but attempts at retrieval and re-interpretation of these data were later made by ACI (Bell, 1972), EZ Exploration (Morland, 1982) and CRA (Weir, 1983) (see below).

ACI/Renison Syndicate (EL48/70, 49/70)

A consortium led by Australian Consolidated Industries explored the country between the Pedder River and Granville Harbour, but most work was around the Interview River prospects, outside the area under discussion (Bell, 1972). A crude aeromagnetic survey was flown over the licence, and reconnaissance mapping and stream sediment sampling done, mainly near the coast. Dune sands at Kenneth Bay and between Sandy Cape and the Interview River were found to contain a low heavy mineral content (<0.3% rutile + zircon). The Norfolk Range area was not visited. A tentative stratigraphy for the lower Rocky Cape Group was suggested; this is discussed above (*Discussion* section).

Esso Exploration (EL2/73)

The Arthur–Pieman region was targetted for syngenetic base metal deposits, but little field work was done in the Norfolk Range–Sandy Cape area. A magnetic and electromagnetic (INPUT EM) survey over the licence located numerous EM anomalies, including several in the current area, but after ground follow-up these were attributed to either 'graphitic black slates' or surficial hydrological effects. No EM anomalies were coincident with the 'Balfour Trend' copper mineralisation, which was considered localised, shear-related and unpromising (Neale, 1974).

Mt Lyell Mining and Railway Company (EL27/78)

The lower Donaldson River area was explored, mainly by geochemistry with limited mapping (Hutton, 1981). Most work was to the south near Corinna, but trenches and dumps at the Toner River copper prospects (seven samples from three sites) were also examined. A picked sample of a 50 mm wide pyrite-chalcopyrite lens from the Copper Reward prospect (371105) returned 12.2% Cu, but the prospects were considered "patchy, localised and unlikely to be economic at depth." None of their stream-sediment samples (including those from 11 sites in the Toner River area) was considered strongly anomalous for base metals.

Electrolytic Zinc (EL56/80)

Tin was sought in the area west of the Norfolk Range behind Sandy Cape. An aeromagnetic survey was flown and interpreted by Bishop (*in* Morland, 1982) and Leaman (*in* McDonald, 1983) and four priority targets identified ('anomalies 1, 2, 4 and 6'). These were investigated by gridding, surface mapping, ground magnetics and pulse electromagnetics (PEM), augering and soil sampling (McDonald, 1983, 1984). Most work was done on 'anomaly 1' (east of Sandy Cape, around 316 000 mE, 5 413 000 mN), culminating in two diamond-drill holes (the only ones in the entire study area). Further details are summarised above (see *Geophysics – magnetics*).

Other work included limited geological traverses, a stream sediment survey (117 samples from the Lagoon, Italian, Pedder and North Pedder rivers and Native Hut Creek), and a commissioned photogeological interpretation (Morland, 1982).

CRA Exploration/Geopeko (EL1/77, 12/80, 36/80)

These companies explored a large area around the Arthur and Pieman rivers, including much of the current study area, initially for tin and tungsten.

Carey (1981, 1982) was commissioned by Geopeko to undertake a 1:100 000 scale air photo interpretation of the Arthur–Pieman area, which he subdivided into a number of 'photogeological groups'. His boldest speculation was the 'Kappa Group' occupying the core of the Norfolk Range. This was interpreted as a basic igneous unit, although he noted the absence of accompanying magnetic anomalies on data considered old even then. He also concluded that the abrupt western 'front' of the Norfolk Range is not a Tertiary fault, but considered that the adjoining coastal peneplain is a wave-cut platform formed when Cretaceous to Palaeogene marine transgressions periodically reached the base of the range.

CRA compiled previous stream sediment geochemistry and did some infill sampling, including of streams in the upper Lagoon River–Lindsay River area and on the western flank of the Norfolk Range. The stream sampling logs contain some sketchy but useful lithological and structural information. The only rock types reported in the area were quartzite, siltstone and vein quartz, apart from 'amphibolite' (dolerite?) at one site. Siltstone outcrops were noted in the upper Toner River (e.g. around 336 100 mE, 5 411 100 mN and 334 100 mE, 5 411 500 mN) and mainly quartzite further west, e.g. in streams (334 300 mE, 5 408 500 mN) south of Mt Edith. The old Toner River workings were described as dominantly pyrite with subordinate arsenopyrite and chalcopyrite in quartz-filled fault zones (Dickson, 1982; Weir, 1984*a*, 1984*b*, 1985*a*).

Nine aeromagnetic anomalies (five in the current study area, near the upper Leigh River in the extreme northwest) were defined from an earlier (1981) Department of Mines survey and followed up by gridding, ground magnetics and soil sampling. 'River Anomaly' (337 700 mE, 5 419 200 mN), 'River South Anomaly' (337 000 mE, 5 417 700 mN) and 'Leigh South Anomaly' (336 500 mE, 5 418 200 mN) were attributed to pyrrhotite and/or pyrite in siltstone, 'End Anomaly' (337 800 mE, 5 416 800 mN) to weathered 'amphibolite' and 'Odd Anomaly' (336 900 mE, 5 417 600 mN) to surface noise (Weir, 1984*b*).

The north-trending aeromagnetic anomaly south of Boulder Rivulet (342 400 mE, 5 420 800 mN to 342 500 mE, 5 417 500 mN, just west of the current study area, was also partly gridded and attributed to pyrrhotite in siltstone (Weir, 1985*b*).

Geopeko Ltd (EL17/83, 37/82)

These tenements lay in the west of the area under discussion, in the Pyramid Hill–Mt Vero–Donaldson River region. Twelve aeromagnetic anomalies in the Mt Vero–Mt Bolton area were identified on the 1981 Department of Mines aeromagnetic survey. Seven of these (roughly at 342 600 mE, 5 412 600 mN; 342 600 mE, 5 407 300 mN; 339 000 mE, 5 412 900 mN; 339 100 mE, 5 411 500 mN; 337 500 mE, 5 412 900 mN; 337 700 mE, 5 410 800 mN; 338 300 mE, 5 409 600 mN) were followed up by gridding, ground magnetics and (discouraging) soil sampling. At each anomaly, laminated black, grey, green or cream siltstone was reported, sometimes accompanied by 'amphibolite' (probably dolerite of the Rocky Cape Dyke Swarm). Most of the 'erratic magnetic highs' were attributed to 'disseminated syngenetic pyrrhotite', disseminated magnetite and in one case 'amphibolite'. Anomalous Zn, Ba, Fe and W in stream sediments were also noted in area (Pemberton, 1984*a*).

Further south (outside the study area), similar anomalies at 'Longback 2' (near 337 800 mE, 5 403 200 mN) and Longback 1 (near 342 200 mE, 5 396 600 mN) were also attributed to a similar combination of disseminated pyrrhotite and/or 'felsic amphibolite'. At the latter, drilling intersected more than 240 m of 'black shale and fine dololutite with disseminated, veined and bedded pyrrhotite and pyrite' giving an average magnetic susceptibility of 2.5 10^{-3} SI. Although the Longback 2 sequence is now known to be part of the Neoproterozoic Ahrberg Group, rather than the older Rocky Cape Group (e.g. Turner *et al*., 1991) it may be significant that a high Koenigsberger ratio (i.e. remanence) was considered necessary to fully explain the anomaly (Pemberton, 1984*b*).

Wolston Developments, Monier Ltd (EL34/85, 6/88)

These adjoining tenements lay in the Mt Bolton–Pyramid Hill and Mt Edith–Mt Holloway–McDougalls Lookout areas respectively. Work included regional stream sediment, soil and rock chip sampling. Regional geological information is sketchy but quartzite was reported at Mt Holloway (331 100 mE, 5 412 000 mN), Mt Edith (333 000 mE, 5 409 100 mN), Mt Bolton (338 700 mE, 5 411 500 mN) and at Mt Vero (337 000 mE, 5 407 600 mN). One analysed quartzite was considered suitable as a source for metallurgical silicon (Harrison, 1987). Old copper workings about two kilometres southwest of Mt Bolton, near the Toner River (around 333 700 mE, 5 410 500 mN) were located, gridded, ground magnetics and self potential surveys done, and elevated Au in soil samples found. Coincident magnetic anomalies were attributed to magnetite in sediments. Petrographic descriptions include 'finely recrystallised quartzite' and 'partly altered, foliated and deformed very fine-grained claystone with siltstone bands'. Drilling was recommended but not done prior to relinquishment (Harrison, 1989). Elevated Cu and Au values were also reported from poorly located old workings in gossans east of Mt Lily (Anon., 1988).

New Holland Mining NL (EL26/87)

This tenement lay between the Norfolk Range and Sandy Cape. A preliminary interpretation of gravity data available at the time was commissioned (Leaman, 1988) and previous exploration reviewed but little field work was done (Cromer, 1988).

Soloriens Mining P/L (EL53/88)

This tenement included much of the Balfour–Norfolk Range area. The main activity was to partially fund a detailed regional gravity survey conducted by the Department of Mines, which extended west to the coast. This new data was interpreted by Leaman (*in* Hofto and Morrison, 1989; see above).

Bach Holdings (EL33/86)

Coastal areas between Arthur River and Sandy Cape were explored for mineral sands. Subeconomic levels of heavy minerals, including rutile, zircon, leucoxene and monazite were found, but most work was north of Ordnance Point. Two shallow auger holes were drilled behind Sandy Cape and Kenneth Bay, where further work was recommended but not done prior to relinquishment (Lee, 1988).

National Mineral Sands and others (EL49/86)

Although the tenement extended northward along the coast to Sandy Cape, the only field exploration done was at Ahrberg Bay, well south of the area under discussion (Dove and Lee, 1988).

Pacific Nevada Mining PL (EL27/97, EL4/98)

These tenements impinge on the northern part of the study area (extending south to 5 408 000 mN) but all work was in the Temma–Balfour area further north (Newnham, 2000, 2001).

Ausvaal Projects PL (EL9/2002, EL10/2002)

This company briefly held much of the Norfolk Range. Data from the WTRMP helicopter EM survey were processed and targets for ground investigation were identified but no field work was done (Jenke, 2004).