

1984/84. Geological maps and summary of the Cambrian stratigraphic units and relationships in the Henty River - Williamsford area

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Abstract

Geological mapping has clarified some important stratigraphic relationships within the Mt Read Volcanics and adjacent sedimentary sequences in the Basin Lake - Howards Road - Williamsford area. There is a marked stratigraphic mis-match across the Henty Fault system, and the wedge of flysch sediments together with andesitic-basaltic volcanic rocks and ultramafic rocks between the North and South Henty Faults does not relate to the sequences on either side. This raises the possibility that considerable tectonic transport has been involved in the juxtaposition of the three sequences. An abundance of mafic dykes along the North Henty Fault suggests that this structure was a locus of intrusive activity in the Cambrian, and that at least some of the movement is pre-Devonian.

The stratigraphic sequence south of the South Henty Fault comprises a western volcano-sedimentary sequence (rich in fine-grained vitric tuff with associated siltstone and greywacke) passing gradationally upwards into a central volcanic sequence of rhyolitic feldspar-phyric pyroclastic rocks and lavas and andesitic volcanic and intrusive rocks. The central sequence is overlain by the late Middle Cambrian to Late Cambrian Tyndall Group, of quartz-feldspar-phyric lavas, pyroclastic rocks and volcanolithic conglomerate. The Tyndall Group appears to occupy a meridional graben-like structure with the Great Lyell Fault close to its western margin. The Owen Conglomerate, of middle Late Cambrian age at the base, has conformable to probably unconformable relationships with the Tyndall Group, and is largely confined by the Great Lyell Fault.

North and west of the Henty Fault Zone, a central volcanic sequence dominated by massive feldspar-phyric ignimbrite-like tuffs and lavas is overlain, disconformably and probably unconformably, by a very thick (>3 km) volcano-sedimentary sequence which is overlain by fossiliferous Dundas Group rocks on Howards Road. The contact with the central sequence is irregular and erosional, with large embayments and projections, and dips shallowly to steeply west. A coarse mass-flow breccia occurs at the base in some areas, and contains clasts of massive pyrite to boulder size as well as smaller clasts of hematite, galena and schistose volcanics and large rafts of siltstone and tuff. The contact transgresses both hangingwall and footwall volcanic rocks of the Hercules mine sequence. Bedded quartz-feldspar-phyric crystalline-vitric tuffs are abundant in the lower part of the volcano-sedimentary sequence but are rare in the upper part, which is dominated by siltstone and greywacke turbidites of mixed felsic volcanic-Precambrian derivation.

The Dundas Group succession comprises a lower siliciclastic sequence of conglomerate, quartzwacke and siltstone (about one kilometre thick), and an upper sequence of mudstone, greywacke and paraconglomerate. Fossils of early Late Cambrian age occur at the top of the lower sequence, indicating that the sequence contains correlates of the lower Brewery Junction, Razorback, Hodge and Red Lead formations. At the top of the upper sequence, the Misery Conglomerate is overlain, disconformably and possibly unconformably, by a fossiliferous shallow-marine sandstone-siltstone unit containing

late Late Cambrian fossils and correlated with the Owen Conglomerate. Contacts between Cambrian sequences and the Ordovician Gordon Limestone show significant angular discordance at several localities in the general area.

Only the lower part of the Howards Road volcano-sedimentary sequence is preserved between Moores Pimple and Williamsford. The western contact of the sequence in the Moores Pimple - Upper Bather Creek area appears to be a major fault marked by strong shearing of sediments and intense secondary silicification. The rocks west of the contact comprise a highly disrupted sequence of conglomerate, quartzwacke-mudstone, dolomitic siltstone-sandstone, greywacke, siltstone, mudstone, felsic tuff and mafic volcanic rocks, with felsic, gabbroic and minor ultramafic intrusive rocks. This disrupted sequence is a southerly continuation of the "Rosebery Group". The presence of late Middle Cambrian fossils in one area and of trilobite fragments at another locality, together with obvious lithological similarities to the Dundas Group, indicate that the bulk of the sequence is of Dundas Group origin. The nature and timing of the disruption and folding of the sequence are still to be clarified, but several factors (e.g. localisation of intrusive activity near the major fault, radiometric dates on slate) point to the possibility of significant tectonic activity in the late Cambrian-early Ordovician.

Introduction

This report presents a summary of results from geological mapping in the SW portion of the Murchison Quadrangle and adjacent parts of the Zeehan Quadrangle. The mapping assists in elucidating the stratigraphy and relationships within the Cambrian Mt Read Volcanics and adjacent sedimentary sequences, including the Dundas Group. The area spans the southern part of the Henty Fault Zone, and clarifies the changes which occur across this major structure. Some revisions to the geology as shown on the Zeehan Sheet (Blissett and Gulline, 1962) have been made, particularly in the designation of the siliciclastic rocks in the Farrell Rivulet-Tom Creek area and in the area east of the Professor Range. Some 34 chemical analyses of volcanic and intrusive rocks from the area are included.

The accompanying maps (figs 1,2) comprise an overall plan of the mapped area at 1:25 000 scale, and a detailed map of the Williamsford - Moores Pimple - Jones Creek area at 1:10 000 scale. The maps have printed symbols to facilitate hand-colouring, but better results will probably be obtained by referring to the coloured master copies held in the Geological Survey Cartographic Section. As the mapping is part of an on-going programme in the Murchison area, the maps are of a preliminary nature pending colour production at a later date. Earlier mapping by the author in the Red Hills area (Corbett, 1975) has been incorporated.

The Henty Fault System

The major NNE-trending fault zone extending from Tullah (where it forms the western margin of the Farrell Slates belt) to The Gooseneck has been referred to as the Henty Fault Zone. Where exposed on the Red Hills track and at the Henty River bridge near Julia Creek it consists of a sub-vertical 20-30 m wide zone of highly schistose rocks including altered basalt, siltstone, mudstone and tuff. The fault splits into two parts south of Julia Creek, with the northern branch (North Henty Fault) following the narrow gorge of the upper part of the Henty River and the southern branch (South Henty Fault) following the main Henty Gorge southwards from

the Newton Creek junction.

The North Henty Fault curves gently into an E-W orientation and stops abruptly in the head of Hall Rivulet. Narrow belts of highly sheared serpentinite and secondary carbonate-talc rock occur on the fault at the White Spur Creek junction, and further to the west a thicker belt of serpentinised pyroxenite, gabbro and basalt follows the fault to its apparent termination at Hall Rivulet. This ultramafic-gabbro belt then follows a perpendicular fault for at least 1.5 km southwards to where outcrop is lost under Pleistocene moraine. This N-S fault is also marked by strong shearing and serpentinisation in the ultramafic-mafic rocks, such that it resembles the North Henty Fault, but no continuation of it could be found in the sedimentary sequence to the north. The probable continuation of the North Henty Fault is represented by a west-trending zone of shearing and carbonate-talc development forming the northern boundary of a large gabbro body west of Hall Rivulet. This fault does not appear on Howards Road to the west, and it seems likely that it is again displaced southwards at the western margin of the gabbro body. The fault's ultimate westerly continuation may be represented by the Little Henty Fault, a major E-W structure in the Zeehan Quadrangle extending from the Zeehan Highway to Trial Harbour.

The South Henty Fault crops out as a zone of intense shearing along the bed of the Henty River to a point 1.5 km NE of the Bradshaws Road - Zeehan Highway junction. Shear planes in the latter area dip east at 72° but elsewhere appear to be subvertical. The probable continuation of the fault is covered by glacial deposits at the highway, but connection with a major lineament extending SW to the East Sister seems likely. A SW-trending fault in the latter area causes a 3 km dextral displacement of the WNW-trending Firewood Siding Fault system (Baillie et al., 1977).

The wedge-like block between the North and South Henty Faults is occupied by a predominantly sedimentary sequence of greywacke and mudstone, but includes a major sequence of andesitic volcanic rocks near Hall Rivulet and another of basaltic to andesitic volcanic rocks near the Zeehan Highway. There is no apparent correlation between this belt of rocks and those to the north and south, nor do the sequences to the north and south correlate with one another. It is possible, therefore, that the three sequences have been juxtaposed by significant movements on the two faults.

Sequence south and east of Henty Fault Zone

BRADSHAW'S ROAD VOLCANO-SEDIMENTARY SEQUENCE

This sequence dips and faces west from the highest point on the old Bradshaws Road, and is easterly facing to the east of this. The oldest rocks, in the core of the anticlinal structure, are mainly siltstone and greywacke with interbedded vitric tuff. Overlying this is a thick, rather monotonous sequence of fine-grained, massive to laminated vitric tuff with relatively minor siltstone, sandstone, and coarser-grained vitric-lithic tuff and quartz-feldspar-phyric crystal-vitric tuff. Greywacke and siltstone become more abundant west of the Zeehan Highway.

Several felsic porphyry bodies intrude the sequence along Bradshaws Road. The westernmost of these are two small bodies of quartz-feldspar (± muscovite) porphyry, followed by a much larger body of brown-weathering feldspar-pyroxene-quartz porphyry which continues southwards to the Howard Plains area. A pink-weathering feldspar porphyry occurs on the highest part of the road and contains large xenoliths of shale and vitric tuff.

The easternmost body is a pale-weathering quartz-feldspar porphyry of tabular form which also crops out in the Langdon River. Another similar porphyry occurs in the Yolande River SE of Basin Lake.

CONTACT WITH CENTRAL VOLCANIC SEQUENCE

The volcano-sedimentary sequence has a conformable and apparently interfingering relationship with the central volcanic sequence except where masked by intrusive andesite bodies. Conformity is evident north of Bradshaws Road and on the track to Leech Hill. In the latter area, typical vitric tuffs are overlain by a feldspar-phyric lava, followed by a siltstone-shale horizon, followed by a fiamme-bearing feldspar-phyric crystal-vitric tuff of ignimbrite type typical of the central sequence. On Leech Hill itself an altered east-facing vitric-lithic tuff, with intercalated shale lenses, is largely surrounded by andesite but resembles the volcano-sedimentary sequence. A separate report on the drilling and alteration at Leech Hill is being prepared.

CENTRAL VOLCANIC SEQUENCE

Descriptions of the central volcanic sequence in the Red Hills area are given in Corbett (1975). A belt of grey feldspar-phyric rocks occurs west of the ridge of pink-weathering lavas at Red Hills, and includes many welded ignimbrites (see analyses Table 1). Good exposures of the sequence in the lower part of Newton Creek show abundant feldspar-phyric crystal-vitric tuffs, some of which appear to be ignimbrites, with intercalated laminated vitric tuff and agglomerate. This sequence grades upstream into andesitic tuffs containing hornblende.

Hornblende andesites dominate the sequence south of Newton Creek to the Langdon River. Tuffs and agglomerates are abundant in Newton Creek, but autobrecciated lavas and massive (intrusive?) hornblende-plagioclase porphyries also occur. Several outcrops of quartz-feldspar (hornblende) porphyry in this area appear to be varieties of the andesitic intrusive rocks.

In the Tyndall Creek - Howards Anomaly area, adjacent to the base of the Tyndall Group, the upper part of the andesite sequence includes bedded, strongly cleaved, purplish andesitic tuff with intercalated shale and minor lenses of jaspery hematite and carbonate. Several east-dipping and facing lenses of shale and tuffaceous sandstone occur along strike from this to the head of the Langdon River, associated with andesitic breccias and tuffs.

Massive andesite dominates the sequence north and south of Leech Hill, and may be largely intrusive. A large intrusive body of hornblende-plagioclase-quartz-phyric andesite intrudes the sequence just south of Leech Hill (see analyses, Table 1).

A sequence of feldspar-phyric pyroclastic rocks, including typical fiamme-bearing ignimbrite, occurs in the upper part of the Yolande River.

TYNDALL GROUP

This east-facing sequence of quartz-feldspar-phyric lava, tuff, agglomerate, volcanoclastic conglomerate and minor shale overlies the central volcanic sequence and is exposed northwards from Tyndall Creek. It is truncated by the Henty Fault Zone. The eastern boundary at The Gooseneck is probably a fault defining the margin of the original depositional basin. Several small upfaulted inliers of the sequence are exposed beneath Owen

Conglomerate NE of Lake Julia. A lower unit consisting predominantly of lavas can be distinguished north of Newton Creek but further south the sequence consists predominantly of pyroclastic rocks with sparse intercalations of lava (commonly showing flow-banding and autobrecciation textures). Some of the massive pyroclastic units contain fiamme and resemble ignimbrite. The sequence north of The Gooseneck includes both lavas and pyroclastic rocks. More detailed descriptions of the sequence are given in Corbett (1975). Two analyses of lavas (Table 1) show a rhyolitic composition.

The relationship to the Owen Conglomerate varies from apparently conformable and gradational at Mount Julia, where a unit of volcanoclastic conglomerate separates the sequences, to erosional and probably unconformable at The Gooseneck.

The base of the Tyndall Group is generally not exposed, but appears to be sub-conformable, although possibly erosional, to the north and south of Newton Creek. Best exposure of the contact area is in a bulldozed costean on the east bank of Tyndall Creek, 620 m south of Newton Creek. Here, highly cleaved purple andesitic tuff and agglomerate with jaspery lenses, of the central volcanic sequence, is overlain by a massive green crystal tuff with feldspar and minor quartz (20 m), followed by shale with possible carbonate (2 m), agglomerate with blocks of quartz-feldspar porphyry (12 m), quartz-phyric lava (10 m), and a thick sequence of typical Tyndall Group tuff and agglomerate. The author has taken the base of the Tyndall Group as the base of the green crystal tuff unit, which appears to mark a significant break in the degree of alteration and schistosity development as well as the incoming of quartz-phyric detritus. However, Komysan (*in* Meares et al., 1982) places the boundary some 50 m further east, at the base of the more massive Tyndall Group tuffs, and includes the lower tuff and shale in the underlying sequence. He correlates the shale-bearing unit with the lower carbonate-hematite-bearing unit of the Tyndall Group as defined by Corbett et al. (1974) in the Comstock Valley near Mount Lyell, and suggests that the Tyndall Group be re-defined to exclude this unit. However, shale and siltstone form the base of the Tyndall Group near the Mt Lyell Company mill (Corbett, 1981), and it is suggested that the boundary remain as defined pending further work (particularly re-examination of drill holes in the Comstock Valley). The matter is of some economic significance, as elevated silver values are associated with the shale-carbonate-hematite unit in both areas (Meares et al., 1982).

Sequence between North and South Henty Faults

The narrow north-eastern part of this wedge consists of a folded sequence of interbedded greywacke, siltstone and mudstone, with rare tuff units, conglomeratic beds and occasional carbonate-rich beds. The only mappable horizon recognised is a N-S trending, west-facing unit of pink-weathering granule-pebble conglomerate and conglomeratic greywacke at Hall Rivulet. Distinctive red to purple mudstone occurs close to the North Henty Fault in the upper Henty River, and in several other localities. Many of the greywackes are volcanic-lithic wackes with felsic and some intermediate-mafic detritus (e.g. detrital hornblende), but some quartz-wackes with quartzite detritus also occur.

A major sequence of andesitic volcanic rocks occurs south of Hall Rivulet, and is well exposed along the drill access track south of the Rivulet and along the Henty River. The sequence dips west for the most part, and faces west in at least one area. The sequence includes hornblende-plagioclase-phyric lava and breccia as well as bedded agglomerate and tuff. Vitric tuff, siltstone and greywacke are interbedded with the andesites, and

dykes of basalt and dolerite intrude the sequence. An analysis of an andesite from the Henty River 500 m south of Hall Rivulet is given in Table 1.

West of the andesite sequence, rocks exposed along the Henty River are mainly siltstone and greywacke with interbedded vitric tuff, passing into a basaltic-andesitic complex near the Zeehan Highway. Fossils of Middle Cambrian age occur in a siltstone sequence east of the basalts (Banks, 1982; Blissett, 1962), and indicate equivalence with the Dundas Group.

The basaltic-andesitic sequence comprises pillow lavas, massive lavas, breccias, agglomerates and tuffs with interbedded siltstone, greywacke and felsic tuff and intrusions of gabbro. The lavas include pyroxene-bearing types (with or without plagioclase phenocrysts) of mainly basaltic composition (Table 1) and plagioclase-phyric types (lacking pyroxene) of andesitic composition (Table 1). Basaltic rocks exposed in small outcrops on several old logging tracks north of the Henty River are mainly of the pyroxene-bearing type. The felsic tuffs associated with this sequence include bedded units and also massive feldspar-phyric vitric-crystal tuff containing fiamme-like pumice clasts and bearing a striking similarity to tuff of the central volcanic sequence. Bedded vitric tuff, crystal tuff, siltstone and greywacke occur to the south of the andesitic-basaltic sequence.

The ultramafic rocks associated with the North Henty Fault in the head of Hall Rivulet appear to be mainly highly altered and serpentinitised pyroxenites associated with later gabbroic intrusive rocks. Analyses of an ultramafic rock and an associated gabbro, as well as the large gabbro body west of the ultramafic belt, and the gabbro from the Zeehan Highway, are given in Table 1.

Sequence north and west of Henty Fault Zone

CENTRAL VOLCANIC SEQUENCE

Howards Road area

The central volcanic sequence as exposed along Howards Road consists predominantly of feldspar-phyric pyroclastic rocks, lavas and intrusive rocks of rhyolitic-dacitic composition. Mafic dykes, ranging from less than one metre to several tens of metres in thickness, occur throughout the sequence but are particularly abundant east of Jones Creek and adjacent to the Henty Fault Zone. The only major sedimentary unit is the Jones Creek shale, a 250 m-thick sequence of interbedded grey shale, tuffaceous siltstone, sandstone, tuff and agglomerate which extends NNW from Howards Road to east of the Hercules mine. The unit dips moderately to steeply west, and several probable west facings have been obtained. Felsic intrusive rocks, some of them notably quartz-phyric, are closely associated with the Jones Creek shale, and complicate the boundary relationships.

Massive to eutaxitically foliated, albite-phyric crystal-vitric tuff, often containing fiamme, is the most abundant rock type west of the Jones Creek shale. Most varieties are greenish-grey in colour, but some show a distinctive splotchy pink and green colouration. The majority appear to be welded ignimbrites. East of the Jones Creek shale, feldspar-phyric lavas and intrusive rocks are about equally as abundant as pyroclastic rocks. Bedded tuff and agglomerate, dipping steeply east, occurs in three areas on the Red Hills track, and may represent a single horizon, possibly correlating with the Jones Creek shale. Analyses of some lavas and

ignimbrites from Howards Road are given in Table 1, and show rhyolite to rhyodacite compositions.

Mafic dykes within the sequence are generally somewhat chloritised and altered, with epidote as a common alteration phase. The dykes range from fine-grained aphyric types to coarsely feldspar-phyric and doleritic types. Phenocrystic and groundmass pyroxene is present in some varieties. A distinctive pale grey, coarse-grained gabbroic variety forms an elongate dyke east of the Jones Creek shale, and consists of intergrown pyroxene and altered feldspar with skeletal opaque minerals and abundant zoisite. Some analyses of the dykes are given in Table 1.

Hercules area

A more complex stratigraphy is evident in the Hercules mine - Mount Read area (fig. 2). The Jones Creek shale unit appears to be narrowing northwards, and only one siltstone horizon is evident within it. An agglomerate unit at the western margin contains clasts of shale, quartz-feldspar porphyry and "quartz-eye" porphyry similar to adjacent intrusive bodies containing quartz-eyes. A small pod of such agglomerate occurs at the western margin of an intrusive (and partly extrusive?) mass of porphyry NE of Mount Hamilton, suggesting there may originally have been a connection with an east-dipping quartz-phyric tuff horizon to the NW. This latter unit extends along strike from the hangingwall position of the major shale lens at the Hercules mine, suggesting that the Hercules shale and Jones Creek shale are equivalent units on opposite flanks of a syncline. However, further work is needed to clarify this relationship.

A complex series of felsic porphyry bodies, many with quartz as well as feldspar phenocrysts in a richly-spherulitic groundmass, occurs on either side of the Jones Creek shale. Most of these appear to be intrusive bodies with sharply cross-cutting boundaries in some cases, but some show auto-breccia and flow-banded textures typical of lavas and may be partly extrusive. Similar porphyries, with small quartz phenocrysts, occur near the old Jupiter mine and on the Mount Read road east of Williamsford. A flow-banded variety in the South Hercules area shows froth-like textures in thin section, and resembles the highly vesicular rhyolite lavas associated with some extrusive dome complexes in the Taupo Volcanic Zone, New Zealand.

The east-dipping east-facing Hercules shale, of interbedded siltstone, sandstone and tuff is terminated abruptly at its northern end by a fault which upthrows footwall schists. A fine-grained quartz-phyric vitric-crystal tuff unit occurs at the top of the shale near Mount Hamilton. Along strike to the north from the latter unit is a prominent lens, about 25 m thick, of bedded, coarse-grained, quartz-phyric agglomerate and tuff comprising at least two graded mass-flow units. Similar quartz-phyric agglomerate and tuff, containing ripped up shale clasts, occurs south of the main shale lens towards South Hercules, within the hangingwall sequence, and a small lens of similar material truncates the Hercules shale at its southern end on White Spur. A thick ignimbrite unit of coarse-grained feldspar-phyric crystal-vitric tuff, with abundant large fiamme, overlies the Hercules shale on Mount Hamilton. Overlying this is a unit of bedded feldspar-phyric crystal-vitric tuff, also east-dipping, followed by vitric tuff, felsic intrusive, and fiamme-bearing feldspar-phyric ignimbrite abutting the Jones Creek shale. The axial area of the syncline, if it exists, is occupied by the intrusive rock.

Underlying the Hercules shale north of Baker Creek is a bedded, fine-grained vitric tuff, locally altered and mineralised, and which is underlain

by, or grades into, a variable "host-rock" unit of schistose tuff, quartz-sericite schist and carbonate lenses showing nodular and oolitic textures, containing the lens-like, structurally modified sulphide orebodies. Augen-textured quartz schists occur in the lower part of this unit, and grade into a thick sequence of altered, schistose footwall tuffs, showing remnant fiamme textures, exposed down the steep slopes north and south of the Haulage. The belt of schistose rocks continues northwards to the Jupiter mine area, although alteration is less pronounced north of the Ring River. The eastern margin of the schist belt is gradational over a few metres or tens of metres with massive, welded, feldspar-phyric fiamme-bearing ignimbrite along the Hercules access road. Three small east-dipping lenses of bedded sulphide (mainly pyrite) and shale, 80-150 mm thick, occur within the schist zone on the lower part of this road at CP7632568020.

South of Baker Creek, the exposed footwall sequence consists largely of bedded vitric tuff and vitric-crystal tuff showing patchy alteration and mineralisation. Bedding shows a broad gentle anticlinal structure, with NNW trend, and a syncline near the main West Hercules adit. The footwall sequence is truncated by the basal contact of the volcano-sedimentary sequence to the west, which transgresses the Hercules shale position at White Spur, and various hangingwall units further south.

CONTACT BETWEEN CENTRAL VOLCANIC SEQUENCE AND HOWARDS ROAD VOLCANO-SEDIMENTARY SEQUENCE

This contact can be traced with some accuracy from near Hercules to south of Howards Road, and is exposed at several localities. Best exposure is in a shallow costean near the foot of the Mount Read track [CP77156212] where the contact dips west at about 40° and shows a basal breccia overlying massive, homogeneous feldspar-phyric tuff. A Department of Mines drill hole (report pending) intersected this contact at a depth of 55 m some 150 m west of the costean, indicating a shallowing of the westerly dip to about 10°. A small "window" of the underlying massive tuff, surrounded by moraine, is exposed at the surface on the access road some 500 m west of the costean, suggesting considerable variations in the relief of the contact surface.

The contact is apparently steeply-dipping and fairly linear south of Howards Road, although concealed beneath glacial cover. A lens of quartz-feldspar-phyric lava occurs at the contact on Howards Road. An exposure of the contact on the Mount Read track at CP77246305 shows shallowly west-dipping bedded lithic-crystal tuff overlying and butting against massive feldspar-phyric tuff. The contact swings NW around the head of a large valley beyond this, past a small outlier of the younger, bedded quartz-phyric tuff exposed beside the track.

The contact is again exposed on a drill access track on a narrow spur at CP761639. The contact undulates at the nose of an anticlinal fold, and is overlain to the south by breccia and to the north by quartz-rich tuffaceous sandstone, both dipping shallowly west.

On White Spur, the Moores Pimple track exposes a thin west-facing unit of siltstone and sandstone near the base, underlain by several metres of quartz-phyric tuff resting on schistose tuff of the central volcanic sequence. Sharp contacts between basal quartz-rich tuff and underlying feldspar-phyric volcanic rocks are also apparent 200 m north and south of this track.

Near Williamsford, the contact is exposed beside the Haulage and on

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a power-line track 150 m further north. The basal unit in this area is an agglomerate containing clasts of quartz porphyry and other lithologies, and overlies strongly schistose footwall volcanic rocks.

The irregular nature of the contact, the presence of large projections and embayments, and the occurrence of different basal units in different areas, indicates an erosion surface with considerable relief which has been progressively buried by the younger sequence. Some degree of structural discordance is indicated by transgression of the contact across the Hercules shale position at White Spur. Later folding of the sequence appears to have been controlled to some extent by irregularities in the surface. The marked contrast between the massive subaerial-type feldspar-phyric ignimbritic rocks of the central volcanic sequence and the clearly submarine bedded quartz-phyric sequence above suggests a significant change in volcanism accompanied by considerable subsidence.

HOWARDS ROAD VOLCANO-SEDIMENTARY SEQUENCE

This sequence, between the central volcanic sequence to the east and the conglomerate-quartzwacke sequence at Tom Creek to the west, may be subdivided into a lower tuff-rich formation and an upper greywacke-siltstone formation. The boundary between the two, although gradational, is taken as the top of the major tuff unit on Howards Road at CP76255825.

Lower tuff-rich formation (suggested formal name: "White Spur Formation")

This unit is of the order of one kilometre thick, and contains two major tuff-agglomerate units (each one composite and including lenses and beds of siltstone and greywacke) separated by a greywacke-siltstone unit. A lower siltstone unit is present at Howards Road, together with a basal quartz-feldspar-phyric lava, but these units apparently wedge out northwards. The middle greywacke unit is poorly represented on White Spur, where the sequence is dominated by tuffs, but this may be partly an artefact of the folding. The sequence north of White Spur, in Conliffe and Baker Creeks, is again rich in sediments.

The basal lava unit on Howards Road is a dense pink flow-banded rock containing abundant plagioclase phenocrysts, less abundant embayed quartz phenocrysts, and scattered pseudomorphs of chlorite, epidote and opaques after a ferromagnesian mineral, in a finely crystalline felsic groundmass. An analysis (Table 1) shows a rhyodacite composition.

The lower tuff-agglomerate unit rests directly on the central volcanic sequence north of gridline 5362000 mN. It comprises a basal breccia-tuff unit followed by a thin siltstone-vitric ash unit and an upper composite unit of tuff and agglomerate with lenses of siltstone. The basal breccia-tuff unit, where drilled by the Department of Mines, is about 60 m thick, and shows distinct overall grading, as do many of the tuff units in the sequence. Irregular rafts of shale and laminated tuff, up to five metres long, occur in the lower coarse breccia, together with smaller clasts of quartz-feldspar porphyry, feldspar porphyry, fine-grained felsic volcanic rocks, schistose and altered volcanic rocks, pumice, hematite and sulphide minerals. The sulphide minerals include at least one boulder (400 mm across) of massive pyrite, as well as many smaller clasts of pyrite and rare small clasts of galena. The breccia grades up through lithic-vitric-crystal tuff (feldspar-quartz-phyric) to faintly laminated fine-grained vitric tuff. The unit is clearly a single large submarine mass-flow deposit which has eroded sedimentary material from the seafloor as well as volcanic material and mineralised rocks. The sulphur isotope values for the pyrite boulder ($\delta S_{34} = 3.3$, G.R. Green, pers. comm.) do not

support an origin from the Hercules deposit, although the size of the boulder suggests a relatively nearby source.

The overlying vitric ash-siltstone unit contains beautifully preserved fine-scale lamination and load structures in places, and is erosionally overlain by another mass-flow breccia-tuff unit containing clasts of siltstone. This unit grades up into typical quartz-feldspar-phyric crystal-lithic-vitric tuff.

The greywacke-siltstone member in the middle part of the sequence consists of lithic-wacke turbidites interbedded with grey to black siltstone and shale. Pyrite is abundant on bedding planes and joints of some of the finer-grained units. Detrital grains include various felsic volcanic rocks, mudstone, carbonate, volcanic quartz, feldspar and chlorite, and indicate derivation predominantly from a felsic volcanic terrain.

The upper tuff member is folded about two fold axes, and forms a prominent ridge north of Howards Road. The tuff member has a coarse basal breccia and an erosional contact on the underlying greywacke sequence. The upper part is a crystal-vitric tuff containing abundant feldspar grains, less abundant embayed quartz grains, and recrystallised pumice clasts in a felsic matrix. The abundance of pumice clasts suggests the mass-flow may have been triggered by an explosive eruption.

Upper greywacke-siltstone formation

This sequence of interbedded greywacke, siltstone, mudstone and minor tuff crops out almost continuously along Howards Road, the only major gap being the moraine-covered area due south of Mount Dundas. Bedding is mainly steep westerly to slightly overturned, with uniform westerly facings. Folding of the sequence on N-S axes becomes prominent to the east and north-east of Mount Dundas, but the general westerly facing is preserved.

The sequence typically consists of greywacke-rich units, 50-200 m thick, alternating with siltstone-rich units of similar thickness. The uppermost 100 m or so is mainly siltstone in the Farrell Rivulet. Tuff is most abundant in the basal part, and includes quartz-feldspar-phyric crystal tuff, crystal-lithic tuff, crystal-vitric tuff, and lithic units rich in shale clasts and having a mud-rich matrix. Nearly all units appear to be of submarine mass-flow origin. Coarse-grained to conglomerate volcanic-lithic-wacke occurs at the base of the sequence and in several units near the top of the sequence. Derivation of the greywackes appears to have been dominantly from felsic volcanic rocks.

Only the lower part of the sequence appears to be represented in the Moores Pimple - Baker Creek area, where the unit is faulted against the "Rosebery Group" to the west. A unit of white-weathering quartzwacke and grey siltstone occurs near the base of the sequence on the Moores Pimple track. The quartzwacke beds are commonly graded, and contain abundant volcanic quartz and less common Precambrian-derived quartz.

The only fossils so far recovered from the Howards Road sequence are a number of small inarticulate brachiopods from a siltstone on Howards Road at CP74155690, these being similar to acrotretids and of Cambrian age (J.B. Jago, pers. comm.), and some brachiopod fragments reported by Blisset (1962) from the old Howards tram south of the road.

DUNDAS GROUP CORRELATES

Lower siliciclastic sequence, Tom Creek area

The basal conglomerate of this sequence is of the order of 100 m thick, and is mainly a white-weathering pebble-cobble conglomerate with interbedded quartzwacke. Rare clasts to boulder size (maximum 450 mm) occur on the ridge north of Farrell Rivulet. Clasts are rounded and consist predominantly of quartzite, quartz-schist and vein quartz, but include felsic volcanic clasts on some horizons. Fresh drill core shows a variegated red and green colouration. The basal contact of the conglomerate on the underlying siltstone is sharp and locally erosional, possibly to a depth of several metres, but appears to be generally conformable.

Overlying the conglomerate is a unit of thin-bedded, grey to black siltstone and slaty mudstone, about 100 m thick, followed by a second granule to cobble-grade conglomerate unit about 50 m thick. Above this is a quartzwacke-siltstone sequence of the order of 750 m thick, consisting of thin to medium-bedded, white-weathering sandstone beds and grey to black siltstone and mudstone. Some of the sandstone beds show typical turbidite features (grading, sole marks, Bouma sequences, etc.), but many are not obviously graded and show planar or cross-lamination only. The siltstones are generally mica-rich, and fine white mica is evident on bedding planes in many of the sandstones. A dominantly Precambrian source is indicated.

The sequence shows clear similarities with the extensive quartzwacke-siltstone sequence between the Professor Range and Zeehan Highway, and with the quartzwacke-mudstone units and conglomerates in the "Rosebery Group" north of Moores Pimple. The presence of early Late Cambrian fossils at the top of the sequence in Tom Creek (Blissett, 1962; Banks, 1982) indicates correlation (in descending order) with the lower Brewery Junction formation, Razorback Conglomerate, Hodge Slate, and Red Lead Conglomerate of the Dundas Group type section at Dundas (Blissett, 1962; Jago, 1979). Equivalents of the poorly defined "Judith Formation", from which middle Middle Cambrian fossils were recovered (Jago, 1979), probably occur in the upper part of the underlying Howards Road sequence.

Upper Dundas Group sequence and Cambrian-Ordovician relationships

Conformably overlying the quartzwacke sequence in the lower part of Tom Creek is a mixed sequence of calcareous sandstone and siltstone, micaceous siltstone and tuffaceous greywacke. Fossils occur in this sequence as mentioned above. An undifferentiated sequence of mudstone, siltstone, greywacke and conglomerate occurs along the Zeehan Highway north and south of Mariposa Creek, but apparently does not include equivalents of the lower siliciclastic sequence.

The uppermost unit of the Dundas Group in this area is the Misery Conglomerate, which forms the crest of Misery Hill. It is sharply overlain by a sequence of white-weathering sandstone and conglomerate, and green to grey siltstone, correlated with the Owen Conglomerate. Trace fossils are abundant in the white sandstone, the sandstone showing cross-bedding in places and appearing to be of shallow-water origin, in contrast to the graded-bedded, flysch-like facies of the Misery Conglomerate. Fossils discovered by the author in the sandstone-siltstone sequence indicate a latest Late Cambrian age (J.B. Jago, pers. comm.). The contact with the Misery Conglomerate appears to be slightly discordant on the north-west flanks of the hill and markedly discordant at the southern end of the hill, although faulting could affect the contact in the latter area.

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Marked angular discordance between Cambrian beds and the overlying sandstone-Gordon Limestone succession can be seen east of Professor Range [CP67755030], where a north-trending, steeply west-dipping quartzwacke sequence is abruptly overlain by north-dipping sandstone, and also near the Henty River bridge on the Zeehan Highway [CP73154910], where Cambrian beds dipping steeply south-east are erosionally overlain by Owen Conglomerate correlate dipping north-east. A spectacular angular discordance is apparent at Farrell Rivulet between the lower siliciclastic Dundas Group sequence, which is tightly folded on NNE-trending axes and shows overturning from the east, and the adjacent Gordon Limestone-Eldon Group sequence, which trends north-westerly and shows moderate westerly dips. Although the contact in this area is probably faulted, as indicated by Department of Mines drilling, the contrast in trends and intensity of deformation indicates at least two phases of folding, and suggests, along with the discordances noted, that the Cambrian sequences were folded prior to deposition of the Ordovician limestone.

"ROSEBERY GROUP" DISRUPTED SEQUENCE, MOORES PIMPLE - RING RIVER AREA

The western contact of the Howards Road volcano-sedimentary sequence at Moores Pimple and in the creek to the south is marked by a 10 m wide zone of multiply-veined chert-like silica. In the head of Bather Creek, the contact is marked by intense shearing of the greywacke sequence associated with secondary silicification and dolomitisation, and by the occurrence of narrow slivers of contorted quartzwacke-quartzite. These features, together with the apparent lithological and structural discordances across the contact, are interpreted to indicate a major fault zone. The continuation to the north may be represented by a fault zone several metres wide in the Ring River between a dolomitic sequence to the west and a quartzwacke sequence to the east. However, this latter fault lies within the "Rosebery Group", and the contact with the Howards Road sequence lies further east in a confused zone around Baker Creek. North of Williamsford, the "Rosebery Group" appears to directly abut the central volcanic belt along a faulted contact.

Conglomerate in Moores Pimple area

A thick sequence of pebble-cobble conglomerate with interbedded sandstone and minor siltstone and tuff occurs on Moores Pimple and on the ridge to the north. Bedding dips steeply north-east to vertical, and faces east, on the western flanks of the Pimple. Clasts are mostly rounded, and clast types include quartzite (abundant), dolomite, chert, sandstone, mudstone, felsic volcanic rocks, mafic volcanic rocks, gabbro and fuchsite. The matrix material is partly volcanoclastic, and includes shards in some examples. The fuchsite occurs as wispy irregular clasts and also, on the western flank, as stringers similar to those in an adjacent altered, silicified dyke-like body. Analyses of the clastic fuchsite (Green, 1984) show a chromian muscovite composition with about 1% Cr₂O₃. The associated sandstones vary from lithic-wacke to quartzwacke, and contain both volcanogenic and Precambrian-derived detritus. Several beds of pale grey vitric tuff, rich in glass shards and with scattered quartz and feldspar crystals, occur on the upper western flank of Moores Pimple adjacent to the quartz porphyry body.

Several smaller conglomerate units occur interbedded with sandstone and siltstone in the vicinity of Bonnie Point on the North East Dundas Tram. A fuchsite-like clast was noted in one of these.

Quartz-feldspar porphyry

A large body of grey quartz-feldspar porphyry occurs within the conglomerate sequence on the highest part of Moores Pimple, and probably connects with a similar porphyry in the creek to the south. The porphyry consists of small embayed quartz phenocrysts, commonly with reaction rims, and sericitised feldspar remnants, in a variable groundmass showing snowflake or spherulitic texture in some cases. Autobreccia texture is well developed in the porphyry near its western margin on Moores Pimple, and the presence of several flow-like units within the sedimentary sequence here suggests a partially extrusive origin. However, the bulk of the porphyries, including those on the east flank of the ridge north-east of Moores Pimple, appear to be intrusive.

An unusual altered "quartz-eye" rock, of uncertain origin, occurs around the southern end of the gabbro body north-east of Moores Pimple.

The localisation of the porphyry intrusive rocks along the major faulted contact suggests that the fault is at least partially a Cambrian structure.

Dolomitic sandstone-siltstone sequences

A sequence of reddish-weathering sandstone and siltstone occurs west of Moores Pimple. The sequence dips and faces east for the most part, and appears to have a faulted relationship with the conglomerate sequence. Many of the sandstones are of greywacke type, with turbidite features, and thin sections show abundant carbonate grains and less common volcanic quartz, quartzite, siltstone and feldspar grains in a dolomitic-hematitic matrix. Similar rocks, together with some massive dolomite (secondary?) were noted in the head of Avon Creek. Dolomitic siltstone also occurs on the lower northern slopes of Moores Pimple, and a dolomitic greywacke-siltstone sequence abuts the western margin of the conglomerate in the head of Svengali Creek.

A large belt of mainly dolomitic rocks, with some interbedded grey micaceous siltstone and tuffaceous greywacke, occurs along the Ring River downstream of Baker Creek, and along Bather and Svengali Creeks. Dips are somewhat variable, but the bulk of the sequence dips and faces east. A small lens of quartzwacke-quartzite, apparently fault-bounded, occurs within the sequence near the mouth of Bather Creek. Many of the fresher rocks show a distinctive fawn or orange-yellow colour. Some sandstone beds show typical turbidite features (grading, sole marks, Bouma sequences, etc.), but other types, including units with abundant cross-lamination, also occur. The grain component is dominantly carbonate, but also includes volcanic quartz and feldspar, felsic volcanic clasts, pumice and shards. Much secondary dolomitisation is evident in the matrix, and carbonate veining is ubiquitous.

Similar dolomitic rocks occur immediately west of the Fahl-Rich P.A. fault line in the Ring River, and in track exposures south of this.

Quartzwacke-quartzite-mudstone sequences

This distinctive lithology consists of white-weathering quartzwacke sandstone (grading to quartzite) interbedded at various scales with grey to black siltstone and mudstone, the latter commonly resembling phyllite. The rocks are typically tightly folded and contorted, and may be cut by numerous shears and fault zones. Bedding thickness in the sandstone varies from a few millimetres to one metre or more, and variations from

sandstone-rich to siltstone-dominated sequences occur.

The units as mapped appear to be of two main types: (i) lenses more or less surrounded by other lithologies and bounded by faults or discordances (e.g. Williamsford, Svengali Creek, mouth of Bather Creek, Ring River 500 m downstream of Bather Creek, south of Rich P.A. prospect), and (ii) narrow belts which appear to be normally interbedded with adjacent rocks (e.g. near Bonnie Point, Colebrook Ridge). The type (i) units appear to be either tectonic "fish" or large gravity slide deposits, or possibly a combination of both.

The sandstone beds only rarely show internal structures, but plane lamination and cross-lamination are occasionally seen, as are sole marks and grading. Thin sections show a preponderance of quartz grains, mostly of metamorphic (Precambrian) origin but including embayed volcanic grains in a few cases, with detrital mica as a common constituent and tourmaline and zircon as common accessories. Overgrowths on quartz grains, and sutured grain boundaries, are common. Small nodules and lenses of pyrite occur in some siltstone layers in the major unit at Williamsford. This unit also contains a narrow intercalation of felsic tuff and another of shale and siltstone.

Undifferentiated greywacke-siltstone sequences

A fairly distinctive sequence of interbedded siltstone, greywacke and crystal tuff occurs in the central part of the area between the Fahl-Rich P.A. line and the quartzwacke lens to the east. The sequence shows undulating subhorizontal bedding at the Ring River, but irregular steep bedding elsewhere. The tuff units appear to be graded from coarse crystal-lithic tuff in the lower part to laminated vitric-crystal tuff at the top. They are typically rich in feldspar, with only minor quartz grains, and have a chloritic, carbonate-rich matrix. Abundant large opaque grains occur in some samples. A greywacke from the sequence contains both volcanic and metamorphic detritus. An Electrolytic Zinc Company drill hole through this unit showed a thick section of disrupted siltstone, greywacke and slump-type breccias towards the western margin.

A complex sequence of greywacke, siltstone, mudstone, tuff, conglomerate, quartzwacke and carbonate occurs between the Rich P.A. area and Bonnie Point. The sequence is complexly folded and disrupted, such that individual units can seldom be traced far along strike. A distinctive unit of trough cross-bedded tuffaceous sandstone occurs in the Ring River in the central part of the sequence, and appears to be overlain to the east and south by a lithic-quartzwacke sequence with some associated pebble conglomerate. The latter appears to pass along strike southwards into a quartzwacke-black mudstone unit. A thin east-facing conglomerate unit is interbedded with greywacke and pink siltstone at Bonnie Point, the latter containing fossils at one locality.

A more mafic sequence of red-weathering, poorly-bedded greywacke and mudstone is exposed along the Colebrook Ridge track northwards from the highest part of the ridge [CP746688], to the junction with the access road from the east. The fresh greywacke is dark greenish-grey and chloritic. Thin sections show abundant chlorite grains, as well as grains of basaltic rock, felsic volcanic rocks, shale, quartz and feldspar in a dusty chloritic matrix. The greywackes are of mixed mafic-felsic provenance, and may have affinities with the Crimson Creek formation. A unit of altered, fine-grained feldspar-phyric basalt occurs within this sequence, close to an altered gabbro dyke, and a major ultramafic-serpentinite dyke lies some 600 m west of the road.

Curtin Davis basalt

Basalts occurring at Montezuma Falls have been referred to as Curtin Davis basalts (Elliston, 1954), and were sampled for comparison with basalts on a ridge east of Severn Creek in the mapped area. The ridge basalt occurs within siltstone and greywacke, and is a highly vesicular, greenish, chloritised lava with remnant porphyritic texture replaced by secondary minerals. Vesicles are mainly filled with quartz or carbonate. Samples from Montezuma Falls, where the basalt is associated with polymict conglomerate, also have abundant carbonate/quartz-filled vesicles and remnant feldspar(?) phenocrysts altered to carbonate and felsic material. The groundmass shows remnant pilotaxitic texture in the abundant alteration minerals.

An unusual mafic-intermediate rock somewhat similar to the Curtin Davis lavas occurs within the conglomerate sequence 1.2 km north-east of Moores Pimple. The rock is highly altered, and shows a variable vesicular-porphyritic texture in secondary minerals (mainly carbonate and chlorite) and a groundmass dominated by sheaf-like laths of chlorite(?).

Gabbroic dykes

Small dykes of altered coarse-grained gabbro occur on Colebrook Ridge (intergrown feldspar and chloritised orthopyroxene), in the Ring River dolomite sequence (2 m thick, of altered feldspar intergrown with pyroxene pseudomorphed by carbonate), 400 m south-west of the mouth of Bather Creek (intergrown texture replaced by chlorite), and at Svengali Creek falls (2 m thick, intergrown feldspar and carbonate-chlorite pseudomorphs after pyroxene).

A much larger gabbro body occupies the crest of the ridge north-east of Moores Pimple. It is also highly altered, and is bordered by a zone rich in secondary carbonate and quartz (with relict igneous textures in patches) up to 100 m wide. Fresh kernels of rock from near the junction of the old walking track and the recent track show an interlocking texture of plagioclase and amphibole, the crystals having a slight preferred orientation. The amphibole is pale brown to green in colour, with very faint pleochroism. A chemical analysis is given in Table 1.

Ultramafic(?) dyke

A dyke-like mass of secondary carbonate and silica, with abundant stringers of fuchsite, relict opaque minerals (mainly chromite?), and patchy mineralisation (mainly pyrite, minor galena, sphalerite, chalcopyrite) occurs on the west flank of Moores Pimple and probably represents a highly altered ultramafic body. Reid (1925) reports serpentine in an old adit driven into the dyke from below the track. The body lies partly along the contact between the conglomerate and a dolomitic sequence to the west, and is capped with ferruginous gossanous material in places.

Age, correlation and origin of the "Rosebery Group"

The fossil locality east of Bonnie Point contains trilobites of latest Middle Cambrian age (Banks, 1982; Jago, 1979). This part of the sequence contains most of the typical lithologies of the "Rosebery Group", but is clearly equivalent to the Dundas Group. Elliston (1954, p. 169) also records trilobite fragments from the east side of the ridge north of the Moores Pimple "serpentine" (now known to be gabbro), i.e. within the dolomitic sequence between Svengali and Bather Creeks. Although not

identified, the presence of trilobites strongly suggests correlation with the Dundas Group.

Most of the lithologies of the "Rosebery Group" can be related to units in the Dundas Group and correlates. The conglomerates at Moores Fimple are referable to the Razorback and/or Red Lead Conglomerates, and were mapped as Razorback Formation by Elliston (1954). They appear to continue south-westwards towards Mount Dundas. There is also good correlation with the conglomerates overlying the Howards Road sequence at Farrell Rivulet. The quartzwacke-mudstone sequences are very similar to the quartzwacke sequence at Tom Creek, and are possibly equivalent to the lower Brewery Junction Formation of the type area. The dolomitic sandstone-siltstone sequences are not as easily referable to the Dundas Group type section, but contain trilobite fragments at one locality and are possibly equivalents of the upper Brewery Junction Formation.

The irregular juxtaposition of lithologies, the abundance of disrupted zones, shears and faults, the discordant contacts of many of the lenses, the presence of "broken formation" (brecciated sandstone beds in matrix of schistose mudstone) in some of the quartzwacke units, the complex folding (including isoclinal and rootless folds) in some areas, and the evidence for large-scale slump-type deformation, all suggest considerable disturbance by a combination of tectonic and gravity processes to produce a virtual *mélange* which is the "Rosebery Group". Devonian folding and cleavage development appear to have been superimposed on this *mélange*, together with faulting (or reactivation of faults) and associated introduction of carbonate and hydrothermal mineralisation. Further studies are required to determine the nature and timing of the processes involved in the production of the *mélange*. K-Ar dates on slate from the "Rosebery Group" at Rosebery give concordant Ordovician ages around 480 Ma (Adams et al., 1984), indicating that at least some of the deformation and cleavage formation is of Late Cambrian-Early Ordovician age.

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[7 December 1984]

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Table 1. CHEMICAL ANALYSES OF ROCKS FROM THE HENTY - WILLIAMSFORD AREA

	1	2	3	4	5	6	7	8	9
	(%)								
SiO ₂	72.5	77.7	59.5	55.3	60.86	75.4	75.2	55.3	56.43
TiO ₂	0.23	0.20	0.51	0.54	0.33	0.19	0.17	0.99	1.54
Al ₂ O ₃	11.4	10.9	13.0	16.0	14.30	11.3	13.0	18.5	17.39
Fe ₂ O ₃	1.6	1.0	2.2	3.1	2.14	0.48	0.58	2.2	2.90
FeO	3.4	1.2	5.1	5.4	3.81	1.4	1.0	5.3	7.97
MnO	0.07	0.04	0.11	0.14	0.11	0.08	0.02	0.18	0.14
MgO	0.74	0.12	5.5	4.2	3.32	0.31	0.30	4.7	3.89
CaO	0.05	0.12	6.3	3.6	5.55	1.2	0.19	0.87	1.17
Na ₂ O	0.15	2.3	3.4	5.0	2.32	3.6	3.6	5.2	4.00
K ₂ O	7.5	5.4	0.94	2.4	2.97	3.7	5.7	1.3	0.36
P ₂ O ₅	0.05	0.04	0.35	0.19	0.19	0.03	0.02	0.17	0.17
SO ₃	0.01	0.07	0.02	0.11	0.39	0.02	0.02		
CO ₂	0.22	0.37	0.01	0.12	1.44	1.2	0.18	<0.02	0.08
H ₂ O ⁺			2.8	2.6	2.19			4.3	4.09
H ₂ O ⁻			0.20	0.21	0.09			0.73	0.32
L.O.I.	1.4	0.61				1.5	0.54		
	ppm								
As					11				
Ba	5300	2540	828	1670	1050	1750	1750	371	185
Co	12	<6	19	22	17	<6	<6	16	22
Cr	46	56	174	36	51	50	18	41	<5
Cu	8	<5	65	7	27	<5	<5	33	
Nb			9	6	3			4	<3
Ni	<4	7	38	19	22	9	28	33	<3
Pb	12	<6	<6	8	6	7	<6	12	
Rb	163	131	32	50	84	83	128	57	17
Sc			17	13	18			16	28
Sr	101	84	496	519	460	100	109	89	220
V	<13	<13	165	150	130	<13	<13	217	200
Y	27	42	21	20	16	41	54	38	48
Zn	71	30	52	93	48	120	37	354	
Zr	246	63	214	181	115	186	189	179	89

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Table 1. (continued)

	10	11	12	13	14	15	16	17	18
SiO ₂	60.34	50.79	47.72	51.09	43.14	38.32	68.6	72.2	72.8
TiO ₂	0.70	1.53	0.42	0.16	0.40	0.09	0.38	0.31	0.33
Al ₂ O ₃	15.13	14.24	18.80	14.55	17.89	3.67	16.1	13.7	13.1
Fe ₂ O ₃	2.27	5.24	2.07	0.98	0.54	4.77	1.2	1.3	0.40
FeO	4.45	8.65	4.53	5.41	4.03	2.83	3.1	1.5	1.5
MnO	0.14	0.25	0.10	0.11	0.11	0.12	0.07	0.06	0.03
MgO	3.66	4.85	6.42	12.78	6.62	36.94	1.2	0.65	0.46
CaO	4.11	5.76	11.01	9.46	22.12	0.05	0.41	1.5	1.2
Na ₂ O	3.09	3.39	2.20	0.70	0.07	0.02	6.9	3.4	4.0
K ₂ O	2.44	1.25	2.02	0.23	<0.01	<0.01	0.62	4.2	4.3
P ₂ O ₅	0.21	0.20	0.07	0.06	0.11	0.02	0.07	0.06	0.08
SO ₃	0.24			<0.05	<0.05	0.06	0.01	0.02	
CO ₂	0.10	0.13	0.06	0.12	0.10	0.12	0.04	0.05	<0.02
H ₂ O ⁺	3.00	2.75	3.72	4.50	5.02	12.80			0.65
H ₂ O ⁻	0.15	0.16	0.08	0.17	0.13	0.33			0.13
L.O.I.							1.6	1.2	
				<i>ppm</i>					
As	<10			<10	<10	<10			
Ba	770	590	560	59	<11	11	140	1270	1320
Co	16	33	31	39	22	85	6	<6	<9
Cr	20	<5	145	580	63	1600	22	53	29
Cu	31			13	12	14	<5	<5	275
Nb	6	<3	<3	<3	3	<3			15
Ni	8	11	71	280	82	1800	10	7	27
Pb	100			4	4	8	8	19	123
Rb	79	34	64	11	6	4	28	105	115
Sc	17	29	27	30	33	11			<2
Sr	390	290	320	96	15	<2	74	174	121
V	165	380	145	80	105	39	<13	25	<5
Y	30	35	13	7	14	3	30	44	33
Zn	230			56	44	57	97	63	24
Zr	175	105	30	18	59	14	258	228	252

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Table 1. (continued)

	19	20	21	22	23	24	25	26	27
SiO ₂	70.3	69.8	74.7	76.3	48.6	53.2	48.7	53.2	47.7
TiO ₂	0.47	0.47	0.34	0.30	1.0	1.6	0.84	0.63	0.83
Al ₂ O ₃	13.3	13.4	12.9	12.1	16.0	15.4	16.9	14.7	21.0
Fe ₂ O ₃	1.0	1.6	0.73	0.77	2.7	3.9	3.2	1.5	3.1
FeO	2.2	1.7	1.6	1.0	6.0	7.9	6.3	7.7	3.7
MnO	0.06	0.05	0.04	0.03	0.16	0.32	0.16	0.18	0.18
MgO	1.3	1.2	0.79	0.85	7.1	4.1	7.0	7.1	5.0
CaO	1.5	1.5	1.2	0.47	11.0	5.2	7.4	9.9	9.5
Na ₂ O	2.9	3.1	3.8	3.7	3.4	4.8	4.2	2.3	3.5
K ₂ O	4.1	4.0	1.9	1.9	0.16	0.74	0.29	0.87	1.1
P ₂ O ₅	0.10	0.12	0.03	0.03	0.08	0.19	0.11	0.08	0.08
SO ₃						0.01		0.07	
CO ₂	<0.02	<0.02	<0.02	<0.02	0.06	0.08	0.07	0.25	<0.02
H ₂ O ⁺	1.8	1.6	1.4	1.7	3.0		3.6		3.6
H ₂ O ⁻	0.58	0.58	0.29	0.48	0.41		0.44		0.36
L.O.I.						2.2		1.6	
						<i>ppm</i>			
As									
Ba	1160	1100	790	727	135	150	147	260	711
Co	<9	<9	<9	<9	34	32	38	44	17
Cr	<13	<13	<13	<13	140	84	50	140	61
Cu	36	<4	<4	<4	63	<5	<4	78	69
Nb	10	13	13	10	<4		<4		<4
Ni	31	22	12	20	51	12	43	83	38
Pb	154	132	13	11	41	123	23	<6	107
Rb	119	139	82	118	3	40	<3	20	33
Sc	8	8	2	<2	29		19		17
Sr	233	216	619	273	256	224	264	152	393
V	22	20	9	<5	240	165	228	227	155
Y	43	36	29	22	25	46	26	24	22
Zn	253	134	38	19	113	306	128	87	133
Zr	254	258	240	221	99	152	59	103	66

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Table 1. (continued)

	28	29	30	31	32	33	34
SiO ₂	71.6	73.1	78.1	76.7	72.8	53.65	50.77
TiO ₂	0.43	0.33	0.24	0.31	0.40	0.52	0.19
Al ₂ O ₃	13.4	13.9	11.4	12.1	13.8	14.21	14.05
Fe ₂ O ₃	0.83	0.51	0.37	0.46	0.90	1.56	1.82
FeO	2.2	2.0	1.6	1.5	1.8	7.61	6.04
MnO	0.04	0.03	0.04	0.02	0.07	0.18	0.16
MgO	0.68	0.60	0.28	0.28	0.60	6.68	10.15
CaO	0.41	0.32	0.08	0.14	0.39	10.79	13.99
Na ₂ O	3.6	4.0	5.0	5.8	4.3	1.56	0.92
K ₂ O	4.6	3.2	1.3	0.59	2.2	0.74	0.32
P ₂ O ₅	0.09	0.04	0.03	0.06	0.05	0.14	0.03
SO ₃						0.24	
CO ₂	<0.02	<0.02	0.06	<0.02	<0.02	0.79	0.13
H ₂ O ⁺	1.3	1.5	0.94	0.69	1.8	1.51	1.89
H ₂ O ⁻	0.38	0.45	0.39	0.27	0.58	0.21	0.18
L.O.I.							
				<i>ppm</i>			
As						10	32
Ba	1070	1640	998	453	1610	198	360
Co	<9	<9	<9	<9	<9	39	45
Cr	<13	<13	<13	<13	<13	105	760
Cu	<4	<4	<4	6	<4	85	200
Nb	9	8	6	9	13	3	<3
Ni	31	26	22	21	35	73	160
Pb	13	9	<6	27	<6	47	32
Rb	129	82	43	23	85	30	16
Sc	3	3	<2	<2	5	40	57
Sr	115	223	117	178	295	132	200
V	33	24	<5	6	<5	220	280
Y	23	29	31	33	58	22	16
Zn	19	34	21	44	31	150	105
Zr	219	173	190	208	299	89	4

Notes to accompany Table 1.

1. Pink rhyolite lava, central volcanic sequence, crest of Red Hills [CP82556520].
2. Grey feldspar-phyric ignimbrite or lava, central volcanic sequence, 650 m west of Red Hills [CP819656].
3. Hornblende andesite, central volcanic sequence, beside Bradshaws Road [CP802557].
4. Hornblende andesite, central volcanic sequence, Drill Hole Tyndall 1, (Mt Lyell Company), east of Bradshaws Road [CP810556].
5. Hornblende-feldspar-quartz-phyric andesite, central volcanic sequence, south of Leech Hill [CP796532].
6. Pink quartz-feldspar-phyric lava, Tyndall Group, north of The Gooseneck [CP81256600].
7. Pink quartz-feldspar-phyric lava, Tyndall Group, south of Newton Creek [CP813588].
8. Andesite lava, between North and South Henty Faults, south of Hall Rivulet [CP776544].
9. Feldspar-phyric andesite lava, Zeehan Highway NW of Bradshaws Road [CP742503].
10. Intermediate tuff, bed of Henty River near Zeehan Highway [CP742511].
11. Pyroxene basalt, Zeehan Highway NW of Bradshaws Road [CP74305025].
12. Gabbro, Zeehan Highway near Bradshaws Road [CP74655025].
13. Gabbro, between North and South Henty Faults, beside Howards Tram [CP75255565].
14. Gabbro, between North and South Henty Faults, within ultramafic zone beside Hall Rivulet track [CP76055630].
15. Altered pyroxenite, beside Hall Rivulet track [CP76055625].
16. Feldspar-phyric lava, central volcanic sequence north of Henty Fault, beside Red Hills track [CP79656415].
17. Feldspar-phyric lava, central volcanic sequence, intersection of Howards Road and Red Hills track [CP79706275].
18. Feldspar-phyric lava, central volcanic sequence, near creek on Howards Road [CP794627].
19. Feldspar-phyric intrusive or lava, central volcanic sequence, ridge between Dobson and Jones Creeks [CP77706345].
20. Feldspar-phyric intrusive rock or lava, central volcanic sequence, ridge between Dobson and Jones Creek [CP77606335].
21. Feldspar-phyric ignimbrite breccia, central volcanic sequence, east bank of Dobson Creek on Howards Road [CP77656150].
22. Feldspar-phyric ignimbrite, central volcanic sequence, White Spur Creek bridge on Howards Road [CP77556095].
23. Basalt intrusive, central volcanic sequence, Howards Road east of Jones Creek shale [CP78906245].
24. Basalt intrusive, central volcanic sequence, Howards Road near junction with Red Hills track [CP79656275].
25. Coarse-grained basalt intrusive, central volcanic sequence, within Jones Creek shale NW of Lake Johnston [CP778657].
26. Dolerite (tholeiitic), intrudes central volcanic sequence but could be Jurassic (see Corbett, 1975, p. 15), on Red Hills track just west of Henty Fault Zone [CP805662].
27. Gabbro intrusive, central volcanic sequence, side track south of Howards Road [CP79256255].
28. Quartz-feldspar-phyric lava, base of Howards Road volcano-sedimentary sequence, junction Howards Road and Mount Read track [CP77506045].

Table 1 notes (continued)

29. Medium-grained quartz-phyric tuff, Howards Road volcano-sedimentary sequence, east of White Spur Creek bridge on Mount Read track [CP766618].
30. Fine-grained quartz-phyric vitric-crystal tuff (upper part of unit 29), west side of road at previous locality [CP766618].
31. Bedded quartz-phyric tuff, Howards Road volcano-sedimentary sequence, lower tuff member, loop track north of Howards Road [CP77055950].
32. Bedded quartz-phyric tuff, Howards Road volcano-sedimentary sequence, upper tuff member, Howards Road at south end of large ridge [CP76205815].
33. Basalt dyke, intrudes Howards Road volcano-sedimentary sequence on south slope of Mount Dundas on logging track (could be Tertiary?) [CP730579].
34. Gabbro, within "Rosebery Group", ridge NE of Moores Pimple [CP74506485].