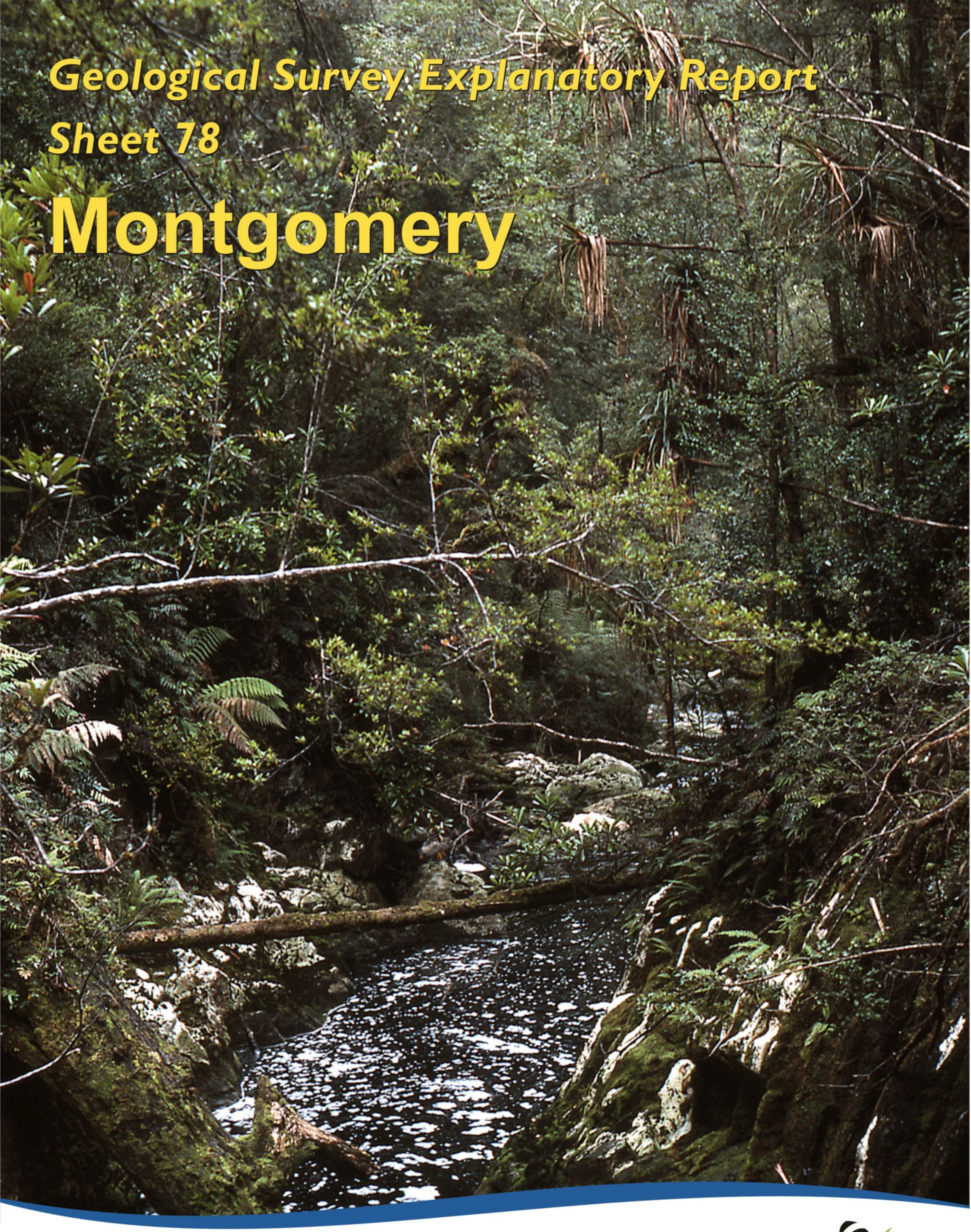
Geological Survey Explanatory Report

Sheet 78

Montgomery



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Cover: Typical outcrop of tholeiitic basalt in the upper reaches of the Mainwaring River (Mo568; 376300/5253500)

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Geological Survey Explanatory Report

Geological Atlas 1:50 000 Series Sheet 78 (7912S)

Montgomery

by A. V. Brown

March 2011

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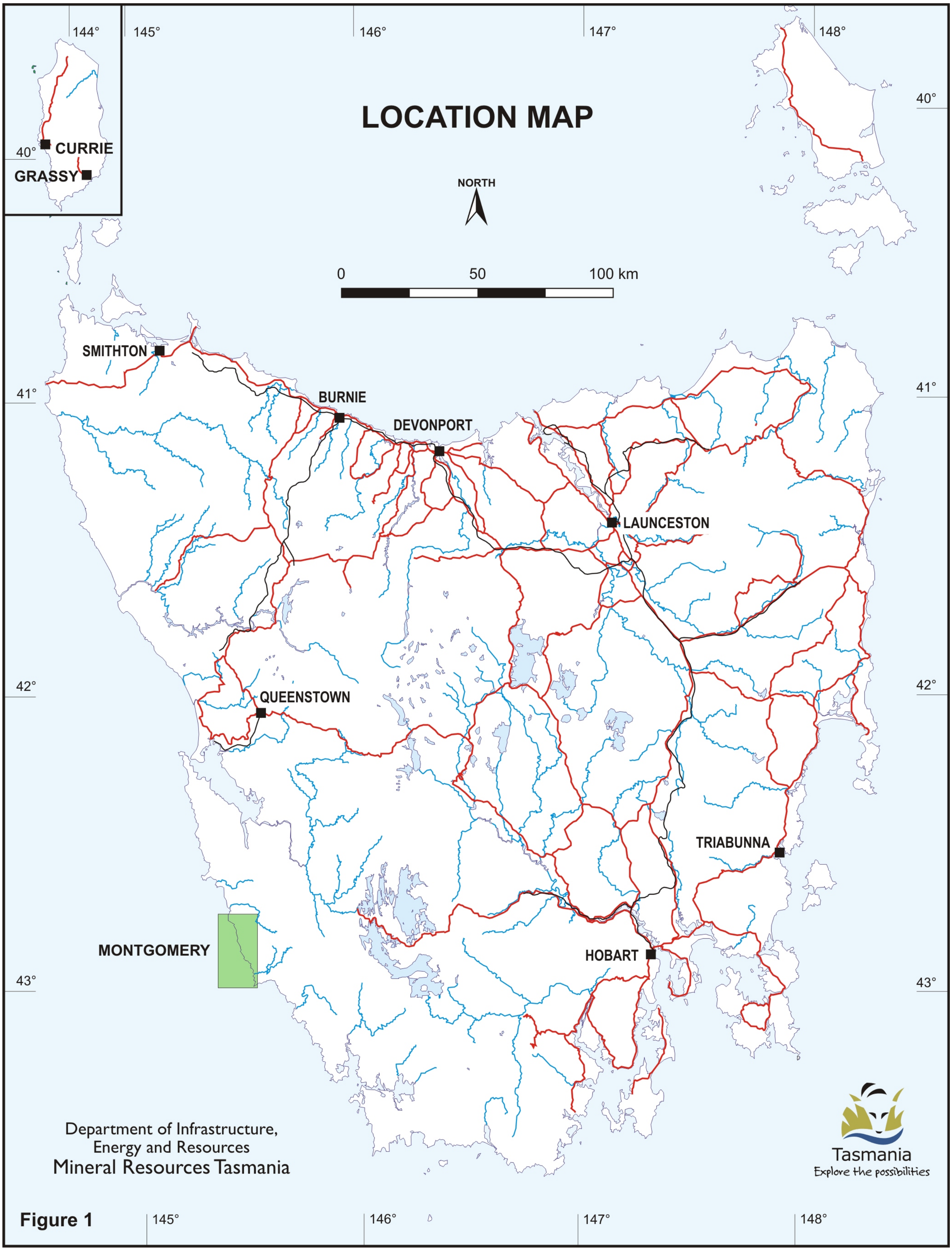

Figure 1

Brown, A. V. 2011. Geological atlas 1:50 000 series. Sheet 78 (7912S). Montgomery. *Explanatory Report Geological Survey Tasmania.*

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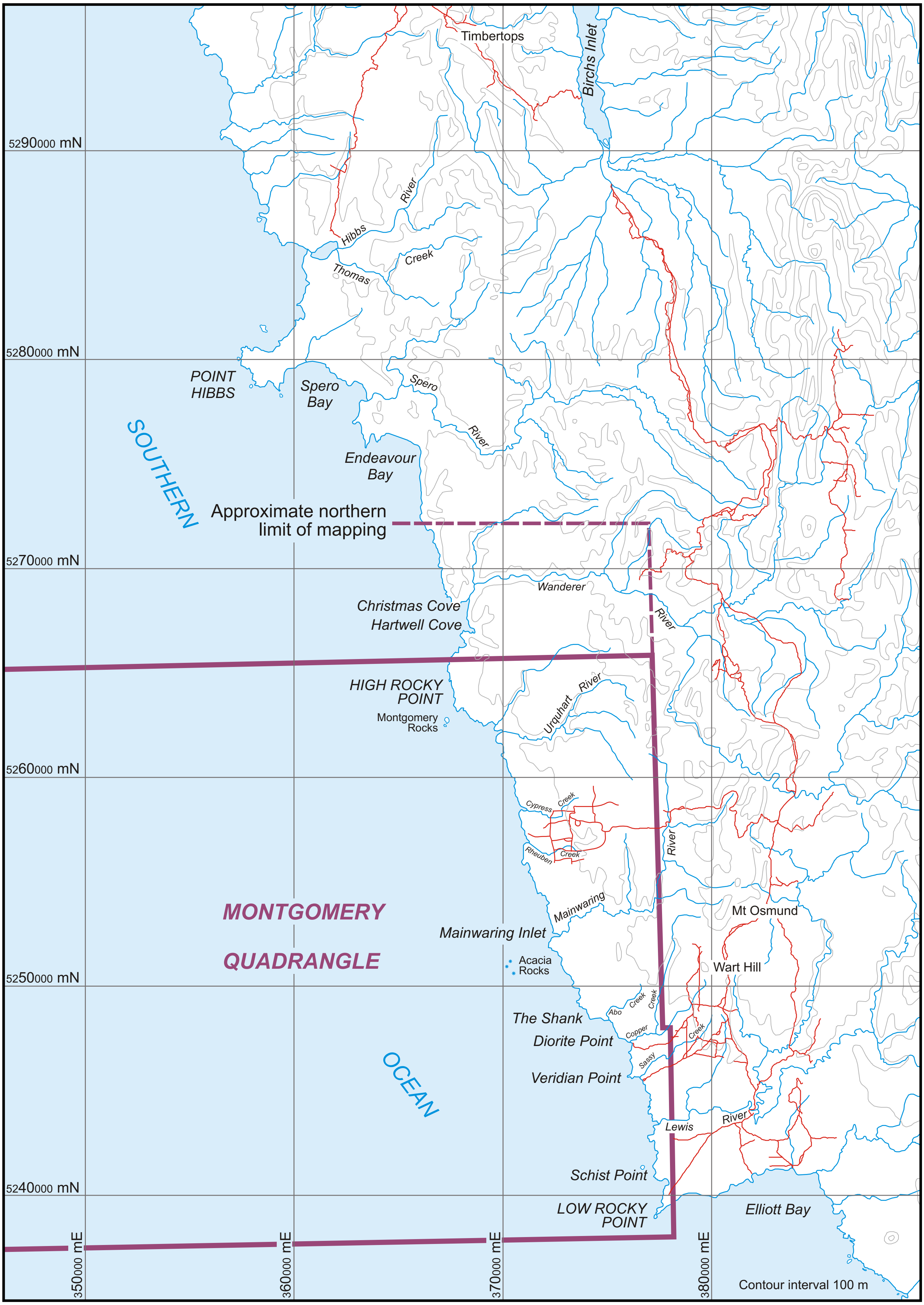

Figure 2

Location of Montgomery quadrangle and main geographic features.

INTRODUCTION

The preparation of this explanatory report was started in 1989, but due to numerous organisational changes in the then Department of Mines between 1989 and 1993, which culminated in the formation of Mineral Resources Tasmania in 1994, preparation of the report was 'shelved' with the author undertaking a managerial role from the end of 1993 until mid-2010.

With the cutback in regional mapping and associated activities at the time (1989) a general summary of the area was produced (Brown *et al.*, 1991). The explanatory report for the Macquarie Harbour map sheet (McClenaghan and Findlay, 1993) was published in 1993, but reports for the Montgomery and Point Hibbs sheets were, unfortunately, not produced.

Later 1:10 000 scale mapping, carried out during the Mount Read Volcanics Project, allowed for a better and more detailed knowledge of the rock units along the eastern one kilometre of the Montgomery map sheet boundary. This information is now contained in the MRT 1:25 000 scale digital regional map series and is summarised in Corbett (2003).

Location and access

The Montgomery 1:50 000 scale map sheet lies on the seaward side of the centre of the southwestern quadrant of Tasmania (fig. 1). The map quadrangle extends from Low Rocky Point in the south, to approximately two kilometres north of High Rocky Point in the north, and covers approximately 145 km^2 of land (fig. 2). Field mapping was undertaken during eight ten-day field trips between early January and mid-March 1986 and mid-January to the end of March 1987.

Included in this report are data and descriptions of the geology collected on a six-day field trip in January 1989 to the southern part of the Point Hibbs 1:50 000 scale map sheet, this map being the northern continuation of the Montgomery map sheet. This trip was undertaken at the beginning of what was to be the mapping of the Point Hibbs quadrangle, but this project was discontinued at the end of January 1989.

All coordinates quoted in this report are based on the 1966 Australian Geodetic Datum (AGD66) and are AMG co-ordinates in Zone 55, not the more recent GDA94 grid. Grid references in the text are quoted in the form xxxxxx/yyyyyyy, where the first six numbers are metres east and the last seven numbers are metres north.

Field numbers are used as location points throughout the text; a listing of field numbers, locations, analysis numbers and MRT registered numbers is given in Appendix 2. Photomicrographs of rock sample numbers marked with an asterix are included in Appendix 3.

Practical access to the region is by helicopter although access during good weather can be obtained to certain, but very limited, places on the coast by boat. Access to the central and southern parts of the sheet could, until the mid-1990s, be made via an old bombardier track from the southern end of Birchs Inlet or by foot from the airfield at Moores Valley. Both of these routes are now (2010) closed.

Because of the nature and sensitivity of the coastal flora, camping spots were mainly confined to sites already established, e.g. at the permanent camp at Wart Hill (379300/5249200); at the back of the beach at the mouth of the Mainwaring River (372800/5252300); on the northern side of the old helipad on the upper reaches of the Mainwaring River (376600/5253500); and at the old BHP helipad near Cypress Creek (372300/5257000). Two new camps were established, one on the northern side of a major gravel bank 400 m inland from the mouth of the Urquhart River (370100/5262200) and the other behind sand dunes on the eastern side of Pegg Creek at Hartwell Cove (368600/5267100), on the southern end of the Point Hibbs sheet. The camp site for the January 1989 trip was located behind the foredunes of the beach at Christmas Cove (368300/5268400) on the western side of the Wanderer River.

With the exception of the Hartwell Cove camp, which is unsafe due to wind turbulence during strong westerly and southwesterly winds, all camping sites were safe and had a plentiful supply of fresh water. An old sea cave exists halfway up the cliff face on the southern bank of the Lewis River (377800/5243800). This cave could be used as a stop-over camp if required. An open area on top of the cliff is a safe helicopter landing spot and is easily accessible from the cave.

The coastal platform can be traversed along the whole of the map sheet with the exception of three places in the northern part of the sheet. In two of these locations (369200/ 5262600 and 367800/5263100) steep-sided gulches run into an undercut cliff and the area must be traversed by going inland. In the third location (369500/5261600) a sheer cliff dropping into the sea also made it necessary to go inland. A number of similar gulches are encountered to the north of Christmas Cove on the Point Hibbs map sheet (between 368100/5266200 and 368500/5266900).

The only tracks in the Montgomery quadrangle are to the east of the Cypress Creek–Rheuben Creek area. Although covered by 25 years of regrowth, these tracks could still (1989) be traversed from near the mouth of Flat Creek (371000/5257300), inland via the southern route (from 372300/5257200 to 372400/5256500), past 373300/5256500 to 374900/5257400, then west over the Mainwaring River and out of the forest to the western edge of the button grass plains to a helipad at 378400/5258500. This track then continues to the old Moores Valley light aircraft landing strip and then to the southern end of Macquarie Harbour at Birchs Inlet.

The low topography and dense scrub of the coastal and inland areas covered by the Montgomery quadrangle basically restrict outcrop to the coastal strip, especially the tidal platform, and deeply incised rivers. Because of poor off-coast outcrop, contacts between different rock successions are rarely seen.

The *position approximate* geological boundary was used to represent a change of rock sequence, irrespective of its nature, as in most cases the nature of the change, whether gradational, faulted or thrusted, was not observed.

Previous literature

The four most useful early references to the area at the time of mapping were Corbett (1968), Hall and Corbett (1968), Large (1981) and Strickland (1978). All of these reports contain references to earlier workers.

Since the publication of the Montgomery 1:50 000 scale map in 1988, there have been changes to the geology depicted along the eastern boundary of the quadrangle following publication of the Mount Read Volcanics Mapping Program maps 10 (Pemberton *et al*., 1991) and 11 (Vicary *et al*., 1992). A summary of the Mount Read Volcanics Mapping Program mapping in this area (Corbett, 2003; Vicary, 2005) and the latest versions of the 1:25 000 scale digital geological map series (Seymour and Green, 2003*a*–*d*) contain these changes. The digital geological maps are being converted to the GDA94 map grid, so care needs to be taken when using ADG66 coordinates.

Except where otherwise indicated, the rock codes used in this report are those from the published Montgomery 1:50 000 map sheet (Brown, 1988). Symbols relating to the current (2011) digital geological atlas series are indicated by being italicised and in brackets.

Acknowledgements

Professor Mike Hall of Monash University, and Dr David Seymour and Michael Vicary of MRT, are thanked for their critical reviews of the draft manuscript. Dr Daniel Bombardieri and Mike Vicary are thanked for their assistance with the interpretation of remote sensing data (fig. 21–24) that resulted in the production of Figure 20. Any confusion or contradictions, especially in the *Structure* section, are the responsibility of the author.

Ocean currents

During the mapping of the Montgomery quadrangle over thirty CSIRO float cards were found along the shoreline over a distance of three kilometres either side of Mainwaring Inlet. None were found along the rest of the shoreline of the Montgomery quadrangle. The float cards found were dropped into the Great Australian Bight and were carried in a strong current which passes down the western side of Bass Strait and into the Southern Ocean, and ended up coming ashore within three kilometres either side of Mainwaring Inlet.

The barque *Acacia*

Early on the morning of 21 June 1904 the 200 ton barque *Acacia* was totally wrecked during stormy weather, with the loss of all hands, after hitting a group of rocks approximately two kilometres offshore from Mainwaring Inlet. These rocks now carry the barque's name. *Acacia* was built at Battery Point by John Ross and launched in 1871. Her main use was as a coastal trader between different Australian and New Zealand ports.

On 20 June 1904 *Acacia* sailed from Port Esperance for Adelaide with a cargo of timber. The log of the Maatsuyker lighthouse for 21 June 1904 records that at "9 am barque Acacia passed S., bearing w.s.w., distance two leagues; wind n.w.; force 7; weather ugly; sea force 6." The ship was not seen again and was reported missing when it did not arrive in Adelaide on time.

Early in March 1905 wreckage from the *Acacia* was discovered along the southwest coast, just south of Mainwaring Inlet, by Samuel Brown, an eighteen year old fisherman and beachcomber, who at that time was a member of the crew of the smack *Ripple*. A few days later, after Brown reached Port Davey, the news of the find was sent to Hobart by 'pigeon post', arriving there on Tuesday 14 March.

On Thursday 16 March 1905, HMS *Cadmus*, a naval steam sloop belonging to a visiting fleet of naval ships, set out for the area to "...examine wreckage, and also to recover the bodies reported by fishermen as lying on the beach near Mainwaring Inlet". The remains of five bodies, out of a crew of nine, were located. The report from the captain of HMS *Cadmus* was published, along with other information, in the Hobart *Mercury* of 20 March 1905. In part, the report reads:

> *"The beach is strewn with wreckage from Mainwaring Inlet to about three miles south. Nearly all of the vessel is broken up, and lies well up on the rock, and is easily recognised as belonging to the barque Acacia. In my opinion, the Acacia struck one of the outlying reefs in the vicinity of the Black Rocks. The wreckage along the beach did not contain any of the lower hull or the cargo of green, blue-gum."*

The distribution of the wreckage ranged over a very similar area to that of the CSIRO float cards, although considering the drift-card data and that the wind was from the northwest on the night that the ship foundered, there is the possibility that *Acacia* actually sank further to the north of Acacia Rocks and the wreckage drifted south to its landfall.

The 'Black Rocks', now Acacia Rocks, are a collection of eleven outcrops, just above water level over an area of approximately 500 metres diameter. They consist of glassy dacite and probably represent a remnant feeder or volcanic plug.

The crew of the *Acacia* at the time of her sinking were A. V. Saunier, age 55, Captain; Alexander Noble, age 60, Chief Mate; Sydney Charles Herbert (a son of the owners), age 21, Acting Second Mate; George Philador, age 45, Steward; Thomas Gambrill, A. Hansen and E. Karlsen (ages unknown), Able Bodied Seamen; J. Bradshaw, age 21, and William Joseph Carter, age 18, apprentices.

Further information on the disaster can be found in:

- *The Mercury* (Hobart): 15 March 1905, p.4, c.2; 17 March, p.5, c.5; 18 March, p.4, c.7; 20 March, p.6, c.2–3; 21 March p.4, c.7 and p.6, c.1–2;
- *The Tasmanian Mail* (Hobart): 20 August 1904, p.23, 18 March 1905, p.16, c.1; 25 March, p.32, c.3–6; Photograph of the barque *Acacia* 20 August 1904, p.23.

Neoproterozoic (Ediacaran)–Cambrian(?)

Introduction

Geologically, the Montgomery quadrangle is dominated by three marine volcano-sedimentary rock successions. The westernmost succession, Cvu (a southern continuation of the Noddy Creek Volcanics; White, 1975), comprises andesitic to dacitic lava, volcaniclastic and epiclastic sandstone and autobreccia with phenocrysts of clinopyroxene and/or plagioclase or hornblende and associated sedimentary rocks. Even though the succession is complexly folded, overall sedimentary facing characteristics indicate that the succession faces east.

The lower part of the Cvu succession, Cvs, crops out along the coastal section between just north of High Rocky Point to Hartwell Cove (in the Point Hibbs quadrangle) and consists dominantly of extrusive and autobrecciated porphyritic basaltic-andesite/andesite interbedded with laminated siltstone and mudstone and minor lithic sandstone and wacke beds. The lavas burrowed into semi-consolidated sediment causing numerous irregular basal structures to the lava units including, in places, rip-up clasts of sediment up to a metre in length.

The Cvs sequence is gradationally followed upwards by interlayered, extrusive, porphyritic andesitic lavas, some with pillow structures, and autoclastic breccia flows (Cvv), which crop out from Montgomery Rocks, through High Rocky Cape to Hartwell Cove, where they are fault offset to the northwest and then continue north along the coastal area to the west of Christmas Cove. The lavas and autobrecciated units in both the Cvs and Cvv successions have calc-alkaline chemical characteristics and are correlates of part of the Middle Cambrian Mount Read Volcanics succession in western Tasmania.

Inland of the Cvs and Cvv sequences is a fault-shuffled sequence of highly folded, dominantly lithic sandstone and wacke with interbedded laminated siltstone and mudstone (Cvl). This succession crops out along the coast from Minder Cove (just east of High Rocky Point), south to just east of The Shank. Intruding this sequence are varying thickness dykes and sills of hornblende-bearing andesite (Cmv); one outcrop on the coast at 371600/5254400 exceeds 100 m in thickness.

Between just south of the Mainwaring River and The Shank the Cvu succession is dominantly composed of pebble conglomerate and lithicwacke with interbedded siltstone (Cvc). The upper sequence of the Cvu succession is exposed in the Urquhart River and along a small section of the coast to the south, where it dominantly consists of felsic volcaniclastic sandstone and wacke with interbedded lithicwacke and laminated siltstone and mudstone (Cvt).

The northern extension of the Cvu succession is the southern end of the Noddy Creek Volcanics (White, 1975) which extends from the Macquarie Harbour 1:50 000 scale map sheet (Ctu etc., McClenaghan and Findlay, 1989), south through the Point Hibbs quadrangle and down the coastal area to The Shank in the Montgomery quadrangle. The Cvu succession has been correlated with the Middle to Late Cambrian Mount Read Volcanics succession in western Tasmania (Corbett, 2003).

Inland of the Cvu succession is a succession of submarine flows of olivine-phyric picritic to clinopyroxene and/or plagioclase phyric, sub-alkaline basalt lavas and associated fine-grained sedimentary rocks (Evu). The basaltic rocks have a tholeiitic chemical character.

Because of common usage over the years, this succession (Evu) has become known as the ‘Mainwaring Group’ or ‘Mainwaring Basalts’ (now Montgomery Basalt) (Corbett, 1968; Hall and Corbett, 1968). The term Mainwaring Group, of which the ‘Montgomery Basalt’ is a part, will shortly be formally defined, following Corbett (1968).

The Evu succession appears to have undergone a higher degree of structural and metamorphic modification in comparison to the andesitic-dacitic lava succession (Cvu). Based on the writer’s experience elsewhere in western Tasmania, the Evu succession is part of the Neoproterozoic to Early Cambrian oceanic rock successions that were obducted onto the siliceous Neoproterozoic rock of proto-western Tasmania during the Middle Cambrian and formed the basement for the early Mount Read volcanism. Evu is thus the older of the three successions. The Evu succession (‘Mainwaring Group’) is also considered to be a correlate of the Miners Ridge Basalt (now Guilfoyle Basalt) in the Queenstown area (Dower, 1991; and this study).

The inland-most succession in the Montgomery quadrangle, Cfv (Lewis River Volcanics; White, 1975), is composed of quartz crystal vitric lavas, volcaniclastic sandstone and wacke interbedded with quartz-rich conglomerate, and sandstone associated sedimentary rocks. This sequence was not studied in detail and samples were not collected for geochemical analysis. From thin section examination, rocks from this succession are derived from quartz-phyric and minor plagioclase-phyric lavas of a dacitic to rhyolitic character, which is a totally different volcanic phase to the volcanic event that produced the Cvu succession lavas and intrusions (Noddy Creek Volcanics).

Because of the acid to intermediate, dominantly volcaniclastic nature of this dominantly quartz-phyric succession (Cfv) it is considered to be the youngest of the three successions on the map sheet. It has a highly sheared faulted contact with the basaltic succession (Evu) along the eastern side of the Montgomery map sheet. The zone of deformation continues for an unknown distance further east, in which many highly sheared zones and lenses of exotic material occur.

Later mapping of this area, during the Mount Read Volcanics mapping project (1991–1992), and integration of all mapping into MRT’s 1:25 000 scale digital map series, has assigned these rocks to a ‘mixed sequence of volcano-sedimentary, sedimentary and volcanic rocks ranging from felsic to andesitic in composition’ (Cdvs; Seymour and Green, 2003*a*–*d*). At present these rocks are correlated with the Eastern Volcano-sedimentary Succession of the Mount Read Volcanics in western Tasmania (Vicary, 2005).

Neoproterozoic (Ediacaran) to/or Early Cambrian

Evu — mafic basalt and associated sedimentary rocks

A major change in the percentage of basaltic flows to sedimentary rocks within this succession occurs in a north–south direction over the area covered by the map sheet. To the north of the upper reaches of Cypress Creek (around 375000/5260000) the succession is dominated by basalt and to the south by sedimentary rocks with interbedded basaltic horizons. To the north of the upper reaches of the Urquhart River the basalt succession disappears beneath a cover of interbedded, partially consolidated silt, sand and gravel of Tertiary age (Ts).

The regional aeromagnetic expression of this succession within the Montgomery quadrangle indicates that the succession continues northwards, under the Tertiary cover, along the eastern side of the Point Hibbs quadrangle and into the Birchs Inlet area of the Macquarie Harbour quadrangle. In the latter area basaltic rocks, with similar chemical characteristics to those in the Montgomery quadrangle, are found along the southwestern side of Birchs Inlet (Etbc, McClenaghan and Findlay, 1989).

Coastal outcrops between Diorite Point and Veridian Point show the highly deformed nature of this mudstone, siltstone and calcareous sedimentary rock sequence, into which picritic lavas flowed and intruded (Plates 1–4). The succession can also be observed in the upper reaches of the Mainwaring River (between 375500/5253400 and 377000/52536000) where tholeiitic lavas dominate (Plates 5, 6), and along access tracks heading inland between Cypress and Rheuben creeks (from 372000/5257000 to 377000/5257500) where both picritic and tholeiitic rocks are found. Because of sparse outcrop, areas dominated by lava flows, as opposed to interbedded sedimentary sequences, can only be inferred away from mapped traverses by using aeromagnetic data.

Differences in inferred areas of basaltic rock between the published Montgomery 1:50 000 scale map sheet and the current (2010) version of the 1:25 000 scale digital geological map coverage of the area are a result of later authors using the 2001 WTRMP airborne magnetic coverage of the area to interpret the boundaries. The new magnetic data indicate that the Evu succession has been dissected by numerous faults.

Evl — dominantly volcaniclastic lithicwacke and siltstone with interbedded mudstone and mafic volcanic units

This sequence is well exposed in parts of Rheuben, Copper and Sassy creeks, as well as along the shoreline between Sassy and Abo creeks, where the sequence consists of interbedded volcaniclastic lithicwacke and siltstone with interbedded mudstone, minor carbonate and picritic lava flows and syn-sedimentary dykes and sills. Isoclinal folds are commonly observed in the finer grained sedimentary rocks (Plates 7, 8).

Outcrops along the coastal area demonstrate that the original sediment was intruded by syndepositional picritic lava while still wet to plastic, resulting in the formation of disrupted bedding and bedding-parallel to sub-parallel sills with chilled margins and/or irregular boundaries (Plates 3, 4). As well as disruption by the lava intrusion, the background sedimentation was further disrupted by mass flow, cobble-grade conglomerate units. Basaltic breccia flows also occur within the sequence around Diorite Point. Throughout the sedimentary rock pile, grading and channel structures, as well as lava flows with scoured bases and flat tops, indicate both west and east facings, implying that fault dissection of regional scale folds has occurred.

Evv — dominantly interlayered mafic volcanic flows with minor interbedded sedimentary rocks

Outcrops of the tholeiitic basaltic sequence (Evv) consist of vesicular, pillow and sheet flows of basaltic lava interlayered with hyaloclastite (e.g. Mo227*), basaltic breccia and minor lithicwacke, siltstone and mudstone. In some places, for example around 372500/5258000 and 376500/52535000, the basalt contains a high percentage of native copper. Overall, outcrop is poor and no field-based stratigraphic succession could be established. Geochemical analyses indicate that, on a regional scale, west of the eastern boundary of the Evmc and Evv sequences, the succession youngs to the west and that the western side youngs to the east. The magnetic data also indicate a major fault along this boundary. Basal lava flows along the old access tracks to the east of Cypress and Rheuben creeks are picritic and are followed up-sequence by at least two of the four batch-melting episodes of tholeiitic magma, each with increased TiO_2 content. Although picritic lavas were not found in the upper Mainwaring River traverse the tholeiitic lavas to the west of the Evmc sequence also face west.

In hand specimen the lavas are usually fine grained, at times vesicular, and can either contain phenocrysts of chromite and pseudomorphs after olivine, or clinopyroxene and/or plagioclase; the former have a picritic composition and the latter have a sub-alkaline basalt composition. The picritic basalt usually weathers to a pale to mid-green colour and has associated yellow-brown soil, whereas the sub-alkaline basalt weathers to a purplish-grey colour and has associated red-brown soil.

As well as in the coastal region between Diorite Point and Veridian Point, picritic lavas were found interlayered with laminated mudstone and interbedded carbonate beds (Evcs) around 375200/5257500 between two areas of dominantly tholeiitic lava flows. Field evidence could not resolve whether this was fault repetition or due to regional folding or thrusting.

In the areas of Evv transected by the upper reaches of the Mainwaring River (375600/5253500 and 376500/5253500) (Plates 5, 6) the sequence is highly foliated and sheared and contains a well developed, steeply west-dipping foliation that strikes SSE, indicating that, in latter phases of deformation, the succession was thrust eastward against the eastern Mount Read Volcanics succession correlates. Outcrops of

Plate 1

Bedding-conformable picritic lava flow, one kilometre north of Diorite Point (Mo48; 375100/5248300).

Plate 2

Pillowed picritic lava flow and conformably overlying sedimentary rocks at Diorite Point (Mo120; 375500/5247500). Steeply dipping spaced cleavage observable in overlying sedimentary rocks associated with open, upright folding and tectonic compositional banding formation.

Plate 3

Rip-up raft of sedimentary rocks within picritic intrusive rock (dyke) at Diorite Point (Mo120; 375500/5247500).

Plate 4

Nose of picritic lava intrusion into soft sediment with rip-up clasts in basal zone at Diorite Point (Mo120; 375500/5247500).

Plate 5

Typical massive tholeiitic basalt outcrop in the upper reaches of the Mainwaring River (Mo568; 376300/5253500).

Plate 6

Typical massive tholeiitic basalt outcrop in the upper reaches of the Mainwaring River (Mo584; 375500/5253500).

Plate 7

Outcrop-scale tight fold in dominantly thinly-bedded laminated zone 0.5 km southeast of Diorite Point (Mo21; 376100/5247000).

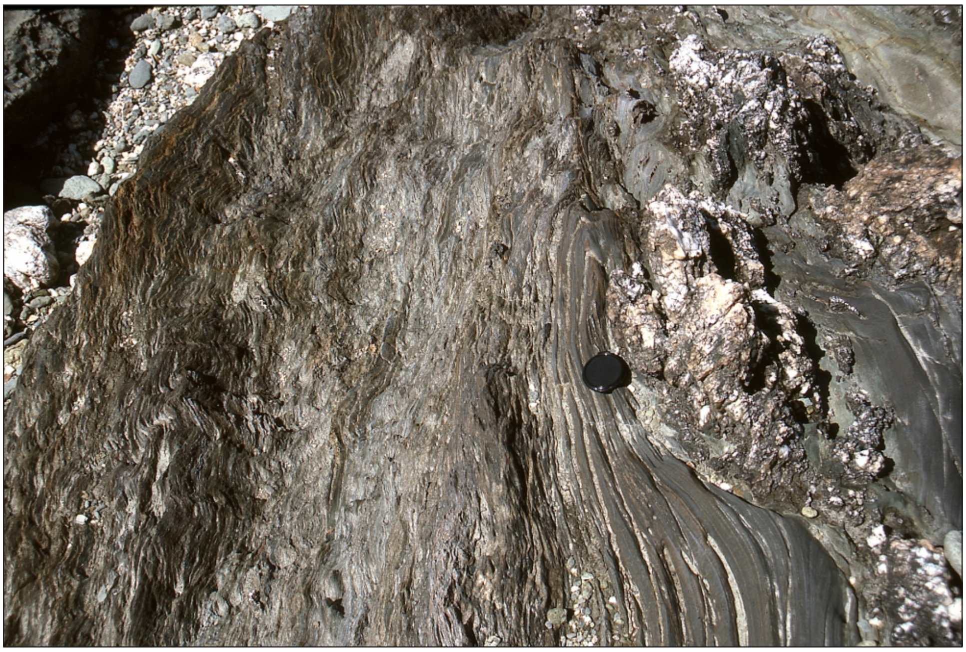

Plate 8

Rootless isoclinal fold with sheared out limb (centre) and crenulated compositional banding (left) at Veridian Point (Mo30; 376000/5245500).

basaltic rocks in this area are similar in character to those along the Cypress Creek access track to the north.

Evlv — syndepositional mafic volcanic intrusive rocks

Numerous flows, sills and low angle transgressive dykes of picritic basalt occur within the area of the Evl sequence between Sassy and Abo creeks (376500/5245500 and 375000/5248300). These are petrologically and chemically similar to the picritic lavas within the Evmc sequence and lower apart of the Evv sequence around 375600/5257700 and 374700/5256700 on the Cypress Creek walking tracks.

Evmc — dominantly laminated mudstone and laminated chert

Laminated mudstone and chert (Evmc), separating two areas of Evv rocks, is exposed along access tracks around 374800/5257400 and in the Mainwaring River (376000/5253500). The core of this sequence is an approximately 100 m thickness of one to five millimetre laminated black and white chert, which forms a prominent ridge down the middle of the outcrop area. On the western margin of this ridge the chert is interbedded with vesicular basalt, with laminated mudstone occurring on the eastern side. The mudstone sequence varies in colour from green to black or grey. The eastern edge of this sequence contains picritic lava (around 375500/5257600). The contact is covered by alluvium so the stratigraphic relationship is unknown. Another thin sequence of laminated chert and mudstone, with an interbedded basalt flow, also crops out along the Cypress Creek access track (around 376300/52575000).

Evsc — dominantly laminated siltstone/ mudstone with minor carbonate beds

At the time of mapping, based on traverses within Sassy and Copper creeks, the Evl sequence was interpreted to stratigraphically pass upwards into the Evsc and then Evss successions. This interpretation was based on the similarity of structures within a changing lithology either side of a stretch of alluvium in both Sassy Creek (377000/5246200) and Copper Creek (377100/5247700). Passing upward from the Evl sequence in Sassy Creek, volcaniclastic lithicwacke units cease and the sequence becomes dominated by laminated grey siltstone and black mudstone, then after a break in outcrop, passes into dominantly black mudstone, in places pyritic, with minor siltstone and sandstone beds and minor carbonate lenses.

Mapping during the Mount Read Volcanics Project (Pemberton *et al*., 1991) reassigned both the Evsc and Evss successions in the Montgomery quadrangle as Mount Read Volcanics correlates. The current interpretation used in the 1:25 000 scale digital map series (Seymour and Green, 2003*a–d*; Corbett, 2003) assigns the Evsc succession as 'Cdqsh — dominantly thinly bedded siltstone' and the Evss as 'Cdqsc — siliceous conglomerate, sandstone and breccia'. Both are shown as being correlates of the Eastern Quartz-phyric Sequence of the Mount Read Volcanics.

In the area depicted as Evsc, the first 750 m of the Sassy Creek section consists of mylonitised to compositionally banded, interbedded laminated black pyritic mudstone and grey siltstone with a high degree of quartz veining. The siltstone units are from 5 mm to 10 mm thick, with the mudstone forming units up to 20 mm thick with 1–2 mm laminae. This sequence is followed by 40 m of alluvium, before a sequence of pyritic black mudstone and grey siltstone dominated by compositional banding crops out. Areas of remnant bedding, containing isoclinal folds, exist in this area.

In thin section, a typical foliated siltstone (Mo151) consists of angular quartz fragments (0.07–0.12 mm) in a groundmass of partially recrystallised quartz and mica (0.005–0.15 mm). The quartz grains are aligned with their long axis parallel to the penetrative cleavage. This is cross cut by a crenulation cleavage that forms a transposition surface which, in places, becomes compositional banding. At 377300/5246500 (Mo152), a graded sandstone unit scours into underlying laminated mudstone, indicating an east-facing sequence at this point.

In the Copper Creek traverse the western half of the Evsc sequence is dominated by foliated black mudstone with observable bedding where grey siltstone units are present. In the eastern part a transposition surface dominates and forms compositional banding, with only minor areas of observable remnant bedding.

The boundary between the Evu and Cfu successions, now referred to as the 'Copper Creek Fault' is, on aeromagnetic and gravity data, interpreted as a major crustal-depth boundary fault or thrust (Leaman and Webster, 2002) and is consistent with west over east thrusting of the Evu succession against the Mount Read Volcanics succession to the north of Elliot Bay.

At the coast, the contact between Evl and Cfv (378600/5245100) is in a sand-filled gully. In detail the gully is bounded to the east by a well-bedded felsic volcaniclastic rock sequence (Cfu) and to the west by a deformed siltstone-carbonate sequence belonging to the Evu sequence.

Evss — dominantly siliceous pebbly quartzwacke/lithicwacke with minor siliceous pebble conglomerate units

Graded sandstone units start to occur within the Evsc sequence around 377500/5246600 and this area is depicted as Evss on the Montgomery map. The sandstones show scoured bases into underlying mudstone beds, indicating eastward facing for the succession at this locality. Further east the sequence undergoes a rapid gradational lithological change, with decreasing siltstone and mudstone and increasing quartzwacke, granule lithicwacke, granule conglomerate and pebble conglomerate (Evsc). Sedimentary structures (cross bedding and basal flame structures) indicate that the succession faces east at the transition from Evsc to Evss in both Sassy Creek and Camp Creek (377500/5246600 and 377600/5247700 respectively).

To the south, from the old bombardier track (377500/5246200) to around 377800/5245100, a ridge of the Evss sequence consists of similar but coarser-grained units to those found in the creek sections. Some clasts within the conglomerate units are up to 100 mm in diameter but the majority are between 30 mm and 40 mm. The dominant clast type is well rounded, foliated or massive quartzite.

In thin section, samples from outcrops along the main ridge of Evss (377600/5246200 to 377800/5245100) vary between quartzwacke, lithic-quartzwacke and granule conglomerate. Typical quartzwacke samples vary in grain size from 0.25 mm to 1.0 mm and contain angular to sub-rounded grains of quartz. Some grains are of volcanic origin, with minor amounts of quartzite, foliated mudstone and clastic muscovite in a partially recrystallised groundmass of quartz and mica. The lithic-quartzwacke units contain less quartz grains, up to 1.0 mm across, and more siliceous rock fragments up to 2.0 mm. Granule conglomerate units contain clasts, up to 2.5 mm across, of volcanic quartz, quartzite and mylonitised mudstone, as well as pebbles of well-rounded quartzite. The groundmass again consists of partially recrystallised quartz and mica.

In Sassy Creek the sequence depicted as Evss consists of sandy siltstone units that contain angular to sub-rounded quartz grains (0.5–1.0 mm) and minor plagioclase crystal fragments in a partially recrystallised silt-grade matrix. Interbedded quartzwacke units are similar to those described from the south, although some samples (e.g. Mo154) also contain micaceous quartzite clasts. Granule conglomerate units contain volcanic quartz grains (1.0–1.5 mm) and angular clasts of quartzite (4.0 2.0 mm) and foliated mudstone (1.0 0.5 mm).

Middle–?Late Cambrian

Cvu — porphyritic andesite/dacite lavas, with associated pyroclastic, volcaniclastic and epiclastic units, and interbedded sedimentary rocks

The westernmost of the two main volcanic rock successions (Cvu) is characterised by the presence of calc-alkaline andesite and dacitic lavas associated with sedimentary rocks that are derived, in part, from the interlayered felsic volcanic rocks and in part from a quartzite/chert-rich (Precambrian?)

terrane. Each of the sequences (Cvs, Cvv, Cvt, Cvl and Cvc) within this succession are dominantly east-facing, based on sedimentary structures, although because of folding some areas of west-facing strata were mapped.

Cvs — dominantly extrusive porphyritic andesitic volcanic rocks with interbedded, laminated siltstone and mudstone

The oldest exposed part of this sequence crops out along the coastal platform between 367300/5265000 and the northern margin of the map sheet (367300/5265600), then continues north to Hartwell Cove (Point Hibbs quadrangle) where it is fault offset to the northwest of Christmas Cove before continuing northwards along the coast to Endeavour Bay, then inland into the Macquarie Harbour quadrangle.

In the southern part of the Point Hibbs quadrangle (to the west of Christmas Cove) the sequence consists of laminated mudstone and siltstone with minor volcaniclastic, granule to fine-cobble conglomerate beds and lenses, interbedded with porphyritic and aphyric lava and breccia flows.

The sedimentary rock units vary in thickness, but are dominantly between 50 and 100 mm thick with the thicker sand to pebble-grade units being approximately 1.5 m thick. The sand and coarser grade beds often have irregular scoured bases into underlying finer grained units, as well as containing numerous other sedimentary structures including flame structures, multiple truncated cross bedding, and convolute folding. Some beds show truncated cross bedding in the upper part of the bed only, while other beds show it throughout. Multiple cross-bedded sandstone beds are in some places (367300/5265000) overlain by lenses of granule conglomerate that scoured down into the underlying sandstone. Zones of soft-sediment slump folds and disrupted bedding are often associated with laminar lava flows and units of autoclastic and volcanic breccia.

Volcanic units, within the areas dominated by sedimentary rocks, vary between pillow, sheet, volcanic xenolith-bearing and porphyritic flows and breccia flows. The majority of flows are usually thin autobrecciated lava or volcanic xenolith-bearing porphyritic lava, derived in part from earlier lava flows. Some of the volcanic xenolith and porphyritic units contain rip-up clasts and fragments of what was originally soft sediment. In one area (Mo533) there is a repeated sequence of alternating flows of well-bedded aphyric and porphyritic lava, and crystal, vitric, lithic volcaniclastic conglomerate and sandstone, with associated pillow lavas and intercalated, minor sedimentary rock units. The lava pillows vary in shape from near spherical and 300 mm in diameter to 1–2 m tabular bodies (Plate 9).

Granule to pebble conglomerate units contain clasts of locally-derived volcanic rocks as well as angular, rip-up black mudstone clasts. In some units the main clastic component is derived from quartz-rich felsic volcanic rocks, with minor metamorphic rock and exotic volcanic clasts.

In thin section, a typical quartzwacke (Mo507) is poorly sorted (grain size ranging from 0.05 to 0.3 mm) and contains angular clasts of quartzite, devitrified volcanic glass, chert and mudstone, with grains of quartz with sharp (volcanic) to undulose (metamorphic) extinction (the larger grains showing polygonisation), plagioclase, microcline, opaques (leucoxene), clastic muscovite, brown biotite and minor zircon. Some of the quartz grains show embayments and a number of these grains still have some areas of devitrified glass attached. The groundmass has recrystallised around the clastic components, especially in pressure shadows at ends of the larger grains, into cryptocrystalline quartz and white mica.

A typical granule to pebble conglomerate unit in this sequence contains numerous clasts of different lava types, including clinopyroxene phyric andesite, plagioclase-rich felsic lava, fine-grained vesicular lava (now replaced by a felsic mat of actinolite), acicular hornblende crystals in black glass, and devitrified (snowflake textured) volcanic glass. Single grains of volcanic quartz and minor amounts of blood-red chrome spinel (up to 0.4 mm across) and smaller clasts of quartzite, chert, siltstone and mudstone form the groundmass, indicating a partially non-volcanic source.

Plate 9

Pillow lavas in an andesitic lava flow at the top of the Cvs sequence, 2.5 km north of High Rocky Point (Mo502; 368000/5266200).

In the lowest part of the sequence exposed on the coastal section, one sample (Mo513/2*) contains a 5.5 4.0 mm clast of chlorite and serpentine(?) group minerals replacing a porphyritic (boninitic) lava that contains red-brown chrome spinel grains. Electron microprobe analyses of seven spinel grains from this sample, including two from inside the large chloritised lava clast, gave an average Cr/(Cr+Al) ratio [Cr*] of 91.8, with a range of 90.5 to 92.6, confirming that the clast was originally boninitic lava (Brown and Jenner, 1989). Another reddish spinel grain, which appears to be attached to the side of a plagioclase phyric felsic lava clast (Mo513/2b*), has a Cr* of 76.6, a value similar to spinel grains (72.4–74.6) in spinel-bearing basaltic lavas from the hanging wall at the Hellyer mine (Jack, 1989).

Where volcanic rocks dominate the sequence, the units are predominantly interlayered pillow or laminar flows (e.g. 367400/5264400) of porphyritic (clinopyroxene and/or feldspar) and non-porphyritic andesitic lava. In places the lavas are relatively felsic but still contain a small amount of black clinopyroxene phenocrysts.

Progressing stratigraphically upwards (eastwards and inland from the coast), the sequence consists of lensoidal sedimentary rock units intercalated with thicker volcanic flows. Numerous 2–5 m thick volcanic breccia flows, which incorporate 10–25 mm long angular rip-up clasts of siltstone, are overlain by 10–15 m wide lenses of quartzwacke.

As the volcanic flows thicken (10–12 m) and become more numerous, they consist of either autobrecciated units or volcanic xenolith-bearing, porphyritic flows interbedded with thin (2–3 mm) volcaniclastic siltstone with preserved angular glass shards (Mo530/1*), and 10–15 mm thick volcaniclastic sandstone and wacke units. The volcaniclastic siltstone beds contain angular silt-grade quartz grains and feldspar microlites in an altered glass groundmass. Equant to elongate (0.35–0.7 mm) grains with a perlitic texture also occur. The volcanic sandstone/wacke beds are between 10 and 15 mm thick and consist of tightly packed, broken, clinopyroxene and feldspar crystals with semi-rounded, fine-grained clasts of devitrified quartzo-feldspathic lava and minor secondary carbonate. Some of the volcanic grains contain small clinopyroxene and/or plagioclase crystals.

The thicker volcanic units consist of blocks of coarse-grained andesite lava with a finer grained lava matrix. In outcrop, some of the volcanic units appear to be porphyritic lavas (e.g. Mo535), although in thin section they are densely packed, crystal-rich rocks with a vesicular, fine-grained groundmass, similar to the matrix within the andesitic xenolith-bearing units.

Just to the north of the map sheet (Mo515), a continuation of this succession contains similar volcanic and sedimentary rocks together with flows of vesicular clinopyroxene phyric andesitic lava. In thin section, clinopyroxene crystals range from one millimetre up to five millimetres long and occur in a groundmass of interlocking anhedral plagioclase laths (0.2–0.3 mm) with areas of secondary chlorite and actinolite.

Still higher up in the sequence, as exposed along the coast from 367500/5264300 to 367500/5264000 (Point Hibbs quadrangle), the volcanic unit becomes more common and the sequence consists of 0.5–5 m thick flows of aphyric or porphyritic lava, interlayered with volcanic xenolithic porphyritic lava and volcanic-wacke units. In this part of the sequence the flows are mainly laminar with only minor pillow lava flows. Thinly interbedded siltstone units usually overlie pillow flows, indicating spalling of the submarine lava flows.

Towards the top of the succession (around 367400/5264000), the volcanic units increase in proportion to sedimentary rocks and volcanic activity becomes more explosive (Plates 10–12). The volcanic flows consist of a variety of types, with three main varieties dominating. The first is vesicular lava with small phenocrysts and a fine to medium-grained groundmass; the second contains large zoned phenocrysts in a fine-grained groundmass; while the third contains andesitic xenoliths in a porphyritic, variable grainsize groundmass.

Thin sedimentary rock lenses occur between the pillow and laminar lava flows but not between the more explosively generated flow types, such as the volcanic xenolith-bearing porphyritic and volcanic breccia units. The sedimentary

Plate 10

Interbedded autoclastic breccia flows (up to 6 m thick) with thin, interbedded lava (50–150 mm) and sedimentary units (5–20 mm thick) at Christmas Cove (PH22; 3677600/52680000). Note irregular base on bottom right side and thickening of unit from left to right.

[Scale: Field assistant approximately 1.96 m tall]

Plate 11

Reworked autoclastic breccia unit in the upper part of the Cvs sequence at High Rocky Point (Mo530; 367400/5264000).

Plate 12

Close up of breccia unit at High Rocky Point (Mo530; 367400/5264000).

rocks interbedded with the pillow and laminar flows are dominantly volcanic crystal wacke, derived from broken phenocrysts of plagioclase and clinopyroxene, with a groundmass of fragmented andesitic lava clasts and secondary epidote, chlorite, sericite, quartz and pyrite alteration. The volcanic siltstone units (e.g. Mo502/1) have a devitrified snowflake texture superimposed on very fine plagioclase-rich glassy lavas that also enclose granular, anhedral clinopyroxene grains up to 0.35 mm across.

Cvv — interlayered extrusive porphyritic mafic volcanic rocks including pillow, sheet, volcanic xenolith-bearing porphyritic, volcanic breccia and autobreccia flows

The transition from Cvs into Cvv is sharp and observable around 367600/5264000, as well as along the southern shore of Hartwell Cove (around 368000/5267000 and in a small cove about one kilometre to the south at 368100/5266200). In all locations the contact is taken as the base of an approximately 500 m thick succession of interlayered extrusive sheet lava, volcanic xenolith-bearing porphyritic andesite flows, volcanic breccia and volcanic wacke units. This succession forms the prominent ridge from High Rocky Point north to Hartwell Cove, where it is fault off-set to the northwest and forms the coastal ridge to the north of Christmas Cove. The southernmost outcrops of this succession form the Montgomery Rocks (367300/5262700).

The Cvv sequence varies between large thicknesses of repeating porphyritic and non-porphyritic lava flows interlayered with thin pillow or sheet flows (100–200 mm), autoclastic breccia units and volcaniclastic sandstone beds with minor intercalations of volcanic wacke and siltstone (e.g. around 367600/5263300).

Autoclastic breccia flows typically contain blocks of porphyritic lava within a glassy, small feldspar-phyric groundmass, while some flows grade up into block free, flow-banded tops (367600/5263300). Areas of numerous interlayered pillow lavas are also common.

The overall nature of the Cvv sequence indicates an increase in explosive volcanic activity which swamped the sedimentary environment and produced the dominantly volcanic succession, with minor sedimentary units, by a combination of pyroclastic and epiclastic processes in a submarine environment.

The sand-grade to granule-grade volcaniclastic units contain grains of granular, stubby, clinopyroxene and plagioclase crystals up to 1–2 mm long, and clasts of lava with small phenocrysts in a devitrified glassy matrix. All the samples have undergone epidote, quartz, chlorite and sericite alteration. Some units are produced by an intermixing of pyroclastic and epiclastic processes resulting in a flow comprising angular fragments of broken, once euhedral, crystals of clinopyroxene (up to 4.5 1.5 mm) and altered plagioclase and clasts of porphyritic lava, in a groundmass of vesicular glass. The groundmass has been fractured and the glass altered to an intergrowth of a brown cloudy mineral along the fractures and green chlorite. Perlitic glass clasts are common in some areas.

The southernmost outcrops of Cvv are on the two islands that form Montgomery Rocks (Mo305). These islands are composed of a very thick pile of intermixed massive autoclastic volcanic breccia, without obvious bedding, that contains three textural and grain size varieties of lava similar to those already described above.

Cvl — dominantly lithic sandstone/wacke with interbedded laminated siltstone and mudstone

The transition at the top of the Cvv sequence (around 367900/5263100), as at the base, is relatively abrupt along at least six kilometres of strike, but gradational over approximately 50 metres of section. This change reflects the cessation of a major andesitic-dacitic volcanic phase and the beginning of a period of sedimentation with minor, distal beds derived from an acid volcanic source. The volcanic wacke and breccia units in the transitional zone are dominantly composed of the coarser-grained varieties of andesitic lavas including groundmass clasts and euhedral grains of clinopyroxene, some up to 3 mm across.

At Hartwell Cove (368500/5267000), just to the north of the Montgomery map sheet, the transition is marked by a sequence of black mudstone with interlayered, graded, medium-grained quartzwacke interbedded with a number of volcanic wacke and breccia flows. Some of the volcanic wacke units contain angular rip-up clasts of laminated black mudstone.

The lowest felsic volcaniclastic sandy-siltstone beds crop out just above the transitional boundary in the Hartwell Cove area (Mo492, 506). These horizons comprise irregularly packed glass shards, devitrified glass, fragmentary plagioclase crystals and minor angular grains (0.1–0.15 mm) of metamorphic quartz. The grains are partially recrystallised into a fine-grained quartzo-feldspathic mass, although good shard outlines are still observable under plain light.

The felsic volcanic derived unit is interbedded with lithicwacke beds composed of rounded grains of quartzite and micaceous quartzite, and angular grains of mudstone, devitrified glass, quartz, clastic mica and carbonate that contain water escape structures. The rock fragments dominantly range between 0.35 and 0.55 mm in size, but some are up to 1.0 mm across. The quartz grains are between 0.25 and 0.35 mm. Most of the quartz grains are of volcanic origin, having sharp to undulose extinction with some grains containing embayments.

Volcaniclastic siltstone beds, with a similar but more recrystallised texture to the massive glass shard unit described above, also occur on either side of an embayment to the west of the mouth of the Urquhart River (369300/5262500).

Progressing up through the sequence, from McGuire Creek (368100/5263300) east to the mouth of the Urquhart River (369700/5262100), the nature of the associated volcanism changes from that typical of Cvv to minor, thin, syndepositional dykes, sills and flows of hornblende phyric andesitic/dacitic lavas (Cmv) (Mo464) with sedimentary units (e.g. around 369200/5262500) derived from a distal rhyodacitic lava terrain.

Individual laminar and thinly bedded mudstone and siltstone are between one and three millimetres thick and form sequences up to 10–15 m thick. Turbiditic quartzwacke and granule conglomerate beds, often with their bases scoured down into underlying siltstone/mudstone beds are, on average, between 40 and 50 mm thick. The lower 20 to 25 mm of these beds are graded, with the upper part showing laminar bedding. Some of the thicker beds (50–60 mm) contain convolute folds or other irregular internal disruption features due to water escape. Interlayered minor fine to pebble-grade conglomerate forms beds or lenses between 400 and 500 mm thick.

Towards the upper part of the succession, around the mouth of the Urquhart River, the sand-grade units are more siliceous (higher percentage of quartz grains, lower labile component) than similar units within the sequence exposed along the shore platform south of Fletcher Creek to the Mainwaring River area.

The volcaniclastic sandstone and wacke units vary from individual beds, 2–5 mm to 3 m thick with a typical thickness of 1.0–1.5 m, to multiple flow units up to seven metres thick. The multiple flow units contain internal laminations and flow fabrics parallel to external bedding. The thinner beds (2–5 mm) are usually boudinaged within the laminated siltstone/mudstone sequence and have a cherty appearance. The thicker beds (>10 mm) have a snowflake texture and are very uniform in thickness for the extent of outcrop, which can be up to 50 m along the coastal platform. One three metre thick bed (Mo414) was followed across the floor of the bay for approximately 200 metres.

In thin section, typical units are poorly sorted and consist of angular grains of quartz (with sharp to undulose extinction, some with embayments), plagioclase, microcline, opaques (leucoxene), plagioclase, microcline and clastic epidote with a minor amount of quartzite, micaceous quartzite, mudstone, devitrified volcanic glass clasts and grains consisting of parallel intergrowths of white mica and chlorite. Some samples contain one or two grains of elongate (0.2 0.1 mm), semi-rounded zircon.

The groundmass component of the quartzwacke has recrystallised between and around the clastic components, especially in pressure shadows at the end of grains and along penetrative cleavage directions, into secondary fine-grained quartz and white mica (e.g. Mo425). Rock fragments vary in size. A typical sample (Mo401) contains rock fragments between 0.35 and 0.55 mm with quartz grains of 0.25 to 0.40 mm. Some samples have two populations of grains, one between 0.20 and 0.35 mm and the other between 0.45 and 0.7 mm. In finer grained samples (e.g. Mo426) the two populations of grains are between 0.15 and 0.25 mm and 0.35 and 0.45 mm. The interbedded sandy siltstone and siltstone beds are still finer versions of the sand-grade samples.

Granule conglomerate lenses and channel fill (e.g. Mo421*) consist of 1.0–4.0 mm clasts of fine to medium-grained muscovitic quartzite, medium to coarse-grained quartzite, mudstone, chert and large (up to 3 mm) quartz grains (some with undulose extinction, while other grains are sutured into sub-grains) and plagioclase-phyric andesitic lava clasts. Some clasts have a devitrified glass groundmass while others have a fine-grained mat of partially crystalline plagioclase. The majority of coarser than sand-grade samples dominantly consist of metamorphic rock clasts with minor amounts of volcanic-derived fragments (e.g. PH4/1*).

Numerous syndepositional sills and dykes of hornblende-bearing andesite intrude the succession. Some incorporate blocks of rip-up soft sediment, which were in a plastic state on incorporation as internal sedimentary features are preserved. The units generally vary in thickness between 0.5 and 3 m, but are usually between 1.0 and 1.5 m thick. At least three sills (around 371600/5254400, 371800/5254300 and 371000/5255500) are in excess of 50 m thick.

The southern area of Cvl, extending down the coast from Fletcher Creek (370500/5260000) to Abo Creek (375000/5249000) is very similar to that described above, with the exception that the syndepositional hornblende phyric andesitic-dacitic sills and dykes are more frequent and, in places (e.g. around 371000/5255500 and 371600/5254400), much thicker than in the northern area.

Cvc — pebble conglomerate and lithicwacke with interbedded siltstone

An area of graded granule to pebble conglomerate and lithicwacke with interbedded siltstone (Cvc) occurs along the coast between 372500/5251300 and the mouth of Abo Creek (375100/5248400). In places bedding is still undeformed but granule clasts are aligned with the compositional band forming cleavage (Plate 13). The conglomerate beds are dominantly composed of volcaniclastic material and are interbedded with wacke and siltstone beds derived from a similar source. One six metre thick, fine-sand grade unit (around 373700/5249500) is derived totally from a quartz crystal, vitric source.

This sequence also contains a zone of dominantly interbedded siltstone, with thin (5–15 mm) sand-grade lenses, that crops out along the coast from 373300/5250000 to 372900/5258000. The zone contains two sub-zones rich in crystalloblastic augen. The lower (western) sub-zone is eight metres wide, with the upper zone five metres wide. These two zones are separated by ten metres of interbedded fine to medium sand-grade wacke beds topped by laminated mudstone. In outcrop, the augen are red-brown discs and are usually between 2 and 3 mm in diameter and aligned along the main cleavage direction (Plate 14). In the upper portion of the lower sub-zone the spots reach 5 mm in diameter (Plate 15). In thin section the augens are siderite that occurs in a matrix of quartz, muscovite, chlorite and dolomite.

The southernmost exposures of the succession have been affected by a substantial tectonic deformation. This deformation totally destroyed sedimentary bedding and replaced it with a compositional banding. In places original mudstone units have been destroyed and become mudstone flakes within a tectonic conglomerate derived from a combination of the interbedded pebble to granule conglomerate, wacke, siltstone and mudstone.

Original pebble conglomerate units contain black mudstone rip-up clasts in a granule to sand-grade matrix of volcaniclastic wacke. Most of the beds are turbidite flows.

Plate 13

Graded granule conglomerate beds with clasts now aligned along cleavage, two kilometres northwest of The Shank (Mo333; 373300/5250000).

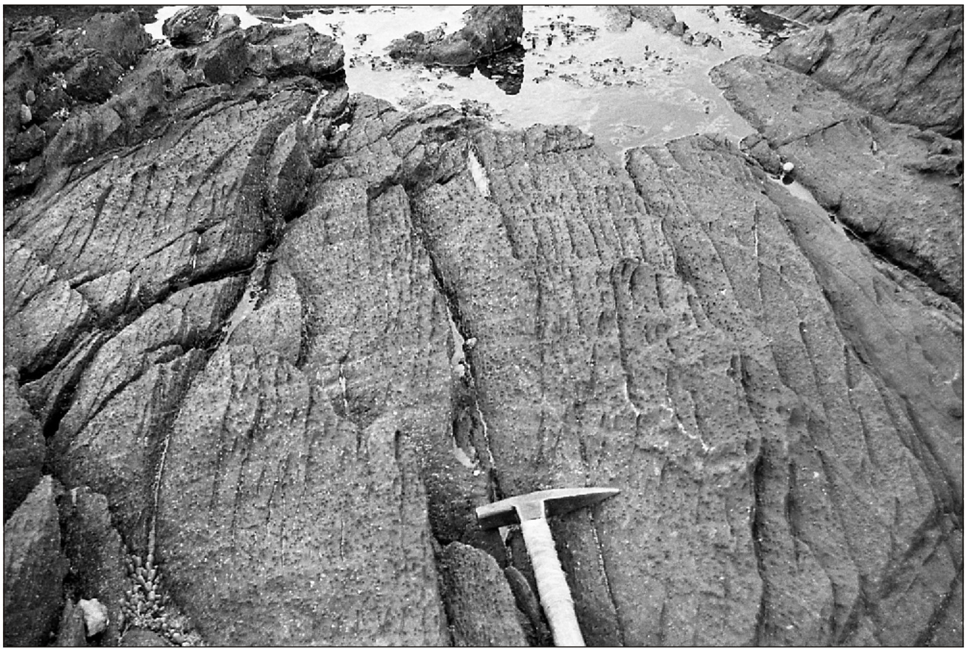

Plate 14

Siderite spots aligned in cleavage of folded sand-grade units, 2 km southeast of Mainwaring Inlet (Mo338; 373200/5250500).

Plate 15

Large (~5 mm diameter) siderite spots, 2 km southeast of Mainwaring Inlet (Mo338; 373200/5250500).

In some parts of the succession Bouma sequences are highly truncated, such that the sequence consists of repeated Bouma A units only. Most wacke and conglomerate beds are graded and from 100 to 900 mm thick. In some places the coarser units are overlain by up to 150 mm of cross-bedded siltstone and then up to 50 mm of laminated siltstone/mudstone, although in most places the cross bedded part of the sequence is missing (Plate 13). The wacke beds often have basal flame structures derived from underlying mudstone. Some of the fine-sand to coarse-silt grade beds, which are usually between 40 and 50 mm thick, contain liquefaction structures, including the formation of tear drop and roll shapes by the sand fraction.

In thin section, samples of all grain sizes are composed of a mixture of grains from both a sedimentary rock and felsic volcanic rock terrain. Overall, this sequence is derived from the same terrain as the Cvl succession, but due to faulted contacts, an exact stratigraphic position is not known.

Pebble and granule conglomerate in the southern part (around 374000/5248400, e.g. Mo44) of the sequence contains elongated and flattened clasts of mudstone and muscovitic siltstone, ranging in size from 4.0 0.2 mm to 7.0 0.25 mm, as well as volcanic quartz and quartzite grains and minor plagioclase, microcline and clastic mica (0.3–1.0 mm) in a recrystallised quartz groundmass with a mosaic texture (0.03–0.05 mm).

In the northern part (around 372700/5251200, Mo328), granule conglomerate units consist of sub-rounded clasts of quartzite, mudstone and recrystallised siltstone as well as clasts of various volcanic rocks (up to 4 mm) including fine-grained andesite, chlorite pseudomorphed boninitic lava with red-brown chrome spinel grains (up to 0.4 mm across), and intergrowths of altered plagioclase and leucoxene after an iron-titanium oxide mineral. Some samples are pervaded by secondary carbonate. Other samples contain very fine grained acicular pale green actinolite crystals in the recrystallised groundmass.

Wacke samples are dominantly composed of volcaniclastic material with minor sedimentary rock components and consist of angular and broken (0.4–0.5 mm) and sub-rounded (0.8–1.0 mm) embayed quartz and plagioclase grains with minor, angular, but flattened, rip-up mudstone, siltstone and devitrified volcanic glass clasts in a groundmass of recrystallised fine-grained mica and quartz. In thin section, the recrystallised groundmass gives these samples a schistose character (e.g. Mo45*). Other samples are dominantly derived from brecciated porphyritic andesitic lavas, and consist of single plagioclase grains, clasts of interlocking plagioclase laths with devitrified glass, and minor amounts of clastic quartz grains.

Cvt — volcaniclastic wacke and conglomerate (derived from andesitic lava flows) with interbedded laminated siltstone and mudstone

The uppermost sequence in the Cvu succession, Cvt, consists of volcaniclastic granule conglomerate, wacke and sandstone units with interbedded laminated siltstone and mudstone. The volcanic units vary in composition depending on the ratio of vitric, lithic and crystal components. Along the coast, between 370400/5260000 and 370000/5261100, the sequence consists almost entirely of volcaniclastic sedimentary rocks derived directly from plagioclase phyric, fine grained, probably dacitic lava, from a distal source.

In the Urquhart River section (between 370400/5262100 and 372200/5261800), the sequence dominantly consists of volcaniclastic sedimentary rocks derived from a mixed volcanic and metamorphic rock source, whereas in the upper reaches (from 372200/5261800 to 373300/5263200) laminated mudstone and siltstone with minor fine-grained sandstone and lithic wacke dominates the sequence.

Two lava units were encountered within the Urquhart River section. One (Mo464, 371300/5261700) is a 50 m thick clinopyroxene-plagioclase phyric andesite unit, petrologically and chemically similar to the lavas within the Cvv sequence. The other unit (Mo471*, 371700/5261800) consists of a crude graphic intergrowth of quartz and feldspar with opaque minerals, and has not been recorded elsewhere in the sequence.

In the coastal section (370000/5261100 to 370400/5260000) many of the volcanic sandstone, wacke and granule conglomerate units are graded, with clast sizes varying from 1.5 to 2.75 mm in the basal part to 0.25 to 1.0 mm in the upper part of 600 to 800 mm thick beds. Some wacke and conglomerate beds are up to two metres thick. The thicker units contain rip-up mudstone clasts and, in places, later flows disrupt earlier flows by channelling down into and then pushing the lower soft sediment into slump folds. Interbedded, 1–2 mm laminated siltstone and mudstone beds form up to 300 mm thick units between the volcanic wacke and conglomerate units.

In thin section, granule conglomerate beds from the coastal section are composed of a poorly sorted mixture of angular to sub-rounded clasts of plagioclase-phyric lava with groundmasses of various grain size: broken, altered and/or partially replaced plagioclase crystals; devitrified glass and minor embayed quartz grains; and irregularly-shaped patches of chlorite and rip-up mudstone clasts. Clasts in the basal part of graded conglomerate beds range in size from 1.0 to 6.0 mm (Mo406/1). The larger clasts are of rock fragments, mainly mudstone. In the upper part of the conglomerate units the grain size is finer (0.25–1.0 mm), with the constituent grains being angular and dominantly composed of devitrified volcanic glass and fragments of brown hornblende crystals up to 1.5 mm across, rather than plagioclase phyric lava fragments.

Volcanic wacke beds contain angular clasts and grains of devitrified glass, plagioclase, hornblende, clastic chlorite and muscovite intergrowths, and mudstone clasts in a groundmass of recrystallised, fine-grained, quartzo-feldspathic material with intergrowths of muscovite, acicular pale green actinolite and secondary carbonate (Mo410). Mineral grains vary from 0.1 to 0.2 mm across and rock fragments between 0.2 and 0.4 mm. Finer grained wacke units are composed of a minor amount of altered plagioclase grains and devitrified volcanic glass fragments (0.08–0.1 mm) in a rock dominantly composed of broken and flattened glass shards (Mo408*, 370300/5260200).

In the Urquhart River section some of the granule conglomerate and volcanic wacke units have been derived from a mixed source of plagioclase-phyric andesitic or dacitic lava, crystal vitric lava and metamorphic rocks. Some beds are derived from plagioclase-phyric andesite only, similar to the coastal rocks. Other units are quartz wacke, very similar in grain size and composition to the quartz wacke units within the Cvl sequence (e.g. Mo460).

The mixed source granule conglomerate units are poorly sorted, and contain angular to sub-rounded clasts of plagioclase-phyric fine-grained andesitic lavas; shard-bearing, crystal vitric lava; devitrified volcanic glass; large 0.75–1.25 mm embayed quartz grains; and 1.0–1.5 mm clasts of quartzite, micaceous quartzite, mudstone and muscovite. One sample, typical of the mixed source granule conglomerate beds (Mo453/1*, 370400/5262100) is overlain by a bed of volcanic wacke composed of angular, broken, volcanic quartz fragments (0.15–0.25 mm), devitrified glass and quartzite clasts (0.35–0.45 mm) with a dominantly glass shard matrix (Mo453/2*).

Cfv — felsic volcanic rocks, dominantly quartz phyric, and associated volcaniclastic sandstone and minor interbedded siltstone and mudstone

Along the eastern edge of the map sheet, to the east and south of the Evu succession, a succession of highly tectonised, now dominantly mylonitised, felsic volcanic and interbedded sedimentary rocks occur. In the area covered by the Montgomery map sheet the succession originally consisted of quartz-phyric, felsic volcaniclastic sandstone interbedded with quartz-plagioclase-chlorite/leucoxene (pseudomorphs after hornblende) phyric lava flows, siltstone, mudstone and minor carbonate beds.

Exposures around 377300/5257600 consist of tectonically deformed plagioclase embayed quartz crystal-rich volcanic rocks that have been altered to phyllitic and schistose rocks. Some samples (e.g. Mo284) were derived from plagioclase-phyric andesitic lava. These samples now contain flattened and elongated areas of chlorite and epidote, as well as euhedral and broken clinopyroxene and plagioclase crystals with anhedral to subhedral grains of leucoxene after iron-titanium oxide minerals. Chlorite grains show light green to dark green or light brown pleochroism and the anomalous 'Berlin Blue' extinction colour, indicating penninite. The groundmass is a semi-recrystallised mat of quartzo-feldspathic material.

Other tectonised rocks in this sequence contain both quartz and plagioclase crystal grains, within a recrystallised quartzo-feldspathic groundmass (e.g. Mo285*). The quartz crystals are felsic volcanic derived, broken, subhedral to euhedral and contain numerous embayments. A third variety of tectonised volcanic rock forms an irregularly banded green and white schist which, in thin section, consists of alternating irregular bands (1–2 mm) of actinolite, epidote and chlorite (green) and recrystallised quartzo-feldspathic (white) intergrowths (e.g. Mo286).

The rocks mapped as Cfv in the upper reaches of the Mainwaring River (around 377200/5253500) were dominantly acid volcanic lavas, most probably of dacitic to rhyolitic composition. These again have been tectonically altered to phyllite or schist. The majority of the samples from this area show extensive shearing and polygonisation of quartz grains (e.g. Mo553*). In thin section, pressure shadows at either end of large quartz grains contain small areas of devitrified volcanic glass. Embayed quartz grains range in size from 1.0 to 1.5 mm, with the least deformed being fractures and having undulose extinction. The groundmass of phyllite-schist samples is an intergrowth of muscovite surrounding fragmented, embayed quartz grains. Overall, the rocks in the river section are now a well foliated biotite-quartz-muscovite phyllite-schist.

The few un-tectonised felsic volcanic rocks encountered in an area mapped as Cfv occur in the upper reaches of Sassy Creek (Mo156). This sample is a quartz-feldspar phyric lava with a devitrified glass groundmass. The quartz phenocrysts occur as single crystals, up to 2.0 mm across, whereas plagioclase and the chlorite/leucoxene pseudomorphs of hornblende(?) occur both as single crystals and in glomeroporphyritic patches. These patches are up to 4.0 2.5 mm and consist of roughly 0.5 mm equant plagioclase grains. Some of the chlorite/leucoxene intergrowths have subhedral crystal cross sections consistent with original hornblende. The groundmass is partially recrystallised, but remnant feldspar microlites are still recognisable in a dominantly cryptocrystalline quartzo-feldspathic matt. Similar rocks crop out over the next 200 m of the creek section. Most outcrops are featureless, but some show a well developed foliation.

The coastal exposure of the western contact of the Cfv sequence with rocks of the Evu succession (around 376800/5245200) is a fault, locally known as the 'Copper Creek Fault'. Just to the east of the contact, and for at least 300 m south (from 376800/5245200 to 376800/5244900), a series of parallel faults dipping between 60° to 65° west and striking 160° to 180° cut the felsic volcanic sequence and produce mylonitised versions of the original quartz-plagioclase lava and associated volcaniclastic sandstone, wacke and siltstone sequence.

Samples from the contact on the beach are partially recrystallised, deformed, quartz-feldspar phyric lava (Mo40*). The volcanic quartz grains are up to 1.0 mm across, have undulose and sweeping extinction, and the groundmass is partially recrystallised quartz and feldspar (0.01–0.015 mm) with minor secondary carbonate, mica and stringers of deformed opaque grains. Some samples also contain remnant plagioclase grains (0.1–0.3 mm). The plagioclase-phyric lavas contain phenocrysts between 0.75 mm and 2 mm in length, and skeletal areas of leucoxene/limonite with secondary carbonate, in a groundmass of partially recrystallised quartzo-feldspathic material with secondary, white and pale green micas and carbonate.

Similar rocks occur along the coastal section to the south. Some samples of altered volcanic rocks (e.g. Mo39, 376800/5245100) contain elongate fragments of earlier quartz veins, as well as secondary epidote and chlorite. Other samples (e.g. Mo38/2, 376800/5244000) contain larger quartz (0.5–2.0 mm) and plagioclase (up to 1.0 mm) phenocrysts with accessory subhedral grains of apatite

(0.15   0.5 mm) in a partially recrystallised groundmass of quartz and pale green to pale brown pleochroic mica. At the southern end of this zone a typical volcanic-derived sample (Mo37*, 376800/5244900) consists of volcanic quartz grains ranging in size from 1.0 to 4.0 mm, with the smaller grains containing undulose extinction and the larger grains being fractured into sub-grains and containing sweeping extinction, and fragments of recrystallised quartz veins within a groundmass of very fine-grained (0.01–0.015 mm) quartz and colourless and pale green to pale brown pleochroic fibrous mica with patches of secondary epidote and stringers of limonite and fragmental pyrite grains, all aligned within the dominant foliation. Within this area, tectonism is also responsible for originally interbedded mudstone units now occurring as 25 m long lenses ranging from 10–50 mm to 1.5 m in thickness within foliated volcanic units.

Inland of the coastal section, both outcrop and individual samples exhibit a higher degree of tectonic deformation and a greater degree of recrystallisation within the groundmass; for example, areas of cryptocrystalline groundmass quartz between 0.02 and 0.04 mm occur, compared to the usual 0.01 to 0.015 mm. Some samples (Mo64) exhibit a greater degree of brecciation of the quartz crystals and have a larger percentage of the groundmass formed by mica rather than recrystallised quartz. Compositional banding within the sequence around 376900/5245200 is accentuated by green mica-rich and mica-poor bands interbanded with brecciated volcaniclastic units, some of which are up to two metres thick.

A small, roughly elliptical body of a fine-grained, small feldspar phenocryst granitoid (Cbt) intrudes the Cfv sequence around 377400/5244700. Because of poor outcrop, the precise nature of the boundary between the volcanic rocks and the granitoid body is uncertain, although the existence of hornfelsed screens of volcanic rocks (Cbgs) along the boundary of the Clv succession and the granitic rocks (Cbg) just inland from Schist Point (around 377300/5240700) indicates an intrusive relationship.

In the area south of the granitoid (Cbt) to the Lewis River, the Cfv sequence consists of well layered felsic lavas with minor amounts of interbedded black mudstone, green siltstone and carbonate rocks. In some areas the tectonic deformation has produced compositional banding within the volcanic rocks as well as irregular shaped areas of carbonate and green siltstone lenses that contain rootless isoclinal folds (e.g. around 377100/5243600). In thin section, most samples are tectonised versions of quartz phyric lavas that contain subsidiary apatite and opaque oxide grains and similar grain size, internal deformation and recrystallisation characteristics to the samples described above.

The sequence to the south of the Lewis River consists of felsic lava interbedded with volcaniclastic quartzwacke, some of which contains rip-up fragments of green siltstone (up to 500 mm long, around 377200/5243000) and siltstone. Volcanic wacke samples are partially recrystallised (Mo177/1) and have a schistose character in hand specimen, with the siltstone units altered to chlorite-mica phyllite (Mo177/2).

Structurally controlled, disseminated sulphide with copper mineralisation is prevalent throughout the old pit at Penders Prospect (377200/5242000). Detailed descriptions of this area can be found in Strickland (1978, 1979).

The tectonic deformation that formed the compositional banding becomes more intense to the south of Penders Prospect. Compositional banding is the dominant fabric element on Black Island (376700/5241300), although remnant areas of igneous layering–flow banding and sedimentary rocks occur.

The southeastern contact of the felsic lava sequence with the Low Rocky Cape granitic body is relatively straight but obviously intrusive, as the felsic volcanic rocks show the effects of thermal metamorphism. To the south of the contact (around 377300/5241000) there is a roughly rectangular area (800   300 m) where the granitic rocks contain remnant screens of the volcanic sequence (Cbgs). Both of these features indicate that the granitoid is intrusive and thus younger than the felsic volcanic rocks.

Rocks on the access track traverse across the thin strip of Cfv on the eastern side of the Montgomery quadrangle (between 377200/5258000 and 377200/5253000) comprise interbedded volcaniclastic phyllite, wacke and sandy siltstone. Tectonic modification of the original igneous rocks is such that original layering has been destroyed and a compositional banding formed, giving the rocks a phyllitic character. The compositional banding in this area formed at between 20° and 40° to the original bedding and in places could be confused with bedding.

Following later mapping of the area, carried out during the Mount Read Volcanics Project, the northern area of this succession (as shown on the Mainwaring 1:25 000 scale map sheet along the Cypress Creek access track west of where it crosses the upper Mainwaring River at 377900/5257800 and south below the Mainwaring River traverse between 377000/5253600 and 377200/5253700) is now described as a 'mixed sequence of volcano-sedimentary, sedimentary and volcanic rocks ranging from felsic to andesitic in composition (Cdsv)' and is correlated with the Western Volcano-Sedimentary Sequence of the Mount Read Volcanics in the Queenstown area (Pemberton *et al.*, 1991; Seymour and Green, 2003*a–d*; Corbett, 2004).

The lower area of Cfv, shown on the Mainwaring 1:25 000 scale map sheet in the upper reaches of Sassy Creek (around 377700/5246700), is now described as 'dominantly felsic volcaniclastic rocks, well bedded to massive, includes sandstone, siltstone, minor conglomerate, probable pyroclastic rocks and minor felsic lavas (Cdqvc)' that are correlated with the Eastern Quartz-phyric Sequence of the Mount Read Volcanics to the north of Queenstown. These descriptions of the sequences ignore the mylonitised nature and tectonic destruction of the original succession.

Tertiary

Ts — interbedded, partially consolidated sand, silt, clay and gravel

Bedded sediments belonging to southwestern part of the Tertiary infill of the Macquarie Harbour graben occur in the far northeastern corner of the Montgomery map sheet. Outcrop is restricted to deeply incised creek gullies within the succession. The surface deposits are residual sand and gravel derived from weathering of the underlying sediments, now covered by low scrub. Sand-grade and finer beds are usually a white colour and are monotonously bedded without any distinctive feature. Gravel beds are granule to cobble grade with the clasts being dominantly of well-rounded, grey, white or pink, massive or foliated quartzite with minor red or grey chert. Bedding appears lensoidal, but because of poor outcrop only small sections were observed.

Quaternary

Qra — alluvium, beach sand, river flood plains

Beach sands are restricted to the mouth of Sassy Creek and to the shore platform to the northeast of The Shank. A small sandy beach also occurs at the inland end of Mainwaring Inlet (372800/5252300). A well developed floodplain with alluvium and log jams covers outcrop in the middle reaches of the Mainwaring River. Sandy beaches occur at Hartwell Cove (368600/5267000) and Christmas Cove (368200/5268200) to the north of the map sheet.

Qs — stabilised sand deposits including dune sand

At the back of the shore platform, for about two kilometres to the northwest of Abo Creek, a well stabilised dune system has developed over the remnants of an old raised beach. On the western side of the mouth of Abo Creek (375100/5248400) the dune system has been breached by erosion and large scale cross bedding can be seen within the dune.

Qms — older marine sands and raised beach deposits

Remnants of older sand dunes occur in three locations in the vicinity of High Rocky Point. The base of all three deposits is the local country rock (Cvu) but at a level 15–20 m higher than present mean sea level. One of the deposits (at 367500/5264700) contains cross bedding indicative of aeolian conditions and is now partly protected by vegetation (Plates 16, 17). The other two deposits (at 367800/5263200 and 369200/5262600) occur in saddles behind the present shore platform, while remnants of an old beach horizon exists approximately 15 m higher than present sea level along the back of the present shore platform.

Plate 16

Semi-consolidated sand dunes on an old beach level over 15 m above present sea level at High Rocky Point. In the foreground is another old beach level at two metres above present sea level (Mo526; 367700/5263800).

Evidence of old raised sea levels can also be found in a number of localities along the coast between High Rocky Point and Low Rocky Point. At numerous other points along the coast, present day sea caves have roofs of semi-consolidated talus deposits within a soil profile. The base of all these deposits is approximately ten metres above present mean sea level. Most of the large sea caves are roofed by semi-consolidated material belonging to this old level (Plate 18) . If the old soil/scree horizon is less than one metre thick the sea cave roof has collapsed. Where thicker, and most are between 1.5 and two metres thick, angular blocks up to 200 mm across, in flat section, hang from the roof.

Plate 17

Close up of old sand dunes at High Rocky Point (Mo526; 367700/5263800) shown in Plate 16.
[Scale: Field assistant approximately 1.8 m tall]

Plate 18

Two different gravel horizons representing old beach levels at Hartwell Cove (Mo494; 368500/5267000). The base of the lowest horizon is now ten metres above present sea level. The lower (darker) zone is partially solidified and hard enough to roof sea caves if over one metre thick. [Scale: Field assistant approximately 1.8 m tall]

STRUCTURAL GEOLOGY

Stereographic plots of structural data were plotted for each of the fault-bounded rock sequences depicted on the map. Following comparison of these plots, areas with similar results were amalgamated and three structural domains (SD) were defined (fig. 3–7). These domains correspond to the three main volcano-sedimentary successions mapped (SD1 = Cvu, SD2 = Evu, SD3 = Cfv) and are based on the fact that the dominant penetrative foliation, associated compositional banding, and some crenulation cleavages are similar in orientation within each domain but have been later rotated between domains. At least three later phases of cleavage formation, associated with chevron folds and kink band deformation, are consistent in orientation across all three domains.

Of the six phases of deformation identified, phases one to three are considered to have been due to tectonic activity in the Cambrian period which included thrust and major strike-slip faulting as well as folding. The later three (plus?) deformations are considered to have been formed during the Middle Devonian Tabberabberan Orogeny.

The boundaries between each of the three structural domains are major thrust or fault systems. Rocks along the boundaries of each domain are intensely sheared and in most places the country rock has been tectonised into a schistose fabric with fragments of the original coarser grained rock material as porphyroblasts. These have been rotated and now have asymmetric pressure shadows due to later recrystallisation.

The most highly deformed area on the Montgomery map occurs at the southern end of SD2 and crops out between The Shank and Sassy Creek. Here the faulted margins between the three structural domains almost coincide. In this area the later three deformational events, that form chevron folds and kink bands, reactivate and modify earlier structures formed during deformation phases one and two.

The original physical relationship between the three successions is not known, but from a stratigraphic point of view the Neoproterozoic(?)–Early Cambrian(?) Evu succession is the oldest, followed by the andesitic-dacitic Cvu succession and then the dominantly dacitic-rhyolitic Cfv succession. The latter two successions are of Late–Middle to Late Cambrian age and are correlates of the Mount Read Volcanics succession of western Tasmania.

Following a review of this section, Professor Mike Hall, Adjunct Research Fellow, School of Geosciences, Monash University, commented that the deformation sequence for each domain, although similar, does not explain the fact that the central zone (Mainwaring Group, Evu) would have been involved in the Tyennan Orogeny and thus would be (significantly?) more deformed than the rocks in the belts on either side (Cvu and Cfu). A puzzling feature is the lack of recognition of refolding by tight upright folds, and thrust sheets, similar to those commonly seen within Tyennan sedimentary and metamorphic rock successions further to the west and southwest. Because of these comments it is obvious that at least the coastal area, especially between Mainwaring River and south to the Copper Creek fault (Sassy Creek area), needs to be remapped by a specialist structural geologist to allow the complexity of the tectonic history of the Cambrian successions in this area to be fully understood.

Structural Domain 1 (SD1)

This encompasses the succession of andesitic and dacitic lavas and associated sedimentary rocks (Cvu, fig. 3) that crop out along the majority of the west coast of the map sheet (correlate of the Noddy Creek Volcanics). The first phase of deformation produced isoclinal folds, with bedding-parallel cleavage (Plate 19). The dominant second generation structures trend 160–340°. In SD1, large-scale folding is the dominant observable fold phase of D_2 (Plates 20–22). The plunge of these folds is steep in the northern part of the map sheet (~80°) but shallower (50–60°) in the southern part. The second foliation (S_2) is a crenulation cleavage in mudstone and some siltstone beds, whereas in sandstone and coarser grained units the morphology of this cleavage is a penetrative surface and due to diffraction could not be told apart from S_1. In some zones this foliation disrupts bedding and forms the first and dominant compositional banding event (Plates 23, 24).

SD1 can be split into two sub-domains; one encompassing the volcano-sedimentary sequences (Cvs and Cvu) and the other the dominantly sedimentary sequences (Cvl, Cvt, Cvc). Bedding in the Cvv and Cvs sequences faces and dips east in the northern part of the Montgomery quadrangle, but in the southern part of the Point Hibbs quadrangle, from between 5264000 mN and 5265000 mN and to the north and south of the Christmas Cove–Hartwell Cove area, the sequences are overturned and dip to the west. Neither the isoclinal nor large-scale folding that are prevalent within the associated sedimentary sequences to the south were observed in the Cvs or Cvv sequences. As the bedding plots for these two sequences have single maxima, the overturning is probably due to faulting and/or thrusting rather than folding. When bedding data for all sequences are combined the resultant girdle pole is basically identical to that for the bedding in the sedimentary sequences only (52° to 346° compared to 54° to 344°), suggesting that there may be some component due to folding.

Structural Domain 2 (SD2)

SD2 occurs to the east of SD1 and encompasses the picritic to tholeiitic basalt and associated sedimentary rock succession (Evu, fig. 4; Mainwaring Group) that occurs in the central part of the Montgomery quadrangle. In this domain the strike of the main penetrative cleavage (000–360°) is rotated 20° to the west compared to SD1. Airborne magnetic data indicate that this succession is highly faulted and continues to the north of the Montgomery quadrangle, under Tertiary sediment cover, along the eastern side of the Point Hibbs quadrangle to the southeastern corner of the Macquarie Harbour quadrangle where it crops out along the western side of Birchs Inlet.

The first deformation (D_1) observable in this succession formed isoclinal folding with bedding-parallel cleavage. The second deformation (D_2) refolded the isoclinal folds and is easily observed in interbedded siltstone, mudstone and carbonate beds associated with picritic basalt flows and dykes in the Diorite Point area, and within similar sedimentary units between tholeiitic basalt flows inland (fig. 8). The strong foliation associated with D_2 is variably expressed as a penetrative cleavage, compositional banding, or a crenulation cleavage (fig. 9).

Isoclinal folds (F_1) are commonly offset along the axial surface cleavage (S_1) and in places rootless isoclinal folds occur between mylonitised zones or compositional banding (S_2). In places the crenulation cleavage/compositional banding (S_2) is refolded by up to three generations of later chevron folds or kink bands with a northeast to easterly trend (040°; 065°, 090°). Remnant bedding, parallel to the limbs of the isoclinal folds, is usually only observed where there is greater than ten to fifteen degrees separation from compositional banding.

Structural Domain 3 (SD3)

In the third domain (Cfv, correlate of the Lewis River Volcanics) the main penetrative cleavage and first compositional banding are rotated in strike a further 20° west from SD2 to around 010–190°. SD3 encompasses the felsic volcanic and associated sedimentary rocks along the eastern side of the Montgomery quadrangle (Cfvu). These rocks comprise the western margin of the Mount Read Volcanics correlate to the east of the Montgomery quadrangle.

On the Montgomery map the dominantly laminated siltstone/mudstone with minor carbonate sequence (Evsc) and the dominantly siliceous pebbly sandstone/sandstone with minor siliceous pebble conglomerate (Evss) are shown as part of the Neoproterozoic Evu succession. Later mapping, during the Mount Read Volcanics Project, showed these sequences as part of the felsic volcanic Mount Read Volcanics correlates in the Elliot Bay area. When structural data from the Cfvssc (fig. 6) (shown as Evsc and Evss on the Montgomery map) and Cfv (fig. 7) sequences are plotted together (Cfvu; fig. 5) similar results are obtained but with the intriguing result that bedding has a single cluster while both the penetrative foliation and compositional banding show partial girdles (60° to 300°) implying folding. Even though the structural data are similar, a block rotation of 10° appears to have occurred between Cfvssc and Cfv before the later three phases of chevron/kink band and later crenulation cleavage formation. It is these later phases of deformation that are considered to have modified earlier penetrative cleavage and compositional bands. Kink bands in this domain are dominantly 60NW/040.

The effect of the deformation that formed the first crenulation cleavage and compositional banding is very evident in the Diorite Point–Sassy Creek area, where siltstone, mudstone or carbonate units were originally interbedded with the volcanic rocks. Outcrops of the Evu sequence at the mouth of Copper Creek consist of tectonic pebble to cobble conglomerate with the clasts aligned parallel to the dominant tectonic surface which produces the compositional banding. This is then further deformed by later chevron folds associated with kink bands (Plates 27, 28).

A later phase of compositional band formation, associated with crenulation cleavage that formed during one of the deformations that produced kink bands, is well exposed in the area to the southeast of Sassy Creek (around 377000/5245400).

Synthesis

Structural features observed in outcrop, together with data from the stereographic projections, suggest an overall structural history for the three domains. This involved:

- **D_1**: The production of isoclinal folds with a bedding-parallel cleavage. The cleavage is not always obvious in the field and is only clearly apparent where the later (D_2) dominant penetrative cleavage is oblique (over 20°) to it. Later deformation in domains SD1 (Cvu) and SD2 (Evu) produced extensive areas of rootless and monoclinal isoclinal folds bounded by zones of mylonitised rock. Whether D_1 is the result of one or more than one tectonic event could not be ascertained, but with the high degree of deformation associated with the cleavage more than one co-axial deformation may have occurred.
- **D_2**: This event produced both decimetre-scale tight to isoclinal folds and 100 m plus scale open folds. Generally one limb of isoclinal folds has been sheared out. Strain partitioning has produced local zones of intense transposition along the axial plane cleavage that results in the formation of compositional banding. In the low strain zones folds are open to tight and have an axial plane penetrative cleavage. The D_2 folds have only been observed in outcrop in the Cvu succession (SD1), but the D_2 cleavage occurs in all three structural domains.

  In some places the D_2 cleavage is intense enough to deform primary bedding into a compositional banding. When this cleavage is at an angle greater than 20° to bedding and in fine-grained sedimentary rocks, it forms a crenulation cleavage. Within SD2 a common feature of the deformation is for small-scale fold closures to be detached from their limbs by the bounding schistosity.
- **D_3**: Major regional juxtaposition of the three successions, with the Evu succession being up-thrusted between the Cvu and Cfu successions and sliced into numerous fault slices with a steep westerly dip and NNW–SSE strike. This phase of deformation also produced the one to two kilometre wide deformation zone to the east of the Montgomery map presently designated as a correlate of the Western Mount Read Volcanics volcano-sedimentary succession.
- **D_4**: This deformation produced chevron folds and kink bands with an associated well developed cleavage that occurs as either a penetrative cleavage in coarse-grained units or a crenulation cleavage in finer grained units. Structural orientation is the same across all three domains and varies between 020° and 040°, with the 040° direction being dominant. In certain areas this cleavage has also produced a second transpositional

banding, resulting from both original sedimentary bed deformation and reorientation of previously formed compositional banding.

- **D_5**: A deformation that produced a second phase of chevron folds/kink bands. The trend is between 050° and 060°. The deformation is observed because it has folded the compositional banding or crenulation cleavage formed in D_4.
- **D_6**: The third phase of chevron fold/kink band deformation produced an anastomosing system of two synchronous cleavages trending 110° and 140°. It is intensely developed in localised areas. These structures are dominantly found within SD3 (the felsic volcanic succession, Cfv) but also occur within SD2 (Evu succession) as kink bands.

In summary, overall field relationships and structural data indicate a minimum structural history of:

- Phase1 — Isoclinal folding with the development of a penetrative cleavage parallel to bedding. This is well developed in SD1 and SD2 but may be due to a different deformational event.
- Phase 2 — Outcrop-scale tight to isoclinal folding (Plates 7, 19) and larger-scale open folding with a steep, westerly dipping axial surface cleavage (Plates 20–22), which is commonly a penetrative surface but is also recorded as a crenulation cleavage in finer grained beds. In some places, where the deformation was more intense, isoclinal folds become rootless (Plates 23, 24; fig. 8, 9), or highly deformed (Plate 25), with some parts of the sequence having undergone boudinaging of compositional banding following total destruction of bedding (Plate 26).
- Phase 3 — A phase of major regional juxtaposition along the bounding faults/thrusts of the main structural domains, rotating each of the domains (Cvu, Evu, Cfvu) relative to each other and possible causing some rotation of the sedimentary sequences within domain SD3 (Cfvssc) compared to the volcanic sequence Cfv).
- Phase 4 — Chevron folding associated with kink bands. The axial surface foliation generated during this phase is usually present as a crenulation cleavage across the first transposition/compositional banding surface, but in places forms a second compositional banding (Plate 27).
- Phase 5 — Chevron folding and associated kink banding that folds or crenulates the second compositional banding (Plate 28).
- Phase 6 — Late stage deformation associated with a phase of kink banding that produced a spaced crenulation cleavage that cross cuts all other cleavages in SD3 (Plate 29).

Structure	SD1 — Cvu	Variation	SD2 — Evu	Variation	SD3 — Cfv
Isoclinal folds observed	Yes		Yes		No
Penetrative foliation	86W/155	+15°	86W/170	+20°	63W/010
Compositional banding	80W/150	+20°	60W/170	+20°	70W/010
Main kink band directions	60W/050		52W/050		60NW/030

Kink band sets: ~50W/040–060 (in both SD1 and SD2)
~45W/090– 10 (in both SD1 and SD2)
~55W/145 (in some places in SD2 only)
~60W/020–040 (dominant in SD3)

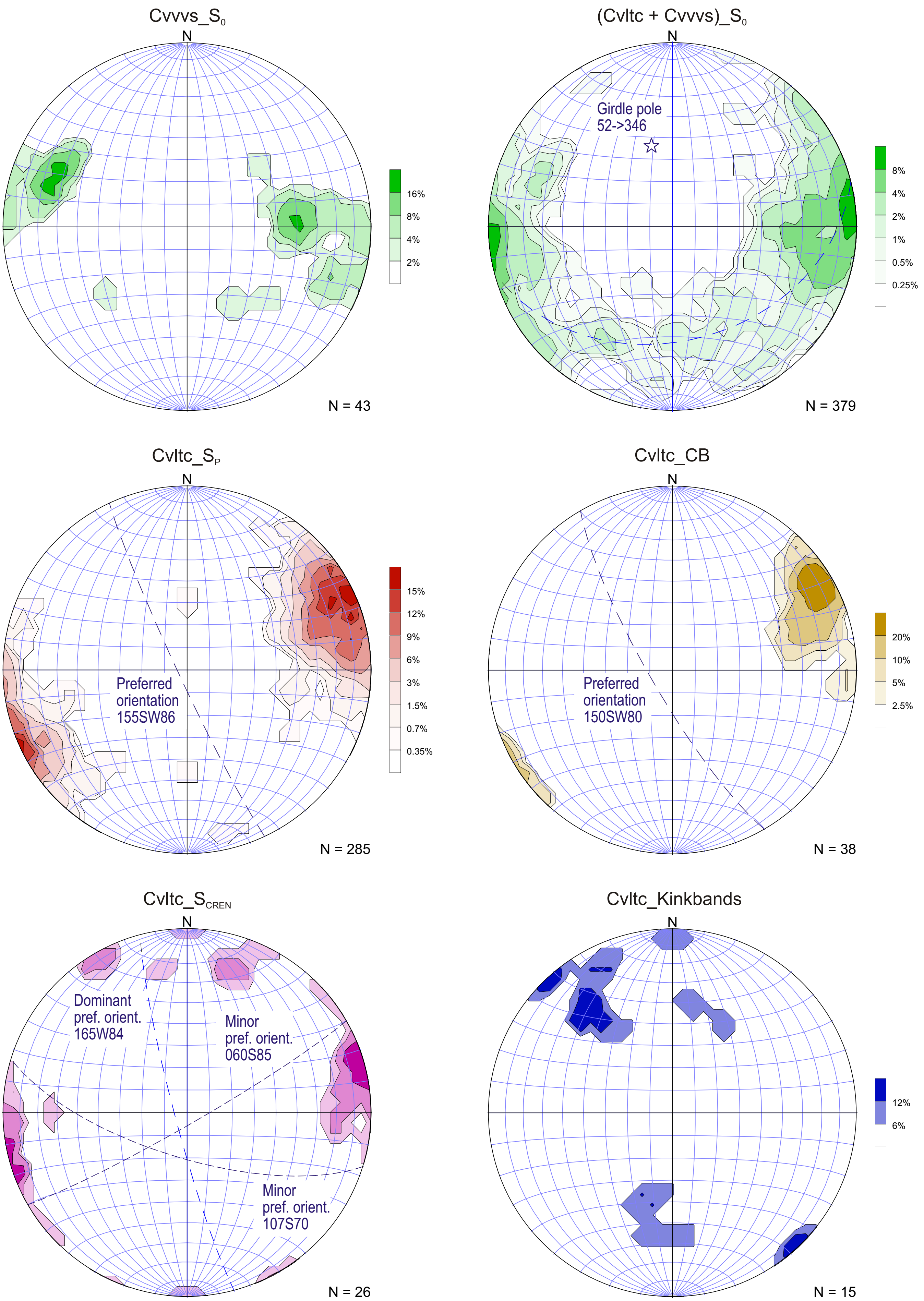

Figure 3

Structural Domain I — Cvu succession

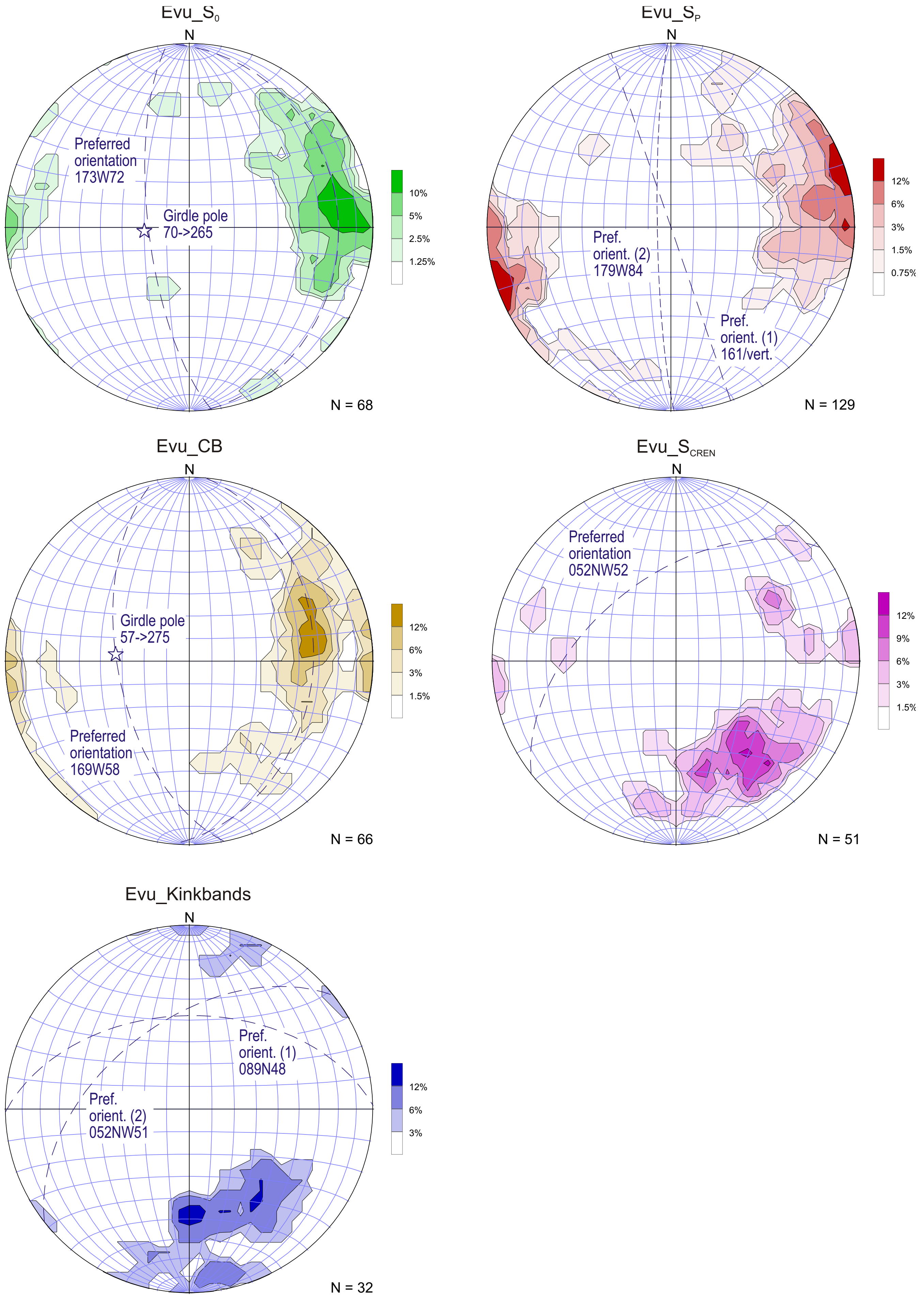

Figure 4

Structural Domain 2 — Evu succession (Mainwaring Group)

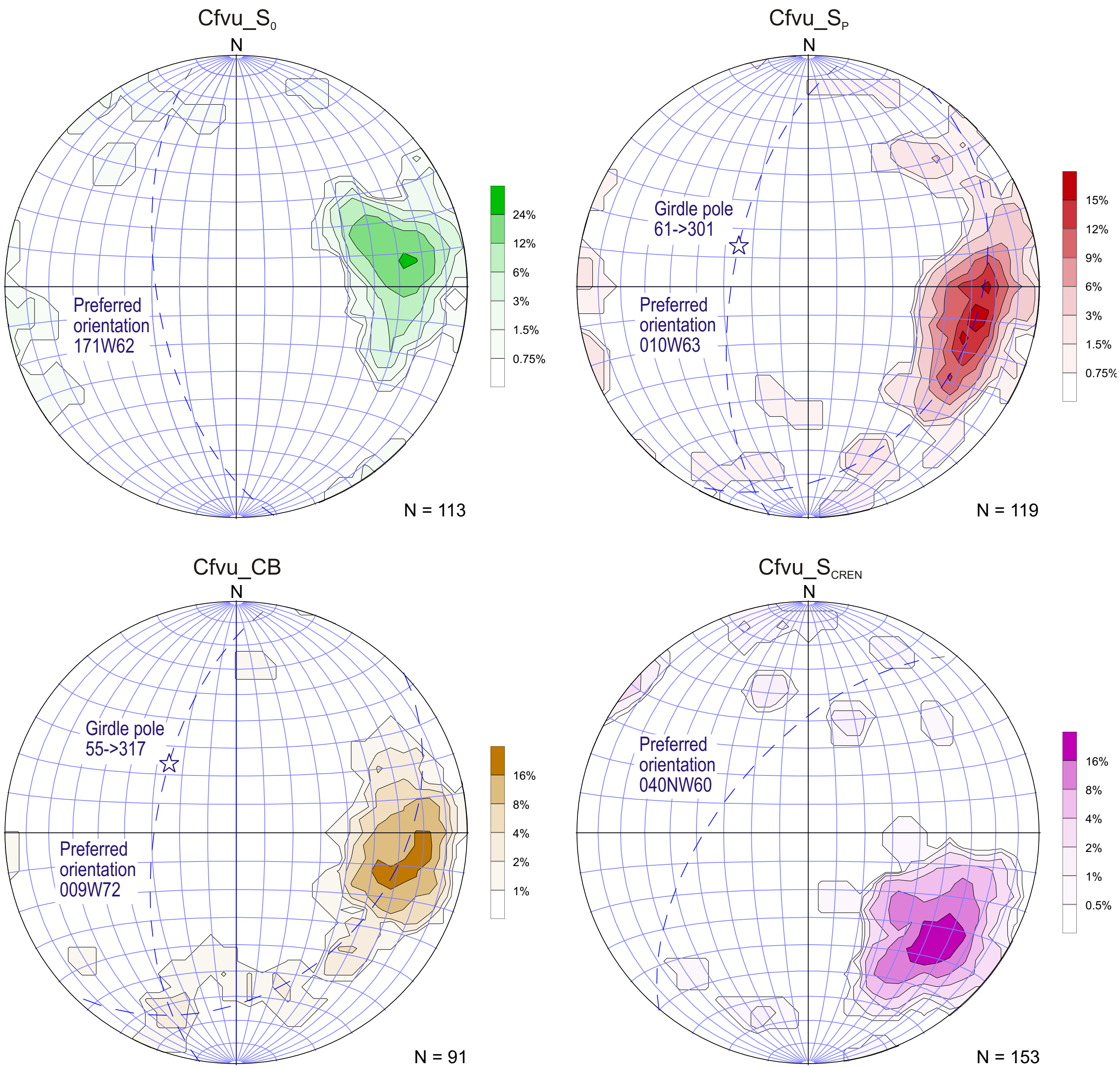

Figure 5

Structural Domain 3 — Cfvu succession – combined volcanic and sedimentary rocks

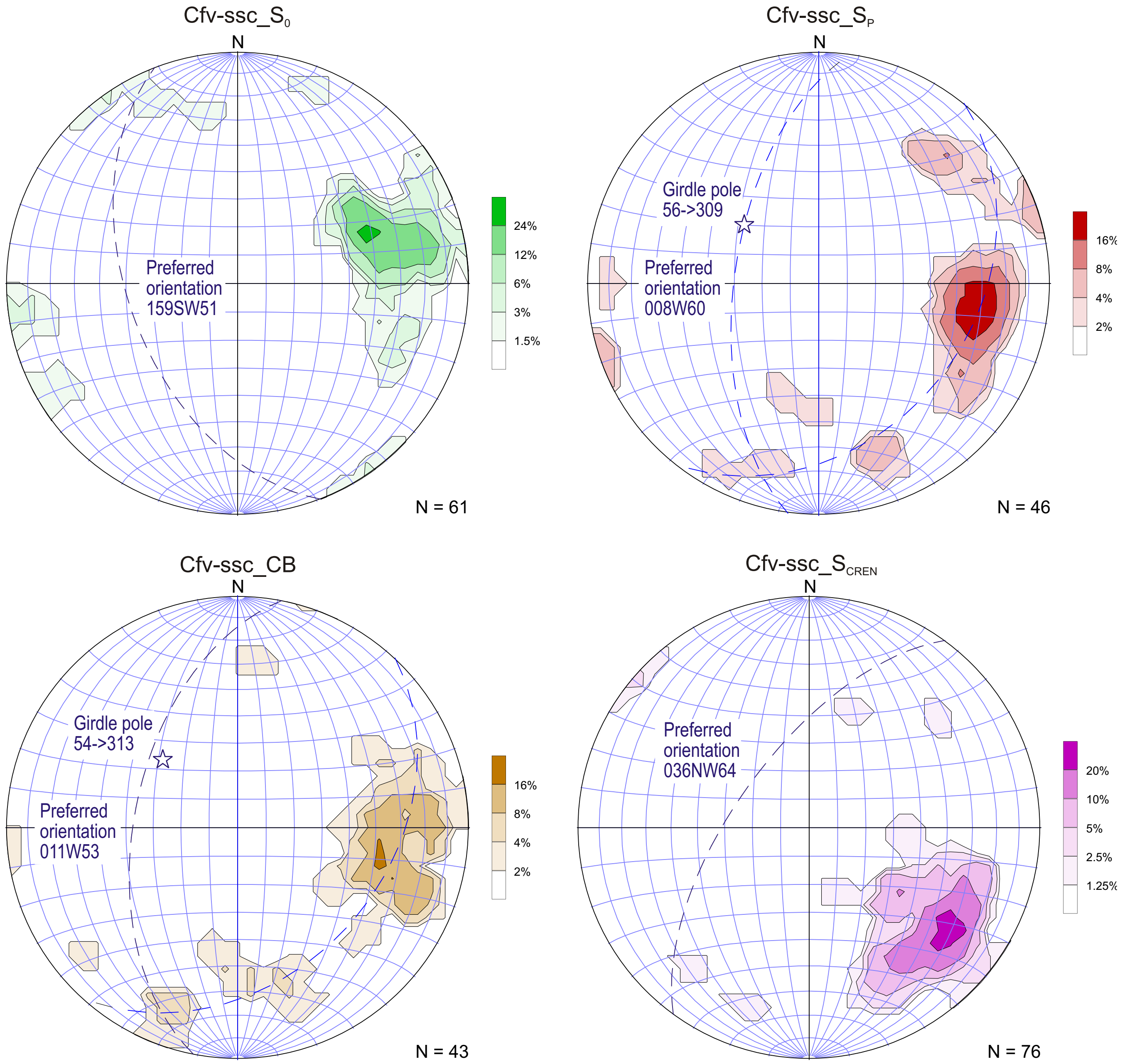

Figure 6

Structural Domain 3 — Cfvss and Cfvsc – sedimentary rocks

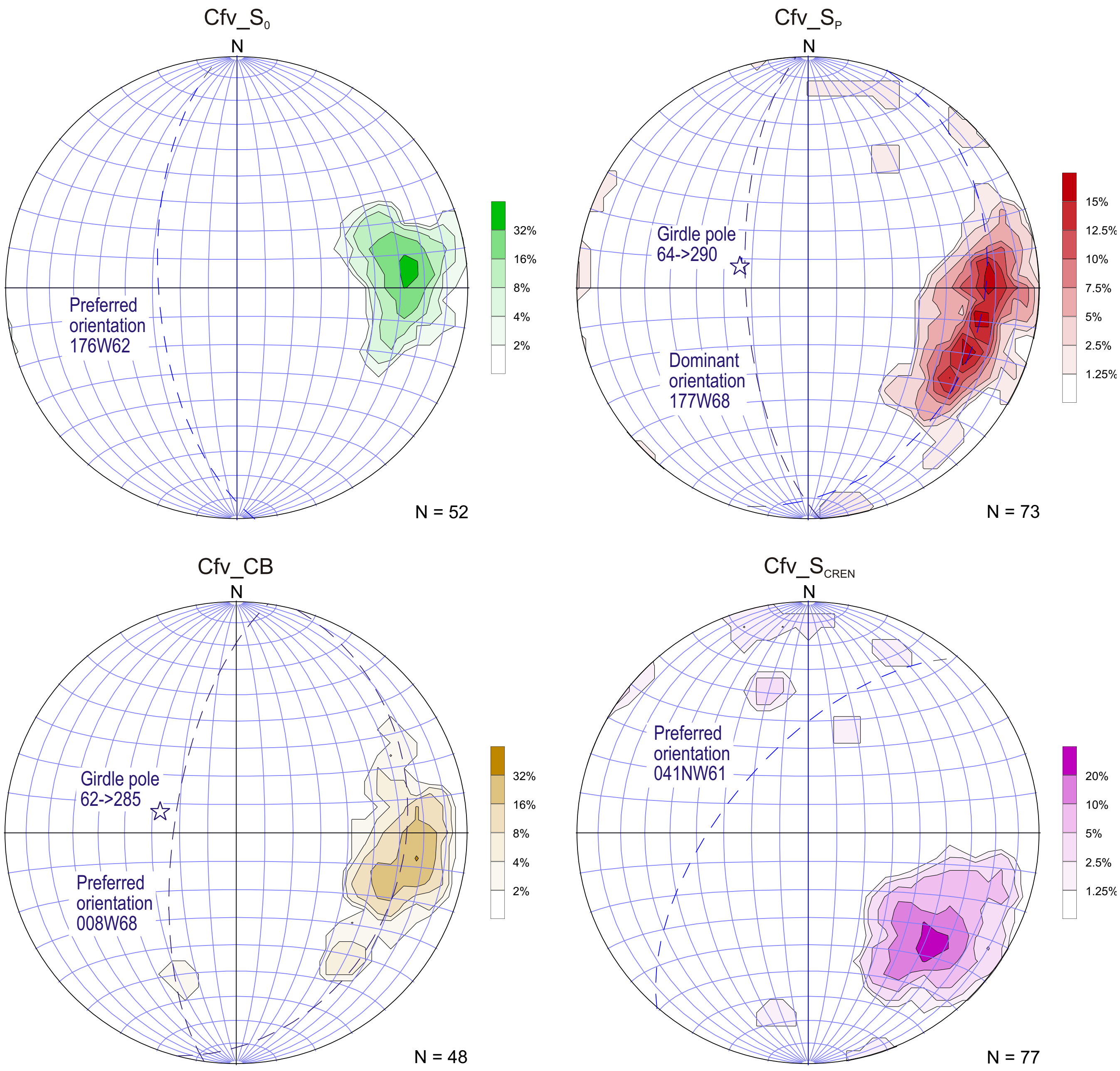

Figure 7

Structural Domain 3 — Cfv – volcanic rocks

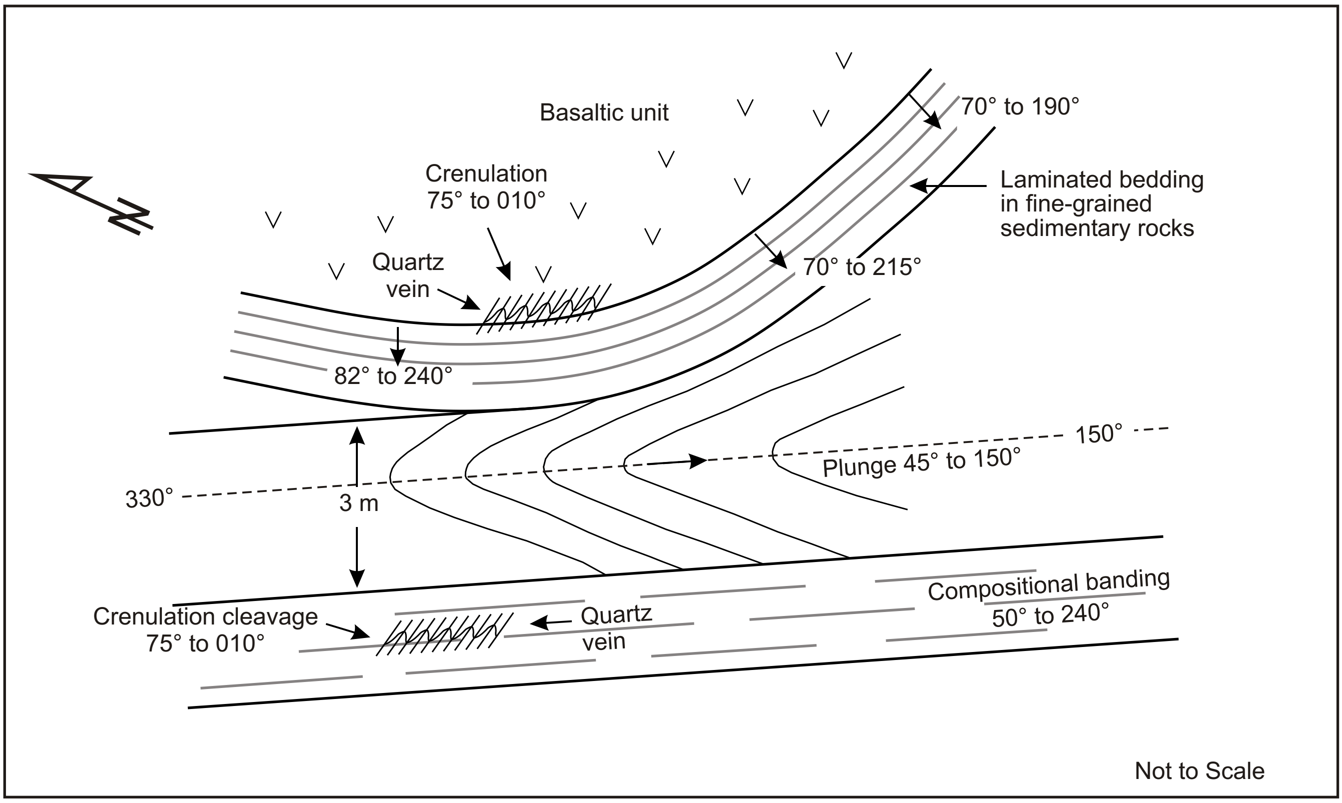

Figure 8

Field sketch of a remnant tight, almost isoclinal fold three metres across [Mo54]. Axial surface of the fold is the same as the foliation in a schistose (compositionally banded) zone to the west (bottom). To the east (top) a folded zone of basaltic rock, bounded by finely laminated and thinly bedded siltstone/fine-grained sandstone occurs. Bedding is only recognised within 1 to 1.5 m away from the lava contact. Thin quartz veins that intrude along the lava-sedimentary rock contact are folded with axial surface parallel to kink bands associated with one of the later phases of deformation.

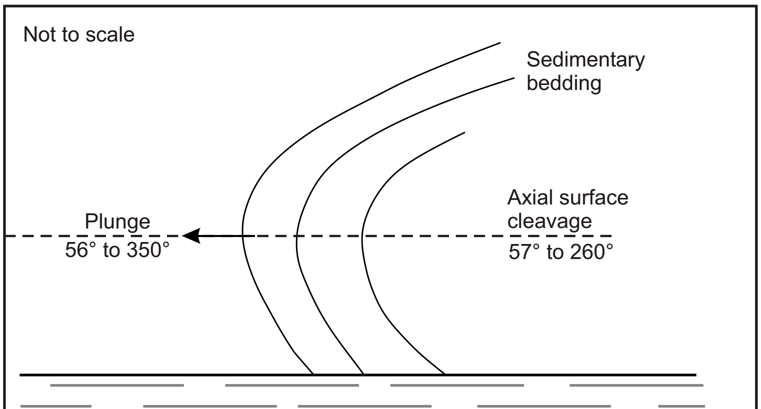

Figure 9

Field sketch of remnant monoclinal fold 0.5 m across [Mo23], bounded on both sides by zones of compositional banding. The compositional banding is parallel to the axial surface cleavage in the tight fold. In laminated and thinly-bedded fine-grained rocks a few metres away, the compositional banding direction is a crenulation cleavage indicating two co-axial phases of deformation. Quartz veins that intruded along the compositional banding near the sheared-out limb are folded with an axial surface parallel to kink bands associated with one of the later phases of deformation.

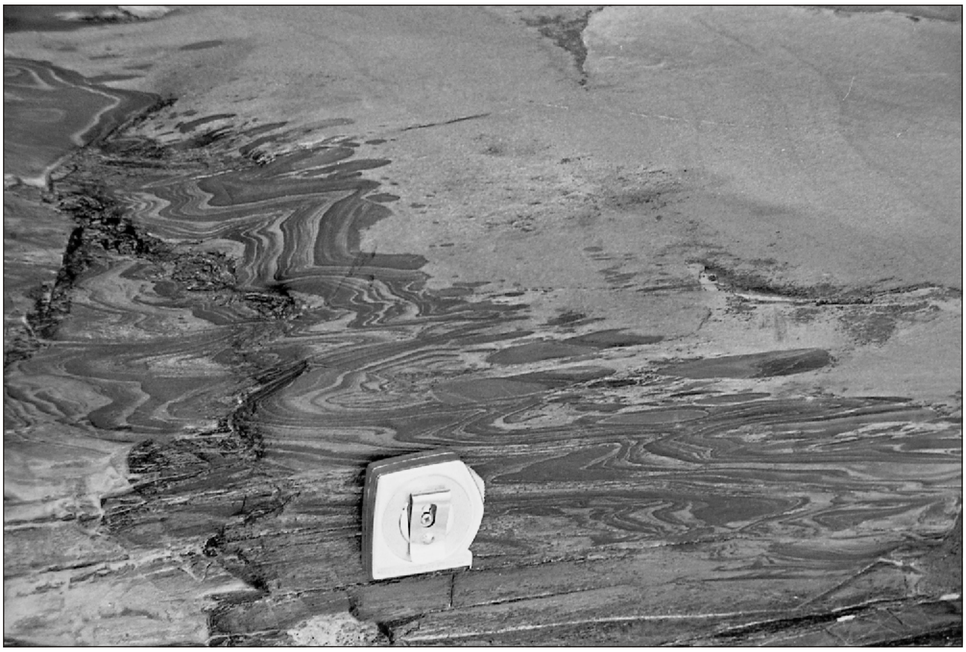

Plate 19

Isoclinal folding in thinly bedded and laminated silt to mud-grade units at Mainwaring Inlet (Mo311; 372400/5252400). The beginning of compositional banding can be seen in the middle upper right.

Plate 20

Open upright syncline (above) and associated anticline (Plate 21, below) with steep sub-vertical axial surface fracture cleavage (70° west to 250°) in competent, dominantly sandstone-wacke units at Mainwaring Inlet (Mo311; 372300/5251700). Fold plunges vary between 30° and 50°, to 345–165° in a 'wave' or 'porpoise' style manner.

[Scale: Field assistant approximately 1.8 m tall]

Plate 21

Anticline associated with syncline shown in Plate 20, Mainwaring Inlet.

Plate 22

Upright fold with steep strong (fracture) cleavage, 1.5 km north of Mainwaring Inlet (Mo368; 372000/5253800).

Plate 23

Remnant isoclinal folds within thinly bedded and laminated layered siltstone and mudstone within tectonic compositional banding zone (top and bottom), southeast of Veridian Point (Mo42; 376700/5245200).

Plate 24

Remnant folded, boudinaged and lensoidal sand-grade units within tectonised zone at Veridian Point (Mo34; 376300/5245600), with beginning of compositional banding.

Plate 25

Remnant, deformed isoclinal folds within high strain zone southeast of Veridian Point (Mo42; 376700/5245200).

Plate 26

Shear zone with attenuated quartz veins and sub-horizontal crenulation cleavage, Cypress Creek (Mo251; 370900/5258400).

Plate 27

Chevron-like folding of tectonically compositional banded rocks at Veridian Point (Mo29; 376100/5245800). Plunge of chevron folds dominantly vertical and associated with late E-NE trending kink band events.

Plate 28

Chevron folding of tectonically formed compositional banding, 0.5 km southeast of Diorite Point (Mo21; 376100/5247000).

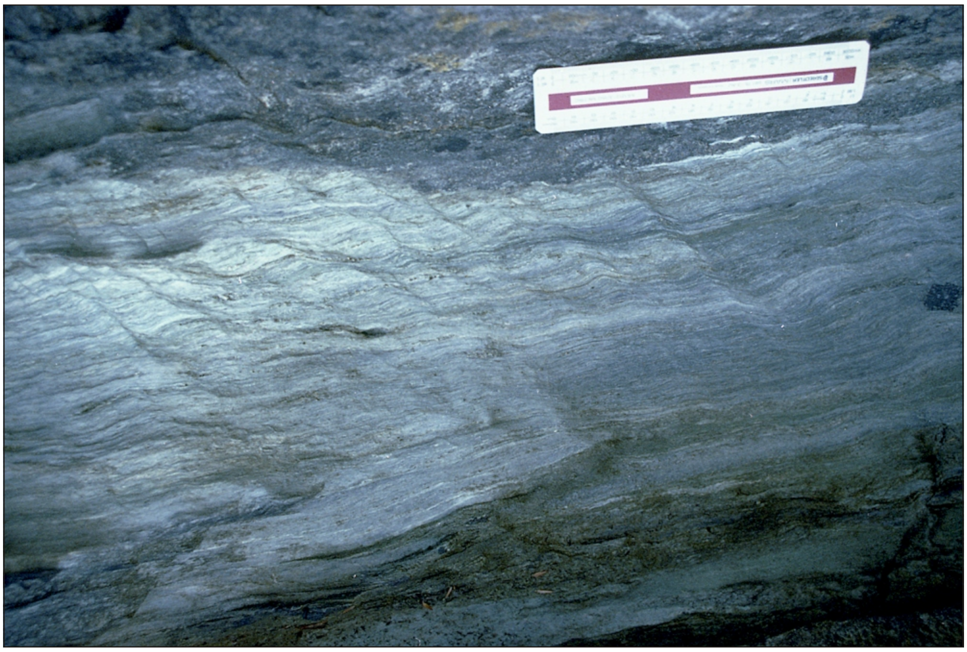

Plate 29

Crenulated tectonically formed compositional banding 0.5 km southeast of Diorite Point (Mo21; 376100/5247000). Crenulation associated with late E-NE trending kink band events.

Plate 30

Folded quartz veins within tectonic compositional banded zone at Veridian Point (Mo34; 376000/5245500).

Ediacaran–Cambrian(?)

Evu — dominantly interlayered, porphyritic and aphyric picritic and tholeiitic lavas with minor sedimentary rocks

Evl — dominantly volcaniclastic lithicwacke and siltstone with interbedded mudstone and mafic volcanic flows

Evv — dominantly interlayered, porphyritic and aphyric picritic and tholeiitic lavas with minor sedimentary rocks

Evmc — dominantly laminated mudstone and interbedded laminated chert

Evlv — syndepositional volcanic intrusive units

Three main areas dominated by outcrops of Evu were traversed during mapping of the Montgomery quadrangle. These were:

- the coastal platform between the mouth of Abo Creek and Veridian Point (Evl and Evlv) (including traverses up the western ends of both Sassy and Copper creeks);
- the upper reaches of the Mainwaring River (Evv and Evmc); and
- along old BHP exploration access tracks that run inland from the upper reaches of Cypress and Rheuben creeks to a helipad approximately four kilometres to the east, at 378200/5257800 (Evl, Evv, Evmc).

The large (3–4 km wide) area of Evv shown on the map to the east and south of the Urquhart River was not traversed due to poor access, lack of outcrop in the first sections of the two creeks traversed off the Urquhart River to the east, and the timeframe for mapping. The areal distribution of Evv shown in this area on the Montgomery 1:50 000 scale map, and subsequent maps, is based on a combination of interpretation of airborne magnetic data with ground data from the three traverses undertaken.

Coastal strip between Abo Creek and Veridian Point

Along the coastal platform north of Veridian Point (376000/5245500) up to Abo Creek (375100/5248300), the basaltic units (Evlv) are dominantly sills, with minor flows, that originally intruded wet sediment mainly along bedding planes, but in some places cross-cutting bedding. Laminar basaltic and volcanic breccia flows with intercalated hyaloclastite units are found in the sequence to the south and east of the area. The background sedimentation, into which the lavas were intruded, consisted of laminated to thinly-bedded siltstone and mudstone with minor carbonate beds and coarser grained turbiditic flows. Numerous occurrences of soft-sediment slumping and brecciation of the sedimentary succession were associated with magma emplacement.

The degree of structural deformation of the sequence is high and outcrop now consists of compositionally banded and tectonically intermixed volcanic and sedimentary rocks and tectonically generated volcanic breccia layers. In this area originally thicker dykes/sills now occur as boudinaged remnants in tectonically generated breccia that is interlayered with zones of rootless folds or detached fold closures along axial plane shear zones in the sedimentary sequence. At least five and possibly six phases of deformation can be recognised across the area. Secondary copper mineralisation is also observed.

The intrusive characteristics of the sills vary from place to place. The sills to the north of Diorite Point (around 375300/5248000) are between 100 mm and five metres thick and most contain both chilled tops and bases (Plate 1). Thicker flows (>5 m thick) have chilled basal zones with the tops of these flows exhibiting flow banding parallel to the margins. Thinner (<2 m) basaltic units (dykes/flows) do not contain obvious flow fabrics, pillow structures or vesicles. Pillow lavas were observed in some flows (Plate 2).

The bases of some sills contain tongues of lava that intruded down into the underlying sedimentary layers (Plate 4). Other sills caused disruptions to, and intermixing of, originally wet sediment. One flow (around 375700/5247400) contains a large number of rip-up sedimentary clasts, ranging from pebble to cobble grade to rafts several metres in length, within the basal two metres of the flow (Plate 3). Some of the larger rip-up clasts contain rootless isoclinal folds. A large number of the sills also have frothy top surfaces, the result of magma intermixing with wet sediment. A large dyke (Evlv), just to the northeast of Diorite Point, caused scouring of the underlying sedimentary units and produced a 30 mm thick contact metamorphic zone in the underlying sediment. Similar features are observed in the area of Evlv between Copper Creek and Veridian Point.

Other intrusive features observed include dykes with irregular top and bottom contacts disrupting sedimentary units; dykes that cross cut tight to isoclinal folds in the sediment pile; and areas where bedding in sedimentary units is only recognisable within the metamorphosed 10 mm to 500 mm zone beneath a dyke. Otherwise the sedimentary sequence has been tectonically destroyed due to later, intense transposition of bedding.

Numerous volcanic breccia units also occur within the sequence between Diorite Point and Veridian Point. These units consist of fragments of dyke material in a matrix of mylonitised, magma-derived material. In nearly all areas it was impossible to decide whether or not the now compositionally banded units were derived from a primary volcanic breccia or from total destruction of the sedimentary/lava sequence.

In thin section, the sills and lavas dominantly consist of secondary minerals, epidote, actinolite, chlorite, quartz and carbonate after olivine phyric basalt (picrite). Vesicles are now filled with quartz and carbonate, and the groundmass by chlorite, actinolite and epidote. Remnant patches of primary groundmass consist of black glass with plagioclase and pyroxene microlites. Opaque mineral grains are anhedral to skeletal and are now leucoxene.

Because of the good exposure of the Evl sequence along the coastal platform from Abo Creek, south past Diorite and Veridian points to Sassy Creek, in comparison to the poor outcrop along inland traverses (upper reaches of the Mainwaring River and along old BHP exploration tracks), a detailed description of the sequence follows due to the significant structural and stratigraphic characteristics of the sequence that is exposed in this area.

The boundary between Cvl and Evl at Abo Creek is a mélange zone composed of a tectonically formed breccia containing boudinaged pebble to cobble-size clasts, within a mylonitic and compositional banded sand to silt-grade matrix. The sequence has been tightly folded with a dominant foliation (compositional banding) striking 155–350°, overprinted by later spaced kink bands (striking 080–260°). The clasts include chloritic schist and quartz-epidote blocks after basalt, all of which are aligned parallel to compositional banding.

Approximately 200 m down the coast (Mo50), basaltic clasts occur within the compositional banding together with secondary copper mineralisation (malachite and azurite). The main sequence in this area consists of pale green tectonically-formed conglomerate consisting of blocks and lenses of partially to fully boudinaged basaltic dykes/flows. These tectonic breccias, with associated boudinaging, are very similar to those occupying some of the shear zones in the Point Hibbs thrust stack (D. Seymour, pers. comm., 2010).

Progressing down the coast towards Diorite Point the sequence contains remnant areas of thinly bedded to laminated siltstone and mudstone with minor carbonate beds; volcanic breccia units; thin basaltic dykes that intruded and cross cut the original wet sediment; and minor basalt flows. Facings from sedimentary rocks all along the foreshore from Abo Creek to Diorite Point indicate that the sequence in this area dominantly faces west. Evidence of the sequence facing both east and west is found at Diorite Point, where lava units exhibit both chilled bases and frothy tops, with incorporated clasts of originally wet sediment and interbedded graded sandstone.

To the south of Abo Creek the sequence is mainly composed of vesicular plagioclase-phyric lavas with a quenched groundmass (Mo51). Phenocrysts are both single laths and clusters of laths in a groundmass of small plagioclase crystals and glass. Vesicles are now filled with epidote and/or recrystallised carbonate. All basaltic units in the area are now composed of secondary minerals (epidote, chlorite, tremolite-actinolite, carbonate, albite and minor serpentine and leucoxene) with minor, remnant grains of the original mineralogy (olivine, clinopyroxene, plagioclase and magnetite) still surviving.

Because of the structural deformation most volcanic units have been physically altered into mylonitised equivalents derived from at least four varieties of lava that form flows and dykes within the sequence. The dominant type is olivine-phyric lava with a groundmass of interlocking plagioclase laths and glass (Mo61, 163, 165, 169, 170); the second variety is olivine and clinopyroxene rich with minor plagioclase (Mo57, 167); the third contains coarse-grained glomeroporphs of clinopyroxene and plagioclase within a groundmass of plagioclase, clinopyroxene and skeletal opaque minerals (Mo56). The fourth variety, mainly occurring as dykes, contains plagioclase both as phenocrysts and in the groundmass (Mo52). In thin section, samples of coarse-grained tectonically generated units from this area (Mo53) consist of clasts of lava composed of single and glomeroporphyritic clinopyroxene crystals (now tremolite-actinolite) and minor olivine (serpentinite, chlorite) in sheared silt-grade volcanic detritus.

One sample (Mo166), from the middle of the large dyke to the northeast of Diorite Point, contains remnant orthopyroxene (0.75 3.0 mm) and stubby clinopyroxene (1 mm) phenocrysts in a glassy groundmass. Another sample, from a now well foliated thin dyke (Mo169), originally consisted of olivine microphenocrysts in a glassy groundmass which also contained opaque mineral grains. Although remnant textures are visible in hand specimen, in thin section the majority of samples consist of a felty mat of chlorite, tremolite/actinolite, and epidote leucoxene.

In the majority of cases, both the upper and lower contacts of basaltic dykes are irregular and disrupted originally wet sediment. Because of the complex folding in this area both eastward and westward facings are observed. The basal margins are usually chilled with the top surfaces being frothy and, in some cases, containing rip-up clasts of sediment. Some dykes cross cut tight to isoclinal folds within the sedimentary sequence. From field evidence it could not be determined whether the isoclinal folds were tectonic or formed by syn-sedimentary slumping. If the former, then two separate ages/phases of dyke intrusion are implied. Associated sedimentary units consist of laminated siltstone and mudstone which, in this area, lack any interlayered (bedded) coarser-grained turbidite, mass flow or soft sediment slump units.

Around 375300/5247900 (Mo54) a basalt flow, associated with thinly interbedded volcaniclastic siltstone and sandstone, is in structural juxtaposition with a three metre wide zone of remnant, rootless isoclinal-folded laminated siltstone and mudstone. The axial surface foliation is parallel to the schistosity (compositional banding) in the finer grained units that underlie the zone. A later crenulation cleavage cross cuts the compositional banding and is axial surface to folded thin quartz veins that intruded along the compositional banding direction. In thin section the lava is fine grained and aphyric and now consists of chlorite, tremolite-actinolite, epidote, albite, serpentinite and leucoxene. Soft-sediment slumping is evident nearby (between Mo59 and 60) due to zones with disrupted bedding and sedimentary rip-up clasts which include rootless isoclinal folds. The rocks were originally volcaniclastic siltstone.

Doleritic-textured basaltic dykes intrude along the main regional foliation. A typical sample (Mo56) has a chilled western margin with the underlying sedimentary rocks but also incorporates rip-up clasts of sediment. The dyke strikes 40° to bedding. A thin section indicates that the lava originally consisted of a coarse-grained clinopyroxene-plagioclase intergrowth with skeletal intergrowths of magnetite (leucoxene).

A thick (up to 75 m wide and 400 m long) basaltic unit (flow/dyke) occurs between 375300/5247800 (Mo56) and 375600/5247400 (Mo167). The basal (western) contact is chilled and parallels sedimentary bedding. The sedimentary rocks below this unit are metamorphosed for a thickness of 100 millimetres. In other places sedimentary flame structures occur within the base of volcanic flows. The eastern contact (top) scoured into the sedimentary sequence and has 30 mm of baked sediment as the marginal zone. Clasts of soft sediment were incorporated in other places along the top contact.

Some samples (e.g. Mo56) contain pseudomorphs of olivine (up to 2   4 mm) and orthopyroxene (1.5   4 mm) phenocrysts. The pseudomorphs consist of intergrowths of chlorite, epidote and actinolite. In some samples chlorite is deep green in colour and exhibits an anomalous Berlin Blue extinction colour. Some porphyritic samples are also vesicular (e.g. Mo61), and comprise plagioclase and clinopyroxene phenocrysts with skeletal opaque oxide grains in a groundmass of glass, feldspar and pyroxene microlites.

Lava units around 375500/5247500 (Mo120) incorporate baked, pebble to cobble size rip-up clasts and rafts up to 1–2 m in length of bedded sediment (Plate 3).

Just north of Diorite Point (375500/5247400, Mo8) pyroxene-phyric basalt flows occur within a turbiditic sedimentary sequence that contains truncated channel fills and units of mass flow deposits, disrupted cobble-size blocks of laminated siltstone, and sand-grade beds. The original sediment was derived from basaltic lavas that consisted of anhedral olivine in a groundmass of interlocking plagioclase laths and minor clinopyroxene and interlayered, tectonised, volcanic siltstone and wacke derived from plagioclase and clinopyroxene-phyric basalt. Similar physical characteristics are seen in dykes/flows on the western shore platform at Diorite Point (Mo59).

In thin section the lavas are now dominantly carbonate-chlorite with minor epidote replacement of devitrified glass and remnant plagioclase laths. The shore platform consists of interbedded lava flows (2–5 m thick) and well laminated sedimentary rock units with occasional pebble-grade volcanic breccia layers. The volcanic units are now mylonitic and clasts are aligned with the cross cutting foliation. Volcanic flows and dykes are between five and ten metres in thickness and are interlayered with 1–2 m of tectonised sedimentary rocks.

Outcrop just to the east of Diorite Point (Mo62) consists of schistose green granule conglomerate, with pebble to cobble-size clasts aligned within the dominant foliation surface, interbedded with original laminated siltstone and vesicular quenched olivine phyric lava. In finer grade beds the dominant surface is a compositional layering. This sequence continues to the east of Diorite Point where sedimentary structures indicate facing to the east. The volcanic fragments are identical to picritic flows in the area, comprising subhedral to anhedral olivine phyric lava with skeletal opaque grains and a quenched groundmass (e.g. Mo87).

Continuing eastwards to the mouth of Copper Creek (Mo88, 89) the sequence consists of compositionally layered, pale greyish green carbonate/siltstone units with red to purple mylonitic mudstone clasts aligned along the compositional layering. Lava clasts are quenched or vesicular small plagioclase lath basalt (Mo88). At the mouth of Copper Creek the sequence is heavily tectonised and consists of a pale greenish grey matrix with purple clasts interlayered with orange-brown carbonate and green basaltic units.

Tectonised, original sedimentary units without any interlayered lava flows or dykes were observed in a 1200 m traverse up Copper Creek (from its mouth to 376700/5247600). The dominant surface along this traverse is a compositional layering with an approximate north–south strike that was later deformed by a spaced kink crenulation (~E–W). Remnant zones of laminated siltstone, with bedding approximately 10° oblique to compositional layering, also occur. A crenulation cleavage striking approximately 025–205° cuts compositional layering in places. At 376500/5247700 (Mo96) the sequence becomes markedly siliceous, and compositional layering strikes ~050–230°.

Continuing south from Copper Creek to Veridian Point the headlands are composed of coarse-grained (doleritic) textured leucocratic flows. These flows show chilled margins and irregular pods of red mudstone between the lava units. The sedimentary sequence varies in grain size from grit to granule-grade, to siltstone interlayered with very weathered tectonised volcanic material (Mo23).

Cropping out along the coastline between Copper Creek and Veridian Point is a highly deformed, complexly folded sequence of sedimentary rocks and basaltic units. The sedimentary rock units comprise finely laminated siltstone interbedded with mud clast conglomerate, and interlayered pyritic black mudstone, indurated grey siltstone and carbonate (Mo28). In places the compositional banding is tightly folded then subsequently kinked. The headlands are composed of mylonitic leucocratic dolerite (Mo23, 25, 30). Multiple-graded sedimentary rock units observed in the cores of folds indicate a westward facing. Numerous outcrop size antiforms and synforms are faulted along their axial surfaces leaving monoclines in this area.

Sedimentary rock units around Veridian Point consist of pebble-grade angular breccia interbedded, or perhaps tectonically interlayered, with other sedimentary and volcanic units. On the headland at Veridian Point, leucocratic doleritic textured units are associated with sedimentary rocks exhibiting truncated cross bedding and in-filled scour structures (Mo30). Sedimentary structures indicate that the succession is eastward facing in this area. Basaltic flows have associated conglomerate and auto-brecciated units that have been foliated, crenulated, and in some cases converted to schist, and then kink banded. The volcanic units are interlayered with laminar flow sedimentary units, as well as laminar flow and breccia units interbedded with siltstone/sandstone. The siltstone/sandstone units contain rootless isoclinal folds, the axial surface cleavage of which is parallel to the flanking compositional banding surface. Overall the sequence is highly weathered and while some units show remnant flow structures, others consist of dark green patches surrounded by pale green and white alteration products.

To the east of Veridian Point the succession consists of highly deformed laminated siltstone/carbonate (Mo31–33), some locations containing rootless isoclinal folds (Mo30, Plate 8), while garnet schist (Mo34) occurs at other locations. The crenulation cleavage associated with refolding of isoclinal folds also forms compositional banding (Mo35) that was later kink banded.

Area inland of, and between Cypress Creek and Rheuben Creek to around 376100/5257600

Exposure in this area is limited with outcrop being rare. Lag deposits form small hummocky occurrences of basaltic boulders along the tracks leading to the east from the coast and in the upper reaches of Cypress Creek. In Cypress Creek the outcrops are also lag deposits of highly weathered and foliated rocks, but kernels of relatively fresh material have survived. Two different types of lava were identified in thin section, one of which corresponds to samples with picritic chemistry and the other to samples with tholeiitic chemistry.

Samples of lavas with picritic affinity were obtained from either side of the sequence of laminated black mudstone and interbedded chert (Evmc). These samples (Mo231, 291*, 292) now consist of a felty mat of actinolite and chlorite with minor epidote. In plain light the textures indicate that the original lava consisted of stubby microphenocrysts (0.2 0.3 mm) in a quenched glassy groundmass containing microlites and spinel grains. Some samples (Mo231) show outlines of olivine microphenocrysts (0.35 0.15 mm) which have skeletal embayments probably due to non-equilibrium reaction with the final groundmass.

The weathering colour of picritic basaltic rocks is pale green and the associated soil a buff colour. This contrasts with the lavas that have tholeiitic geochemical character, which weather to a purplish grey and have associated rich red-brown soil. Most samples of tholeiitic basalt contain native copper.

In thin section, samples with tholeiitic chemistry show a range of physical textures. These include samples which:

- contain clinopyroxene (0.25–0.50 mm) and plagioclase (0.7 0.15 mm) microphenocrysts in a fine-grained groundmass (up to 0.25 mm) consisting of an irregular intergrowth of plagioclase, ferromagnesian and opaque minerals (Mo228);
- have glomeroporphyritic patches (up to 3 2 mm) of plagioclase laths (0.9 0.35 mm) and subhedral clinopyroxene (0.7 0.45 mm) in a groundmass of intermixed plagioclase (0.45 0.15 mm), ferromagnesian and opaque (0.1 0.15 mm) mineral grains (Mo230);
- are coarse grained and consist of an intergrowth of plagioclase (1.35 0.25 mm) laths, subhedral clinopyroxene (0.45 0.75 mm) and anhedral (0.15–0.25 mm) and skeletal opaque grains (up to 0.4 mm) (Mo287); or
- are vesicular, plagioclase-phyric (1.35 0.25 mm), and contain a fine-grained groundmass of intergrown plagioclase, ferromagnesian and opaque mineral grains (up to 0.1 mm) (Mo289).

All samples now have varying degrees of secondary mineral growth consisting of granular to pervasive intergrowths of chlorite, epidote, sericite and tremolite/actinolite, albite and leucoxene.

Upper reaches of the Mainwaring River (between 375500/5253500 and 377000/5253500)

Samples from the third main area of outcrop, in the upper reaches of the Mainwaring River, are all of a tholeiitic nature and have similar petrographic characteristics to those between Cypress Creek and Rheuben Creek. Outcrop occurs spasmodically along the river section with the thicker flows forming waterfalls (Plates 5, 6). Most of the vesicular flows contain native copper. As with the samples described above, all rocks have undergone varying degrees of alteration to chlorite, epidote and sericite with the opaque mineral grains now being dominantly leucoxene. Some samples contain euhedral pyrite grains.

The textural variations within this area include:

- foliated, aphyric, medium-grained basalt with a granular to subophitic textured groundmass of plagioclase (up to 1.25 mm), clinopyroxene and opaque (up to 0.9 mm) mineral grains (Mo559*);
- glomeroporphyritic plagioclase patches (up to 3.0 2.0 mm) and single laths (up to 1.00 mm) within a granular to subophitic basaltic groundmass (grains up to 0.5 mm) (Mo563);
- vesicular, with plagioclase microphenocrysts (1.0 0.15 mm) in a groundmass of intergrown plagioclase (0.9 0.45 mm), clinopyroxene (0.35 0.20 mm) and opaque mineral grains (Mo568);
- patches (1.5 1.0 mm) and single laths of plagioclase (up to 0.6 mm) and equant clinopyroxene (0.45 0.35 mm) microphenocrysts in a fine-grained (up to 0.1 mm) basaltic groundmass (Mo578);
- clinopyroxene (1.2 0.45 mm) and skeletal opaque (0.7 0.9 mm) grains in a fine-grained basaltic groundmass (up to 0.1 mm) (Mo584); and
- patches (2.5 1.5 mm) and single laths (1.6 0.45 mm) of plagioclase phenocrysts in a medium-grained, granular to subophitic (grains up to 0.75 mm) groundmass of plagioclase, clinopyroxene and opaque mineral grains (Mo585).

Cambrian

Cvu succession

Based on stratigraphic and geochemical data, the lowest of the Cvu sequences (Cvs) consists of interbedded laminated siltstone and mudstone with extrusive porphyritic andesitic rocks which gradationally, but sharply (over approximately five to ten metres) pass upwards into a massive, interlayered, extrusive porphyritic lava and autoclastic breccia sequence (Cvv). This in turn has a relatively sharp transition into a dominantly sedimentary rock sequence consisting mainly of lithicwacke, interbedded siltstone and mudstone, with sills and dykes of hornblende phyric andesite/dacite (Cvl). Stratigraphically upwards, at the top of the Cvl sequence, the composition of the sedimentary rocks changes to dominantly felsic volcaniclastic sandstone and wacke with interbedded lithicwacke, laminated siltstone and mudstone that contains minor extrusive/intrusive clinopyroxene-plagioclase phyric andesitic lavas (Cvt). Airborne magnetic data indicate that this sequence is continuous in a northerly direction through the Point Hibbs quadrangle into the Timbertops area of the Macquarie Harbour quadrangle (McClenaghan and Findlay, 1993), where it is known as the Noddy Creek Volcanics (White, 1975; McClenaghan and Findlay, 1993). A felsic intrusive rock from that area has been dated at 502.8 4.4 Ma (Black *et al*., 1997).

Cvs — dominantly extrusive porphyritic andesitic volcanic rocks with interbedded laminated siltstone and mudstone

The volcanic units within both the Cvs and Cvv sequences are geochemically basaltic andesite to andesite, are very similar in physical character and internal structure (lava and autoclastic breccia flows), but have varying chemical characteristics.

Varying proportions of usually thin andesitic lava flows are interbedded with laminated siltstone within the Cvs sequence. Where the volcanic flows are dominant they vary from two to five metres in thickness, with some flows incorporating 100–250 mm thick rip-up clasts of sedimentary rock. In places, after a thick succession of sedimentary units (10–15 m), the first lava unit causes a zone of disruption, up to 0.5 m thick, that consists of blocks of laminated siltstone, irregular lava flows, pebble-grade breccia lenses and blocks of ripped-up black mudstone. Such zones are overlain by up to a 20 m thick pile of interbedded pillow and laminar andesitic lava.

The thinner lava flows dominantly consist of vesicular clinopyroxene phyric andesitic flows which, in thin section, show clinopyroxene phenocrysts (from one up to five millimetres long) in a groundmass of interlocking anhedral plagioclase laths (0.2–0.3 mm). Chlorite and actinolite now replace groundmass glass (Mo515).

In zones where numerous andesitic breccias are interlayered, the volcanic units consist of blocks of coarse-grained lava in a finer grained matrix. The blocks are composed of either twinned and zoned, or glomeroporphyritic clusters of clinopyroxene and ophitic to subophitic textured plagioclase, with accessory anhedral opaque oxide grains. The plagioclase laths (1.0–1.5 mm) are spotted with sericite alteration. Clinopyroxene crystals (0.25–2.5 mm) have both chlorite, with the anomalous deep purple-blue extinction colour, and tremolite-actinolite alteration (Mo536/2). The matrix material (Mo536/3) consists of a crystal mush of anhedral to broken fragments of clinopyroxene and plagioclase with a groundmass varying between vesicular glass and intergrowths of anhedral clinopyroxene (0.4–0.5 mm) and feldspathic microlites in a quenched black glass.

In thin section, some of the units which appear to be porphyritic lavas in hand specimen consist of densely packed, crystal-rich lavas with the inter-crystalline areas filled with a vesicular to fine-grained groundmass (Mo535) similar in composition to the matrix within the enclosing andesitic blocks. The phenocrysts vary from single and multiple intergrowths of euhedral and subhedral grains to broken fragments and consist of plagioclase (0.2–1.0 mm) and clinopyroxene that varies in size up to 1.5 mm for single clinopyroxene grains, and up to 3.5 mm for glomeroporphs. Some of the clinopyroxene crystals are embayed or contain secondary reaction features.

Three main lava types occur towards the top of the succession. The first is a vesicular lava with small clinopyroxene and plagioclase phenocrysts in a fine to medium-grained groundmass. This type has two sub-varieties. One contains small phenocrysts of euhedral to subhedral plagioclase (up to 1.0 mm long) and clinopyroxene (0.15–0.25 mm) in an homogeneous, quartzo-feldspathic glassy groundmass. Vesicles have irregular shapes (0.75–5.0 mm) and are now filled with secondary quartz or an intergrowth of quartz, carbonate, epidote and pumpellyite (Mo530/3). The second sub-variety consists of both single (up to 1.75 mm) and multiple-grained clusters (3 to 5 crystals, each 0.45–0.65 mm across) of phenocrysts, set in a groundmass consisting of anhedral granular clinopyroxene (0.01–0.15 mm) in vesicular, cryptocrystalline, quartzo-feldspathic glass (Mo530/4*).

The second variety is a fine-grained porphyritic lava that contains euhedral to subhedral phenocrysts of zoned clinopyroxene (1.5–2.5 mm) and euhedral to anhedral laths of altered plagioclase (0.75–1.15 mm long, with some up to 2.5 mm long) in a fine-grained (0.01–0.03 mm) groundmass of granular clinopyroxene, plagioclase laths and minor quartz. Some of the phenocrysts are replaced by secondary chlorite and carbonate (Mo530/1*).

The third lava variety contains andesitic xenoliths in a porphyritic but variable textured andesitic lava. The xenoliths consist of 5–10 mm angular clasts of clinopyroxene and plagioclase crystal clusters within a coarse-grained groundmass. The xenoliths are enclosed by a later lava phase consisting of euhedral to subhedral, single grain and multiple-clusters of clinopyroxene and plagioclase (up to 5 mm across) in a variable textured groundmass ranging from vesicular, to fine grained, to plagioclase-lath rich with a flow texture (e.g. Mo530/2).

Cvv — interlayered extrusive porphyritic, basaltic-andesite to andesitic-dacite pillow, sheet, volcanic xenolith-bearing porphyritic breccia and autoclastic breccia flows

The Cvv succession is dominantly composed of varying thicknesses of autobrecciated lava, xenolith-rich lava, and porphyritic lava with minor crystal-rich volcaniclastic units. Most of the flows within the Cvv succession are disrupted and/or brecciated. These vary from:

- fine to coarse-grained crystal mushes with a quenched glass groundmass;

to:

- sheet flows of porphyritic (clinopyroxene and/or plagioclase) andesitic lava with a medium-grained, crystalline groundmass;
- lavas with altered plagioclase and/or clinopyroxene phenocrysts in a plagioclase-rich or devitrified glass groundmass; and
- flows with euhedral to broken grains of plagioclase (up to 3.5 mm long) within a vesicular glassy or fine-grained andesitic groundmass.

Areas of glass are usually devitrified, some patches have snow-flake textures and others are recrystallised to cryptocrystalline quartz (Mo534*). All samples have undergone alteration to epidote, chlorite sericite and quartz (e.g. Mo528). Some units are produced by an intermixing of pyroclastic and epiclastic processes resulting in 'flows' containing angular fragments of broken, but once euhedral clinopyroxene (up to 4.5 1.5 mm), altered plagioclase and clasts of porphyritic lava, in a matrix of fragmented vesicular glass. The glass is now fractured and altered to an intergrowth of green chlorite with a brown cloudy mineral along the fractures (e.g. Mo526). Some units have the appearance of crystal-rich flows, but in thin section show that they are sand to granule grade, volcaniclastic units that contain grains of granular, stubby and elongate clinopyroxene and plagioclase crystals (up to 2 mm) and clasts of lava, with small phenocrysts, in a devitrified glassy matrix.

The southernmost of the two islands that constitute Montgomery Rocks is comprised of a thick pile of massive, autoclastic breccia, breccia and intermixed lavas, characterised by three grain size variations. The fine-grained variety contains microphenocrysts of plagioclase (up to 0.35 mm) and clinopyroxene (up to 0.5 mm) in a cryptocrystalline quartzo-feldspathic groundmass (Mo305/1). The medium-grained variety contains zoned euhedral to subhedral phenocrysts of clinopyroxene (2.0–2.5 mm) in a fine-grained andesitic groundmass which also contains microphenocrysts of plagioclase and clinopyroxene (0.5–0.75 mm), some of which contain spinel grains (Mo305/2). The coarse-grained variety contains single, zoned or glomeroporphyritic patches of clinopyroxene crystals (up to 4 mm across), in a glassy groundmass containing plagioclase laths and granular, anhedral clinopyroxene (1.0–1.5 mm) (Mo305/3).

Cvt — dominantly clinopyroxene-plagioclase andesitic lavas with interbedded volcaniclastic sandstone and lithicwacke

Flows of andesitic lava were are also found within the Cvt sequence in the Urquhart River (Mo464) and in the Cvl sequence in the Wanderer River (Ph23) in the Point Hibbs quadrangle to the north. The geochemistry of these flows indicate that volcanism of the Cvs/Cvv type was still active, but minor, at this later stage in the geological history of this area.

Cmv — hornblende phyric dacitic/andesitic dykes and sills

Numerous hornblende and/or clinopyroxene-phyric dykes and sills intrude the Cvl succession between the Mainwaring River and High Rocky Point. The dykes strike between 120° and 150° and cut across bedding. There are also two main sills; the larger (Mo392) is approximately 45 m thick and the smaller (Mo393), which occurs approximately 200 m south of the larger sill, is approximately 15 m thick.

Two physical variations of the hornblende dacitic dykes exist. The majority of the dykes contain either phenocrysts of pseudomorphed clinopyroxene (chlorite) hornblende, or hornblende without clinopyroxene, in either a randomly-orientated quartzo-feldspathic matrix or a matrix consisting of ophitic intergrowths of quartzo-feldspathic material and plagioclase. Samples of this variety were obtained from along the coast between the mouth of the Urquhart River and 368700/5263600 (Mo424, 437/1, 437/2, 446); to the south of Fletcher Creek at 370600/5259400 (Mo300*, 301); and in the area to the north and south of the mouth of the Mainwaring River (Mo363, 360, 351).The coarsest grained samples of this variety (Mo300*) came from the middle of a lensoidal intrusion, 30 m long and 10 m thick in the centre. This is dominantly composed (70%) of euhedral to anhedral hornblende (0.7–1 mm across and up to 4 mm long with green to brown pleochroism) in a quartzo-felspathic groundmass. Elongate sections of hornblende exhibit twinning. One sample, from a 7.5 m wide multiple intrusive dyke (Mo360), has an internal chilled margin zone (2.25 mm wide) which possibly indicates near simultaneous multiple phases of lava injection. The magma contained microphenocrysts of hornblende in a groundmass of intergrown hornblende and plagioclase. The lava with the internal chilled margin contains equant hornblende laths (up to 1.25 mm across) in a groundmass of interlocking fine hornblende laths with the interstices filled by quartzo-feldspathic material.

The second variety forms two thick sills (Mo393 and Mo392) and numerous thin dykes that crop out in Rheuben Creek (Mo238, 241, 243) and Cypress Creek (Mo293). This variety consists of anhedral to granular euhedral and subhedral hornblende in a matrix of acicular to granular plagioclase laths with interstices filled with quartzo-feldspathic material and accessory opaque oxide grains.

The coarser-grained samples (e.g. Mo293) of this variety contain hornblende grains (up to 2 mm long) in a groundmass of interlocking hornblende crystals (up to 0.9 mm long).

Medium-grained samples (e.g. Mo241, 243) contain phenocrysts of hornblende up to 1.5 mm in length.

The area of Cmv around 370900/5255500 is composed of interlayered mylonitic flows of autoclastic breccia lava clasts and blocks within a vesicular matrix composed of microphenocrysts of clinopyroxene and plagioclase with a very fine-grained andesitic matrix.

This body of lava intruded wet sediment and contains small sedimentary rip-up clasts along the basal eastern margin, and is sub-parallel with bedding in the underlying sedimentary rock succession. The upper margin has a more uneven contact with bedding and includes numerous offshoots and tongues of lava intruding into the sedimentary pile. This body also contains internal evidence that multiple intrusions of lava occurred.

Cva — dacitic-rhyolitic autobreccia (Acacia Rocks)

A group of eleven large rocks, cropping out within an area of half a kilometre in the Southern Ocean approximately two kilometres offshore, are collectively known as Acacia Rocks (370500/5251000). These rocks consist of autobrecciated rhyolitic-dacite (Cva) with feldspar and quartz micro-phenocrysts in a quartzo-feldspathic groundmass (Mo306) and probably represent the remnant plug of a volcano.

Cbg — medium to very coarse-grained, equigranular, biotite granitoid with irregular patches and dykes of aplite

The southern portion of the land mass covered by the Montgomery map sheet is occupied by granitic rocks (Cbg) which include an associated area of granitic rocks with felsic volcanic screens (Cbgs). Traditionally, the granitic rocks (Cbg) in this area have been considered to be of Cambrian age and similar to the Murchison (K-Ar, 512–538 Ma) and Dove (K-Ar, 476–509 Ma) granites of western Tasmania (McDougall and Leggo, 1965). A zircon age (498.8   3.3 Ma, Black *et al*., 2005) for the granite has confirmed the Cambrian age and correlates the body with the South West Cape granitic body (498   3 Ma, Black *et al*., 2005). A younger K-Ar radiometric age of 414 Ma was obtained for this body (McDougall and Leggo, 1965), but it has always been considered a minimum age due to 'leakage' of the relevant radioactive isotopes.

Field evidence shows that the granitic body is younger than the felsic volcanic (Cfv) rocks. In an area of approximately 750   500 m around 377500/5241000, granitic rocks intrude the volcanic sequence resulting in numerous screens of volcanic rocks (Cbgs) being incorporated and partially absorbed into the granitoid. Between 377300/5241400 and 377700/5242200 the volcanic succession contains contact thermal metamorphic effects associated with the granitic body.

Overall, the granitic rocks in this area are dominantly medium to very coarse-grained, equigranular, biotite granite/adamellite, with minor irregular patches and dykes of aplite. Grain size ranges from medium (3–5 mm) to coarse (5–7 mm) and very coarse (7–9 mm). Feldspar grains are altered and weathered, and cream, pink or green in colour. Quartz grains show extensive fracturing and zones of recrystallisation and the percentage of biotite varies at outcrop scale. Larger biotite grains show kink bands. Thin dykes and small areas of aplite intrude the main granitic rocks, especially inland between Schist Point and Low Rocky Cape.

Cgf — fine-grained, small feldspar phenocryst granitoid

A small area of granitic rock (Cgf) intrudes the felsic volcanic (Cfv) rocks around 377400/5244700. This granitoid is fine grained and contains small (>10 mm) phenocrysts of feldspar. It has an irregular boundary with the felsic volcanic rocks and contains numerous blocks/screens of the volcanic rocks within its surface exposure.

In thin section, a typical sample (Mo78) consists of intergrowths of roughly circular areas of quartz (1–2 mm) with subhedral areas of perthitic alkali feldspar. The areas of alkali feldspar contain smaller (0.5–1.0 mm) plagioclase crystals and are partially altered to sericite and muscovite. Fractures within the sample are filled with a colourless to pale brown pleochroic mica (biotite?), and leucoxene after opaque oxide grains.

Devonian (?)

Dmv — mafic dykes intruding the granitoid rocks in the Low Rocky Point area

Numerous thin (200 mm–1.5 m wide) mafic dykes intrude the granitoid rocks along a roughly ENE–WSW fracture system in the Schist Point–Low Rocky Point area. These dykes all have chilled margins and are now highly chloritised and pervaded by carbonate minerals. One of the dykes (Mo216) contains phenocrysts of quartz. Other dykes (e.g. Mo217) originally contained microphenocrysts of pyroxene and plagioclase.

Although there is no definite proof of age for these dykes, they are probably younger than mid-Devonian as they do not show internal deformational features.

Devonian(?)–Cretaceous(?)

Cl — lamprophyre dyke

Two biotite-rich lamprophyre dykes, both striking east–west, intrude the Cvl sequence. One occurs on the coast on the south side of the mouth of the Urquhart River at 369600/5261900 (Mo400) in the Montgomery quadrangle, with the other on the western shore of Christmas Cove at 367900/5268000 (PH10) in the Point Hibbs quadrangle.

The dyke at the mouth of the Urquhart River is 100 mm thick and runs parallel to bedding (165–345°) for ten metres then takes a right angle bend to follow a strong foliation (090–270°) that results in kink banding in other localities. The dyke near Christmas Cove is 400 mm thick and cuts across bedding. Neither of the dykes shows a tectonic fabric.

Similar lamprophyre dykes are known from further north in the Macquarie Harbour quadrangle (McClenaghan and Findlay, 1993) and in the Queenstown area (Baillie and Sutherland, 1992). Radiometric dating of six lamprophyre dykes from the Macquarie Harbour and Port Hibbs area

(McClenaghan *et al.*, 1994) gave a Late Devonian age (366–377 Ma), whereas similar dykes from other areas in Tasmania (King Island, Cygnet and Cape Portland) have a Cretaceous radiometric age (c.145 Ma). Because of the ages obtained by McClenaghan *et al.* (1994) it is therefore more likely that the lamprophyre dykes at the Urquhart River and near Christmas Cove are also of Late Devonian age rather than Cretaceous as indicated in the Montgomery map sheet legend.

Petrologically, both dykes can be classified as minette. They are biotite rich and contain numerous xenoliths of cumulate pyroxene, K-feldspar/quartz granulite and other fine-grained igneous rocks. In thin section the lamprophyre at the mouth of the Urquhart River consists of phenocrysts of chloritised biotite as both laths (up to 1.6 0.25 mm) and blades (up to 1.4 0.7 mm) of euhedral to subhedral clinopyroxene and relict olivine, both of which are pseudomorphed by sericite, chlorite and leucoxene, in a quartzo-feldspathic matrix consisting of sheaths and radiating aggregates of plagioclase, with biotite, quartz, chlorite, sericite, carbonate and talc.

The lamprophyre dyke at Christmas Cove (Ph10) has chilled margins that grade into 50 mm thick vesicular zones. In thin section it consists of biotite, remnant equant and elongate grains of olivine and pyroxene (now chlorite), carbonate and quartz, in a biotite-rich quartzo-feldspathic groundmass.

GEOCHEMISTRY

Basaltic suite (Evv)

Samples of lavas and dykes from the Evu suite (Table 1) show an evolving low to medium-potassium tholeiitic fractionation trend from picritic to tholeiitic basalt. This trend is demonstrated by increasing total iron (FeO + Fe_2O_3) and relatively immobile elements (Nb, Ti, Y, Zr,) and decreasing MgO, Cr and Ni contents. The trend is consistent on all the chemical variation diagrams plotted (fig. 10), indicating that the parental magma underwent a typical tholeiitic evolution process that allows a stratigraphic sequence to be established.

There are lavas from at least five, and possibly six, batch melts within the Evv sequence in the Montgomery quadrangle. The earliest lavas are picrite with TiO_2 contents ranging between 0.37 and 0.71wt%. These lavas are olivine phyric, as are associated syndepositional dykes which may be a second batch melt due to variations in trace and Rare Earth Element chemistry. There are four tholeiitic basalt batch melts within the sequence. The first has TiO_2 between 1.10 and 1.20wt% and is a clinopyroxene olivine plagioclase phyric tholeiitic basalt. The second, with TiO_2 between 1.5 and 1.9wt%; the third, with TiO_2 between 2.10 and 2.54wt%; and the fourth, with TiO_2 between 3.12 and 3.51wt%, are all clinopyroxene and plagioclase phyric tholeiitic basalt.

The overall geochemical stratigraphy, from olivine-phyric picritic through to plagioclase-phyric tholeiitic basalt, is demonstrated on all major, trace and Rare Earth Element diagrams (fig. 11, 12) and indicates that the lower part of the stratigraphic succession (picritic and first and second batch of tholeiitic lavas) that crops out along the old BHP tracks (between 374500/5256600 and 375200/5257500), and along the costal section between Abo Creek and Veridian Point, is now overturned and facing west. The upper part of the succession, with lavas from the next two batch melts, occurs along the eastern side of the quadrangle and crops out along the old BHP tracks (around 376100/5257600 to 376500/5257600) and in the upper reaches of the Mainwaring River (between 376200/5253600 and 376900/5253600), and faces east.

Chemical analyses of both picritic lavas flows (Mo170, 231, 233, 291*, 292) and syndepositional dykes (Mo163, 164, 166, 169) were taken from a range of varying thickness flows/sills. Samples from the first (Mo228, 578) and second (Mo230, 584) tholeiitic basalt groups were obtained from areas of Evv in the upper Cypress Creek area (Mo228); along the old BHP tracks around 374300/5256600 (Mo230); and from the eastern area of Evv in the Mainwaring River (Mo578, 584). The two most evolved lava groups (Mo289, 563, 568, 585 and Mo287, 559*) occur along the easternmost area of Evv along both the BHP tracks (Mo287, 289) and the upper reaches of the Mainwaring River (Mo559*, 563, 568, 585).

The overall differentiation trend is also observed in primitive mantle normalised (Sun and McDonough, 1989) (fig. 11) and Rare Earth Element plots (fig. 12). These plots show a continuous fractionation from the picritic lavas, with olivine phenocrysts, to tholeiitic basalt, with varying proportions of plagioclase and clinopyroxene phenocrysts. Samples occur in the same order of differentiation irrespective of which elements are plotted.

Comparison of the geochemistry of the Montgomery samples with samples from the northern continuation (on magnetic data) of the Montgomery lavas on the western side of Birchs Inlet (McClenaghan and Findlay, 1993) shows that samples from the latter area fall on the same trend as samples from similar batch melts, defined by TiO_2 range and other elemental variations, in the Montgomery area. This is also true for lavas further to the north at Miners Ridge, approximately 500 m south of Queenstown (380500/5335000) (Dower, 1991).

Primitive mantle-normalised multi-element diagrams (fig. 11) show the same fractionation trend, by batch melting, as demonstrated on two and three element plots. The only element showing any variation to the norm is scandium, which shows a small negative anomaly for both picritic and tholeiitic samples from all three areas (Montgomery, Birchs Inlet and Miners Ridge).

Plots of Rare Earth Elements (REE) for the Montgomery tholeiitic lavas (fig. 12*a*) also show the batch melting groups with increasing elemental contents with increasing fractionation, and lavas grouping according to their increasing TiO_2 content. Patterns for the picritic lavas (fig. 12*b–d*) show different light rare earth patterns for the dykes (fig. 12*c*) compared to the sills (fig. 12*d*). Whether this is a result of batch melting/fractionation or contamination in the oceanic depositional environment is unknown.

When REE plots of samples from Birchs Inlet (MH193, MH194B, U41508; McClenaghan and Findlay, 1993) and Miners Ridge (MR373, MH414; Dower, 1991) are compared with those from Montgomery (fig. 12*e–h*), the picritic samples from Miners Ridge (MR373, MR607) and from Birchs Inlet (MH194B, U42508) have REE patterns (and TiO_2 contents) similar to, but more evolved than, the picritic lavas from Montgomery, even though immobile element concentrations indicate that most of the Miners Ridge samples are more primitive. The remaining sample from Birchs Inlet (MR193) falls in the mid-range of the Montgomery tholeiitic range, for both REE and TiO_2 contents.

It is interesting to note that other Neoproterozoic(?)–Cambrian(?) basaltic lavas, the Lucas Creek Volcanics in the Macquarie Harbour quadrangle (McClenaghan and Findlay, 1993), are easily separated into two geochemical groups and that each group comes from a different geographical area.

Samples of the first group crop out along the foreshore of Macquarie Harbour to the north of Double Cove/Lucas Creek, as well as from the southwest continuation of the succession on the west coast to the south of Albina Creek (McClenaghan and Findlay, 1989). This group has similar major and trace element geochemical characteristics to lavas from Montgomery, Birchs Inlet and Miners Ridge, but REE show different patterns from these three areas.

The second group crop out on the west coast to the north of Birthday Bay (McClenaghan and Findlay, 1989), and have different geochemical characteristics to the Montgomery, Birchs Inlet and Double Cove lavas (McClenaghan and Findlay, 1989) in that they have alkali basalt to andesitic geochemical characteristics and their own distinctive REE pattern. The geochemical differences of these lavas and their differences from the Montgomery–Birchs Inlet–Miners Ridge lavas indicate a far more complex basaltic geological history and tectonic relationships in this area than previously thought.

Geochemical data obtained from the basaltic suite (Evv) in the Montgomery quadrangle (Table 1) were made available for comparison with basaltic rocks in the Miners Ridge area by Dower (1991). Dower concluded that the basaltic rocks in the Mainwaring Group were correlates of the 'Miners Ridge Basalt' that occurs five kilometres to the south of Queenstown, and physically underlies the Mount Read Volcanics succession. The conclusions of Dower (1991) are supported by this study. [The Miners Ridge Basalt is now known as the Guilfoyle Creek Basalt. This term is now used in MRT's Digital Geological Map Series mapping and is used in the forthcoming *Geological evolution of Tasmania* (Corbett *et al*., in prep.)].

The same geochemical data were used by McClenaghan and Findlay (1993), who correlated the basaltic rocks cropping out on the western side of Birchs Inlet with those within the Evv sequence (Montgomery Basalt) in the Montgomery quadrangle. They also correlated the Mainwaring lavas with the general 'Eocambrian' lavas of western and northwestern Tasmania, including those within the Crimson Creek Formation. On reviewing McClenaghan and Findlay's (1993) geochemical data, the writer does not consider this correlation to be totally valid, as the Crimson Creek Formation formed in an intracontinental rift environment and not an oceanic one, and is around 40 million years older.

Following evaluation of the geochemistry of the basaltic suite (Evv; 'Montgomery Basalt') covered in this report and the nature of the associated sedimentary rocks, this succession is considered to be part of a Neoproterozoic (Ediacaran) to Lower Cambrian oceanic suite that includes the 'Cleveland–Waratah Association' (Brown, 1986) of western Tasmania. The 'Cleveland–Waratah Association' is now known as the Luina Group and the 'Mainwaring Group' is a sub-group of the Luina Group.

All of these successions are considered to have formed in an oceanic setting between ~545 and 515 Ma, and formed part of a mass of various oceanic rock sequences obducted onto the continental rock associations of western Tasmania, c.515–510 Ma (Berry and Crawford, 1988; Brown and Jenner, 1988). Following obduction, these lavas formed part of the basement onto which the Mount Read Volcanics sequence was erupted. The older age for the obduction event (c.515 Ma) is based on the age of eclogite within the Franklin Metamorphic Complex (Turner *et al*., 1998), garnet amphibolite in the Forth Metamorphic Complex (Black *et al*., 1997) and the age of a tonalite associated with the ultramafic rocks at Heazlewood (Kimbrough and Brown, 1992; Black *et al*., 1997).

Table 1

Whole-rock analyses — basaltic rocks (Evu succession)

Field No.	Mo170	Mo163	Mo291	Mo292	Mo231	Mo166	Mo169	Mo233	Mo164	Mo578
Anal. No.	873010	873006	883673	883674	883672	873008	873009	873019	873007	873036
Locality (mE)	375600	375300	375200	375200	374700	375500	377500	374600	375500	375900
Locality (mN)	5247400	5247900	5257400	5257400	5256700	5246700	5247400	5256600	5247800	5253400
Rock type	Evv-pl	Evv-pd	Evv-pl	Evv-pl	Evv-pl	Evv-pd	Evv-pd	Evv-pl	Evv-pd	Evv-t
SiO_2	40.10	48.69	47.85	41.13	45.20	45.71	43.95	52.50	47.00	49.53
TiO_2	0.37	0.38	0.39	0.45	0.46	0.48	0.56	0.68	0.71	1.16
Al_2O_3	16.60	10.36	6.54	12.55	14.98	16.75	13.25	12.23	16.02	14.10
Fe_2O_3	3.75	1.16	1.51	2.43	3.18	1.56	1.78	3.45	4.85	3.67
FeO*	8.60	7.81	7.40	8.48	6.22	7.52	10.11	6.23	7.23	7.39
MnO	0.18	0.20	0.18	0.17	0.16	0.15	0.62	0.16	0.22	0.17
MgO	14.56	15.97	20.77	19.79	14.70	8.88	15.08	6.78	6.70	7.42
CaO	7.78	7.63	9.31	5.36	8.22	11.90	5.63	10.57	9.68	9.29
Na_2O	1.03	1.92	0.14	0.24	2.34	2.23	1.47	4.50	3.34	3.65
K_2O	0.13	0.10	0.10	1.31	0.13	0.82	0.40	0.53	0.13	0.30
P_2O_5	0.03	0.10	0.04	0.04	0.07	0.06	0.04	0.06	0.05	0.12
H_2O	6.51	4.70	4.20	6.84	4.69	3.77	6.17	1.90	3.56	2.92
CO_2	0.08	0.12	0.34	0.54	0.30	0.08	0.10	0.64	0.07	0.44
LOI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr	1100	1550	1650	2200	2000	530	1500	270	210	260
Ni	290	400	530	1050	560	130	510	115	91	95
Co	66	60	58	88	64	36	37	39	41	44
Sc	26	39	37	36	39	41	32	33	45	46
V	140	175	180	250	230	185	230	320	270	370
Cu	20	20	13	6	89	26	120	36	200	86
Zn	82	86	42	53	51	71	83	61	87	93
K	1079	830	830	10875	1079	6807	3321	4400	1079	2490
Rb	8	5	16	47	13	25	15	5	5	8
Ba	69	29	23	145	34	82	90	42	31	42
Sr	125	68	4	4	54	120	22	69	480	140
Ta	0.40	0.26	0.30	0.20	0.00	0.34	0.28	0.31	0.00	1.02
Nb	1	2	1	3	4	1	2	1	1	3
Hf	0.58	0.87	0.48	0.73	0.00	0.46	0.74	1.15	0.00	2.17
Zr	14	44	21	22	26	20	28	39	21	70
Ti	2218	2278	2338	2698	2758	2878	3357	4077	4256	6954
Y	12	10	5	9	21	17	19	18	24	21
Th	0.67	0.37	0.20	0.30		0.68	1.69	0.30		0.42
La	0.67	3.52	0.34	0.32		1.80	3.21	1.63		4.33
Ce	2.00	7.45	1.08	1.52		4.19	7.23	4.40		11.20
Pr										
Nd	2.08	4.70	0.97	1.88		2.37	4.54	4.50		8.80
Sm	0.83	1.10	0.37	0.72		1.08	1.37	1.63		2.72
Eu	0.32	0.28	0.14	0.19		0.44	0.34	0.67		0.98
Gd										
Tb	0.25	0.20	0.10	0.18		0.35	0.29	0.34		0.60
Dy										
Ho	0.41	0.23	0.16	0.28		0.45	0.47	0.50		0.64
Er										
Tm										
Yb	1.33	0.81	0.50	0.75		1.53	2.05	1.12		2.06
Lu	0.21	0.16	0.08	0.12		0.24	0.33	0.20		0.30

Table 1
(continued)

Field No.	Mo228	Mo584	Mo230	Mo563	Mo289	Mo568	Mo585	Mo287	Mo559
Anal. No.	873017	883702	873018	873701	873021	873035	883703	873020	873034
Locality (mE)	372500	375500	374300	376600	365900	376300	376600	376400	376900
Locality (mN)	5258000	5253500	5256600	5253500	5257700	5253500	5253500	5257600	5253600
Rock type	Evv-t	Evv-t	Evv-t	Evv-t	Evv-t	Evv-t	Evv-t	Evv-t	Evv-t
SiO_2	47.70	49.83	49.35	47.99	48.40	48.08	49.42	45.81	46.74
TiO_2	1.17	1.47	1.80	2.11	2.31	2.43	2.54	3.12	3.51
Al_2O_3	14.14	16.13	13.86	13.33	14.75	12.96	12.13	12.54	12.63
Fe_2O_3	5.49	4.10	4.17	6.94	7.52	5.19	7.64	7.38	3.02
FeO*	6.20	5.65	8.11	7.29	6.19	8.52	6.94	9.60	12.46
MnO	0.17	0.13	0.17	0.18	0.16	0.20	0.18	0.23	0.22
MgO	8.62	4.91	7.62	6.15	5.47	5.88	5.26	4.58	5.28
CaO	6.66	9.08	6.24	7.06	6.06	8.62	8.23	8.15	6.81
Na_2O	4.10	2.54	4.16	4.36	4.15	3.95	4.49	2.15	2.70
K_2O	0.12	0.34	0.26	0.09	0.25	0.23	0.09	1.25	1.27
P_2O_5	0.12	0.23	0.14	0.25	0.22	0.25	0.35	0.39	0.34
H_2O	3.59	3.58	3.60	2.91	3.46	2.75	2.12	3.57	3.61
CO_2	0.09	0.40	0.09	0.04	0.39	0.22	0.23	0.34	0.15
LOI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr	310	195	290	180	230	165	130	84	24
Ni	125	88	120	82	100	79	49	30	22
Co	52	51	46	55	42	49	56	53	46
Sc	50	38	36	35	36	40	38	48	45
V	380	350	400	390	420	470	410	610	570
Cu	340	140	200	27	170	240	68	46	67
Zn	105	78	110	100	110	130	95	200	155
K	996	2822	2158	747	2075	1909	747	10377	10543
Rb	7	18	5	18	9	10	21	36	52
Ba	26	68	66	46	25	26	45	380	400
Sr	82	210	140	65	220	150	92	260	260
Ta	0.61	0.20	0.66	0.70	0.70	0.85	0.85	1.10	1.00
Nb	3	7	6	10	10	11	13	16	15
Hf	1.97	2.90	2.96	4.20	5.20	3.84	5.17	6.37	6.58
Zr	74	125	115	167	150	160	190	250	270
Ti	7014	8813	10791	12649	13848	14568	15227	18704	21042
Y	28	22	30	30	24	31	34	43	48
Th	0.59	0.35	0.45	0.89	0.86	1.11	0.94	3.70	4.42
La	4.46	6.29	6.90	10.90	10.90	10.60	12.90	16.70	24.10
Ce	12.40	16.20	18.50	30.00	28.30	30.10	35.10	41.70	55.50
Pr				4.44	4.22				
Nd	8.61	13.10	14.60	21.20	20.10	22.30	25.90	26.40	35.90
Sm	3.08	3.91	4.66	5.82	5.32	6.11	7.89	7.43	8.97
Eu	1.13	1.26	1.62	1.99	1.91	1.94	2.73	2.39	3.03
Gd				6.45	5.42				
Tb	0.76	0.66	0.73	1.00	0.88	0.96	1.24	1.30	1.45
Dy				5.93					
Ho	1.00	0.80	0.90	1.19	1.02	1.28	1.25	1.53	1.80
Er				2.94					
Tm				0.40					
Yb	2.59	1.85	2.06	2.29	2.15	2.31	2.61	4.01	4.49
Lu	0.41	0.27	0.28	0.34	0.31	0.29	0.39	0.66	0.73

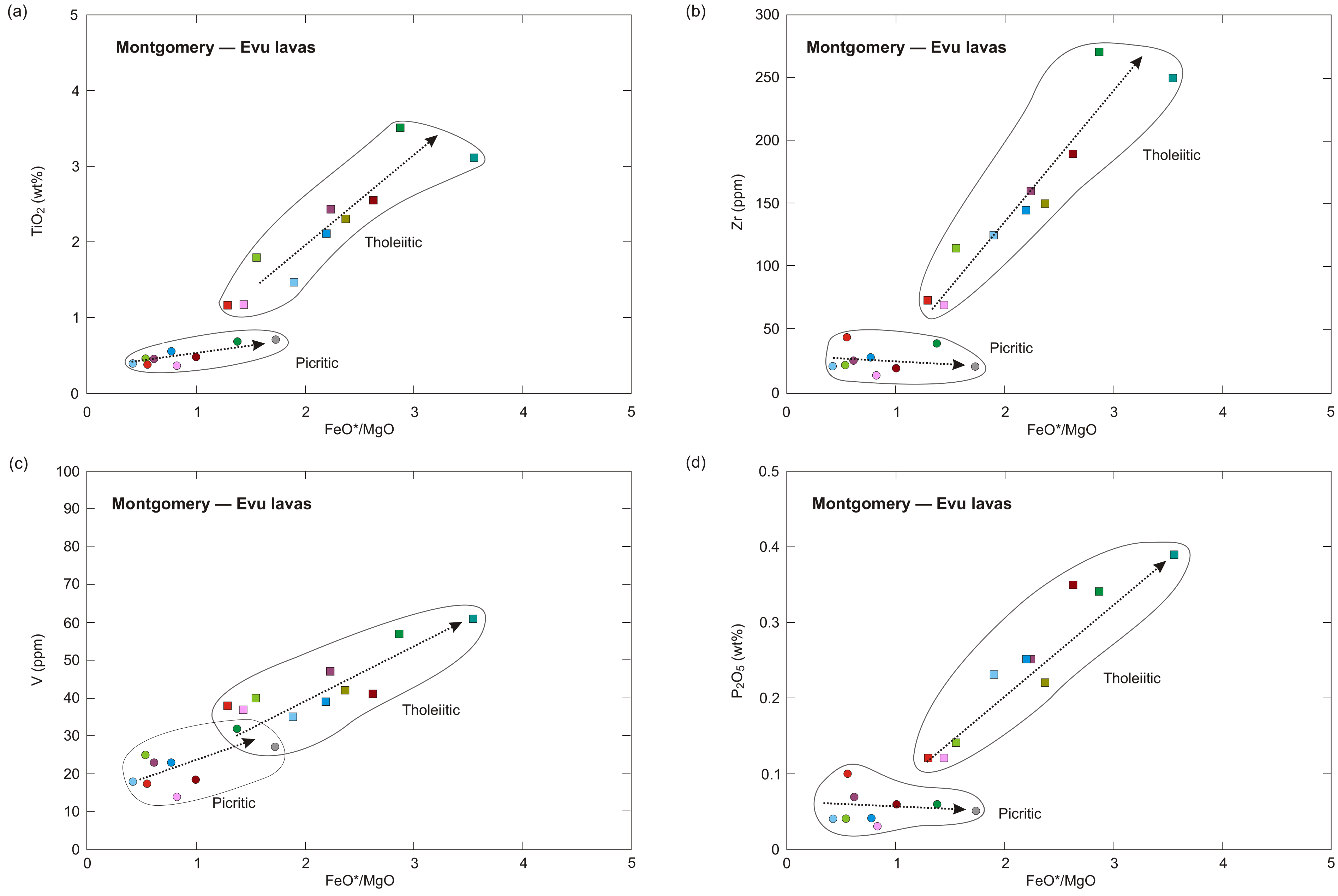

Figure 10. *Chemical variation diagrams, Montgomery Evu lavas.*

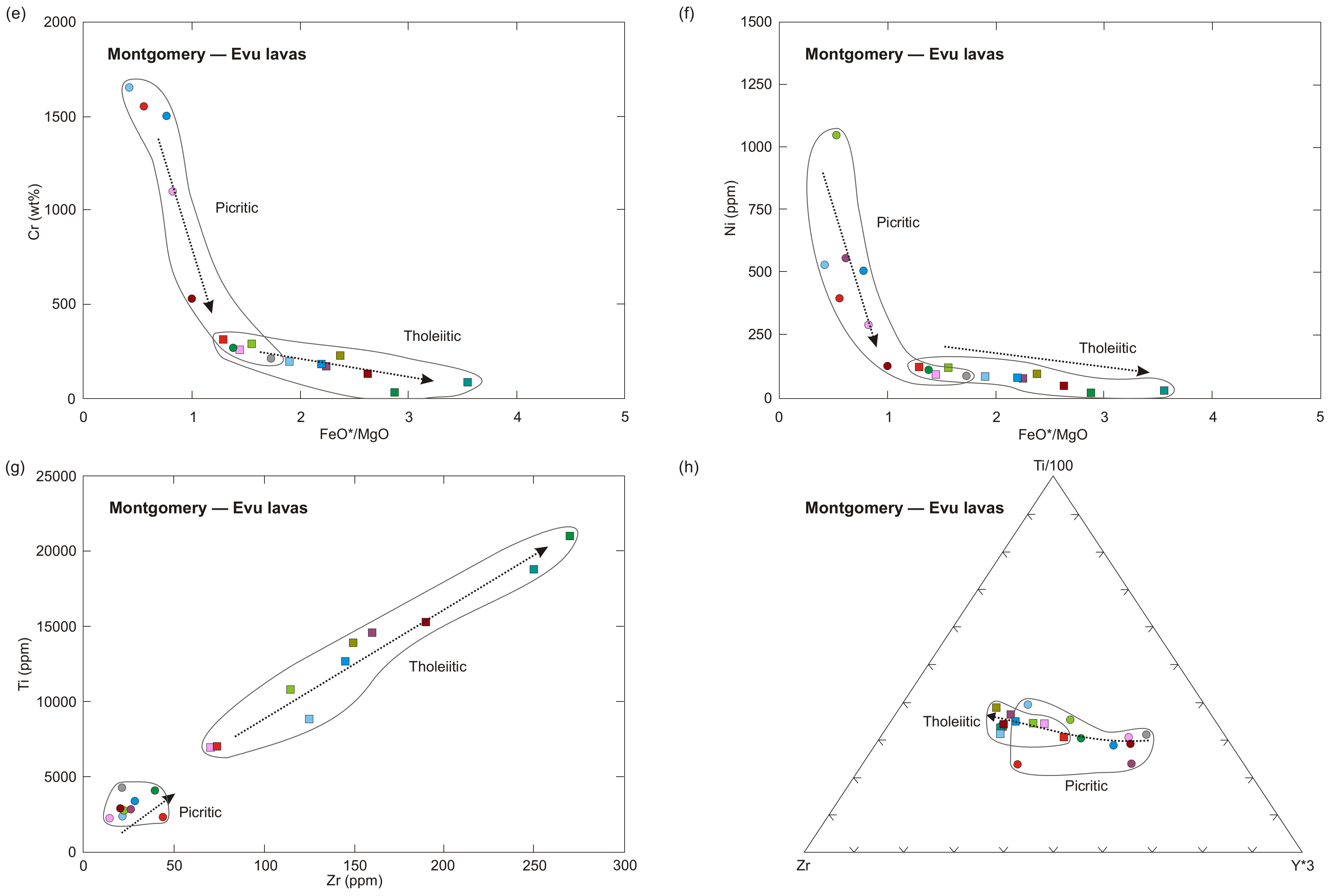

Figure 10. *Chemical variation diagrams, Montgomery Evu lavas.*

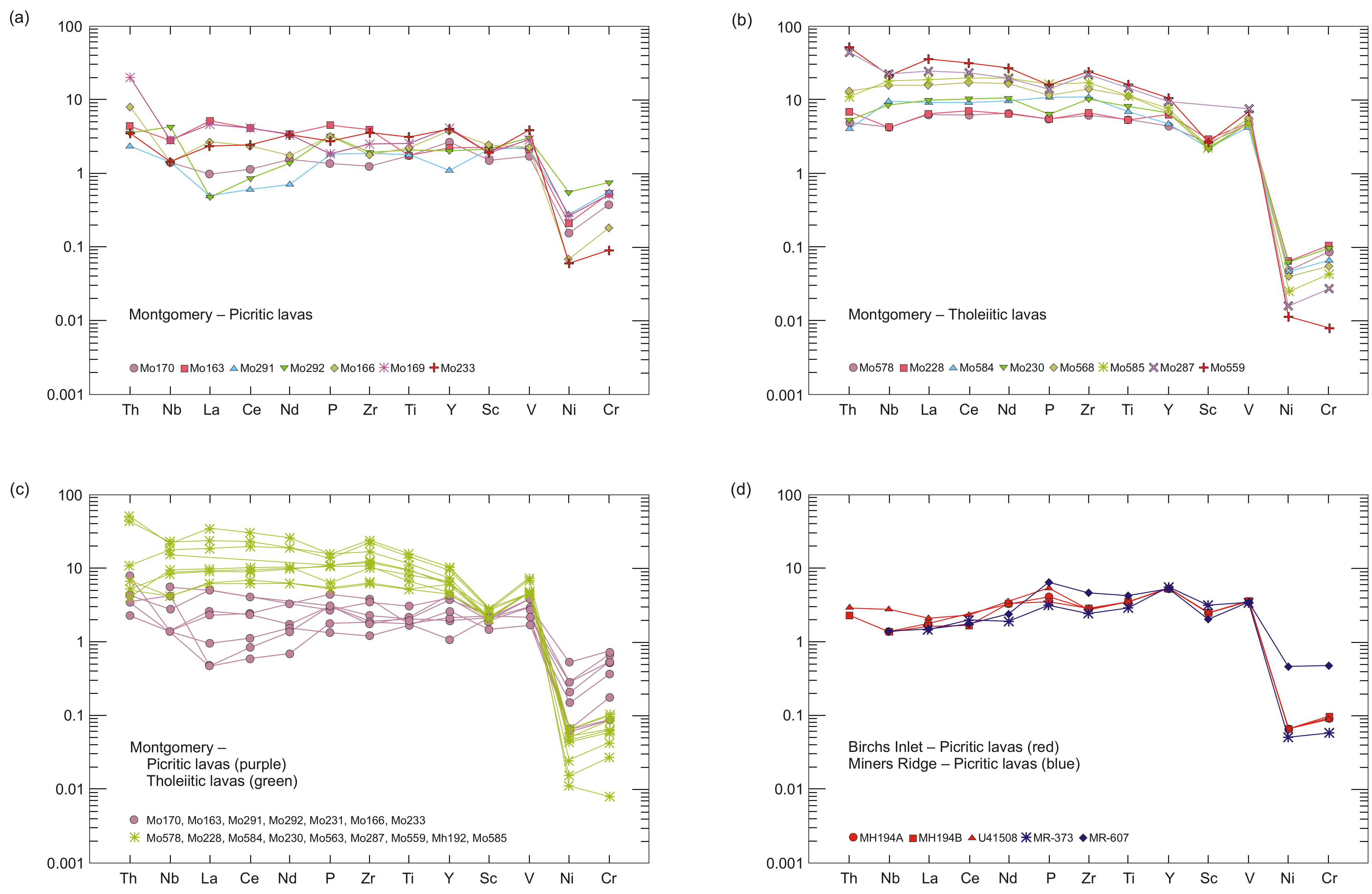

Figure 11. *Multi-element diagrams normalised to primitive mantle.*

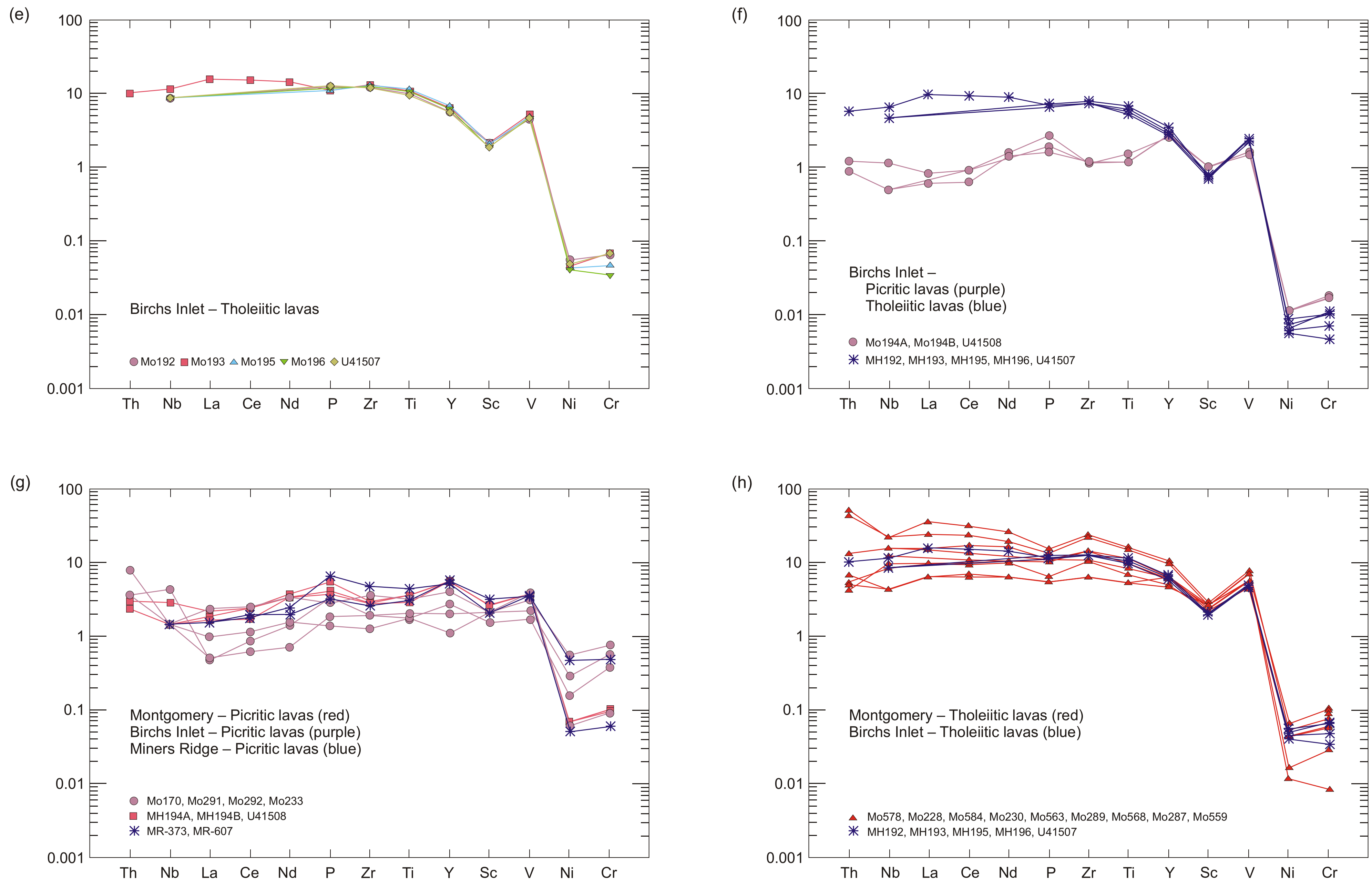

Figure 11. *Multi-element diagrams normalised to primitive mantle.*

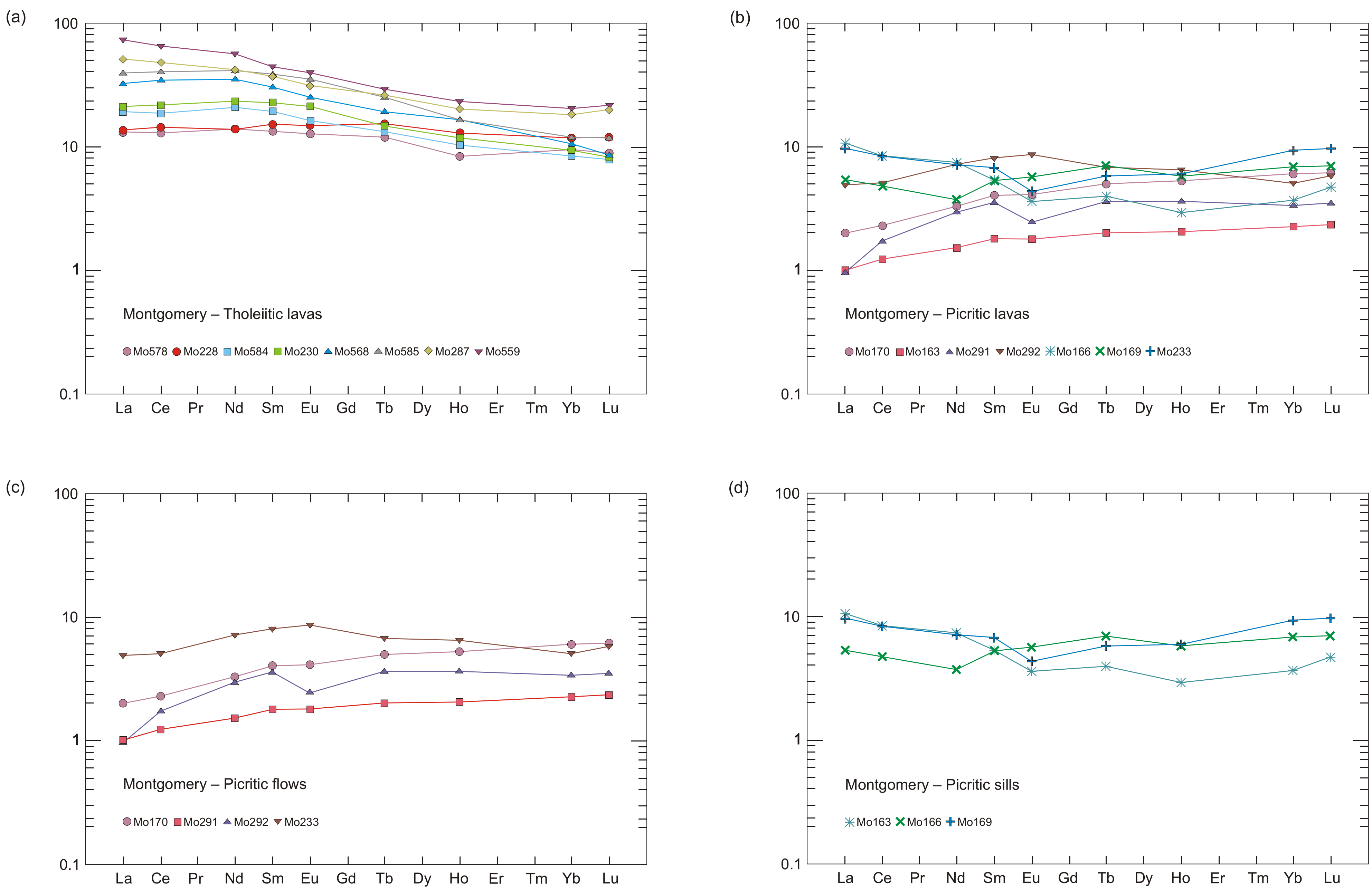

Figure 12. *Rare Earth Element diagrams normalised to primitive mantle.*

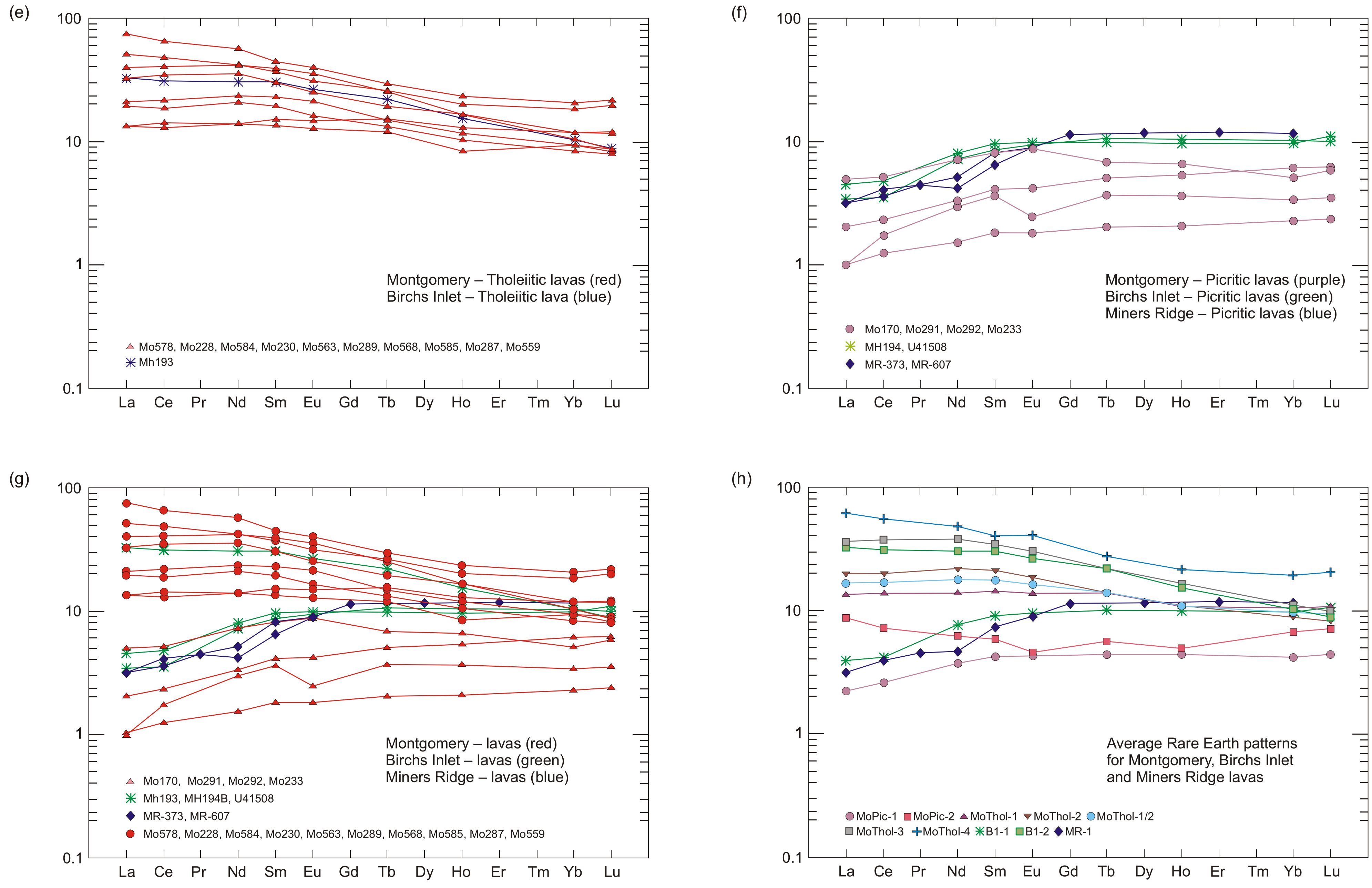

Figure 12. *Rare Earth Element diagrams normalised to primitive mantle.*

Andesite/dacite suite (Cvu)

The Cvu succession in the Montgomery quadrangle consists of andesitic and dacitic rocks (Table 2) and is a southern continuation of the volcanic succession of andesitic to rhyolitic rocks that crops out in the Macquarie Harbour quadrangle, where it is known as the Noddy Creek Volcanics (McClenaghan and Findlay, 1993). This succession continues south from Macquarie Harbour, through the Point Hibbs quadrangle to the Montgomery quadrangle. Descriptions and geochemistry of the northern continuation of the succession from the Montgomery quadrangle into the southern part of the Point Hibbs quadrangle (up to 5271000 mN) are included in this report.

Because of the suspension of geological mapping of the Point Hibbs map sheet, information regarding detailed outcrop distribution and geochemistry is not known for this area, although some areas have been described (Reid *et al.*, 2005).

Major element discrimant diagrams used for igneous nomenclature (fig. 13) indicate that the Cvu lavas range from andesite (Cvs, Cvv) to dacite (Cmv, Cva) and are sub-alkaline. No rhyolitic lavas, as found in the Macquarie Harbour quadrangle, were found in the Montgomery–southern Point Hibbs area. Overall, the geochemistry of the lavas in the Montgomery quadrangle is more primitive than those from the Macquarie Harbour quadrangle.

A classic calc-alkaline trend is observed on a standard Alkali ~ FeO* ~ MgO plot (fig. 13*a–d*), with a SiO_2 ~ K_2O diagram indicating a range from medium K through high K to near shoshonitic nature of the lavas (fig. 14*a*). To the north of Macquarie Harbour, in the Dundas Trough and throughout the main area of the Mount Read Volcanics belt, K, Na, Rb and Sr are unreliable as discriminant elements due to enrichment of these elements in all rock units by later fluids associated with Devonian granitic rock emplacement (Brown, 1986). This enrichment does not seem to be present in the Montgomery area, although some variation in these elements is considered to be due to local hydrothermal alteration (Reid *et al.*, 2005).

Geochemical discriminant diagrams, using averages for the Cvs, Cvv, Cmv and Cva sequences (fig. 14, 15), also show that the andesite/dacite lavas within the Cvu sequence are a medium to high-K, calc-alkaline succession, with the dacitic lavas from Acacia Rocks bordering on being shoshonitic, although this may be due to alteration. Individual lavas have a wide distribution on most discriminant diagrams but demonstrate a continuous fractional crystallisation within batch melts within and between the Cvs to Cvv to Cmv to Cva sequences; that is, up stratigraphic sequence.

Samples from the Cvs, Cvv, Cmv and Cva sequences show a certain degree of overlapping of ranges for major and trace contents on all geochemical discriminant diagrams. When an average of analysed lavas from within each of the sequences is plotted, an overall trend is evident and defines fractionation trends within and between batch melts (fig. 13–15). Plots using average values are used to help simplify the overlap caused by clasts (xenoliths?) from earlier lavas being incorporated in later lava units.

Average analyses for each stratigraphic group (Cvs, Cvv, Cmv, Cva) define a good, near linear calc-alkaline trend for most major, trace and Rare Earth Elements (fig. 13–17). This trend is not always linear for specific trace elements in the hornblende-bearing dacitic dykes and sills (Cmv), as the parental magma for this sequence appears to have received an enrichment component (fig. 15).

Progressing up the stratigraphic sequence, the chemical nature of the lavas for both single and average values, within and between the four sequences, show that with increasing SiO_2 content the major and trace element trends are basically linear and define fractionation trends within and between batch melting events from the Cvs to Cvv to Cmv to Cva sequence lavas (fig. 14). For whole-rock major elements the content of:

- K_2O increases;
- Al_2O_3 is fairly constant around 14wt%;
- Na_2O rises slightly from Cvs-Cvv-Cmv and then drops for Cva;
- CaO, MgO, FeO* and MnO all demonstrate an almost linear decrease (Cvs to Cva); and
- P_2O_5 demonstrates a linear decrease for Cvs-Cvv-Cva, with the Cmv sills and dykes having a relatively increased level defined by the trend of the other three suites.

Again, with the exception of the hornblende dacitic suite (Cmv), trace element contents show consistent trends with increasing SiO_2 and up stratigraphic sequence (fig. 15):

- Zr, Y and Nb increase;
- Hf and Th are relatively constant (however Th >> than Hf and Ta); and
- Cr, Ni, V and Sc decrease.

Samples from the Cmv suite are significantly enriched in a variety of trace elements (fig. 15), specifically:

- Cr, Ni, Zr and Hf (with almost double the trend content defined by the Cvs, Cvv and Cva suites);
- Nb and Sr show small increases from the trend line for the other suites; and
- V contents are lower than, and Y contents fall on, the Cvs-Cvv-Cmv-Cva trend line.

One of the Cmv dykes (Mo300*, 370600/5259300) is anomalously high in MgO, FeO*, CaO, Cr, Ni, Zr and Co, but low in SiO_2, Na_2O, Rb, Ba and Sr. The two thick sills (Mo392, Mo393) are enriched in Zr, Hr, Y and Th and low in MgO compared with the other Cmv samples.

Primitive mantle normalised elemental diagrams (Sun and McDonough, 1989) demonstrate that the average for all Cvu lavas has large negative niobium, hafnium and titanium anomalies and small negative anomalies for phosphorous, strontium, zirconium and europium (fig. 16*a–b*). The averages for each of the four sequences show variations for most elements, indicating batch melting, fractionation and enrichment for and between the Cvs, Cvv, Cmv and Cva sequences (fig. 16*c–d*). Samples from the Cmv and Cva sequences also show negative strontium and positive hafnium, zirconium and ytterbium compared to the Cvs and Cvv sequence lavas (fig. 16*c*). All lavas also have a relatively high thorium and chromium content.

The hornblende-bearing dacitic dykes and sills (Cmv) exhibit a range of chemistry but overall have been enriched in chrome, nickel, zirconium and niobium compared to the other sequences (fig. 16*e*). These can be split into three groups. The first group comprises samples from thin dykes (Mo300*, 363) (fig. 16*f*), while the second group comprises the plug-like intrusion Mo380 and the dacitic breccia from

Acacia Rocks (Mo306) (fig. 16*g*). The third group consists of samples from the thick sills (Mo392, 393) (fig. 16*h*). The first two groups are enriched in Zr, Y, Cr and Ni compared to the third group. Mo392 and Mo393 are further enriched in Zr and Y compared to Mo300* and Mo363.

One of the thin dykes (Mo300*) is anomalously high in MgO, FeO*, CaO, Cr, Ni, Zr and Co but low in SiO_2, Na_2O_3, Rb, Ba and Sr, compared to the other Cmv lavas, and has chemical characteristics that are similar to Suite 1 within the Mount Read Volcanics in western Tasmania (Crawford *et al*., 1992).

Rare Earth Element contents — Cvs and Cvv sequences

The up-stratigraphic chemical evolution of the Cvu lavas, demonstrated by the whole-rock and trace element discriminant diagrams, is reflected in increasing abundances of REE for lavas from both the Cvs and Cvv sequences (fig. 17). However the up-stratigraphic order does not strictly hold for every Rare Earth Element (REE), as samples from both sequences show element variations and overlap with each other, defining four different REE patterns. Fractionation within batch melts is evident for at least three batch melts in the Cvv sequence (fig. 17*b*).

When separated into similar REE patterns, the grouping represents clasts, matrix and lavas from both the Cvs and Cvv sequences (fig. 17*c–f*). The first group consists of samples of lava clasts from autoclastic breccia layers within both the Cvs and Cvv sequences, indicating that previous lava eruption events, the products of which do not crop out along the Montgomery coast, occurred. These samples have a smooth transition from heavy to light REE but with a positive Nd anomaly (fig. 17*c*).

The second pattern is from individual lava flows that occur in the Cvs sequence, plus one sample from the top of the Cvv sequence (Mo438). This pattern (fig. 17*d*) has a steeper, straight HREE distribution, a negative Eu anomaly, a positive Nd anomaly and a steeper and higher LREE content in comparison to group 3 lavas from the Cvv sequence (fig. 17*e–f*).

The third pattern consists of samples of the matrix from the autoclastic breccia layers and single lava flows within the Cvv sequence. These display the positive Nd anomaly of the clasts as well as a small negative Eu anomaly, but have relatively flat REE contents, and either a positive or negative Lu kick (fig. 17*e–f*).

There are two variations from the average patterns. These are Mo528, from the base of the Cvv sequence, that does not have the negative Eu anomaly (fig. 17*f*) and Mo438, from near the top of the Cvv sequence, that does not have the positive Nd anomaly (fig. 17*e*).

Rare Earth Element contents — Cmv and Cva sequences

REE plots for Cmv and Cva samples indicate that there are two specific groups (Mo300*, 360, 380 and Mo306, 392, 393), not three as shown by the major and trace element chemistry. The latter group has elevated HREE contents compared to the former, as well as having negative Eu anomalies (fig. 17*g–h*).

With respect to REE contents, La increases with increasing Zr in the Cvs and Cvv lavas, consistent with their equal incompatible element levels.

Comparison with Mount Read Volcanics in western Tasmania

The Montgomery lavas have been compared with the Mount Read Volcanics geochemical suites (Corbett and Vicary, in prep.). On all plots the Cvs lavas fall in the area for MRV Suite 3b lavas, while Cvv lavas fall in the area for MRV Suite 2c but have low P_2O_5. The hornblende-phyric dacite dykes and sills and the dacitic lava from Acacia Rocks have similarities to both MRV Suite 1 and MRV Suite 2 lavas, with Cva samples being similar to MRV Suite 1 lavas. The comparisons indicate that the Montgomery lavas evolved up sequence (Cvs-Cvv-Cmv-Cva) from MRV Suite 3 through MRV Suite 2 into MRV Suite 1 type.

When comparing the Montgomery lavas to those from the Macquarie Harbour area (McClenaghan and Findlay, 1993), those in the Thomas Creek area are similar to MRV Suite 2 and those from the Timbertops area are a mixture of MRV Suite 1 and MRV Suite 2 with minor MRV Suite 3, but not in any mappable stratigraphic order. It appears that, overall, a geochemical trend from most primitive to most evolved lavas starts with the Montgomery Cvs lavas and goes inland and north through the Point Hibbs quadrangle to the Macquarie Harbour quadrangle.

Comparison of the stratigraphy, geochemistry and synthesis of the magma formation for the felsic lavas covered by the Macquarie Harbour, Point Hibbs and Montgomery map sheets, with that presented by Corbett and Vicary (in prep.) for the Mount Read Volcanics in western Tasmania, indicates that felsic volcanism in this area formed in a submarine environment into which the calc-alkaline clinopyroxene-plagioclase phyric lavas (Cvs; MRV Suite 3 lavas) were intruded during a fast rifting event. This was followed by massive outpourings of andesitic lavas and autoclastic breccia flows (Cvv; MRV Suite 2 lavas). A sharp cessation of volcanic activity then occurred, demonstrated by the sharp transition to the stratigraphically and structurally overlying sedimentary rock sequence dominated by quartzwacke (Cvl), and containing intrusive dykes and sills of hornblende-bearing dacite (Cmv; fractionated MRV Suite 2) followed by a volcaniclastic sedimentary sequence, with minor clinopyroxene-plagioclase bearing flows and/or dykes (Cvt), and then by dacitic volcanism (Cva; MRV Suite 1 lavas).

Geochemically, the lavas follow a differentiation and fractionation trend that evolves up the stratigraphic succession. Trace and Rare Earth Element diagrams indicate that the volcanic rocks within the lower volcano-sedimentary succession (Cvs) are the most undifferentiated followed by those from the stratigraphically overlying massive lava sequence (Cvv), then the hornblende-bearing dacitic dykes (Cmv) within the Cvl sequence, and finally the dacitic lava (Cva).

In comparison to the remnants of a wide range of felsic lavas (andesitic to rhyolitic) that occur in the Macquarie Harbour area (McClenaghan and Findlay, 1993), the only evidence of dacitic volcanism in the Montgomery quadrangle consists of dacitic breccias that crop out as Acacia Rocks. This tightly confined group of eleven rocks, jutting out just above sea level and within a diameter of 500 m, approximately 2.5 km offshore to the west, is probably the residual of a dacitic volcanic plug.

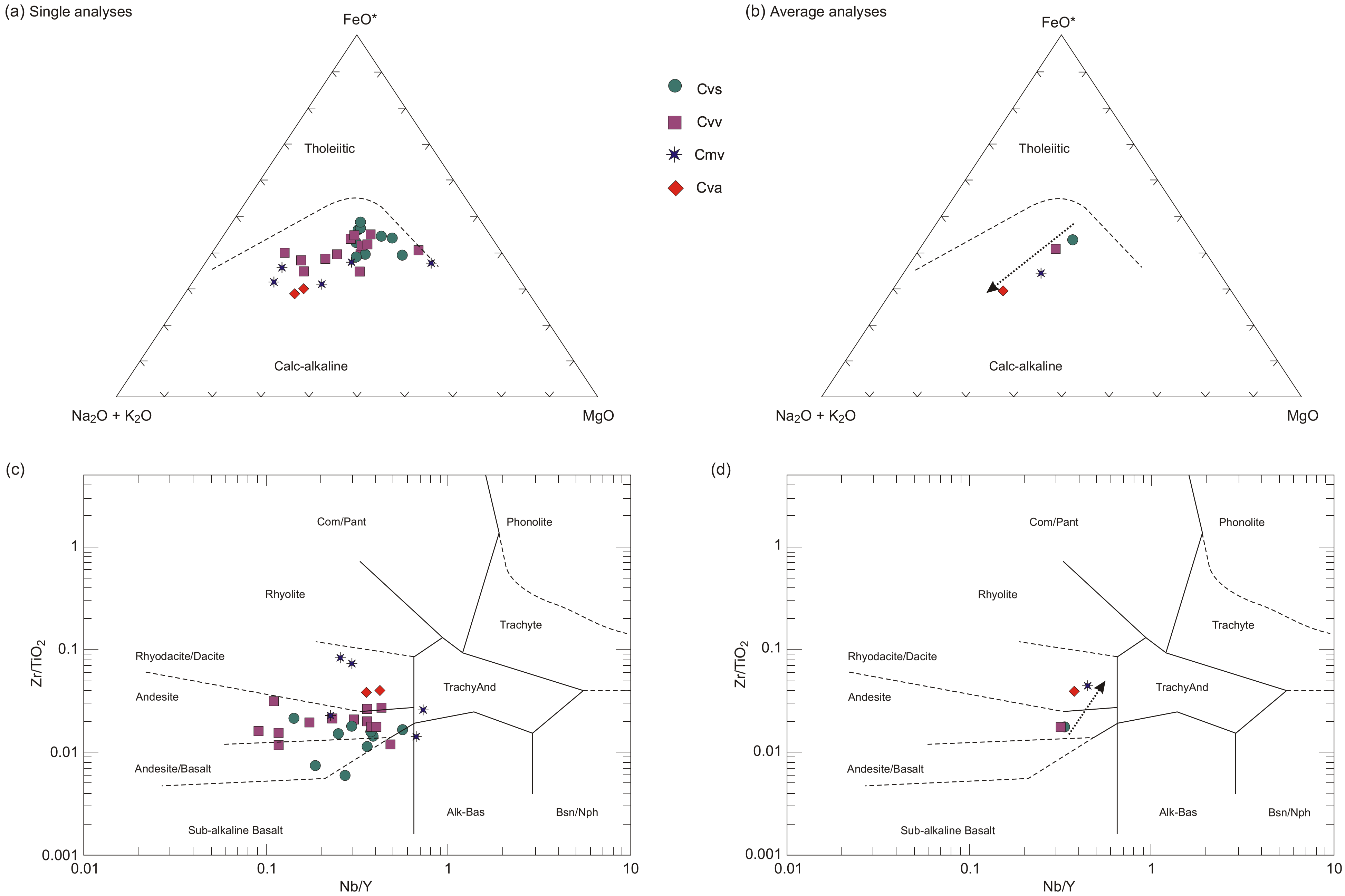

Figure 13. *Geochemical discrimination diagrams of andesitic-dacitic lavas (Cvs, Cvv, Cva, Cmv).*

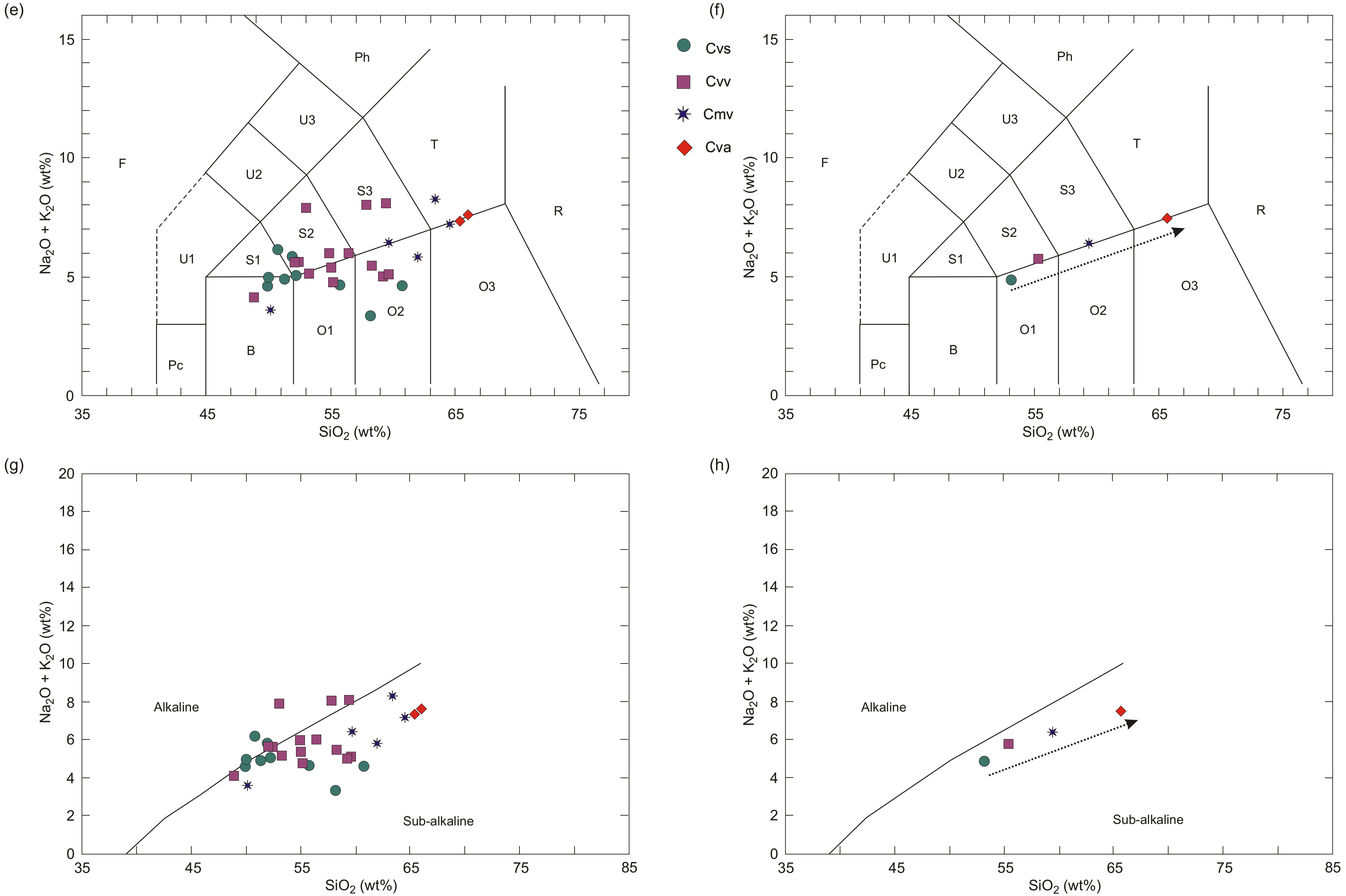

Figure 13. *Geochemical discrimination diagrams of andesitic-dacitic lavas (Cvs, Cvv, Cva, Cmv).*

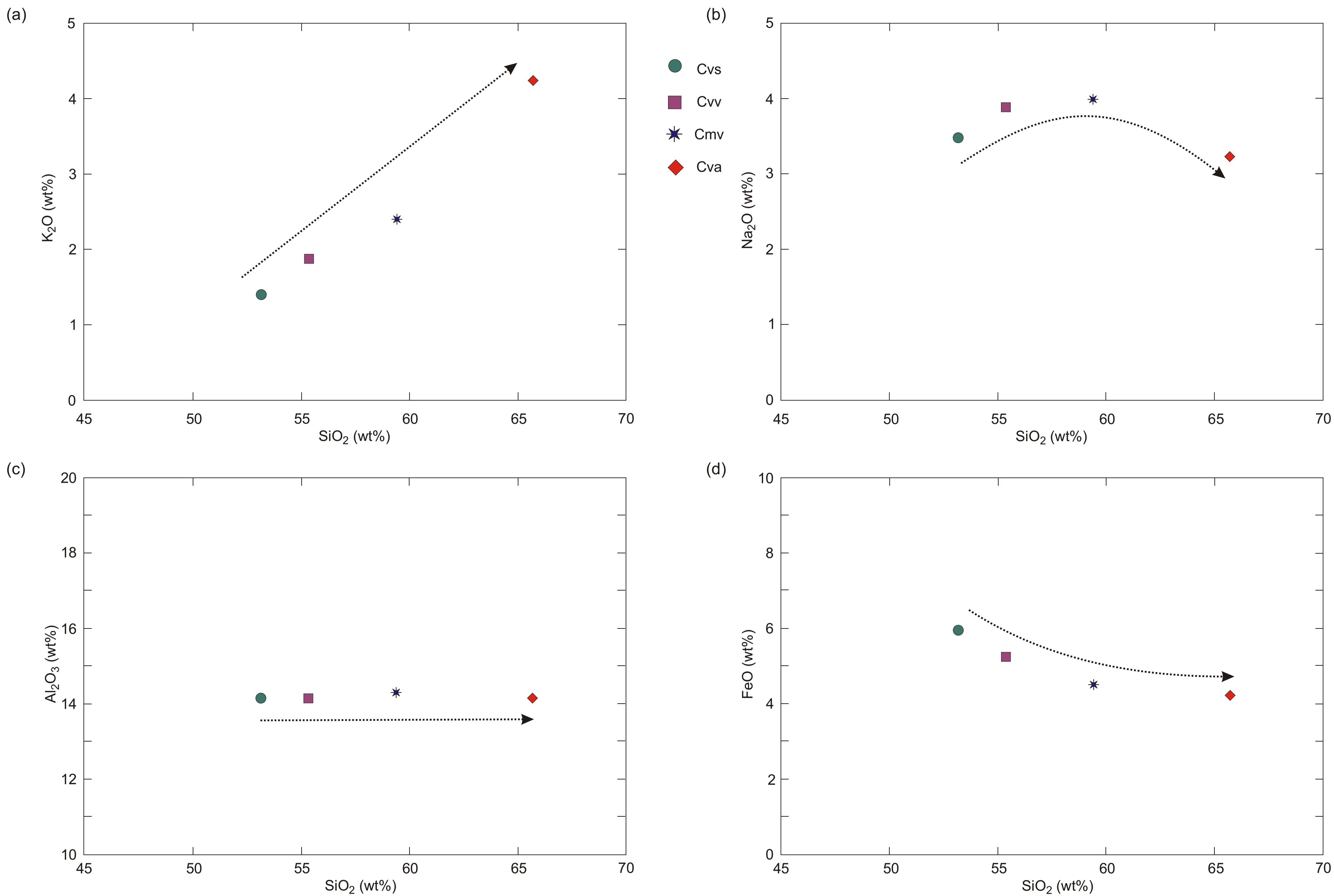

Figure 14. *Geochemical discrimination diagrams of andesitic-dacitic lavas (Cvs, Cvv, Cva, Cmv).*

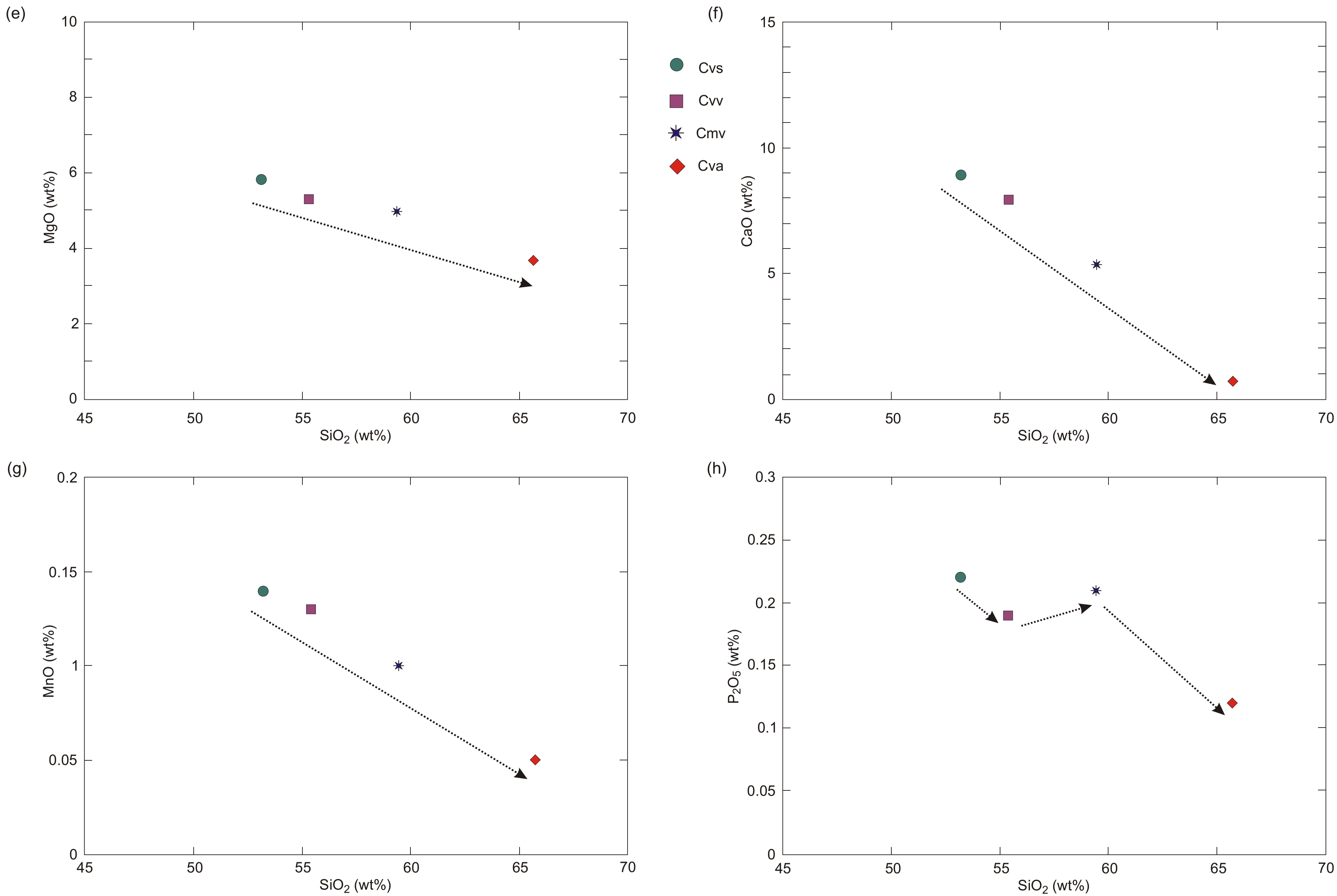

Figure 14. *Geochemical discrimination diagrams of andesitic-dacitic lavas (Cvs, Cvv, Cva, Cmv).*

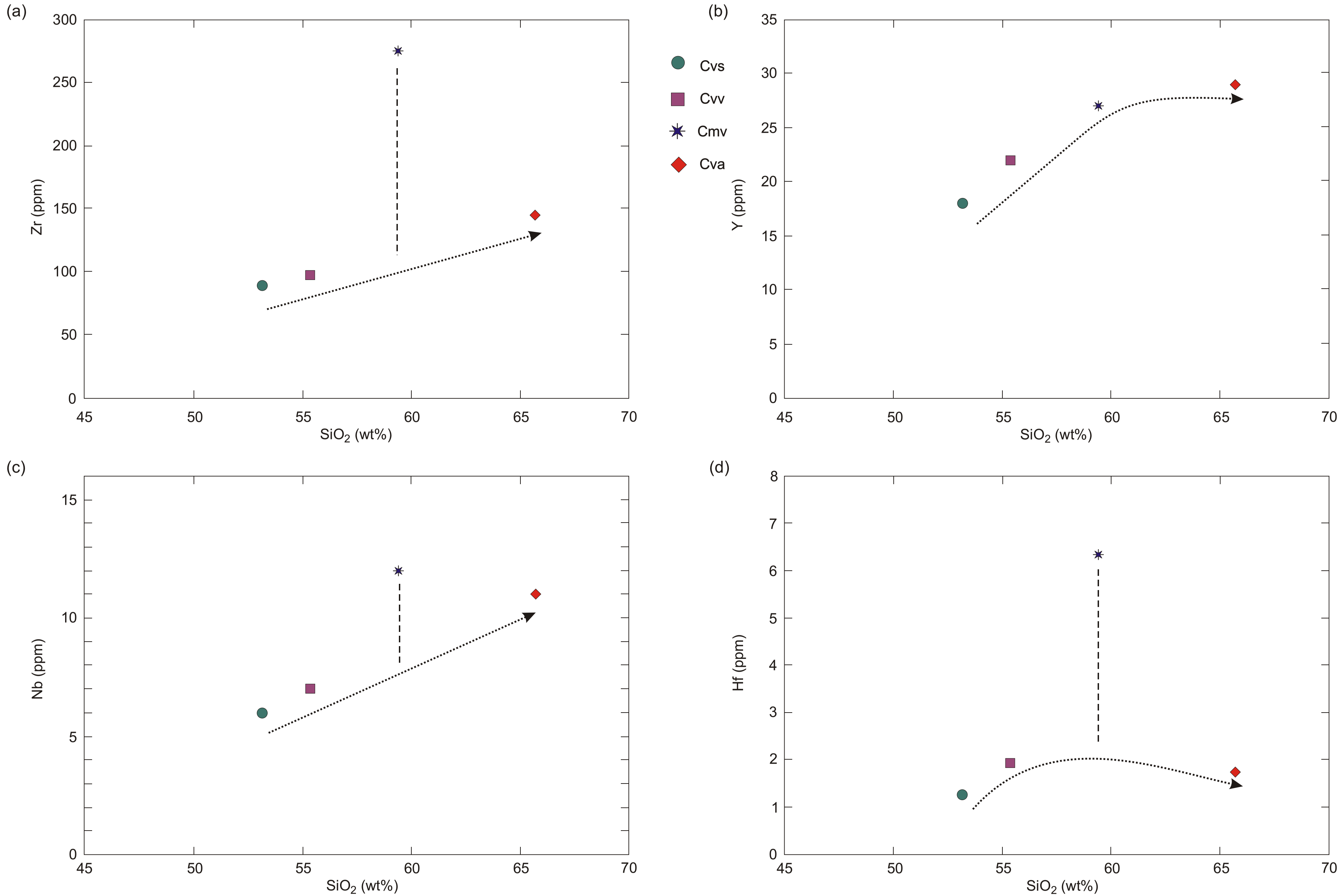

Figure 15. *Variation of Cmv composition to general trend (Cvs, Cvv, Cva).*

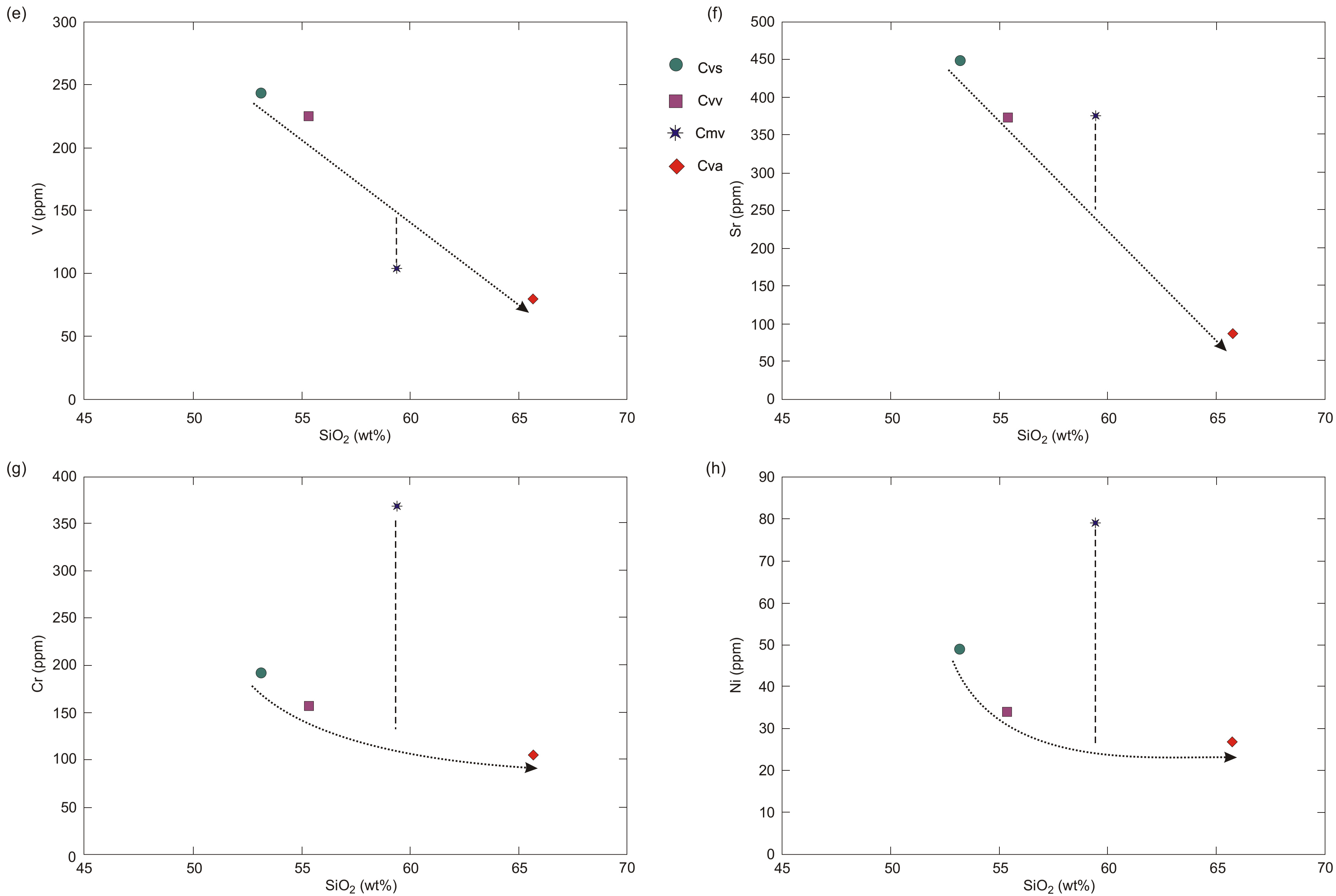

Figure 15. *Variation of Cmv composition to general trend (Cvs, Cvv, Cva).*

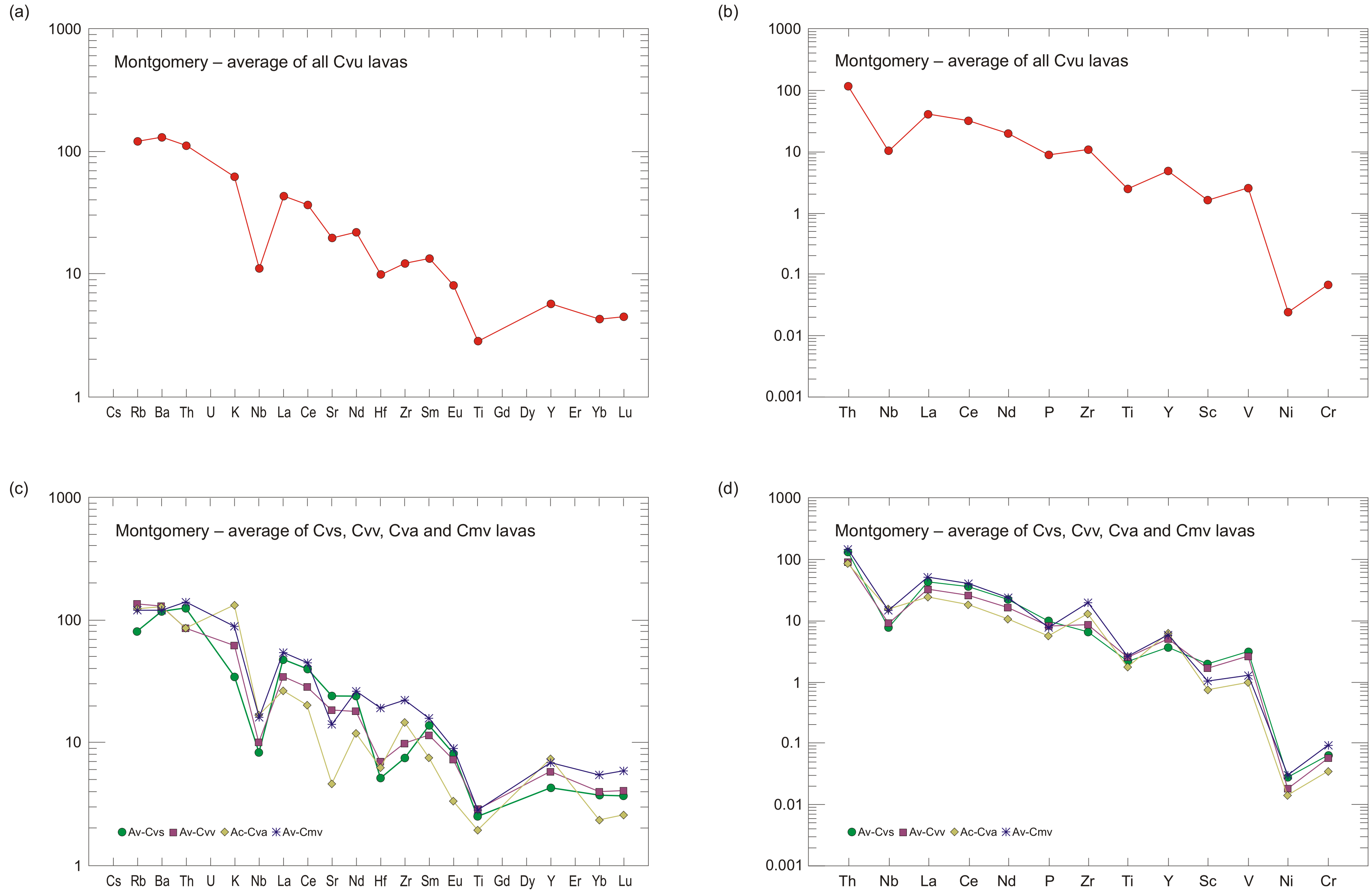

Figure 16. *Multi-element discrimination diagrams normalised to primitive mantle.*

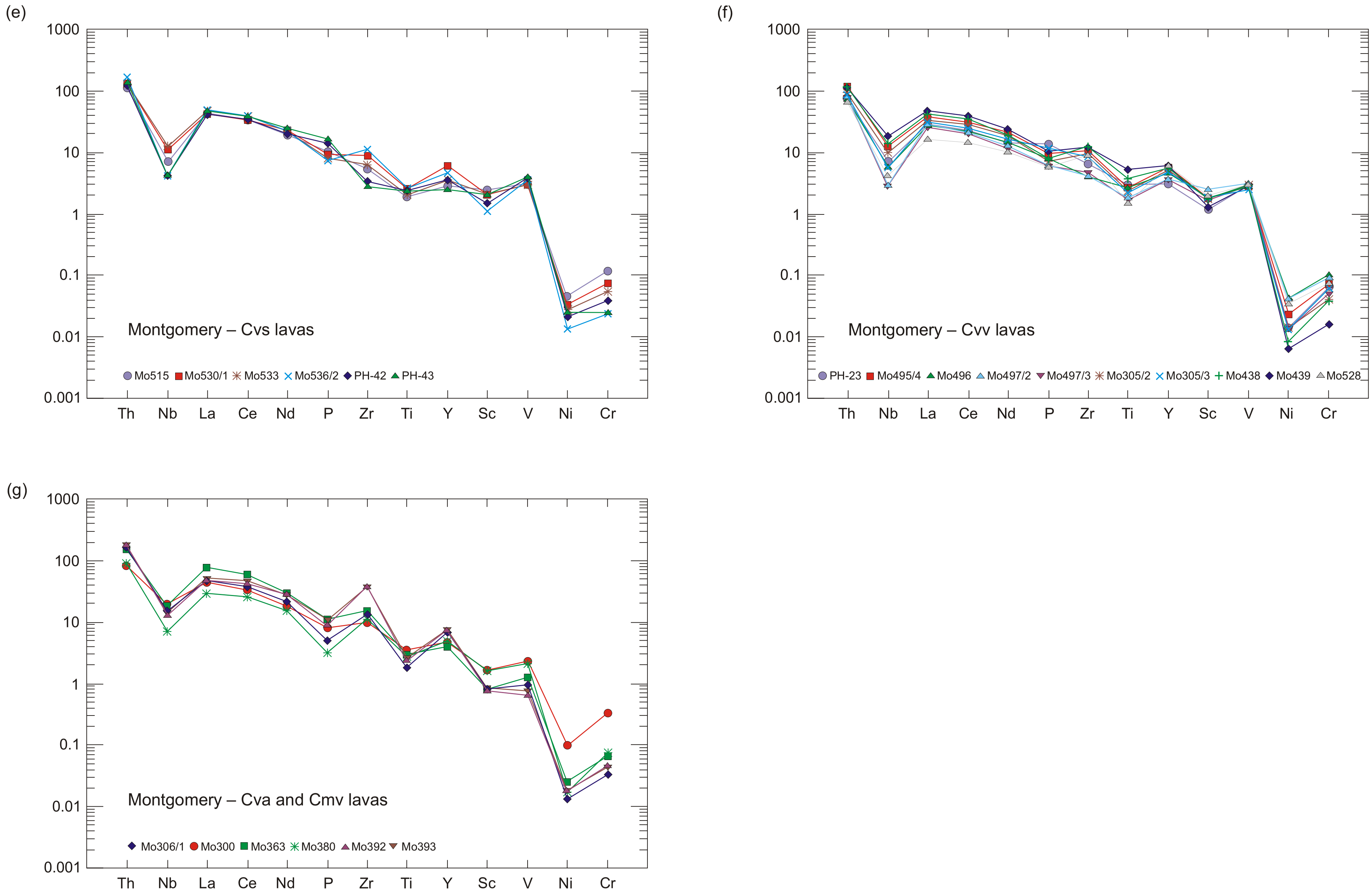

Figure 16. *Multi-element discrimination diagrams normalised to primitive mantle.*

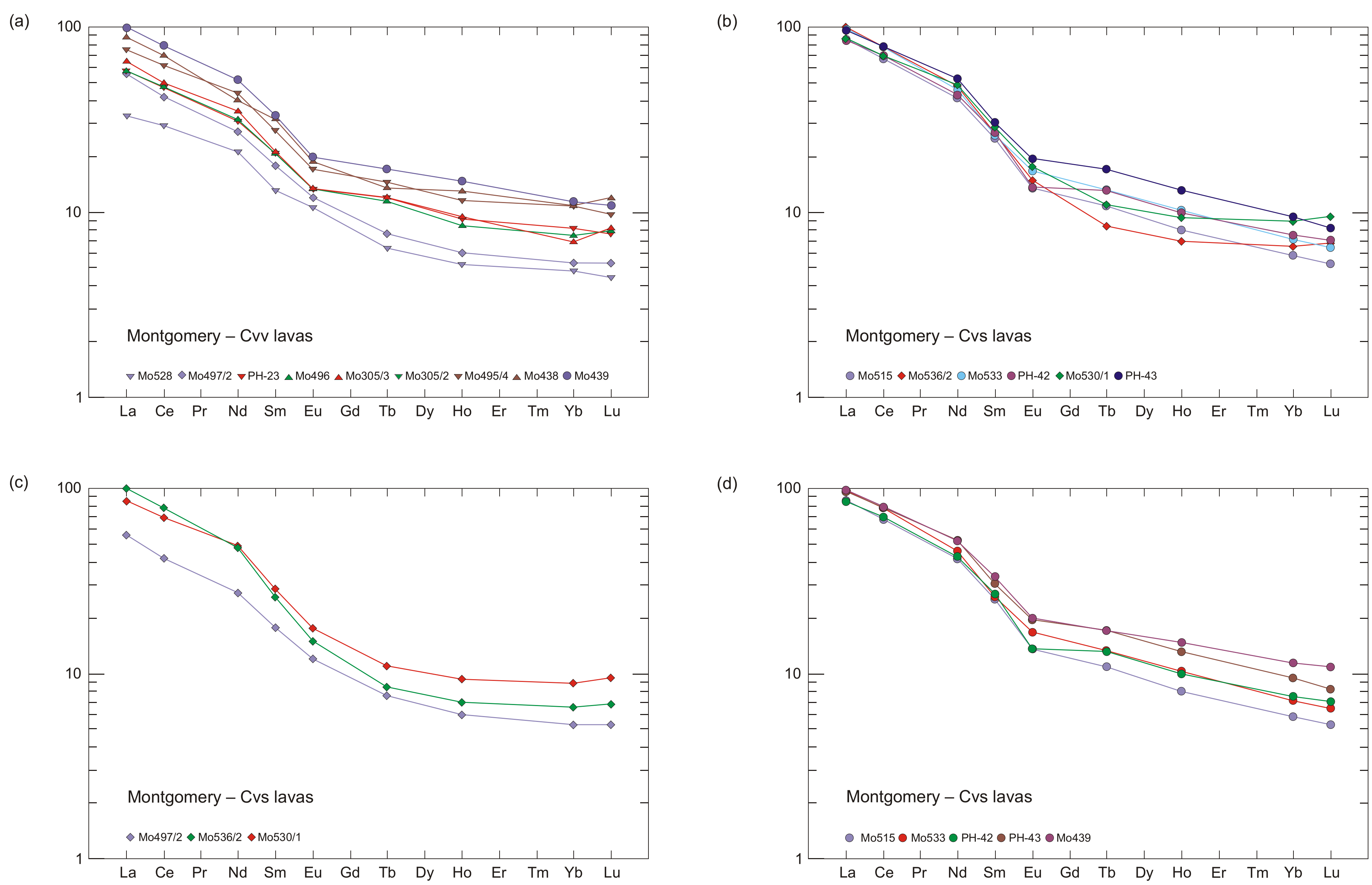

Figure 17. *Rare Earth Element diagrams normalised to primitive mantle.*

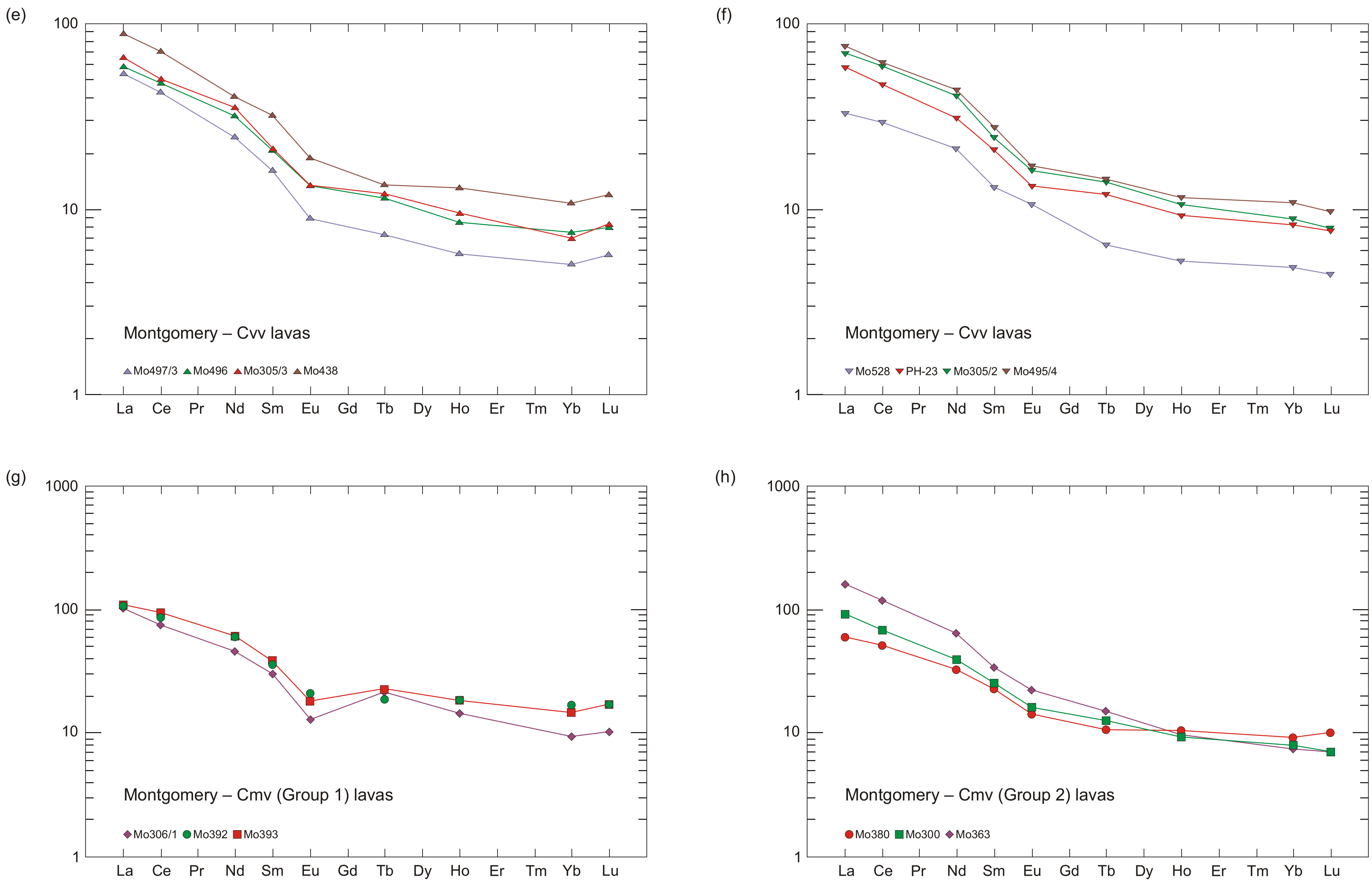

Figure 17. *Rare Earth Element diagrams normalised to primitive mantle.*

Table 2

Whole-rock analyses for andesitic-dacitic rock association (Cvu)

Field No.	Mo530/1	Mo530/2	Mo530/4	Mo533	Mo534	Mo535	Mo536/2	Mo536/3	PH-23	PH-42	PH-43
Anal. No.	883691	883692	883693	883694	883695	873032	883696	883697	895753	895755	895756
Locality (mE)	367400	367400	367400	377500	367500	367400	367400	367400	367500	368000	366600
Locality (mN)	5264000	5264000	5264000	5264300	5264500	5264200	5264800	5264800	5268100	5266800	5271300
Rock type	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs-Hibbs	Cvs-Hibbs	Cvs-Hibbs
SiO_2	50.79	58.19	50.58	51.94	50.65	48.92	55.71	49.95	60.77	52.22	50.02
TiO_2	0.55	0.45	0.42	0.43	0.75	0.53	0.58	0.41	0.63	0.53	0.50
Al_2O_3	15.53	10.84	13.86	15.24	12.24	13.75	15.13	13.17	12.51	15.21	14.84
Fe_2O_3	2.35	0.58	5.46	2.21	2.39	1.90	4.27	3.04	2.17	2.29	3.19
FeO	5.62	5.29	3.35	6.62	6.37	8.36	4.50	7.07	4.43	7.69	6.88
MnO	0.13	0.11	0.14	0.12	0.17	0.20	0.14	0.20	0.12	0.14	0.12
MgO	6.09	3.40	6.74	5.77	12.41	7.78	4.89	7.95	5.15	5.36	7.20
CaO	9.58	13.65	10.98	8.85	8.18	10.01	8.11	10.64	7.39	5.71	8.55
Na_2O	3.12	3.29	0.26	5.21	4.2	2.60	3.18	4.13	2.03	3.66	4.49
K_2O	3.04	0.07	0.85	0.63	1.52	1.95	1.46	0.50	2.59	1.40	0.48
P_2O_5	0.20	0.20	0.18	0.18	0.16	0.17	0.16	0.16	0.29	0.30	0.35
H_2O^+	2.51	6.80	3.59	2.60	2.8	3.28	2.10	2.89	2.57	2.84	3.48
CO_2	0.33	0.21	0.35	0.13	0.19	0.09	0.10	0.10	0.12	0.01	0.01
LOI	0.08	0.08	0.05	0.10	2.28		0.02	0.03	2.39	2.08	2.76
Ba	1750	380	32	260	620	800	1850	200	860	880	240
Rb	97	38	17	26	61	56	80	24	91	55	17
Sr	370	220	90	370	310	40	1450	360	250	520	480
Y	27	16	19	16	13	17	21	16	14	16	11
Zr	98	59	117	71	45	52	125	67	72	39	30
Nb	8	4	8	9	4	3	3	3	5	3	3
Th	11.00	7.54	8.16	10.70	11.20	11.10	13.80	8.63	6.60	10.30	11.32
Zn	39	42	25	40	46	89	210	91	43	55	40
Cu	5	59	1	47	76	115	15	81	15	95	53
Ni	64	66	27	52	41	78	26	68	27	40	47
V	240	230	150	240	250	300	290	270	220	320	330
Cr	220	310	210	160	120	220	71	230	200	115	74
Hf	2.21	1.60	2.80	1.31	1.20	1.40	1.34	1.50	1.78	1.49	1.12
Sc	35	37	24	36	26	40	19	45	20	25	35
Ta	0.44	0.30	0.50	0.30	0.20	0.20	0.62	0.20	0.35	0.48	0.30
Co	37	43	24	45	37	49	39	51	21	40	47
La	28.36	22.80	29.80	31.90	31.80	31.10	32.90	23.70	19.20	28.00	31.70
Ce	59.80	48.00	56.40	67.60	66.60	65.90	67.80	51.20	40.40	60.60	68.40
Pr		5.66	6.35		7.38	7.62		6.25			
Nd	30.60	21.80	23.70	28.90	28.50	29.90	29.80	22.70	19.50	26.90	33.10
Sm	5.84	4.36	4.49	5.29	4.93	5.53	5.28	4.54	4.26	5.46	6.22
Eu	1.35	1.11	0.94	1.29	1.30	1.43	1.15	1.09	1.02	1.05	1.49
Gd		3.59	3.46		3.43	4.07		3.41			
Tb	0.55	0.50	0.57	0.66	0.46	0.56	0.42	0.50	0.60	0.65	0.85
Dy		2.86	3.32		2.68	3.23		2.93			
Ho	0.72	0.63	0.68	0.79	0.50	0.62	0.54	0.60	0.71	0.77	1.01
Er		1.65	1.87		1.38	1.77		1.61			
Tb		0.20	0.30		0.20	0.30		0.20			
Yb	1.94	1.59	1.79	1.58	1.25	1.61	1.45	1.52	1.80	1.65	2.07
Lu	0.32	0.23	0.26	0.22	0.19	0.24	0.23	0.23	0.26	0.24	0.28

Table 2

(continued)

Field No.	Mo495/2	Mo495/4	Mo496	Mo497/2	Mo497/3	Mo537	Mo538	Mo539	Mo305/1	Mo305/2	Mo305/3
Anal. No.	883684	883685	883686	883687	883688	883698	883699	883700	883676	883677	883678
Locality (mE)	368400	368400	368300	368200	368200	368500	368500	368400	367200	367200	367200
Locality (mN)	5266900	5266900	5270000	5266900	5266900	5266900	5266900	5266900	5262500	5262500	5262500
Rock type	Cvv	Cvv	Cvv	Cvv	Cvv	Cvv	Cvv	Cvv	Cvv	Cvv	Cvv
SiO_2	53.24	52.08	54.91	48.85	58.29	57.87	59.47	59.63	52.40	55.06	59.24
TiO_2	0.57	0.57	0.57	0.39	0.35	0.74	0.45	0.27	0.41	0.50	0.48
Al_2O_3	16.13	14.47	12.66	13.36	14.02	16.48	13.58	10.66	15.38	13.86	11.92
Fe_2O_3	1.70	2.92	4.03	1.80	2.68	1.22	2.57	1.67	3.55	3.14	3.71
FeO	6.07	6.19	4.37	8.10	3.16	5.92	4.10	3.99	5.25	5.65	4.09
MnO	0.12	0.15	0.13	0.18	0.09	0.09	0.12	0.11	0.16	0.14	0.12
MgO	5.51	6.51	6.28	10.28	3.54	2.70	4.00	5.25	6.03	5.18	4.58
CaO	8.17	8.87	8.96	7.44	9.08	3.41	6.24	10.95	9.20	7.63	8.71
Na_2O	3.36	4.44	3.85	2.27	3.86	4.07	4.72	4.64	4.02	4.35	3.16
K_2O	1.78	1.17	2.15	1.85	1.60	3.96	3.37	0.45	1.61	1.03	1.85
P_2O_5	0.18	0.20	0.16	0.13	0.13	0.27	0.13	0.14	0.16	0.15	0.25
H_2O^+	3.03	2.19	1.42	3.83	1.59	2.72	1.13	1.25	2.10	2.25	1.57
CO_2	0.21	0.14	0.14	0.08	0.99	0.14	0.28	1.26	0.27	0.18	0.17
LOI	2.65	1.69	1.15	3.09	2.42	0.00	1.05	2.17	1.82	1.85	1.36
Ba	550	590	560	570	860	990	1200	220	530	520	650
Rb	58	42	77	77	63	110	110	29	59	48	76
Sr	200	290	195	190	510	340	330	340	440	550	370
Y	24	25	20	17	17	31	19	10	21	23	23
Zr	100	115	44	46	54	194	23	44	110	105	94
Nb	7	9	4	2	2	13	5	2	6	7	4
Th	7.90	9.67	6.00	6.71	6.70	15.81	7.97	4.68	9.28	8.11	7.36
Zn	40	52	210	220	57	50	67	20	52	46	24
Cu	5	19	110	115	94	1	340	65	13	11	1
Ni	30	43	78	78	25	8	20	42	25	27	25
V	195	220	250	260	220	150	220	220	200	240	200
Cr	180	210	300	270	150	73	150	220	115	120	180
Hf	2.50	2.83	2.16	0.87	0.78	4.70	2.40	0.60	2.40	1.87	2.16
Sc	28	31	32	42	27	19	25	38	20	30	32
Ta	0.50	0.33	0.50	0.32	0.52	0.90	0.30	<0.1	0.50	0.30	0.30
Co	32	33	48	50	25	24	27	30	33	36	29
La	23.00	24.90	19.20	18.30	17.70	45.60	30.40	18.90	29.30	22.80	21.40
Ce	48.80	53.30	40.90	36.20	36.60	97.50	61.60	37.20	58.00	50.60	43.40
Pr	5.70					11.37	7.37	4.32	6.91		
Nd	22.20	27.80	19.90	17.20	15.30	44.70	27.60	16.30	26.70	25.80	22.10
Sm	4.42	5.64	4.18	3.61	3.27	8.43	5.03	2.96	4.90	4.97	4.29
Eu	1.14	1.32	1.02	0.93	0.68	1.96	1.28	0.79	1.26	1.25	1.04
Gd	3.74					6.63	3.84	2.32	3.66		
Tb	0.58	0.72	0.57	0.38	0.36	0.98	0.58	0.33	0.55	0.70	0.60
Dy	3.60					5.66	3.53	1.87	3.35		
Ho	0.76	0.89	0.65	0.46	0.44	1.11	0.70	0.39	0.69	0.82	0.73
Er	1.99					3.04	1.96	1.03	1.82		
Tm	0.30					0.40	0.30	0.20	0.30		
Yb	1.94	2.38	1.63	1.17	1.10	2.81	1.77	1.04	1.95	1.96	1.52
Lu	0.29	0.33	0.27	0.18	0.19	0.43	0.26	0.14	0.29	0.27	0.28

Table 2

(continued)

Field No.	Mo438	Mo439	Mo528	PH-32	Mo306/1	Mo306/2	Mo363	Mo380	Mo392	Mo393
Anal. No.	873028	873029	883690	895754	883679	883680	873024	873025	873026	873027
Locality (mE)	367800	367900	367600	368800	370400	370400	372200	371000	371600	371800
Locality (mN)	5263000	5263100	5263900	5269100	5250600	5250500	5253100	5255800	5254400	5254300
Rock type	Cvv	Cvv	Cvv	Cvl-Hibbs	Cva	Cva	Cma	Cma	Cma	Cma
SiO_2	55.21	53.05	56.44	57.73	65.99	65.38	59.66	61.97	64.51	63.35
TiO_2	0.80	1.13	0.31	0.85	0.39	0.35	0.63	0.55	0.50	0.56
Al_2O_3	13.20	16.95	15.22	16.28	14.20	14.08	15.68	11.82	14.09	14.49
Fe_2O_3	2.77	1.78	2.91	1.58	0.22	0.59	1.40	0.79	1.62	1.09
FeO	6.21	5.34	4.28	4.66	4.24	4.24	3.59	5.92	3.93	4.13
MnO	0.16	0.10	0.09	0.09	0.05	0.06	0.08	0.11	0.09	0.09
MgO	5.87	3.58	4.57	2.88	3.56	3.81	4.20	5.40	2.51	2.73
CaO	8.10	6.58	7.66	4.45	0.61	0.85	4.90	5.08	3.82	3.41
Na_2O	3.40	3.26	5.72	5.04	3.19	3.27	3.73	4.05	4.59	5.28
K_2O	1.37	4.64	0.29	3.07	4.44	4.05	2.72	1.77	2.60	3.00
P_2O_5	0.17	0.22	0.12	0.37	0.11	0.12	0.24	0.07	0.19	0.24
H_2O^+	1.23	2.35	2.19	2.30	2.41	2.32	2.55	1.79	1.45	1.23
CO_2	0.10	0.18	0.11	0.01	0.16	0.36	0.18	0.21	0.11	0.10
LOI	0.03	0.03	2.08	1.99	2.14	2.29	0.01	0.01	0.01	0.03
Ba	550	1850	1750	910	800	780	1150	460	780	930
Rb	54	125	97	90	71	65	72	51	83	92
Sr	320	550	370	400	78	95	860	185	170	165
Y	25	27	27	30	31	26	18	22	35	34
Zr	140	135	98	188	150	140	165	125	420	410
Nb	10	13	3	12	11	10	13	5	9	10
Th	9.98	9.30	5.31	14.86	14.76	13.44	12.90	7.51	15.60	15.60
Zn	70	120	39	42	43	45	67	54	31	23
Cu	19	15	5	12	56	47	37	30	13	15
Ni	16	12	64	12	26	28	49	33	35	36
V	220	230	240	185	78	81	105	170	52	65
Cr	110	46	220	69	100	110	200	230	140	135
Hf	3.43	3.26	0.67	4.70	3.50	3.70	4.23	3.11	8.83	9.04
Sc	30	22	35	18	14	12	14	27	13	15
Ta	0.50	0.69	0.30	0.90	1.38	0.90	0.76	0.53	0.83	0.72
Co	25	19	37	23	17	19	19	24	12	11
La	28.90	32.40	10.90	39.90	33.10	27.90	52.80	19.60	35.00	36.20
Ce	61.10	69.30	25.30	86.00	65.00	61.50	102.00	44.40	74.00	81.20
Pr				10.20		6.94				
Nd	25.50	32.50	13.30	41.30	28.80	26.10	40.80	20.50	37.40	38.20
Sm	6.41	6.78	2.66	7.84	6.08	4.88	6.87	4.62	7.32	7.82
Eu	1.44	1.53	0.81	1.91	1.00	0.83	1.70	1.09	1.61	1.39
Gd				6.32		3.82				
Tb	0.67	0.85	0.32	0.92	1.06	0.60	0.74	0.53	0.93	1.14
Dy				5.25		3.72				
Ho	1.00	1.13	0.40	1.04	1.10	0.76	0.74	0.80	1.41	1.43
Er				2.92		1.97				
Tm				0.40		0.30				
Yb	2.37	2.51	1.07	2.73	2.07	1.90	1.64	2.03	3.68	3.24
Lu	0.40	0.37	0.15	0.42	0.35	0.28	0.24	0.34	0.58	0.58

Granitic rocks

Four granitic samples were chemically analysed (Table 3). From north to south these were:

- Mo203: 500 m NNE of Schist Point. Medium-grained biotite granitoid with chrome spinel-epidote bearing xenocrysts and partially dissolved felsic lava screens.
- Mo221: 400 m NNW of the lighthouse at Low Rocky Point. Coarse-grained biotite granitoid.
- Mo214: 200 m southwest of the lighthouse at Low Rocky Point. Coarse to very coarse-grained biotite granitoid.
- Mo218: 25 m from the southern end of Low Rocky Point. Medium to coarse-grained biotite granitoid.

On a SiO_2 ~ Na_2O + K_2O diagram (Le Maitre, 1989; fig. 18*a*) three samples (Mo221, 214, 218) fall in the rhyolite/granite field, as do most of the Cambrian granitic bodies associated with the Mount Read Volcanics. The fourth sample, from the area intruding the felsic volcanic rock (Mo203), falls in the upper part of the dacite/granodiorite field, indicating contamination from the absorption of sections of the andesitic suite that it intrudes.

All samples, as with the earlier felsic volcanic lavas, are sub-alkaline (fig. 18*c–d*). On a SiO_2 ~ K_2O diagram (Le Maitre, 1989; fig. 18*b*), Mo203 falls within the high-K dacite/granodiorite field, while Mo218 and Mo221 fall in the high-K rhyolite/granite, and Mo214 in the medium-K rhyolite/granite fields. All samples have relatively low rubidium and strontium and high barium. Because the rocks are of Cambrian age, the elements discussed above may have been affected by secondary alteration and may not represent the original compositions.

On Y + Nb (ppm) ~ Rb (ppm) and Y (ppm) ~ Nb (ppm) diagrams (Pearce *et al*., 1984; fig. 18*e–f*) the samples fall in a tight cluster on the divide between Volcanic Arc Granite (VAG) and Within Plate Granite (WPG). On a primitive mantle normalised multi-element diagram (Sun and McDonough, 1989; fig. 18*g*) the rocks show negative Nb and Ti anomalies, similar to the andesite/dacite succession, and thus implying an arc-related geochemical signature.

When comparing the average values for the Cvs, Cvv, Cmv and Cva sequences with the four granitic samples, on both the (Y + Nb) ~ Rb and Y ~ Nb diagrams (fig. 18*e–f*) all samples fall on a fractionation trend. The chemical analysis for Mo203 indicates that it is a hybrid between the granitic magma, as defined by Mo214, 218 and 221, and the absorbed felsic lava screens.

Basaltic dykes (Dmv)

Two samples of the mafic dykes intruding the granitic rocks in the Schist Point–Low Rocky Point area were analysed (Table 3). One sample (Mo216) contains quartz xenocrysts and has been extensively altered to chlorite and carbonate minerals. The alteration is reflected in the H_2O^+ and CO_2 contents of the analysis. The other sample (Mo217) is far less altered and contains remnant microphenocrysts of pyroxene and plagioclase.

On chemical discriminant diagrams both samples fall within the alkali basalt and high-K basalt fields and both have the chemical characteristics of calc-alkaline basalt. The calc-alkaline nature of the parent magma is indicated by the chemistry of the least altered sample (Mo217) but interestingly, Mo216 has lower Ti and higher Zr than Mo217. Primitive mantle normalised multi-element diagrams show that both samples contain similar trace element chemistry, with negative Nb, Ti and Sc anomalies. Mo216 (containing the quartz phenocrysts) has far higher Cr and Ni and lower Rb and Sr contents than Mo217.

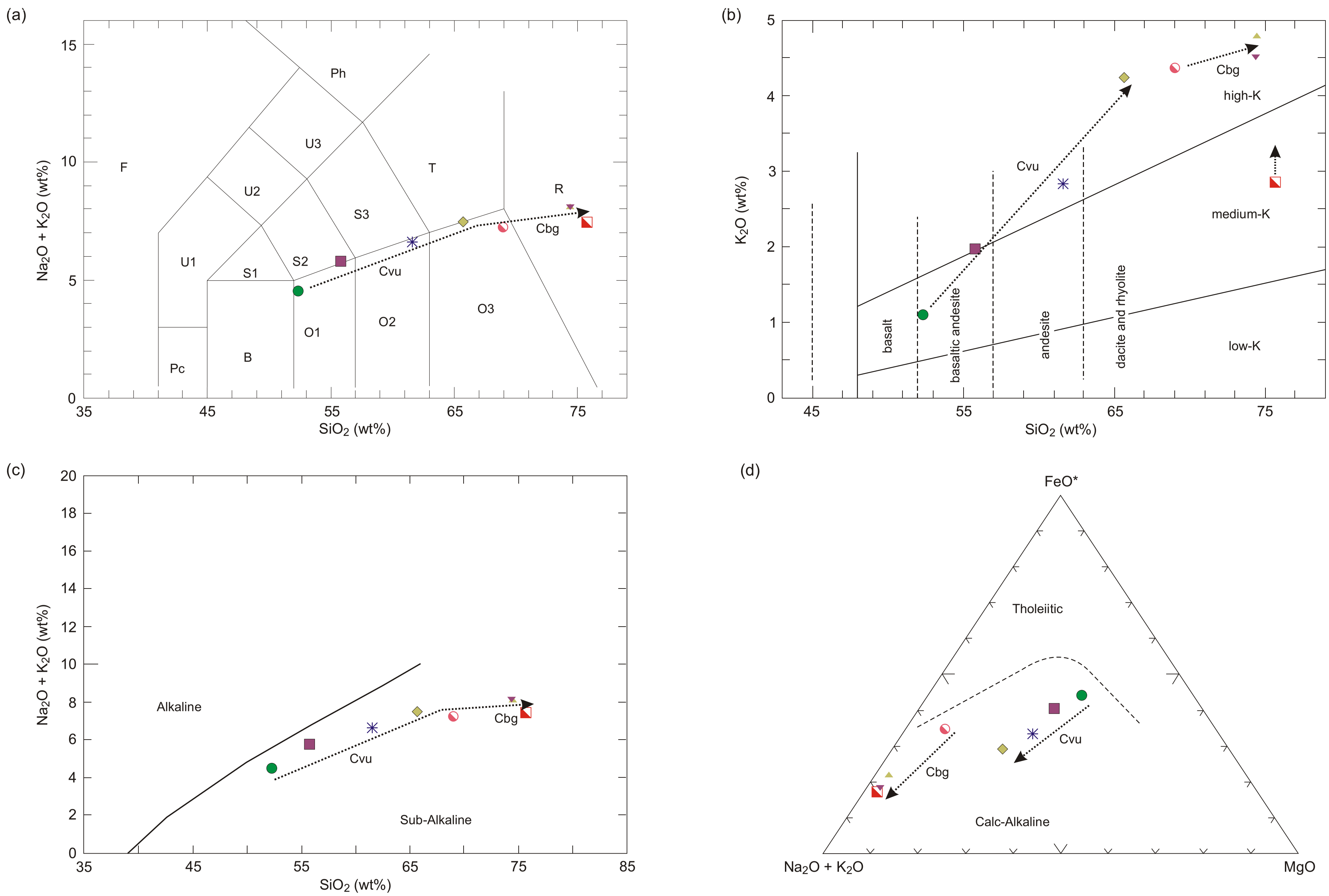

Figure 18. *Geochemical discrimination diagrams for average andesitic-dacitic (Cvu) lavas and granitic (Cbg) rocks.*

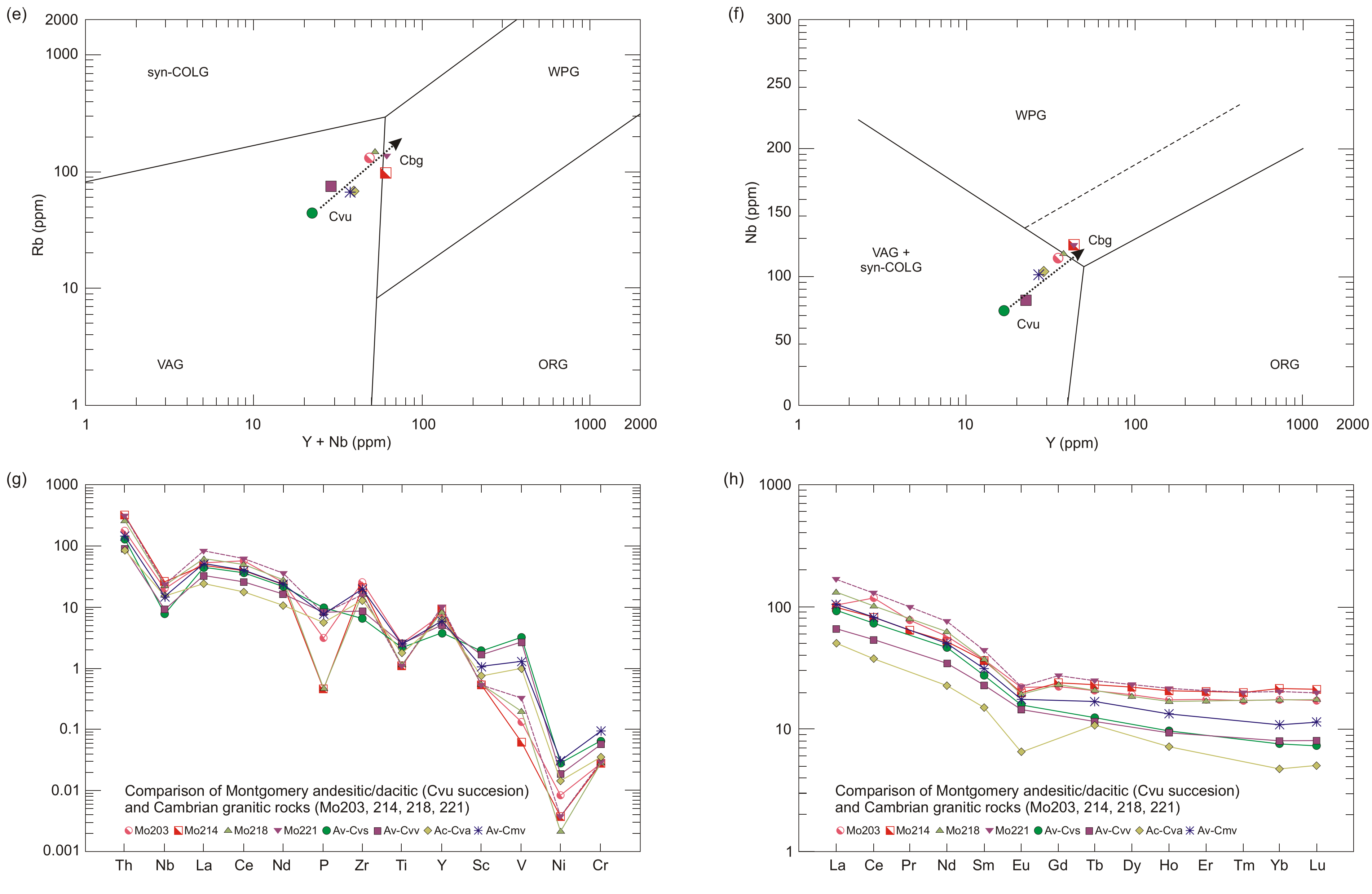

Figure 18. *Geochemical discrimination diagrams for average andesitic-dacitic (Cvu) lavas and granitic (Cbg) rocks.*

Table 3

Whole-rock geochemistry, granitic rocks and mafic dykes

	Granitic rocks (Cbg, Cgf)				*Mafic dykes (Dmv)*		*Av. values for andesitic-dacitic (Cvu) sequences*			
Field No.	Mo203	Mo214	Mo218	Mo221	Mo216	Mo217				
Anal. No.	873011	873012	873015	873016	873013	873014				
Locality (mE)	377400	377700	377200	377600	377300	377300				
Locality (mN)	5241200	5239600	5238800	5240200	5239000	5228800				
Rock type	Cgf	Cbg	Cbg	Cbg	Dmv	Dmv	Av-Cvs	Av-Cvv	Av-Cvv-Ac	Av-Hbl/d
SiO_2	68.98	75.72	74.46	74.37	51.10	48.15	52.30	55.77	65.68	61.57
TiO_2	0.53	0.24	0.24	0.24	0.57	0.83	0.48	0.55	0.37	0.54
Al_2O_3	13.42	12.81	12.58	12.55	12.11	15.01	13.99	14.03	14.14	13.90
Fe_2O_3	3.33	1.04	1.30	1.03	1.46	4.72	2.64	2.58	0.41	1.11
FeO	1.45	0.70	1.18	0.98	7.11	6.14	6.20	5.14	4.24	4.63
MnO	0.02	0.01	0.02	0.02	0.19	0.17	0.14	0.13	0.05	0.09
MgO	1.08	0.27	0.32	0.32	8.94	7.99	6.30	5.27	3.68	4.67
CaO	2.29	1.76	1.01	1.42	5.78	10.37	9.37	7.89	0.73	4.00
Na_2O	2.89	4.61	3.32	3.61	0.89	1.74	3.42	3.81	3.23	3.78
K_2O	4.37	2.85	4.79	4.52	2.05	2.46	1.10	1.98	4.24	2.83
P_2O_5	0.07	0.01	0.01	0.17	0.15	0.17	0.22	0.18	0.12	0.16
H_2O	1.32	0.69	0.84	0.69	5.29	2.67	0.00	0.00	0.00	0.00
CO_2	0.16	0.15	0.16	0.10	3.48	0.16	0.15	0.29	0.26	0.18
LOI							0.58	1.70	2.21	0.65
Cr	80	81	81	89	870	440	192	170	105	274
Ni	16	7	4	7	185	77	53	35	27	57
Co	10	3	3	3	27	27	42	31	18	21
Sc	9	9	9	9	35	46	33	29	13	18
V	11	5	16	27	240	290	259	219	80	107
Cu	24	19	18	21	11	16	53	55	52	35
Zn	23	21	15	12	69	65	95	74	44	49
Bi	7	3	3	5	5	5	0	0	0	0
Sn	9	4	2	2	9	3	0	0	0	0
W	16	390	11	12	30	19	0	0	0	0
K	36277	23659	39763	37522	125	91	9123	16445	35198	23501
Rb	130	97	145	135	120	155	44	74	68	66
P	305	44	44	742	655	742	946	786	523	711
Ba	1200	690	1050	950	300	350	744	817	790	751
Sr	185	155	99	105	68	195	458	350	87	266
Ta	0.90	1.40	1.10	1.30	0.30	0.20	0	0	1	1
Nb	14	18	15	17	5	3	5	7	11	10
Hf	7.80	7.00	5.40	5.20	3.10	2.30	1	2	2	5
Zr	284	236	182	183	131	89	74	97	145	217
Ti	3177	1439	1439	1439			2854	3267	2218	3219
Y	35	43	37	46	20	21	17	23	29	27
Th	15	27	22	26	8	3	11	8	7	12
U	11	5	16	27	<5	<5	0	0	0	0
La	33.90	32.90	42.30	55.60	28.80	12.80	30.16	21.57	16.55	34.37
Ce	101.70	70.60	88.20	112.50	61.70	27.40	63.80	45.71	32.50	70.92
Pr	10.03	8.36	10.32	12.94	7.34	3.35				
Nd	36.20	33.10	39.20	46.60	29.00	13.60	29.20	21.89	14.40	31.73
Sm	7.45	7.33	7.53	8.97	5.82	3.12	5.53	4.61	3.04	6.30
Eu	1.67	1.52	1.48	1.71	1.67	0.92	1.23	1.10	0.50	1.34
Gd	6.10	6.63	6.37	7.58	4.92	3.30				
Tb	1.03	1.15	0.33	1.24	0.72	0.55	0.61	0.58	0.53	0.84
Dy	6.59	7.45	6.36	7.98	4.07	3.51				
Ho	1.33	1.59	1.30	1.66	0.75	0.84	0.74	0.72	0.55	1.03
Er	3.92	4.53	3.77	4.62	1.95	2.28				
Tm	0.60	0.70	0.60	0.70	0.30	0.40				
Yb	3.80	4.69	3.79	4.50	1.60	2.36	1.66	1.75	1.03	2.40
Lu	0.58	0.72	0.59	0.66	0.23	0.39	0.25	0.27	0.17	0.39

Electron microprobe analyses (Table 4) were obtained for 25 clinopyroxene phenocrysts from the andesitic rocks within the Cvs, Cvv and Cvt sequences, as well as three amphibole analyses from the hornblende andesite sills. Clinopyroxene analyses were also obtained from two samples (Mo546, 584) from different batch melts within the Neoproterozoic basaltic sequence, and two biotite and one spinel analyses from the lamprophyre dyke. Three spinel grains were analysed from the boninite clast from within sample Mo513 which was collected on the shore platform at the lowest exposed part (367300/5265500) of the Cvs sequence at High Rocky Point.

Clinopyroxene analyses from the Cpx–plagioclase andesite sequence (Cvu)

Twenty-five clinopyroxene analyses were obtained from single, euhedral to subhedral, zoned and optically twinned grains, as well as intergrown clusters and three grains with different core-rim compositions. The listed analysis (Table 4, analyses 1–25) is an average of five spot analyses from a specific grain, core or rim. The analyses indicate that both the Cvs and Cvv lavas had a common parental source, with the most primitive core of grains within both the Cvs and Cvv sequences being of almost identical composition, but because of different fractionation characteristics each sequence has different rim compositions and chemical trends.

Even though the number of grains analysed is statistically low (eight, with two core-rim pairs in the Cvs sequence and 12, with one core-rim pair in the Cvv sequence plus two from the Cvl sequence), the compositions indicate that clinopyroxene crystals from the two sequences fractionated along different paths. As with the whole-rock chemistry, the clinopyroxene grains define a continuous differentiation trend up stratigraphic sequence, but not as specific as the whole-rock geochemistry demonstrates.

In the Cvs sequence the clinopyroxene composition follows an almost linear trend of increasing iron with decreasing calcium and magnesium from Ca:45.8, Mg:49.1, Fe:5.1 (core of Cpx from Mo515), to around Ca:44.5, Mg:42.3, Fe:13.2 (rim of Cpx from Mo536/3). The trend then makes a right angle bend along an almost steady iron composition but with a fast decrease in calcium and increase in magnesium to around Ca:40.4, Mg:46.1, Fe:13.5 (Cpx from Mo530/4*) (fig. 19). The changed trend cuts across the trend given by Cpx grains from the Cvv sequence (fig. 19). Clinopyroxene grains from the Cvv sequence define a curved, but linear, trend of continuous increase in iron, with a consistent, linearly decreasing calcium and magnesium content (fig. 19).

The fact that the cores of the most primitive clinopyroxene from samples from the stratigraphically lowermost of both the Cvs (Mo515) and overlying Cvv (Mo497/3-1) sequence are almost identical in composition (Ca:45.8, Mg:49.1, Fe:5.1 – Mo515, Cvs; Ca:45.9, Mg:49.3, Fe:4.1 – Mo497/3-1, Cvv), indicates that both sequences came from the same parental magma. Their rim compositions are different (Ca:45.8, Mg:45.7, Fe:8.5 – Mo515; Ca:44.4, Mg:46.5, Fe:9.2 – Mo479/3-1) but are indicative of the different trends for both sequences.

Following the eruption of the Cvs and Cvv sequences the magma source appears to have received more enriched material before the Cvl sequence lavas were produced. This is indicated by the clinopyroxene compositions from a sample (Mo464) of an andesite sill/dyke within the Cvt sequence which has a lower iron content compared to the upper part of the Cvv sequence (Mo438) that is stratigraphically below the Cvl sequence. The two Cpx analyses from this sample show a similar iron-enrichment trend to those from the Cvv sequence but have higher magnesium and lower calcium for a specific iron content.

Hornblende-bearing andesite sills/dykes (Cmv) from the Cvl sequence

Amphibole grains from three samples (Mo241, 243, 360) of hornblende andesite dykes, plus a spinel associated with one sample (Mo241), were analysed (Table 4, analyses 26–29). Two samples (Mo241, 243) contain magnesium hornblende/actinolite with the third (Mo360) containing magnesiohastingsite. The spinel in sample Mo241 is an iron-rich chromite (Cr# = 82.1; Mg# = 14.8).

Boninite clast and chrome spinel grains in Mo513/2 from the Cvs sequence

Five clastic spinel grains and four spinel grains from within a single lava clast, all within a 10 mm square probe section of a sample of pebble conglomerate (Mo513/2*) from the lowest exposed part of the Cvs sequence on the west coast at 367300/5265600, gave average Cr# = 91.7 and 90.5 respectively (Table 4, analyses 30–31). These analyses prove that the clastic spinel grains, and the now highly altered lava clasts, were derived from a boninite lava source. This indicates that part of the source area for the sedimentary rocks associated with the Cvs sequence, and probable basement for them, as indicated by similar rocks mapped in the Macquarie Harbour quadrangle (McClenaghan and Findlay, 1993), consisted of parts of the oceanic succession obducted onto the continental part of western Tasmania before the eruption of the Mount Read Volcanics succession. Glomeroporphyritic clinopyroxene phyric basalt clasts in the sample may have been sourced from another part of the obducted oceanic sequence, the Neoproterozoic sequence (Evv) that crops out to the east of the Cvs sequence in the Montgomery quadrangle and which also underlies the Mount Read Volcanics succession at Miners Ridge to the south of Queenstown (Dower, 1991).

Lamprophyre dyke

Biotite and spinel grains from the lamprophyre dyke at Urquhart River (369600/5261900; Mo400) were analysed. Two varieties of biotite are present, the first an almost equal iron and magnesium, annite-rich biotite and the second a low iron, magnesium-rich biotite (phlogopite). The spinel grain is a ferric-rich chromite.

Table 4

Electron probe analyses of mineral grains

	1	2	3	4	5	6	7	8	9	10
Field No.	Mo515	Mo515	Mo536/2	Mo536/3	Mo536/3	Mo535	Mo534	Mo533	Mo530/1	Mo530/4
Rock unit	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs	Cvs
Mineral	Cpx-Core	Cpx-Rim	Cpx	Cpx-Core	Cpx-Rim	Cpx	Cpx	Cpx	Cpx	Cpx
SiO_2	54.95	53.34	52.38	53.67	52.25	52.53	52.24	52.32	52.98	53.11
TiO_2		0.23	0.27		0.25	0.26	0.25	0.27	0.33	0.39
Al_2O_3	0.96	2.33	2.48	2.01	2.75	2.68	2.50	2.27	2.10	1.81
Cr_2O_3	0.30	0.23		0.29	0.25				0.23	
FeO	3.29	5.45	8.52	5.01	8.23	7.21	7.97	8.08	8.41	8.47
MnO										
MgO	17.91	16.40	15.09	16.80	14.83	15.62	15.47	15.60	15.82	16.26
CaO	23.25	22.83	21.68	22.80	21.73	22.08	21.42	21.23	20.68	19.80
Na_2O										
K_2O										
P_2O_5										
Total	**100.66**	**100.81**	**100.42**	**100.58**	**100.29**	**100.38**	**99.85**	**99.77**	**100.55**	**99.84**
Si	1.9825	1.9412	1.9353	1.9529	1.9316	1.9317	1.9354	1.9400	1.9477	1.9605
Ti		0.0063	0.0075		0.0070	0.0072	0.0070	0.0075	0.0091	0.0108
Al	0.0408	0.1000	0.1080	0.0862	0.1199	0.1162	0.1092	0.0992	0.0910	0.0788
Cr	0.0086	0.0063		0.0083	0.0073				0.0067	
Fe^{3+}										
Fe^{2+}	0.0993	0.1659	0.2633	0.1525	0.2544	0.2217	0.2469	0.2506	0.2586	0.2615
Mn										
Mg	0.9630	0.8895	0.8309	0.9110	0.8170	0.8561	0.8542	0.8621	0.8667	0.8945
Ca	0.8988	0.8903	0.8583	0.8889	0.8607	0.8700	0.8503	0.8435	0.8146	0.7832
Na										
K										
P										
Total	**3.9929**	**3.9995**	**4.0032**	**3.9999**	**3.9979**	**4.0030**	**4.0030**	**4.0029**	**3.9944**	**3.9893**
Mg/(Mg+Fe)	90.7	84.3	75.9	85.7	76.3	79.4	77.6	77.5	77.0	77.4
Cr/(Cr+Al)	17.3	6.0		8.8	5.7				6.8	
Ca/(Ca+Mg+Fe)	45.8	45.8	44.0	45.5	44.5	44.7	43.6	43.1	42.0	40.4
Mg/(Ca+Mg+Fe)	49.1	45.7	42.6	46.7	42.3	43.9	43.8	44.1	44.7	46.1
Fe/(Ca+Mg+Fe)	5.1	8.5	13.5	7.8	13.2	11.4	12.7	12.8	13.3	13.5

	11	12	13	14	15	16	17	18	19	20
Field No.	Mo497/3	Mo497/3	Mo497/3	Mo497/3	Mo305/1	Mo305/2	Mo305/3	Mo495	Mo438	Mo439
Rock unit	Cvv-Nth	Cvv-Nth	Cvv-Nth	Cvv-Nth	Cvv-Sth	Cvv-Sth	Cvv-Sth	Cvv-Nth	Cvv-Sth	Cvv-Sth
Mineral	Cpx/1-C	Cpx/1-R	Cpx/2	Cpx/3	Cpx	Cpx	Cpx	Cpx	Cpx	Cpx
SiO_2	54.44	53.00	52.91	52.58	52.96	52.54	51.89	52.42	52.32	52.73
TiO_2			0.22	0.22	0.35	0.32	0.34	0.45	0.43	0.34
Al_2O_3	1.19	2.42	2.21	2.29	1.39	2.12	2.14	2.21	1.75	1.77
Cr_2O_3	1.09	0.37	0.23		0.24					0.25
FeO	3.02	5.82	6.70	7.96	10.01	8.99	11.42	10.10	10.68	9.67
MnO							0.32		0.30	0.26
MgO	17.69	16.54	16.41	16.09	15.93	15.62	15.29	15.24	15.09	15.78
CaO	22.31	21.96	21.45	20.86	19.34	20.38	18.58	19.44	19.53	19.84
Na_2O								0.29		
K_2O										
P_2O_5										
Total	**100.34**	**100.11**	**100.13**	**100**	**100.22**	**99.97**	**99.98**	**100.15**	**100.1**	**100.64**
Si	1.9711	1.9418	1.9431	1.9411	1.9612	1.9466	1.9387	1.9451	1.9500	1.9472
Ti			0.0061	0.0061	0.0097	0.0089	0.0096	0.0126	0.0121	0.0094
Al	0.0508	0.1045	0.0957	0.0997	0.0607	0.0926	0.0943	0.0967	0.0769	0.0771
Cr	0.0312	0.0107	0.0067		0.0070					0.0073
Fe^{3+}										
Fe^{2+}	0.0914	0.1783	0.2058	0.2458	0.3100	0.2786	0.3568	0.3134	0.3329	0.2986
Mn							0.0101		0.0095	0.0081
Mg	0.9546	0.9031	0.8982	0.8852	0.8792	0.8625	0.8514	0.8428	0.8382	0.8684
Ca	0.8888	0.8621	0.8441	0.8251	0.7674	0.8091	0.7438	0.7729	0.7800	0.7850
Na								0.0209		
K										
P										
Total	**3.9879**	**4.0006**	**3.9996**	**4.0030**	**3.9952**	**3.9982**	**4.0046**	**4.0044**	**3.9995**	**4.0012**
Mg/(Mg+Fe)	91.3	83.5	81.4	78.3	73.7	75.6	70.5	72.9	71.6	74.4
Cr/(Cr+Al)	38.1	9.3	6.5		10.4					8.7
Ca/(Ca+Mg+Fe)	45.9	44.4	43.3	42.2	39.2	41.5	38.1	40.1	40.0	40.2
Mg/(Ca+Mg+Fe)	49.3	46.5	46.1	45.3	44.9	44.2	43.6	43.7	43.0	44.5
Fe/(Ca+Mg+Fe)	4.7	9.2	10.6	12.6	15.8	14.3	18.3	16.2	17.1	15.3

Table 4

(continued)

	21	22	23	24	25	26	27	28	29	30
Field No.	Mo537	Mo542	Mo542	Mo464	Mo464	Mo241	Mo241	Mo243	Mo360	Mo513/2
Rock unit	Cvv-Nth	Cvv-Nth	Cvv-Nth	Cvt	Cvt	Cmv	Cmv	Cmv	Cmv	Cvs
Mineral	Cpx	Cpx/1	Cpx/2	Cpx/1	Cpx/2	Spinel	Amphibole	Amphibole	Amphibole	Spinel/1
SiO_2	52.88	52.93	51.69	53.42	52.99		51.68	49.61	41.81	
TiO_2	0.40	0.26	0.49	0.27	0.27	0.88	0.36	0.74	1.86	
Al_2O_3	2.33	1.79	2.14	1.41	1.58	7.01	2.96	3.51	12.55	4.09
Cr_2O_3		0.48		0.30	0.25	48.11		0.05	0.07	67.73
FeO	8.55	5.33	9.52	8.09	9.26	40.36	18.77	15.78	10.17	18.86
MnO	0.27					1.67	0.53	0.27	0.03	
MgO	15.56	16.75	14.92	16.36	15.75	2.72	12.35	13.59	15.05	9.86
CaO	20.92	21.79	20.58	20.29	19.98		10.31	11.46	11.57	
Na_2O							0.70	1.14	2.23	
K_2O							0.18	0.46	0.80	
P_2O_5										
Total	**100.91**	**99.33**	**99.34**	**100.14**	**100.08**	**100.75**	**97.84**	**96.61**	**96.14**	**100.54**
Si	1.9409	1.9513	1.9366	1.9666	1.9614		7.6426	7.4114	6.2151	
Ti	0.0110	0.0072	0.0138	0.0075	0.0075	0.1843	0.0400	0.0831	0.2079	
Al	0.1008	0.0778	0.0945	0.0612	0.0689	2.3014	0.5161	0.6182	2.1994	1.3027
Cr		0.0140		0.0087	0.0073	10.5916	2.3214	0.0059	0.0082	14.4659
Fe^{3+}						2.9227				
Fe^{2+}	0.2625	0.1643	0.2983	0.2491		6.4772				0.2314
Mn	0.0084				0.2866	0.3939	0.0664	1.9716	1.2643	4.0300
Mg	0.8512	0.9203	0.8331	0.8976		1.1289	2.7219	0.0342	0.0038	
Ca	0.8228	0.8607	0.8262	0.8004	0.8688		1.6337	3.0257	3.3342	3.9700
Na					0.7924		0.2007	1.8345	1.8429	
K							0.0340	0.3302	0.6427	
P								0.0877	0.1517	
Total	**3.9976**	**3.9956**	**4.0024**	**3.9910**	**3.9930**	**24.0000**	**15.1767**	**15.4024**	**15.8704**	**24.0000**
Mg/(Mg+Fe)	76.4	84.4	73.6	78.3	75.2	14.8	54.0	60.5	72.5	49.6
Cr/(Cr+Al)		15.2		12.5	9.6	82.1	0.0	0.9	0.4	91.7
Ca/(Ca+Mg+Fe)	42.5	44.2	42.2	41.1	40.7		24.5	26.9	28.6	
Mg/(Ca+Mg+Fe)	44.0	47.3	42.6	46.1	44.6		40.8	44.3	51.8	
Fe/(Ca+Mg+Fe)	13.6	8.4	15.2	12.8	14.7		34.8	28.9	19.6	

	31	32	33	34	35	36	37	38	39
Field No.	Mo513/2	Mo513/2	Mo228	Mo546	Mo584	Mo563	Mo400/1	Mo400/1	Mo400/4
Rock unit	Cvs	Cvs	Evv	Evv	Evv	Evv	Cl	Cl	Cl
Mineral	Spinel/2	Spinel/3	Illmenite	Cpx	Cpx	Epidote	Biotite/1	Biotite/2	Spinel
SiO_2				51.00	51.28	38.15	33.39	38.30	
TiO_2		0.18	13.68	0.32	0.66		3.29	1.96	1.02
Al_2O_3	4.70	11.95	0.49	3.66	2.14	21.63	13.96	13.93	15.03
Cr_2O_3	66.94	58.39		0.64	0.14		0.01	0.95	41.11
FeO	12.37	18.07	83.78	5.51	10.03	14.49	21.77	5.79	32.88
MnO				0.11	0.22		0.32	0.03	0.18
MgO	15.37	11.18	0.36	16.13	16.37	24.16	10.12	22.05	9.58
CaO			0.60	21.58	18.45		0.02	0.05	0.81
Na_2O				0.22	0.24		0.19	0.20	
K_2O				0.01	0.01		9.20	10.00	
P_2O_5									
Total	**99.38**	**99.77**	**98.91**	**99.18**	**99.54**	**98.43**	**92.27**	**93.26**	**100.61**
Si				1.8913	1.9172	3.1259	5.3989	5.6299	
Ti		0.0353	3.0071	0.0089	0.0186		0.4001	0.2167	0.1963
Al	1.4500	3.6689	0.1688	0.1600	0.0943	2.0894	2.6611	2.4140	4.5346
Cr	13.8500	12.0212		0.0188	0.0041		0.0013	0.1104	8.1371
Fe^{3+}			12.8241						2.9520
Fe^{2+}	0.7016	0.2747	7.6553						4.0851
Mn	2.0057	3.6609		0.1709	0.3136	0.9930	2.9439	0.7118	0.0390
Mg			0.1568	0.0035	0.0070		0.0438	0.0037	3.6537
Ca	5.9943	4.3391	0.1879	0.8915	0.9121		2.4387	4.8305	0.2221
Na				0.8575	0.7391	2.1212	0.0035	0.0079	
K				0.0158	0.0174		0.0596	0.0570	
P				0.0005	0.0005		1.8978	1.8754	
Total	**24.0000**	**24.0000**	**24.0000**	**4.0186**	**4.0239**	**8.3295**	**15.8486**	**15.8574**	**24.0000**
Mg/(Mg+Fe)	74.9	54.2	0.0	83.9	74.4		45.3	87.2	47.2
Cr/(Cr+Al)	90.5	76.6		10.5	4.2			4.4	64.7
Ca/(Ca+Mg+Fe)				44.7	37.6	68.1	0.1	0.1	
Mg/(Ca+Mg+Fe)				46.4	46.4		45.3	87.0	
Fe/(Ca+Mg+Fe)				8.9	16.0	31.9	54.7	12.8	

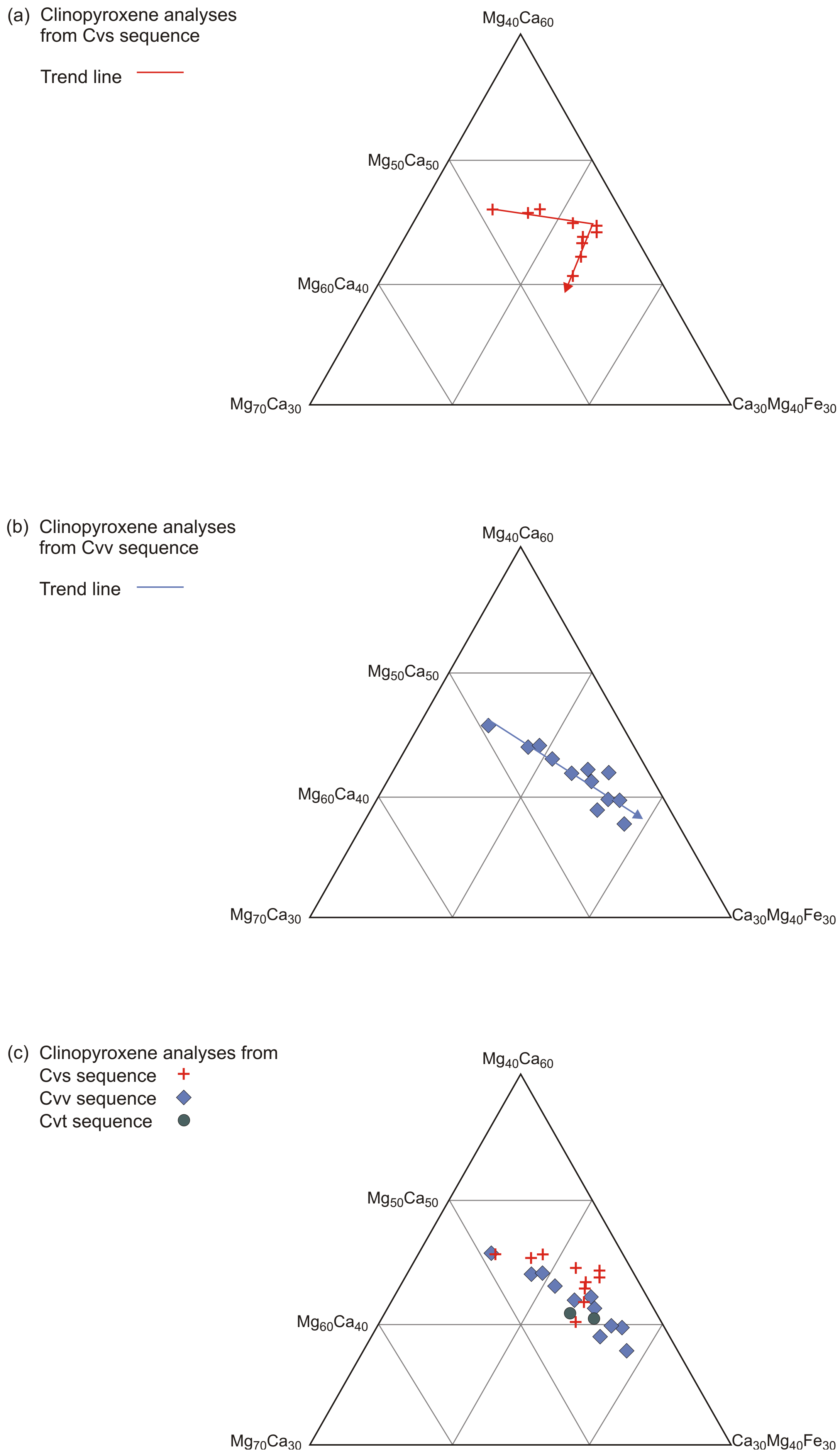

Figure 19

Clinopyroxene mineral chemistry.

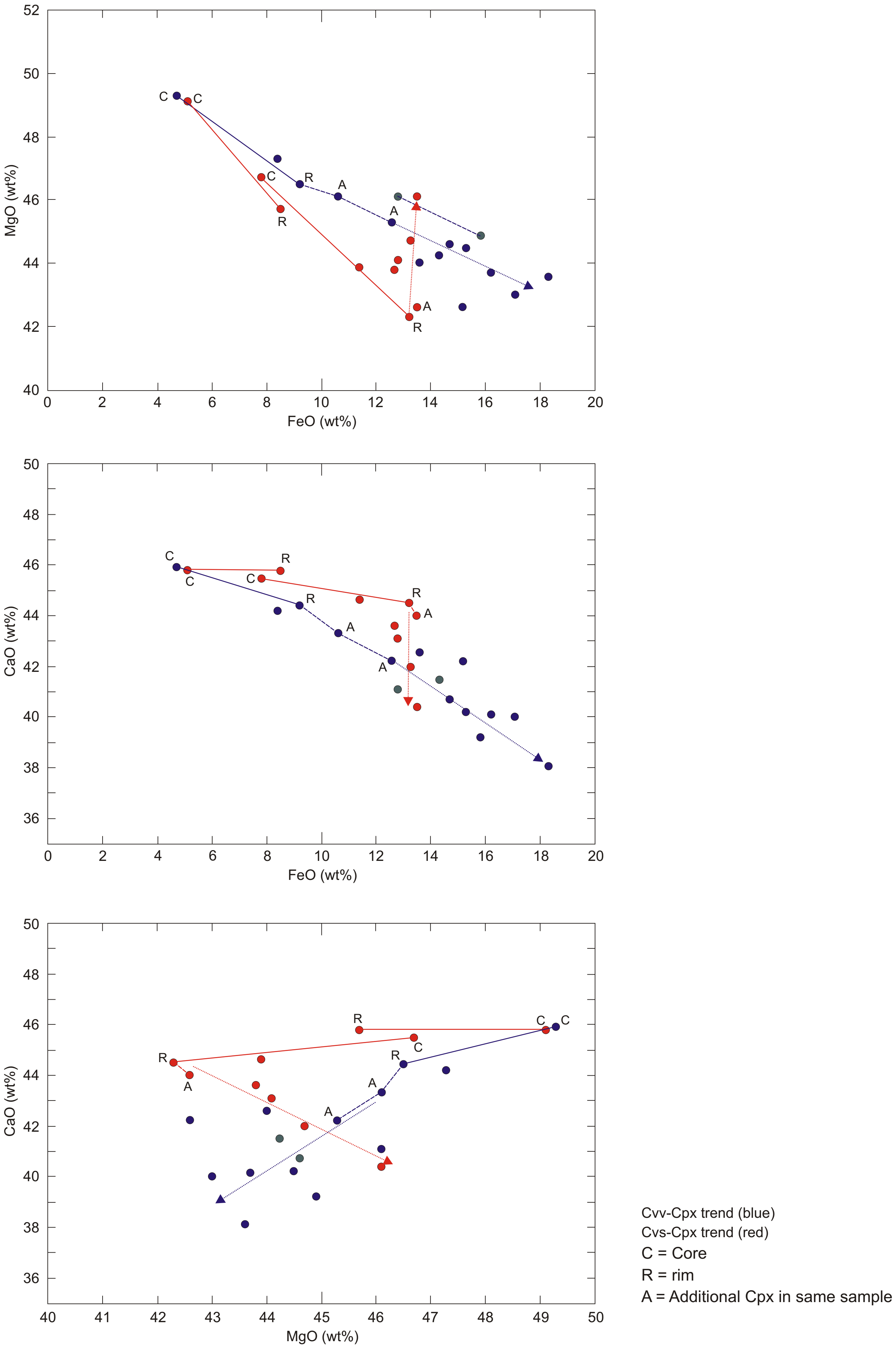

Figure 19

Clinopyroxene mineral chemistry.

SUMMARY AND CONCLUSIONS

Evu Succession (Mainwaring Group)

Based on the writer's experience (elsewhere in western Tasmania) the Evu succession (Mainwaring Group) is part of the Neoproterozoic (Ediacaran) to Lower Cambrian oceanic suite, a correlate of the 'Cleveland–Waratah Association' (Brown, 1986) of western Tasmania, which was obducted onto the siliceous Neoproterozoic rock of proto-western Tasmania during the Middle Cambrian (c.515–510 Ma) (Berry and Crawford, 1988; Brown and Jenner, 1988). Following obduction, these lavas formed part of the basement onto which the Mount Read Volcanics sequence was erupted.

The Evu succession is thus the oldest rock succession in the Montgomery quadrangle. This succession is also considered to be a physical and geochemical correlate of the 'Miners Ridge Basalt' (now known as the Guilfoyle Creek Basalt) in the Queenstown area (Dower, 1991; and this study). The 'Cleveland–Waratah Association' is now known as the Luina Group and the 'Mainwaring Group' is now a sub-group of the Luina Group [as now used in the MRT Digital Geological Map Series and in the forthcoming *Geological evolution of Tasmania* (Corbett *et al*., in prep.)].

Following an integration of current, modern remote sensing data (magnetic, radiometric and gravity), and using constraints of the field mapping and geochemical grouping of the basaltic rocks in the Mainwaring Group, a new outcrop pattern of *en echelon* thrust slices for basaltic/sedimentary rocks has emerged (fig. 20–24).

On geochemical evidence the western two-thirds (basal and middle part) of the succession faces west, with the lower tholeiitic basaltic and lithicwacke sequences being repeated. The eastern one-third (upper part) faces east. Based on the evolving geochemical batch melting (from picritic to tholeiitic lavas, see *Geochemistry* section), the basal Evu chert sequence (Evmc and its southern extension in the Abo Creek–Veridian Point area) contains the earliest picritic lavas. In both the Mainwaring River and along old exploration tracks to the north, the picritic lavas are gradationally followed up sequence (to the west) by lavas from the earliest (first two) tholeiitic batch melting events. The area to the east of the thrust fault on the eastern side of the chert sequence contains the geochemically uppermost tholeiitic batch melts (third and fourth batch melting events) and has an east-facing up sequence stratigraphy.

To the east of the Mainwaring Group is a mylonite zone which consists of north-south trending, thrust juxtaposed slithers of a mixture of Noddy Creek Volcanics, Lewis River Volcanics and Mainwaring Group rocks, as well as a slither of Gordon Limestone on the northeast boundary. This mylonite zone corresponds to a major north-south gravity anomaly (fig. 21) and a major unit within the radiometric coverage (fig. 22). Appropriate modifications to MRTs Digital Geological Map Series will follow to reflect this analysis.

Offshore aeromagnetic data (from Veridian Point past The Shank to the NNW) indicate that large volumes of basaltic rocks are fault stacked against each other with a NNW–SSE strike and steep westerly dip (fig. 23, 24).

Cvu and Cfv successions

Whilst there are numerous similarities between the 'Noddy Creek Volcanics' (Cvu), along the western side of the Montgomery–Point Hibbs area, with Mount Read Volcanics successions (MRV) in western Tasmania, there is no overall definitive one-to-one correlation with any specific part of the MRV sequence.

- ☐ The basal lavas and associated volcaniclastic sedimentary rocks in the area from High Rocky Cape north to Christmas Cove (Cvs, Cvv) have petrological and physical similarities (M. Vicary, pers. comm., January 2011) with the Lynchford Member of the Tyndall Group (White and McPhie, 1996).
- ☐ In both the Montgomery and Lynchford areas the andesitic volcanic succession overlies or is fault bounded against a Neoproterozoic–Lower Cambrian tholeiitic basalt-sedimentary rock succession [the Mainwaring Group (E. B. Corbett, 1968) and Miners Ridge Basalt (K. D. Corbett, 1979) respectively].

Geochemically, the lavas/intrusive rocks/breccias in the basal part of the Cvu succession (southern extension of the Noddy Creek Volcanics) correlate with Mount Read Volcanics Suite 1–3 (Crawford *et al*., 1992), although in the Montgomery area the sequence evolved from the lower/earlier Cvs sequence (MRV-S3) to Cvv (MRV-S2) to late Cmv and Cva (MRV-S1).

The fact that Suite 3 lavas precede Suite 2 lavas then Suite 1 is of interest, as in the Que River–Hellyer area Suite 3 lavas generally post-date Suite 2 which post-dates Suite 1. On a regional scale (M. Vicary, pers. comm., 2011) the relationship between Suite 2 and Suite 3 lavas is poorly known and many andesitic volcanic complexes consist of both Suite 2 and Suite 3 compositions.

- ☐ Overlying the basal volcanic sequences (Cvs and Cvv) in the Montgomery area is a sequence of metamorphic rock derived lithicwacke, siltstone and mudstone with minor felsic volcaniclastic horizons (Cvl). The felsic horizons are composed of glass shards, small fragmented quartz grains, plus other highly altered material, all of which may be distal deposits from quartz-bearing rhyodacitic volcanism similar to that found in the Lewis River Volcanics (White, 1975), which is correlated with the Eastern Quartz-phyric Sequence.
- ☐ The Cvt sequence, which conformably overlies the Cvl sequence, is dominantly derived from a mixture of metamorphic and andesitic volcanic material with minor Cpx-plagioclase-phyric andesitic lavas and derived volcaniclastic sandstone, and minor felsic tuff horizons, similar to those found in the Cvl sequence.
- ☐ The Cfv felsic volcano-sedimentary sequence (Lewis River Volcanics), to the east of the Mainwaring Group and the mylonite zone, was formed by quartz phyric rhyodacitic volcanism and associated sedimentary rocks,

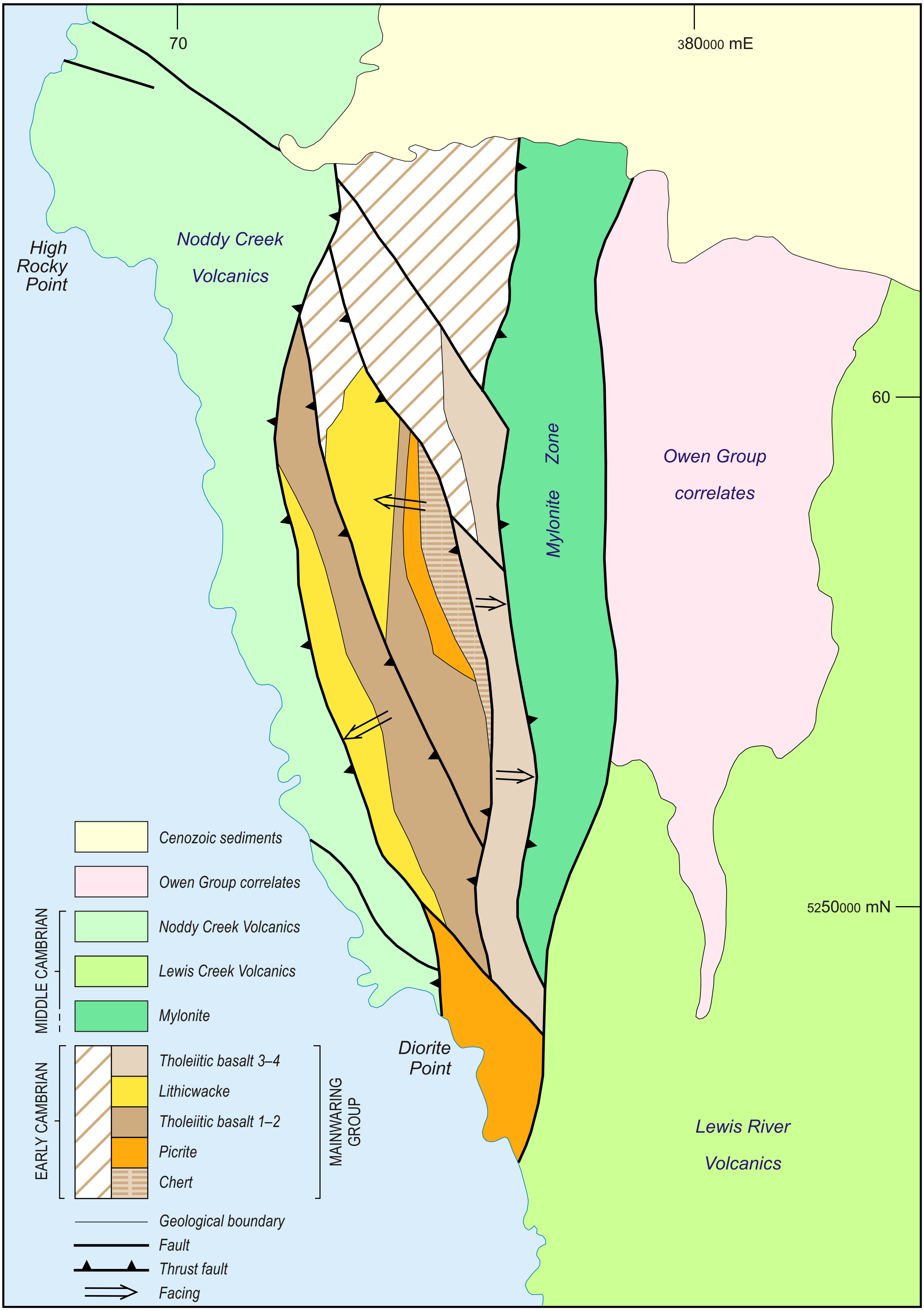

Figure 20

Schematic geological map of the Montgomery area.

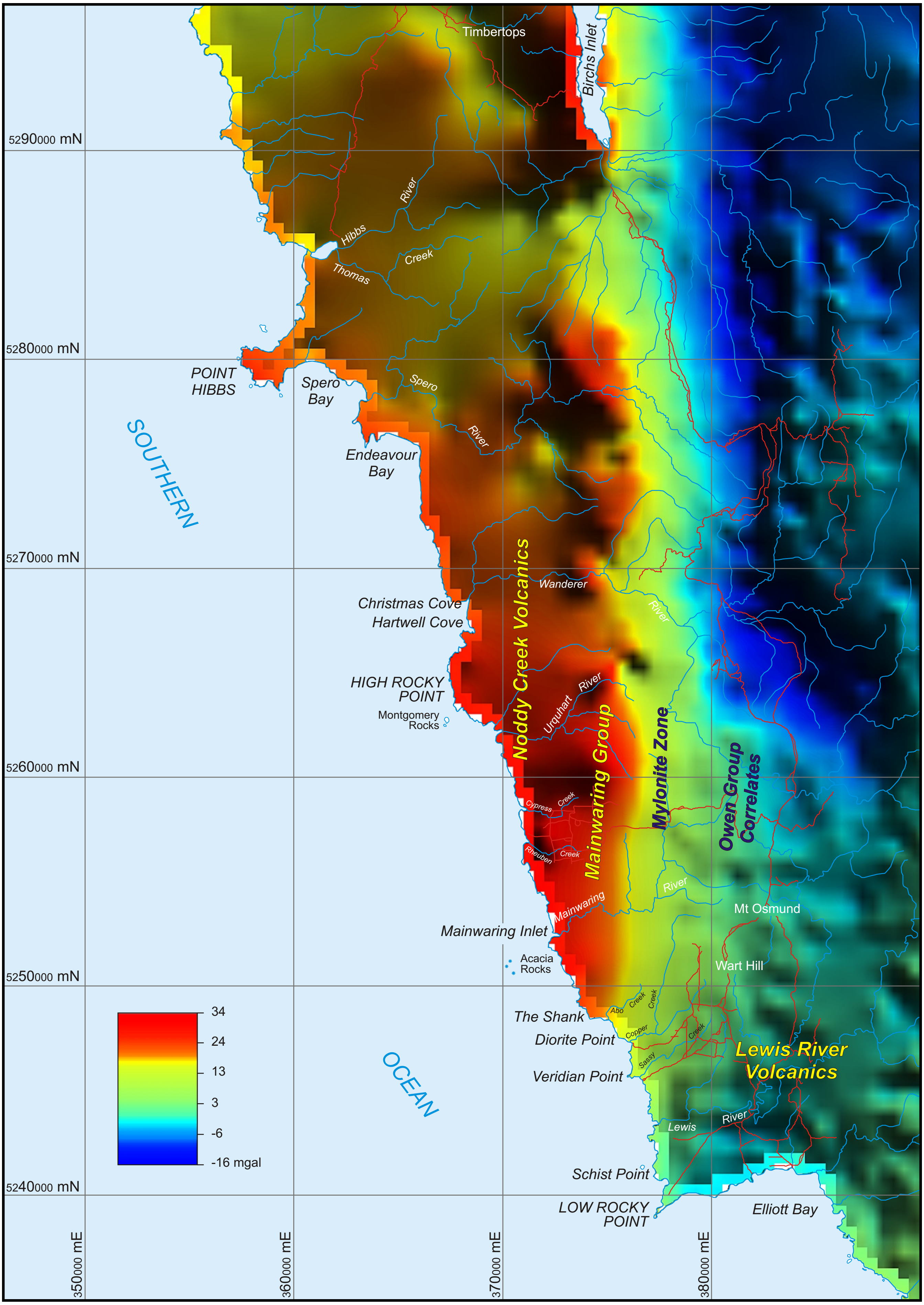

Figure 21

Residual gravity image, Montgomery area.

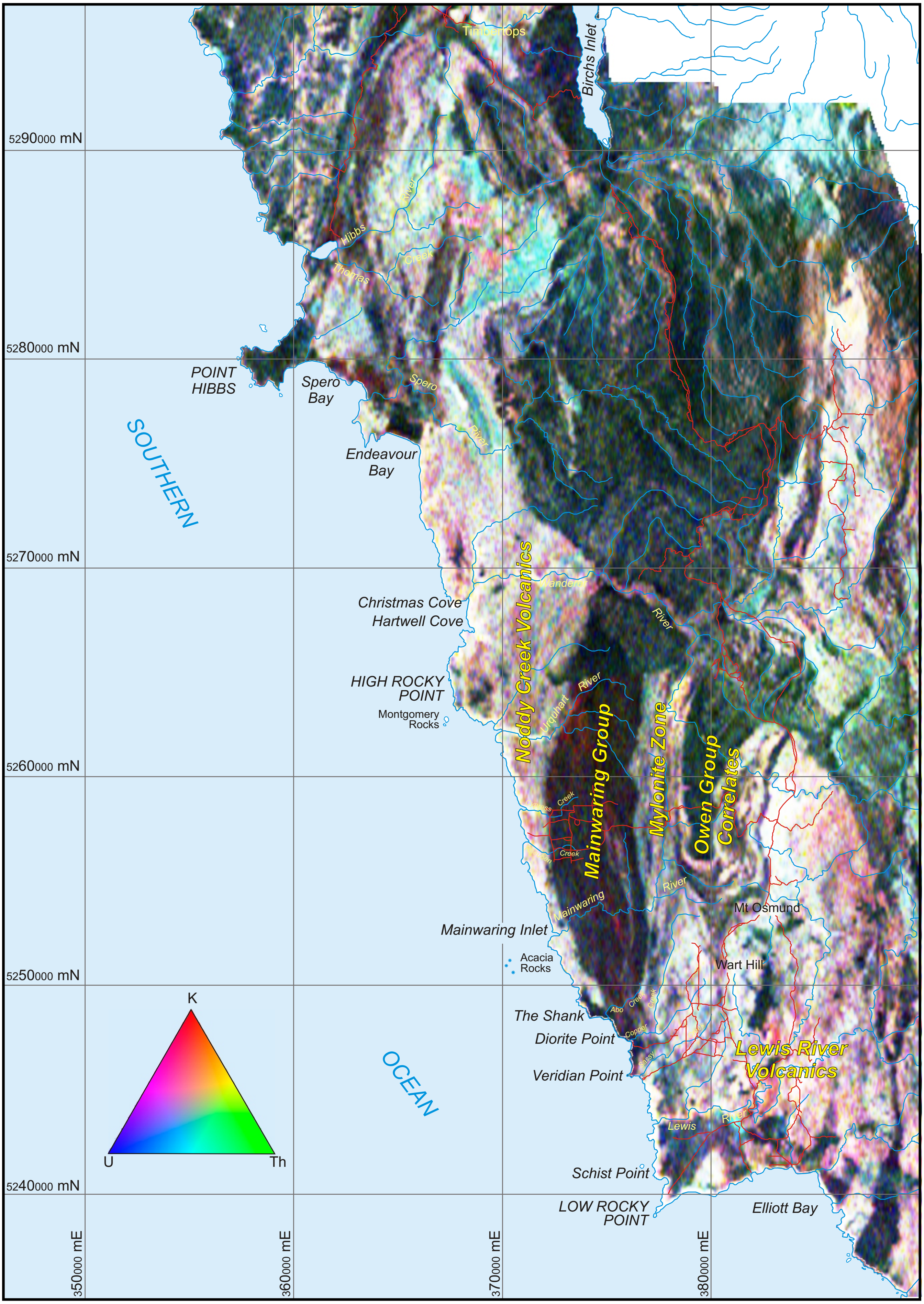

Figure 22

Ternary radiometric image, Montgomery area.

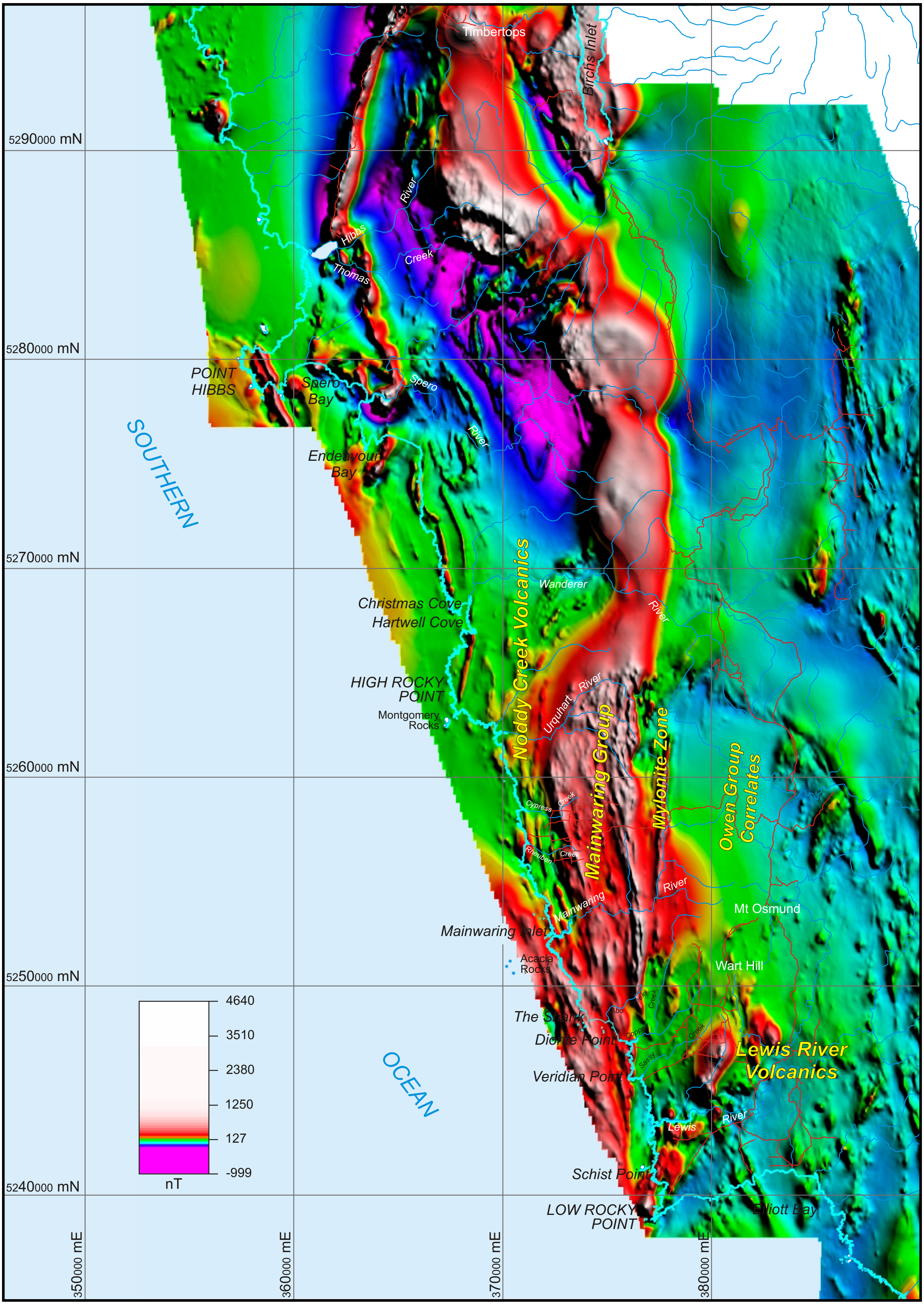

Figure 23

Total magnetic intensity image, Montgomery area.

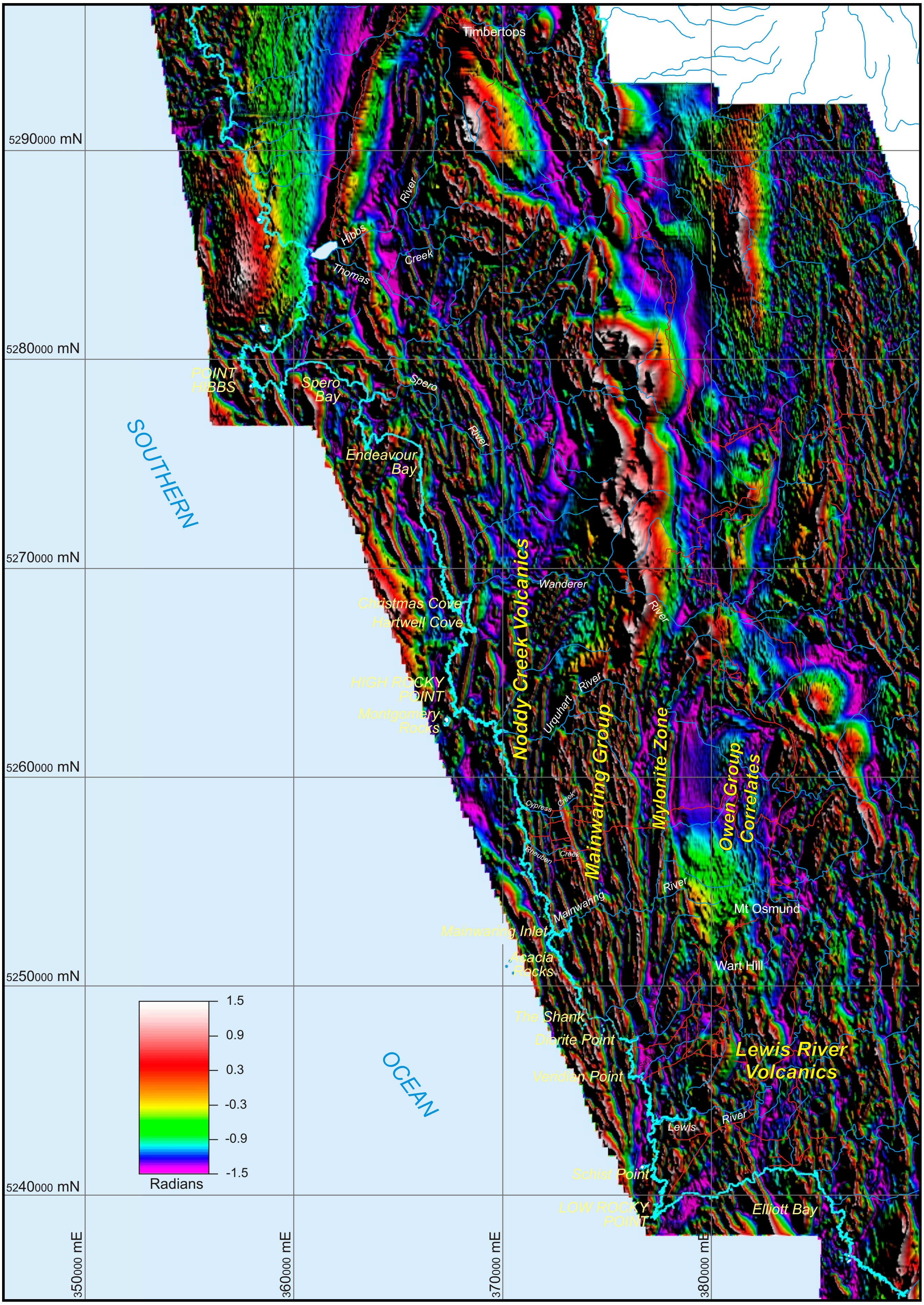

Figure 24

Tilt angle derivative image, Montgomery area.

and is now correlated with the Eastern Quartz-phyric Sequence of the Mount Read Volcanics in western Tasmania (Vicary, 2005). This sequence has, at various times, been correlated with both the Western Volcano-sedimentary and the Eastern Quartz-phyric sequences (Corbett, 2002, 2003, 2004).

- In the Montgomery area, the quartz-phyric volcanic sequence (Lewis River Volcanics) was erupted prior to the intrusion of the granitic rocks in the Low Rocky Point–Elliot Bay area.

Following discussions with Michael Vicary (January, 2011), based on the present knowledge of the rock successions/sequences within the Mount Read Volcanics in western Tasmania and the successions/sequences to the south of Macquarie Harbour, there are at least two (if not more) possible correlations for the Cvu succession (Noddy Creek Volcanics) in the Montgomery area.

The first is that both the Cvu and Cfv successions are pre-Tyndall Group age. The Cvs and Cvv sequences are correlates of the Que–Hellyer Volcanics and the Cvl and Cvt sequence are correlates of the Southwell Subgroup (Upper Western Volcano-sedimentary Sequence), with the Cfv succession a correlate of the Lewis River Volcanics and thus the Eastern Quartz-phyric Sequence.

The second alternative is that both the Cvu and Cfv successions are time correlates of the Tyndall Group, with the Cvs and Cvv sequences being correlates of the basal Lynchford Member (that originally overlay a mixed provenance sedimentary sequence correlated to the Western Volcano-sedimentary Sequence, which is poorly defined in the Montgomery area). The Cvl and Cvt sequences would be correlates of the distal Mt Julia Member, with the Cfv succession a correlate of the proximal Mt Julia Member (middle Tyndall Group).

Whichever of the final correlations are correct, the interesting aspects of the geological successions in the Montgomery area are that the andesitic volcanism in the Cvs and Cvv sequences progress from MRV Suite 3 to Suite 2 to Suite 1 stratigraphy up sequence and that in both the overlying Cvl and Cvt sequences, minor horizons of distal deposits from sub-aerial felsic quartz-rich volcanism occur in an overall submarine succession.

Structurally the dominant cleavage within the coastal outcrops of the Cvu, but especially Cvl sequence, is approximately 70° to 250° with folds plunging, porpoise like, between 30° and 40° northwest and southeast.

Structural geology

The rock successions covered by the Montgomery 1:50 000 scale map have had a complex structural history with the central Evu succession having been involved in at least three periods of tectonic activity (Tyennan to Tabberabberan) and possibly more, with at least five different deformation phases.

The largest scale structure in the area is the mylonite zone along the eastern side of the Montgomery quadrangle. This is a north–south trending zone that forms the boundary between the Mainwaring Group and correlates of the Owen Group and Lewis Creek Volcanics to the east. The zone is of varying width but up to one to two kilometres wide in the middle and northern area before being covered by Cenozoic sediments. In the southern part of the area, to the east of Diorite Point, it becomes a narrow thrust/fault zone referred to as the Copper Creek Fault.

This zone contains numerous lenses of mylonised rock types including andesitic rocks, associated volcaniclastic sedimentary rocks and at least one lensoidal area of Gordon Limestone (around 363000/5278500). This shear zone is currently shown on the 1:25 000 scale digital geological maps of the area (Seymour and Green, 2003*a–d*) as '*Cdsv — Mixed sequence of volcano-sedimentary, sedimentary and volcanic rocks ranging from felsic to andesitic in composition. Includes some non-volcanic sedimentary rocks*'. This will be modified to reflect the current understanding of the zone.

The next scale of deformation is shown by the open, upright folds with half-wavelengths of tens of metres (Plates 20–22) which have an axial surface (fracture) cleavage that dips west at around 60 to 70 degrees and which forms compositional banding in finer grained units. These open folds dominate the coastal section of the Cvu sequence to the north of the Mainwaring River where the sequence is dominantly composed of competent sand-grade beds.

On a still smaller (outcrop) scale, isoclinal folds are observed mainly in zones of interbedded silt to mud-grade beds with minor sand-grade units. Tectonic compositional banding is prevalent in these zones as is later cross-cutting chevron folding with a strong axial surface crenulation cleavage. In these zones, mainly along the coast to the south of the Mainwaring River, the eastern limbs of small scale and isoclinal folds are usually sheared out. The deformation caused by the upright cleavage increases to the south as the sequence becomes finer grained. South of Mainwaring Inlet the Cvl and Cvc sequences are now dominantly composed of compositional bands with clasts of destroyed sand-wacke units. Rootless isoclinal folds and sheared out limbs of tight folds along the axial cleavage occur where the Cvl sequence is dominated by silt to mud-grade units.

The writing of this report indicates that further work is needed to answer many questions presented by the data already obtained. At a minimum, a specialist structural study of the area between The Shank and Copper Creek is needed to try and ascertain the complexity of the tectonic activity which has affected this area.

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APPENDIX 1

Mineral occurrences and exploration reports, Montgomery quadrangle

Only eight mineral occurrences or prospects have been recorded in the Montgomery quadrangle. Extensive mineral exploration has been undertaken in the area over many years. The reports relating to this exploration are tabulated below. Individual reports can be downloaded form the MRT website (www.mrt.tas.gov.au).

Recorded mineral deposits

Name	*AMG east*	*AMG north*	*Type*	*Main commodity*	*Operational status*
Mainwaring River	373800	5253300	Mineral occurrence	Gold	Mineralised area
Penders Prospect (Voyager 1)	377300	5242050	Mine or prospect	Copper	Abandoned
Fletchers Creek	371600	5259500	Mineral occurrence	Gold	Mineralised area
Voyager 23	376120	5245550	Mineral occurrence	Copper	Mineral occurrence
Horburg Creek	371280	5260000	Mineral occurrence	Gold	Mineral occurrence
Voyager 5 (Voyager 1 North)	377580	5243000	Mineral occurrence	Iron	Mineralised area
Voyager 18	376030	5247200	Mine or prospect	Copper	Mineralised area
Rheuben Creek	372350	5256300	Mineral occurrence	Gold	Mineralised area

Mineral exploration reports

TCR No.	*Licence*	*Author*	*Company*	*Title*
57_0150	SPL307 SPL308	Scott, B.	Lyell–EZ Explorations	Report on examination of the Mt Osmund area.
58_0203	SPL307 SPL308	Penney, M; Hall, R.; Burrell, T.	Lyell–EZ Explorations	M. Penney and Party. Diary at Urquhart River and Cypress Creek camps, 14th December, 1957 to 19th February, 1958.
58_0216	SPL307 SPL308	Elms, R. G.	Lyell–EZ Explorations	Report on examination of Hazell Hill and Mount Osmund areas.
58_0220	SPL307 SPL308	Paltridge, I. M.	Lyell–EZ Explorations	Report on Lewis River, Copper Creek, Waterloo Creek area.
58_0221	SPL307 SPL308	Paltridge, I. M.	Lyell–EZ Explorations	Report on examination of the area between Hudson River and Wart Hill.
59_0268	EL1/1959 EL3/1959	Hancock, H. S.	Adastra Hunting Geophysics Proprietary Limited	Geophysical report to Lyell–E.Z. Explorations No. 3.
59_0274	EL3/1959	Scott, B.; Paltridge, I. M.; Boniwell, J. B.	Lyell–EZ Explorations	Geology of airborne geophysical anomaly 20/5, Mainwaring River.
59_0280	EL3/1959	Scott, B.; Boniwell, J. B.	Lyell–EZ Explorations	Report on Anomaly 20/6 and report on Anomaly 20/4.
59_0282	EL3/1959	Scott, B.; Boniwell, J. B.	Lyell–EZ Explorations	Investigation of anomalies — Gordon area 1958/1959.
59_0291	EL3/1959	Scott, B.	Lyell–EZ Explorations	Field programme — November and December, 1959.
64_0379	EL1/1964 EL13/1965	Whitehead, R. C.	Broken Hill Proprietary Company Limited	Summary of investigations southwestern Tasmania.
65_0398	EL13/1965	Hall, W. D. M.	Broken Hill Proprietary Company Limited	Exploration Licence 13/65 Southwest Tasmania, progress report No. 1 — March–June 1965.
66_0424	EL13/1965	Hall, W. D. M.	Broken Hill Proprietary Company Limited	Interim geological report on the south west portion of Exploration Licence 13/65, South West Tasmania, November 1965–May 1966.
66_0443	EL13/1965	Walker, J. L.	Barringer Research Limited; Broken Hill Proprietary Company Limited	Geochemical report on South West Tasmania.

TCR No.	Licence	Author	Company	Title
66_0444	EL13/1965	Anon.	Broken Hill Proprietary Company Limited	Aeromagnetic survey — SW Tasmania.
66_0445	EL13/1965	Curtis, C. E.; Hartman, R. R.	Aero Service Limited; Broken Hill Proprietary Company Limited	Interpretation report, airborne magnetometer survey in Southwest Tasmania.
67_0493	EL13/1965	McIntyre, M. H.; Bumstead, E. D.	Broken Hill Proprietary Company Limited	Southwest Tasmania, geochemical report E.L. 13/65 1966–67.
68_0535	EL13/1965	Corbett, E. B.	Broken Hill Proprietary Company Limited	The geology and petrology of the Mainwaring Group and associated rocks from southwest Tasmania.
68_0541	EL13/1965	Taylor, C. P.	Broken Hill Proprietary Company Limited	Airborne scintillometer survey EL 13/65, Tasmania.
69_0552	EL13/1965	Hall, W. D. M.; McIntyre, M. H.; Hall, K. M.	Broken Hill Proprietary Company Limited	South-West Tasmania EL 13/65. Geological report 1966–67.
69_0555	EL13/1965	Hall, W. D. M.; McIntyre, M. H. Corbett, E. B.; McGregor, P. W.; Fenton, G. R.; Arndt, C. D.; Bumstead, E. D.	Broken Hill Proprietary Company Limited	Report on field work in Exploration Licence 13/65, south-west Tasmania during 1967–68 field season.
69_0555A	EL13/1965	Hall, W. D. M.; Arndt, C. D.	Broken Hill Proprietary Company Limited	The Double Cove Belt.
69_0555B	EL13/1965	McGregor, P. W.; Bumstead, E. D.	Broken Hill Proprietary Company Limited	The Hibbs Belt.
69_0555C	EL13/1965	Hall, W. D. M.; Corbett, E .B.	Broken Hill Proprietary Company Limited	The geology of the Mainwaring Belt.
69_0564	EL13/1965	Corbett, E. B.	Broken Hill Proprietary Company Limited	Petrology of some specimens from the Cypress Creek–north Mainwaring River area, S.W. Tasmania.
69_0586	EL13/1965	McGregor, P. W.	Broken Hill Proprietary Company Limited	Report on 1968-69 field work E.L. 13/65 south west Tasmania.
69_0604	EL13/1965	McIntyre, M. H.; Bumstead, E .D.	Broken Hill Proprietary Company Limited	South-West Tasmania E.L. 13/65. Geochemical methods used during 1966–1968.
71_0749	EL13/1965	Flood, B.	Broken Hill Proprietary Company Limited	Report of fieldwork at Spero River and Hibbs Lagoon, S.W. Tasmania, Feb–March, 1979.
71_0758	EL13/1965	Langlands, J. G.; Rees, R. C.	Broken Hill Proprietary Company Limited	Report to the Tasmanian Mines Department on exploration for chrysotile asbestos in Exploration Licence 13/65, December, 1970 to June, 1971.
71_0805	EL13/1965	Langlands, J. G.	Broken Hill Proprietary Company Limited	E.L. 13/65 Cape Sorell Peninsula, S.W. Tasmania. Exploration for chrysotile asbestos in the Hibbs Belt, Noddy Creek and Pad 2 to Asbestos Point, 1970/71.
72_0862	EL13/1965	McGregor, P. W.	Broken Hill Proprietary Company Limited	Exploration for chrysotile asbestos, Pad 2 to Hibbs Lagoon, E.L. 13/65, S.W. Tasmania. January to March 1972.
72_0889	EL13/1965	Close, R. J.	Broken Hill Proprietary Company Limited	The geology and economic potential of the Hibbs Ultramafic Belt in the Noddy Creek area of South West Tasmania.
72_0926	EL13/1965	Anon.	Broken Hill Proprietary Company Limited	Rock, soil sampling and magnetics, miscellaneous areas, EL 13/65.
78_1304	EL27/1976	Mudge, S. T.	Geopeko Limited	Induced polarisation and magnetometer surveys, Voyager 1 and 5, Elliott Bay, Tasmania.

TCR No.	Licence	Author	Company	Title
78_1317	EL27/1976	Strickland, C. D.	Geopeko Limited	Elliott Bay area — Tasmania. Progress report: Exploration Licence 27/76.
79_1356	EL27/1976	Burlinson, K.	Geopeko Limited	Tin at Elliott Bay, Tasmania, E.L. 27/76. The 1978 field programme.
81_1640	EL27/1976	Strickland, C. D.	Geopeko Limited	Elliott Bay Area — Tasmania. Progress report: Exploration Licence 27/76 Voyager 1 and Voyager 5 prospects. 1978–79 field season.
82_1745	EL27/1976	Wilson, P. A.; Herrmann, W.; Large, R. R.; Heithersay, P. S.	Geopeko Limited	Progress report E.L. 27/76 Elliott Bay South West Tasmania. 1980–1981 field season.
83_2076	EL27/1976	Herrmann, W.	Geopeko Limited	Exploration Licence 27/76 Elliott Bay, Tasmania. Annual report 1982–83 field season.
84_2083	EL27/1976	Sumpton, J.	Geopeko Limited	Report on gravimeter survey Elliott Bay E.L. 27/76 Tasmania.
85_2329	EL27/1976	Herrmann, W.	Geopeko Limited	Exploration Licence 27/76 Elliott Bay, Tasmania. Final report on exploration of areas to be relinquished from EL27/1976 in January 1985.
85_2466	EL35/1983 EL36/1983 EL37/1983	Kary, G. L.	Amoco Minerals Australia Company	Progress report twelve months to September 1985, Sorell Peninsula, exploration licences 35/83, 36/83 and 37/83 Tasmania.
85_2466A	EL35/1983 EL36/1983 EL37/1983	Bishop, J. R.	Mitre Geophysics Pty Ltd	Evaluation of the results from the 1984–85 field season program over the Sorell Peninsula.
85_2505	EL27/1976	Herrmann, W.	Geopeko Limited	Final report on exploration licence 27/76, Elliott Bay, Tasmania.
86_2520	EL27/1976	Strickland, C. D.	Geopeko Limited	Elliott Bay area — Tasmania. Progress report: Exploration Licence 27/76 Voyager 1 and Voyager 5 Prospects. 1978–79 field season.
86_2524	EL27/1976	Poltock, N.; Poltock, R.	Geopeko Limited	E.L. 27/76 Elliott Bay Tas. Jan–Feb. 1981.
86_2525	EL27/1976	Gulson, B. L.; Porritt, P. M.; Large, R. R.	CSIRO; Geopeko Limited	Lead isotope investigations of varying styles of mineralization in the Mt Read Volcanic Belt (Tasmania) and their exploration significance.
86_2526	EL27/1976	Gulson, B. L.; Porritt, P. M.	CSIRO; Geopeko Limited	Lead isotope assessment of additional geochemical anomalies in the Elliott Bay area, S.W. Tasmania.
86_2527	EL27/1976	Gulson, B. L.	CSIRO; Geopeko Limited	Evaluation of lead isotopes in exploration. Assessment of further anomalies from the Elliott Bay area for Geopeko.
86_2528	EL27/1976	Podger, F. D.	Geopeko Limited	Consultants report on *Phytophthora cinnamomi* in the area of Geopeko exploration activities near Birch's Inlet and Elliott Bay, S.W. Tasmania.
86_2535	EL27/1976	McInerney, P.	Geopeko Limited	Report on reprocessing of gravity data, Voyagers 9, 19 and 29, E.L. 27/76 Elliott Bay, Tasmania.
86_2568	EL40/1985	Jones, P. A.	Cyprus Minerals Australia Company	Progress report six months to June 1986, Elliott Bay EL 40/85, southwest Tasmania.
86_2602	EL35/1983 EL36/1983 EL37/1983	Jones, P. A.	Cyprus Minerals Australia Company	Progress report 12 months to September 1986, Sorell Peninsula, exploration licences 35/83, 36/83, 37/83, Tasmania.

TCR No.	Licence	Author	Company	Title
87_2696	EL40/1985	Torrey, C. E.; Poltock, R.; Hartley, R.	Cyprus Minerals Australia Company	Progress report, twelve months to June 1987, Elliott Bay Exploration Licence 40/85, Tasmania.
87_2696A	EL40/1985	Bishop, J. R.	Mitre Geophysics Pty Ltd	Interpretation of electrical and electromagnetic surveys at Elliott Bay (E.L. 40/85).
87_2696B	EL27/1976 EL40/1985	Large, R. R.	Cyprus Minerals Australia Company	Notes on the Voyager 24 gold mineralization, Elliott Bay.
87_2730	EL35/1983 EL36/1983 EL37/1983	Torrey, C. E.; Poltock, R.	Cyprus Minerals Australia Company	Progress report six months to September 1987, Sorell Peninsula exploration licences 35/83, 36/83, 37/83 Tasmania.
87_2730A	EL35/1983 EL36/1983 EL37/1983	Bishop, J. R.	Mitre Geophysics Pty Ltd	Interpretation of electrical and electromagnetic surveys at Elliott Bay (and Sorell Peninsula).
88_2836	EL37/1983	Poltock, R.	Cyprus Gold Australia Corporation	Progress report, twelve months to September 1988, Spero River, Exploration Licence 37/83, Tasmania.
88_2853	EL40/1985	Torrey, C. E.; Poltock, R.; Suppree, J.	Cyprus Gold Australia Corporation	Progress report, 12 months to June 1988, Exploration Licence 40/85, Elliott Bay, Tasmania.
88_2853A	EL27/1976 EL40/1985	Bishop, J. R.	Mitre Geophysics Pty Ltd	A compilation of geophysical surveys carried out at Elliott Bay (E.L. 27/76).
91_3320	EL40/1985	Wallace, D. B.	Aberfoyle Resources Limited	Exploration Licence 40/85, Elliott Bay Tasmania. Partial relinquishment report on exploration to December, 1991.
95_3784	EL4/1992 EL7/1992	Close, R. J.; Reid, R.	Plutonic Operations Limited	Exploration licences 4/92 and 7/92, Sorell Peninsula. Annual report on exploration activity September 1993 to August 1995.
96_3951	EL7/1992	Close, R. J.	Plutonic Operations Limited	Exploration Licence 7/92, High Rocky Point Sorell Peninsula. Report on the southern area relinquished in September 1996.
99_4316	EL20/1996	McNeil, P. A.	Exploration and Management Consultants Pty Ltd	EL 20/96 — Elliott Bay, southwestern Tasmania. Partial relinquishment report.
03_4890		Gilfillan, J. F.	Lyell–EZ Explorations	Regional report — coastal traverse.
04_4993	EL21/1999	Hall, D.	TasGold Limited	SMRV Project EL21/1999 — Wanderer River south west Tasmania. Annual report year ending 27 January 2004.
04_5012	EL21/1999	Hall, D.	TasGold Limited	SMRV Project EL21/1999 — Wanderer River south west Tasmania. Partial relinquishment report January 2004.
05_5169	EL21/1999	Reid, R.	TasGold Limited	EL 21/99 — Elliot Bay, annual report to January 27 2005.
05_5237	EL21/1999	Reid, R.	TasGold Limited	Partial relinquishment of EL 21/1999 — Wanderer.
06_5294	EL21/1999	McDougall, J.; Reid, R.; Allen, N.	TasGold Limited	EL 21/1999 — Wanderer. Annual report to December 26th 2005.
07_5431	EL21/1999	Reid, R.; McDougall, J.; Allen, N.; Ruzicka, P.	Frontier Resources Ltd	EL 21/1999 — Wanderer. Annual report to 26 Dec 2006.
07_5568	EL20/2006	Reid, R.; Fish, G.	Frontier Resources Ltd	EL20/2006 — Lewis River. Annual report to 11 September 2007.
08_5727	EL20/2006	Reid, R.	Frontier Resources Ltd	EL20/2006 — Lewis River. Annual report to 11 September 2008.

APPENDIX 2

Sample identification and location

Montgomery Map Sheet

Field No.	Registration No.	AMG (east)	AMG (north)	Analysis No.	REE analysis	Rock type	Thin section	Rock description
Mo								
8	Location	377700	5245200	N	N	Evsc (Cfv)	N	
21	Location	376100	5247000	N	N	Evl	N	
23/2	R16401	376000	5246800	N	N	Evlv	Y	Foliated basalt from sheared zone with siltstone to granule conglomerate units derived from picritic basalt
24	Location	376100	5246600	N	N	Evlv	N	
25	Location	376100	5246400	N	N	Evlv	N	
26	Location	376100	5246300	N	N	Evl	N	
28	Location	376100	5245900	N	N	Evl	N	
29	Location	376100	5245800	N	N	Evl	N	
30	R16402	376000	5245500	N	N	Evlv	Y	Fine to medium-grained porphyritic (Ol?, OPX) picritic basalt
31	R16403	376100	5245500	N	N	Evl	Y	Laminated calcareous siltstone and spalled volcaniclastic siltstone
32	Location	376100	5245600	N	N	Evl	N	
33	R16404	376200	5245500	N	N	Evl	Y	Schistose (tectonised) muddy siltstone with pyrite
34	Location	376300	5245600	N	N	Evl	N	
35	Location	376400	5245600	N	N	Evl	N	
37*	R16405	376800	5244900	N	N	Cfv	Y	Schistose quartz-phyric felsic volcanic rock
38	R16406	376800	5245000	N	N	Cfv	Y	Schistose quartz-phyric felsic volcanic rock interbedded with silty mudstone
39	R16407	376800	5245100	N	N	Cfv	Y	Highly sheared quartz-phyric lava
40*	R16408	376800	5254200	N	N	Cfv	Y	Highly tectonised felsic volcanic rock
42	Location	376700	5245200	N	N	Cfv	N	
45*	R16409	374000	5248300	N	N	Cvc	Y	
48	Location	375100	5248300	N	N	Cvc	N	
50	Location	375200	5248200	N	N	Evl	N	
51	R16410	375200	5248100	N	N	Evl	Y	Tectonised vesicular plagioclase phyric lava (basalt)
52	Location	375200	5248000	N	N	Evl	N	
53	R16411	375300	5247900	N	N	Evl	Y	Tectonised lava (basaltic) unit, now a schistose volcaniclastic granule conglomerate
54	R16412	375300	5247900	N	N	Evl	Y	Tectonised olivine-bearing fine-grained basalt, now a schistose volcaniclastic granule conglomerate
56	R16413	375300	5247800	N	N	Evl	Y	
57	R16414	375400	5247600	N	N	Evl	Y	Medium-grained picritic basalt
58	R16415	375500	5247500	N	N	Evl	Y	
59	R16416	375500	5247400	N	N	Evl	Y	
60	Location	375300	5247400	N	N	Evl		
61	R16417	375500	5247200	N	N	Evl	Y	Vesicular, quenched groundmass picritic basalt alternating with OPX-CPX pyroxenite?/picritic lava
62	R16418	375600	5247300	N	N	Evl	N	
64	R16419	377200	5245600	N	N	Cfv	Y	Crenulated, schistose, muscovitic felsic lava
78	R16420	377400	5244600	N	N	Cgf	Y	Feldspar phyric granitoid
87/2	R16421	375900	5247300	N	N	Evl	Y	Fine-grained pictritic lava
88	R16422	376000	5247200	N	N	Evl	Y	Very fine-grained vesicular plagioclase phyric lava with flow texture
89	Location	376000	5247200	N	N	Evl	N	
90	Location	376000	5247300	N	N	Evl	N	
92	Location	376200	5247400	N	N	Evl	N	

Field No.	Registration No.	AMG (east)	AMG (north)	Analysis No.	REE analysis	Rock type	Thin section	Rock description
93	Location	376300	5247400	N	N	Evl	N	
94	Location	376400	5247500	N	N	Evl	N	
95	R16423	376600	5247600	N	N	Evl	Y	Crenulated, foliated, volcaniclastic siltstone
96	R16424	376600	5247700	N	N	Evl	Y	Schistose, felsic, volcaniclastic fine-grained sandstone from mixed metamorphic-felsic volcanic sources
97	R16425	376600	5247700	N	N	Evl	Y	Schistose, mixed meta-felsic volcaniclastic (quartz grains) muscovitic sandstone
102	R16426	373900	5248200	N	N	Cvc	Y	Crenulated penetrative foliated muscovitic siltstone
105	R16427	373800	5248800	N	N	Cvc	Y	Partially recrystallised, foliated sandy siltstone with volcanic quartz grains
108	R16428	373600	5249000	N	N	Cvc	Y	Partially recrystallised, foliated sandy siltstone with volcanic quartz and carbonate grains
113	R16429	373700	5249500	N	N	Cvc	Y	Crenulated penetrative foliated muscovitic siltstone
120	Location	375500	5247500	N	N	Evv-p	Y	Vesicular, quenched textured picritic lava interbedded with sheared spalled lava-derived siltstone
151	R16430	377000	5246200	N	N	Evlv	Y	Crenulated mudstone
152	Location	377300	5246500	N	N	Evsc (Cfv)	Y	Crenulated mudstone
154	R16431	377500	5246500	N	N	Evsc (Cfv)	Y	Micaceous sandy siltstone with mixed metamorphic and felsic volcanic clasts
156	R16432	377700	5246700	N	N	Evsc (Cfv)	N	
163	R16433	375300	5247900	873006	Y	Evv-p	Y	Picritic basalt interbedded with spalled basaltic siltstone
166	Location	375500	5247600	873008	Y	Evv-p	Y	
167	Location	375600	5247400	N	N	Evv-p	Y	
169	Location	377500	5247400	873009	Y	Evv-p	Y	
170	Location	375600	5247400	873010	Y	Evv-p	Y	
177/1	R16434	377100	5243100	N	N	Cfv	Y	Muscovitic siltstone
177/2	R16435	377100	5243100	N	N	Cfv	Y	Highly crenulated muscovitic siltstone
203	R16436	377400	5241200	873011	Y	Cbgs	Y	Cambrian granitoid
214	R16437	377700	5239600	873012	Y	Cbg	Y	Cambrian granitoid
216	R16438	377300	5239000	873013	Y	Dmv	Y	Devonian(?) alkali basalt
217	R16439	377300	5228800	873014	Y	Dmv	Y	Devonian(?) alkali basalt
218	R16440	377200	5238800	873015	Y	Cbg	Y	Cambrian granitoid
221	R16441	377600	5240200	873016	Y	Cbg	Y	Cambrian granitoid
227*	R16442	373700	5249500	N	N	Evv	Y	Hyaloclastic basalt from within the Evl sequence
228	R16443	372500	5258000	873017	Y	Evv-t	Y-M	Thin section missing
230	R16444	374300	5256600	873018	Y	Evv-t	Y-M	Thin section missing
231	R16445	374700	5256700	883672	N	Evv-p	Y-M	Thin section missing
233	R16457	374600	5256600	873019	Y	Evv-p	Y-M	Thin section missing
238	R16446	371400	5256700	N	N	Cmv	Y	Hornblende microphenocrysts in hornblende-plagioclase-quartz groundmass, 1–2 mm grain size
241	R16447	372400	5256700	N	N	Cmv	Y+PTS	Hornblende microphenocrysts in hornblende-plagioclase-quartz groundmass, less quartz than Mo238
243	R16448	372300	5256700	N	N	Cmv	Y+PTS	Hornblende phenocrysts, up to 0.5 mm long, in hornblende-plagioclase-quartz groundmass
251	Location	370900	5258400	N	N	Cvl	N	
284	R16449	377500	5257600	N	N	Cfv	Y	Felsic volcaniclastic lithicwacke
285*	R16450	377800	5257600	N	N	Cfv	Y	Highly tectonised felsic volcaniclastic wacke with large embayed quartz grains
286	R16451	377600	5257600	N	N	Cfv-Evv	Y	Highly sheared volcanic lava
287	R16452	376400	5257600	873020	Y	Evv-t	Y-M	Basaltic hyaloclastite
289	R16453	365900	5257700	873021	Y	Evv-t	Y-M	Highly altered picritic basalt — originally small olivine phenocrysts in quenched olivine and glass groundmass
291*	R16454	375200	5257400	883673	Y	Evv-p	Y-M+PTS	Quenched textured olivine phyric picritic lava

Field No.	Registration No.	AMG (east)	AMG (north)	Analysis No.	REE analysis	Rock type	Thin section	Rock description
292	R16455	375200	5257400	883674	Y	Evv-p	Y-M+PTS	Quenched textured olivine phyric picritic lava
293	R16456	371700	5258300	N	N	Cmv	Y	Holocrystalline hornblende-plagioclase-quartz, coarser grained than Mo238 or Mo241
300*	C109853	370600	5259300	873022	Y	Cmv-d	Y	Euhedral to subhedral hornblende phyric lava, feldspar and glass groundmass
301	R16458	370500	5259400	N	N	Cmv-d	Y	Cpx bearing hornblende-plagioclase-quartz intrusive rock
305/1	C109857	367200	5262500	883676	Y	Cvs	Y	Cpx and plagioclase phyric lava with fine-grained groundmass
305/2	C109858	367200	5262500	883677	Y	Cvs	Y	Cpx and plagioclase phyric lava with fine grained groundmass and flow texture
305/3	C109859	367200	5262500	883678	Y	Cvs	Y	Cpx (large) and plagioclase (small) phyric vesicular lava with a glassy quartzo-feldspathic groundmass
306/1	C109860	370400	5250500	883679	Y	Cva	Y	Brecciated, small feldspar phyric lava in a fine grained, quenched, quartzo-feldspathic groundmass
306/2	C109861	370400	5250600	883680	Y	Cva	Y	Fragmental version of Mo306/1, two different textured lavas, carbonate filled fractures
311	Location	372400	5252400	N	N	Cvl	N	
316	R16459	372200	5252000	N	N	Cvl	Y	Lithicwacke up to 1 m thick interbedded with truncated cross-bedded sandy siltstone
321	R16460	372300	5251700	N	N	Cvl	Y-M	Thin section missing
328	R16461	372800	5251100	N	N	Cvc	Y	Tectonised, mixed metamorphic/felsic volcanic terrane lithicwacke
333	Location	373300	5250000	N	N	Cvc	N	
337	R16462	373300	5250400	N	N	Cvc	Y	Schistose muscovitic mixed terrane (metamorphic/felsic volcanic) sandy siltstone
338*	R16463	373200	5250500	N	N	Cvc	Y	Schistose muscovitic siltstone with siderite rhombs
340	R16464	373000	5250600	N	N	Cvc	Y-M	Thin section missing
351	R16465	373400	5251800	N	N	Cmv-d	Y+PTS	Hornblende-Cpx phyric fine grained crystalline quartzo-feldspathic groundmass intrusive
360	R16466	372300	5252700	N	N	Cmv-d	Y+PTS	Euhedral hornblende crystals in acicular hornblende-quartzo-feldspathic groundmass dyke
363	C109870	372200	5253100	873024	Y	Cmv-d	Y	Hornblende phyric lava with quartzo-feldspathic groundmass with Fe-oxide accessory minerals
368	Location	372000	5253800	N	N	Cvc	N	
380/2	C109874	371000	5255800	873025	Y	Cmv-p	Y	Amygdaloidal quartzo-feldspathic flow banded lava
380/3	C109875	371000	5255800	N	N	Cmv-p	Y	Welded fragmental pumiceous tuff (basal part of flow), incorporates rip up clasts higher up
392	C109877	371600	5254400	873026	Y	Cmv-s	Y	Hornblende phyric medium-grained groundmass lava
393	C109878	371800	5254300	873027	Y	Cmv-s	Y	Hornblende phyric medium-grained groundmass lava
400	Location	369600	5261900	N	N	Cal	Y+PTS	Lamprophyre dyke — minette — biotite bearing
401	R16467	369600	5261800	N	N	Cvl	Y	
406/1	R16468	370400	5260000	N	N	Cvt	Y+PTS	Granule conglomerate — mixed metamorphic/ felsic volcanic terrane — fractured glass clasts
406/2	R16469	370400	5260000	N	N	Cvt	Y+PTS	Mixed metamorphic/felsic volcanic terrane, lithicwacke
406/5*	R16470	370400	5260000	N	N	Cvt	Y	Tectonised volcaniclastic wacke
408*	R16471	370300	5260200	N	N	Cvt	Y	Partially recrystallised glass shard-rich siltstone
410	R16472	370100	5260600	N	N	Cvt	Y	Tectonised volcanic wacke
414	R16473	369900	5261100	N	N	Cvt	Y	Mixed metamorphic/felsic volcanic terrane lithicwacke
421*	R16474	369900	5262200	N	N	Cvl	Y	Mylonite, derived from metamorphic and felsic volcanic terranes
424	R16475	369600	5262100	N	N	Cvl-d	Y	Fine-grained andesitic dyke in Cvl
425	R16476	369600	5221100	N	N	Cvl	Y	Mixed metamorphic/felsic volcanic sandstone
426	R16477	369600	5262300	N	N	Cvl	Y	

Field No.	Registration No.	AMG (east)	AMG (north)	Analysis No.	REE analysis	Rock type	Thin section	Rock description
437/1	R16478	369200	5262500	N	N	Cmv-d	Y+PTS	Hornblende-Cpx microphenocrysts in quartzo-feldspathic groundmass — chilled margin of dyke
437/2	R16479	369200	5262500	N	N	Cmv-d	Y+PTS	Fine-grained hornblende-plagioclase — centre of dyke, similar to Mo438
438	C109914	367800	5263000	873028	Y	Cvv	Y	Hornblende and Cpx microphenocrysts in quartzo-feldspathic groundmass — sill
439	C109915	367900	5263100	873029	Y	Cvv	Y	Cpx > plagioclase (small) phyric quenched textured groundmass lava
446	R16480	368700	5262500	N	N	Cmv-d	Y	Hornblende-plagioclase holocrystalline dyke similar to Mo437
453/1*	R16481	370400	5262100	N	N	Cvt	Y	
453/2*	R16482	370400	5262100	N	N	Cvt	Y	
460	R16483	371000	5261800	N	N	Cvt	Y	
464	C109931	371300	5261700	873030	Y	Cvt-lava	Y	Welded crystal vitric lithic andesitic breccia
471*	R16484	371700	5261800	N	N	Cvt	Y	
492	R16485	368700	5267000	N	N	Cvl	Y	Vitric tuff
494	Location	368500	5267000	N	N	Cvv	N	
495/1*	R16486	368400	5266900	N	N	Cvv	Y	Groundmass of crystal-lithic-fragmental volcanic breccia unit
495/2	R014860	368400	5266900	883684	Y	Cvv	Y+PTS	Crystal lithic fragmental volcanic breccia — two lava mix, plagioclase-rich and Cpx-plagioclase rich
495/3*	R16487	368400	5267000					
495/4	R014861	368400	5266900	883685	Y	Cvv	Y	Cpx-plagioclase breccia with fine-grained groundmass, fragmental, autobrecciated
496	R014862	368300	5267000	883686	Y	Cvv	Y	A two lava mix, (1) plagioclase rich fine-grained vesicular lava and Cpx-plagioclase phyric with fine-grained groundmass
497/2	R014863	368200	5266900	883687	Y	Cvv	Y	Cpx phyric vesicular lava with fine-grained groundmass
497/3	R014864	368200	5266900	883688	Y	Cvv	Y	Crystal, vitric lithic brecciated lava, autobrecciated
502/1	R16488	368000	5266200	N	N	Cvv	N	
506	R16489	369100	5266600	N	N	Cvl	Y	Vitric tuff
507	R16490	367400	5264900	N	N	Cvl	Y	Silty sandstone mainly derived from metamorphic terrain
513/2*	R16491	367300	5265500	N	N	Cvs	Y+PTS	Volcaniclastic coarse sandstone with large, euhedral chrome spinel grains and boninite clast
515	R014865	367400	5265800	883689	Y	Cvs	Y	Cpx phyric lava — groundmass dominantly plagioclase with Cpx and glass
526	R16492	367700	5263800	N	N	Cvs	Y	Brecciated Cpx-phyric lava with vesicular, glassy matrix
528	R16493	367600	5263900	883690	Y	Cvv	Y	Spalled graded volcanic wacke (sample from top of flow), interbedded with pillow lava flows
530/1*	R014867	367400	5264000	883691	Y	Cvs	Y	Cpx (large and dominant) and plagioclase (smaller) phyric lava with a glassy groundmass
530/2	R16494	367400	5264000	883692	Y	Cvs	Y	
530/3	R16495	367400	5264000	N	N	Cvs	Y	Fine-grained version of Mo530/2, mixed lava, Cpx phenocrysts zoned and embayed glassy groundmass
530/4*	R014869	367400	5264000	883693	Y	Cvs	Y	Highly vesicular Cpx phyric lava with a fine-grained glassy matrix, from pillow lava
533	R104870	377500	5264300	883694	Y	Cvs	Y+PTS	Crystal, vitric, lithic volcaniclastic sandstone
534*	R014886	367500	5264500	883595	Y	Cvs	Y+PTS	Crystal vitric (tube and bubble pumice) lithic sandstone — breccia flow
535	R014887	367500	5264400	873032	Y	Cvs	Y+PTS	Crystal lithic vitric sandstone — breccia flow
536/1	R16496	367400	5264800	873033	Y	Cvs-S	Y+PTS	Spalled, volcaniclastic sandstone from agglomerate-autobrecciated-volcaniclastic sandstone sequence
536/2	R014874	367400	5264800	883696	Y	Cvs	Y+PTS	Cpx (anhedral) in crystalline plagioclase (post cumulate like) interlocking matrix lava — block in matrix

Field No.	Registration No.	AMG (east)	AMG (north)	Analysis No.	REE analysis	Rock type	Thin section	Rock description
536/3	R014875	367400	5264800	883697	Y	Cvs	Y	Cpx (large), plagioclase-phyric lava with glassy groundmass and glass fragments, matrix for Mo536/2
537	R014889	368500	5266900	883698	Y	Cvv	Y	Plagioclase >> Cpx phyric lava with fine grained matrix with partially resorbed granitoid clast
538*	R014878	368500	5266900	883699	Y	Cvv	Y	Cpx > plagioclase phyric vesicular lava with devitrified glass matrix
539*	R014879	368400	5266900	883670	Y	Cvv	Y	Cpx >> plagioclase phyric vesicular lava with fine grained devitrified glass groundmass and resorbed Cpx
546	R16497	376700	5253600	N	N	Evv	Y+PTS	
553*	R16498	377000	5253500	N	N	Cfv	Y	Schistose quatrz-phyric volcanic rock
558/2	R16499	377200	5253700	N	N	Cfv	Y	
559*	R16500	376900	5253600	873034	Y	Evv-t	Y	
561	R16501	376600	5253500	N	N	Evv-t	Y	Foliated basalt
562	R16502	376600	5253500	N	N	Evv-t	Y	Vesicular basalt with native copper
563	R16503	376600	5253500	873701	Y	Evv-t	Y+PTS	Medium-grained basalt
564	R16504	376600	5253500	N	N	Evv-t	Y	Coarse-grained basalt
568	R16505	376300	5253500	873035	Y	Evv-t	Y	
578	R16506	375900	5253400	873036	Y	Evv-t	Y	
584	R16507	375500	5253500	883702	Y	Evv-t	Y+PTS	
585	R16508	376600	5253500	883703	Y	Evv-t	Y	

Point Hibbs Map

PH

4/1*	R16509	368200	5267900	N	N	Cvl	Y	Cobble to pebble-conglomerate from mixed metamorphic–volcanic terranes
10	Location	367900	5268000	N	N	Cl	Y	Lamprophyre dyke — minette, biotite bearing
17*	R16510	371100	5269700	N	N	Cvt	Y	Siliceous volcanic rock
22	Location	367600	5268000	N	N	Cvc	N	
23	R014856	367500	5268100	895753	Y	Cvv	Y	Crystal-rich volcaniclastic sandstone — Cpx grains dominant, with a variety of grain-sized groundmass
30/2	R16511	367400	5268700	N	N	Cvs	Y	Andesitic lava from Cvs sequence
32	R014857	368800	5269100	895754	Y	Cvl	Y	Plagioclase >> Cpx phyric lava. Cpx zoned and optically twinned. Plagioclase single and multiple crystals
42	R014858	368000	5266800	895755	Y	Cvs	Y	Cpx plagioclase phyric lava — phenocrysts smaller and groundmass glassier than PH43
43	R014859	366600	5271300	895756	Y	Cvs	Y	Cpx > plagioclase phyric lava with dominantly feldspathic groundmass, coarser-grained version of PH42

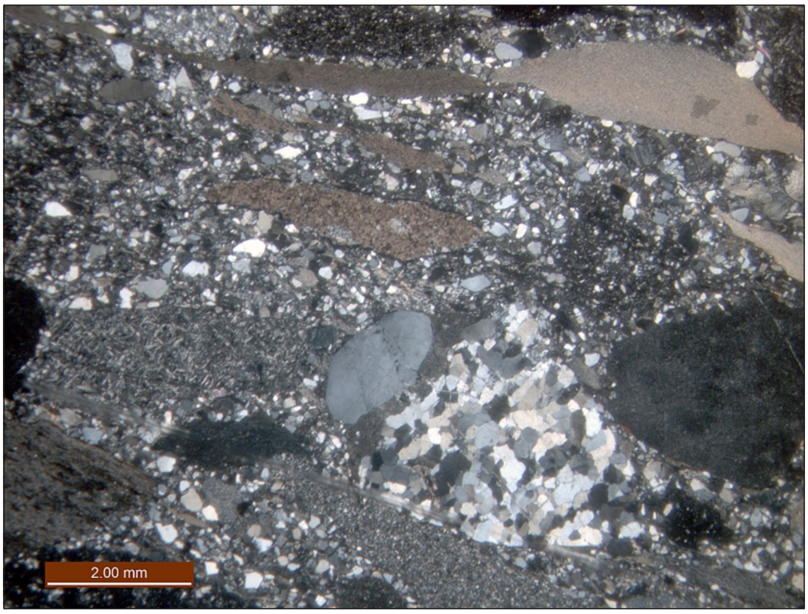
* = Photomicrograph available (see Appendix 3)

PTS = polished thin section

M = thin section missing

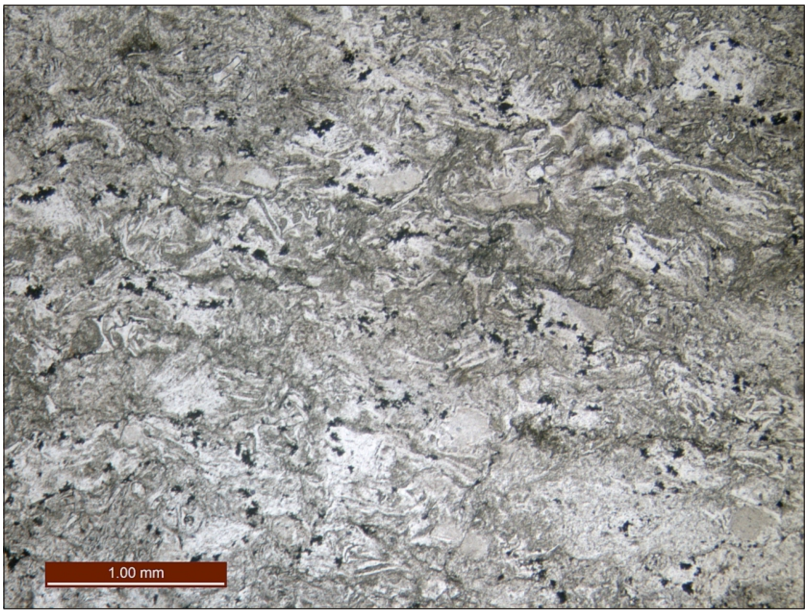
APPENDIX 3

Photomicrographs of rock samples



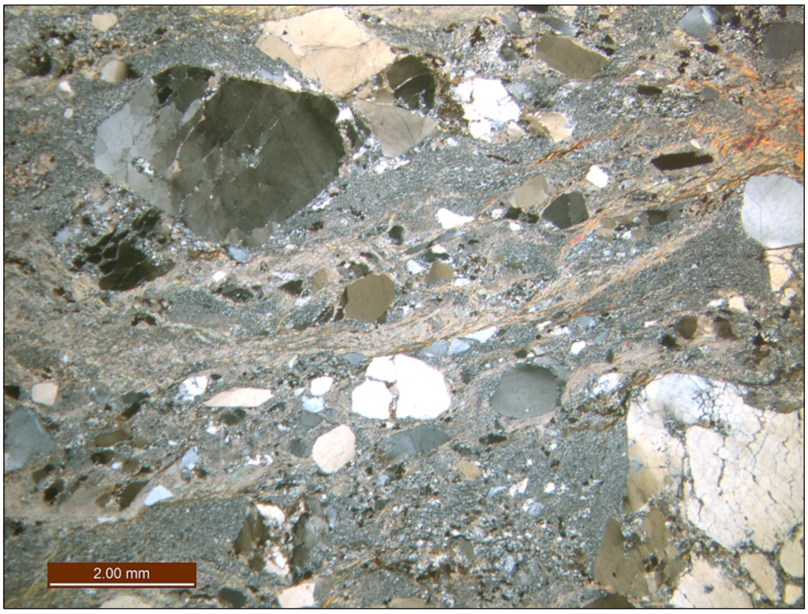
PH4/1

Cobble to pebble-conglomerate derived from mixed metamorphic-volcanic terranes (Cvl).



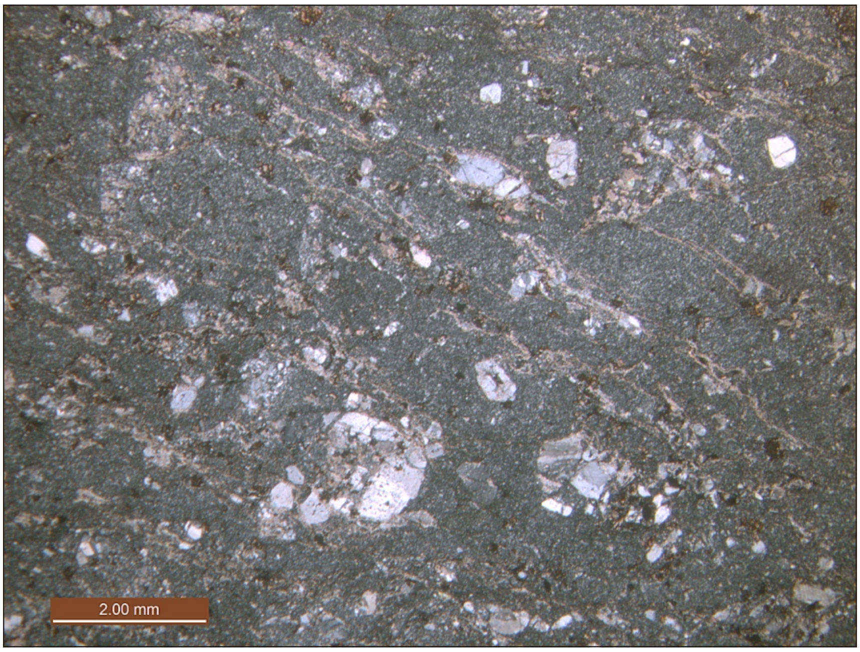
PH17

Siliceous volcanic rock (Cvt) with high proportion of glass shards.



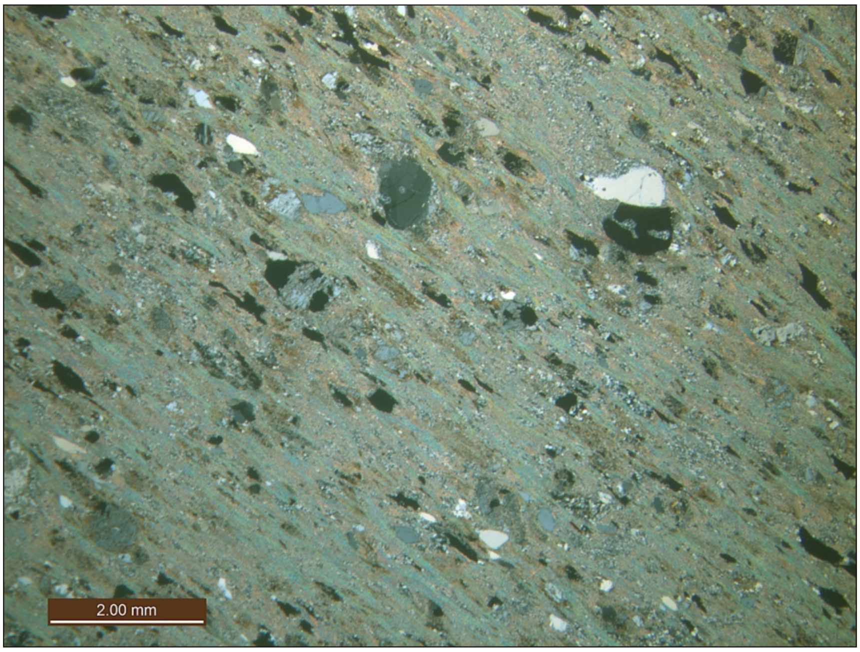
Mo37

Schistose quartz-phyric felsic volcanic wacke (Cfv).



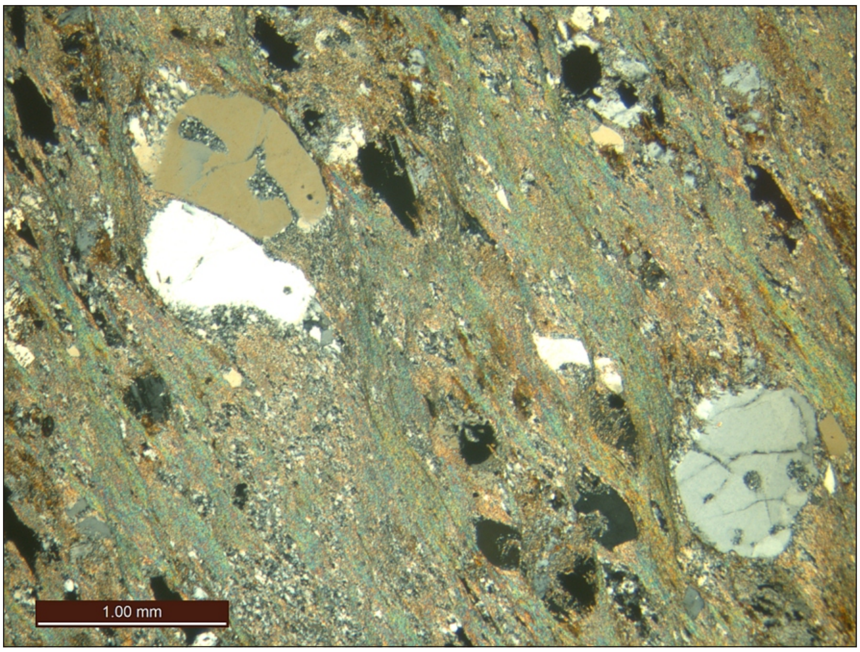
Mo40

Tectonised felsic volcanic rock (Cvc).



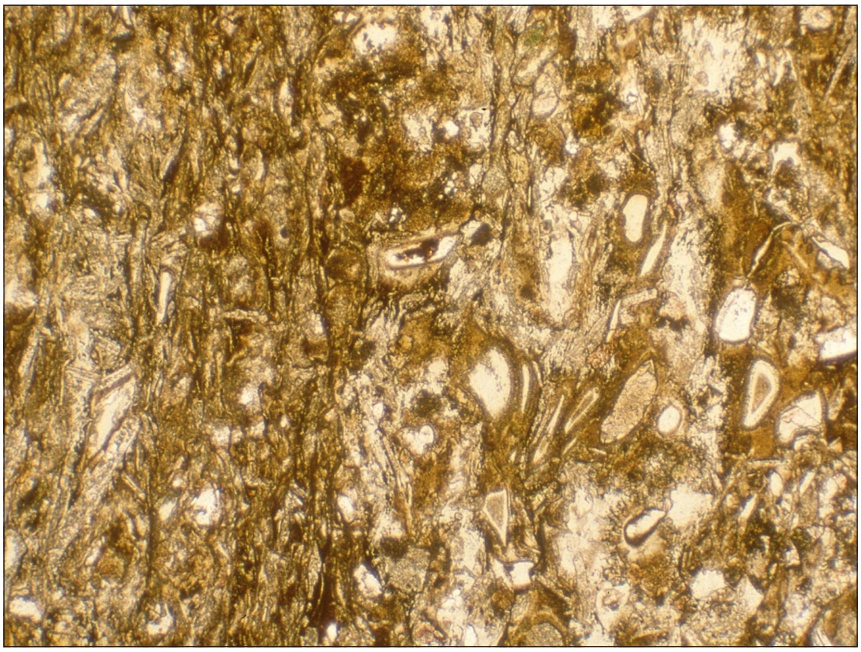
Mo45(a)

Schistose wacke with felsic volcanic and metamorphic rock clasts (Cvc).



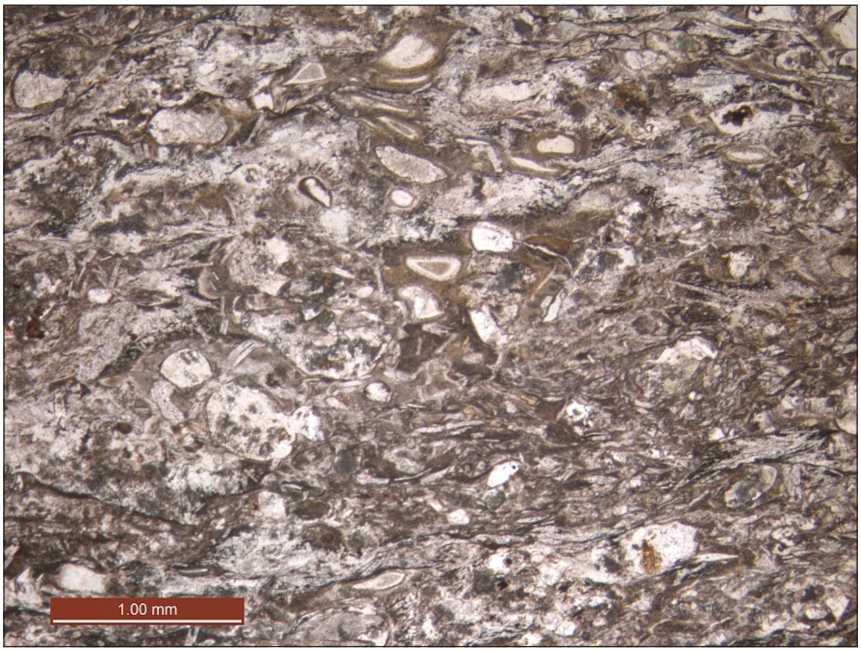
Mo45(b)

Close up of Mo45(a).



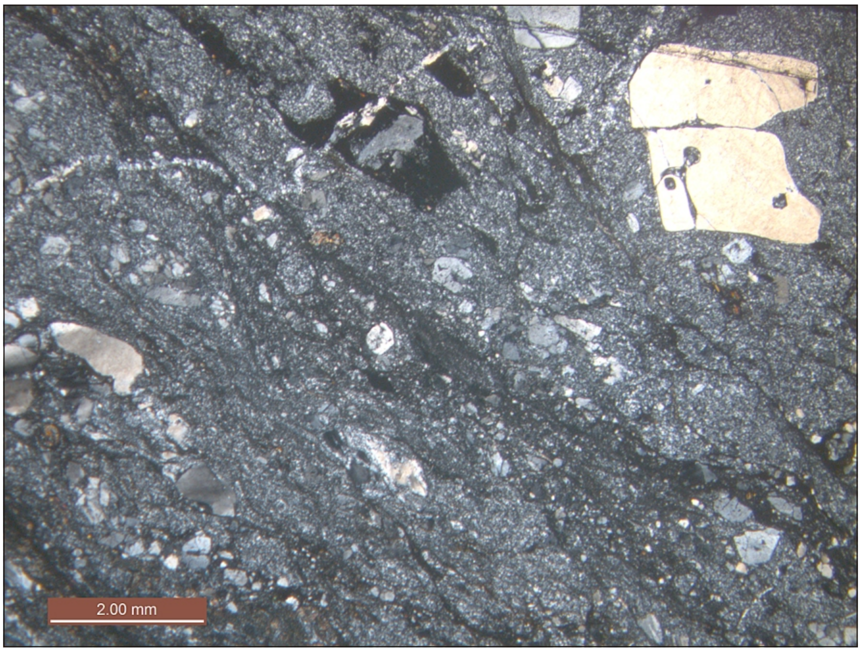
Mo227(a)

Hyaloclastic tholeiitic basalt from within the Evl sequence.



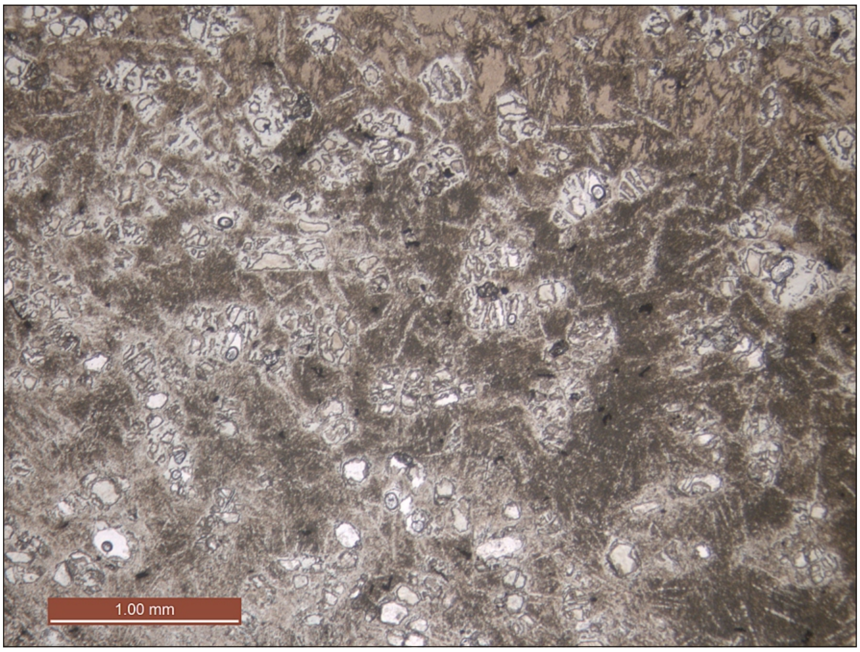
Mo227(b)

Hyaloclastic tholeiitic basalt from within the Evl sequence.



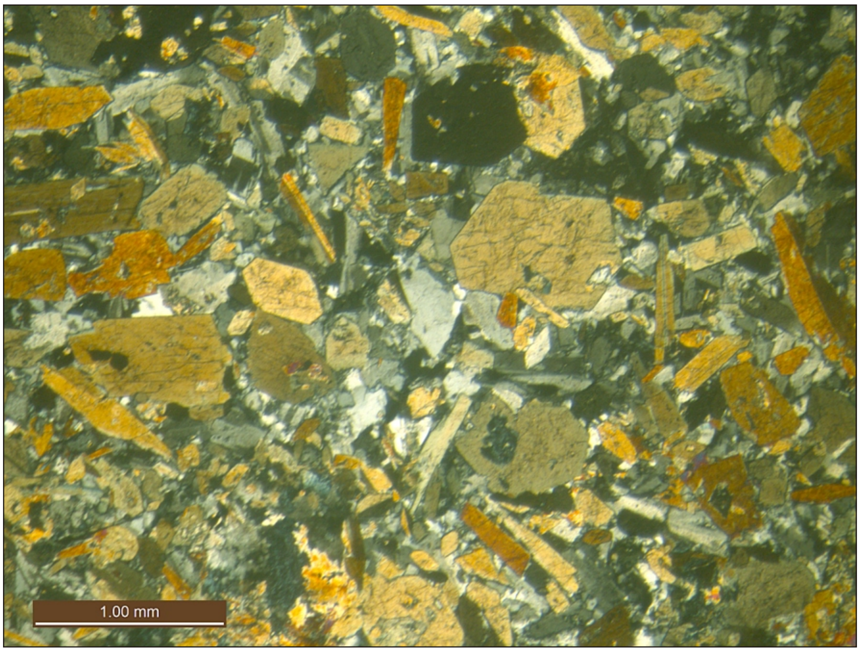
Mo285

Tectonised felsic volcaniclastic wacke with large embayed quartz grains (Cfv).



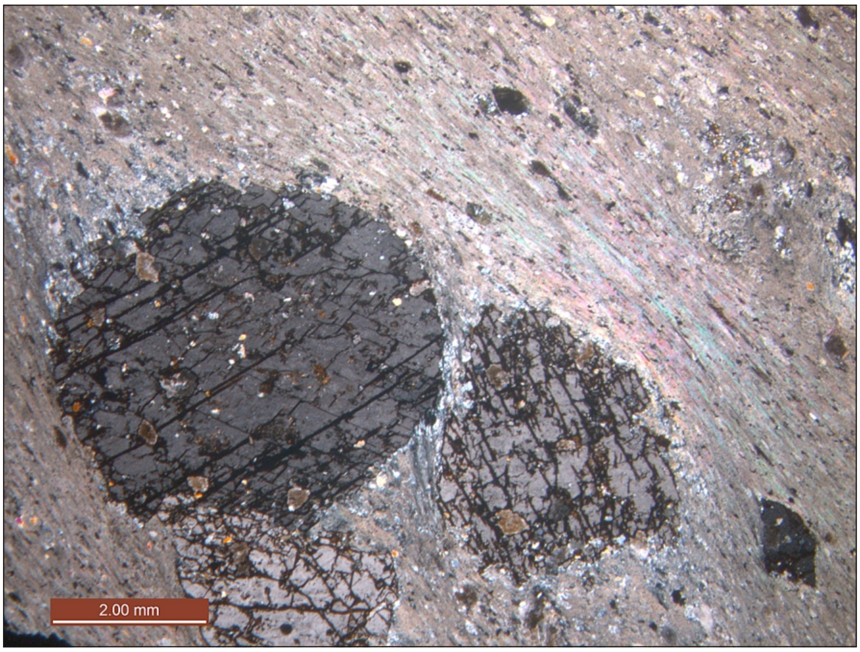
Mo291

Quenched textured olivine phyric picritic lava (Evv-p).



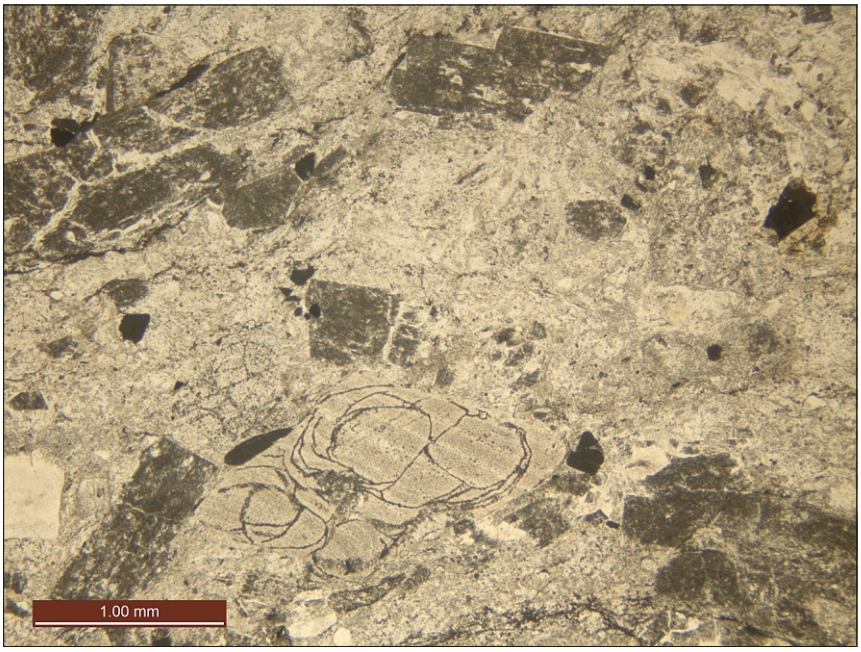
Mo300

Euhedral to subhedral hornblende phyric lava, feldspar and glass groundmass (Cmv).



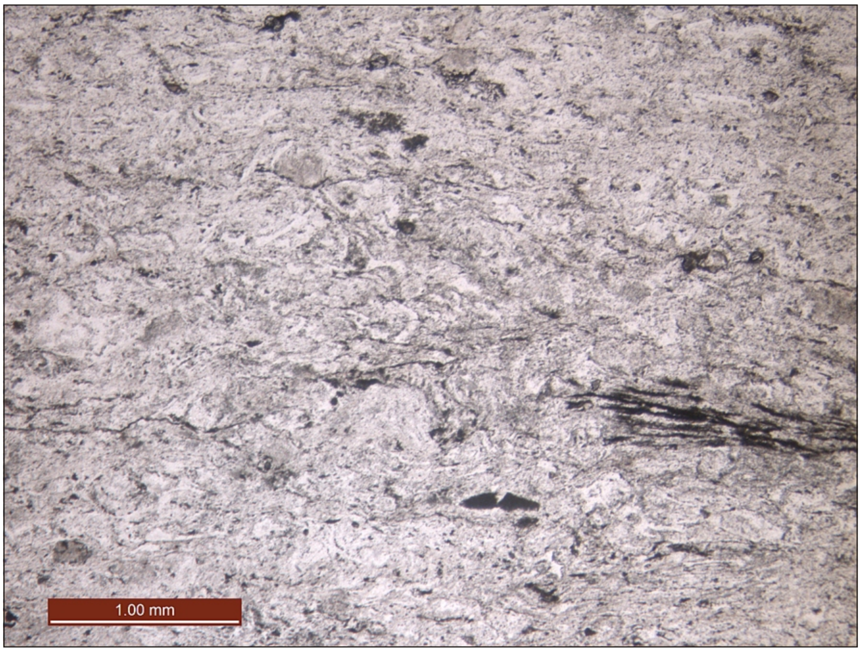
Mo338

Schistose muscovitic siltstone with siderite rhombs (Cvc).



Mo406/5

Tectonised volcaniclastic wacke with perlitic textured glass clasts (Cvt).

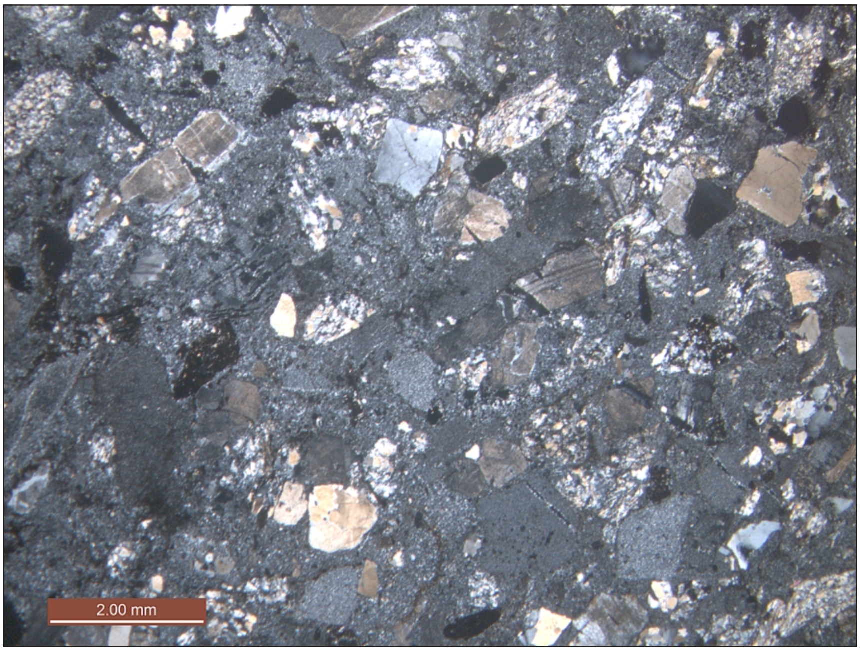


Mo408

Partially recrystallised glass shard-rich siltstone (Cmt).

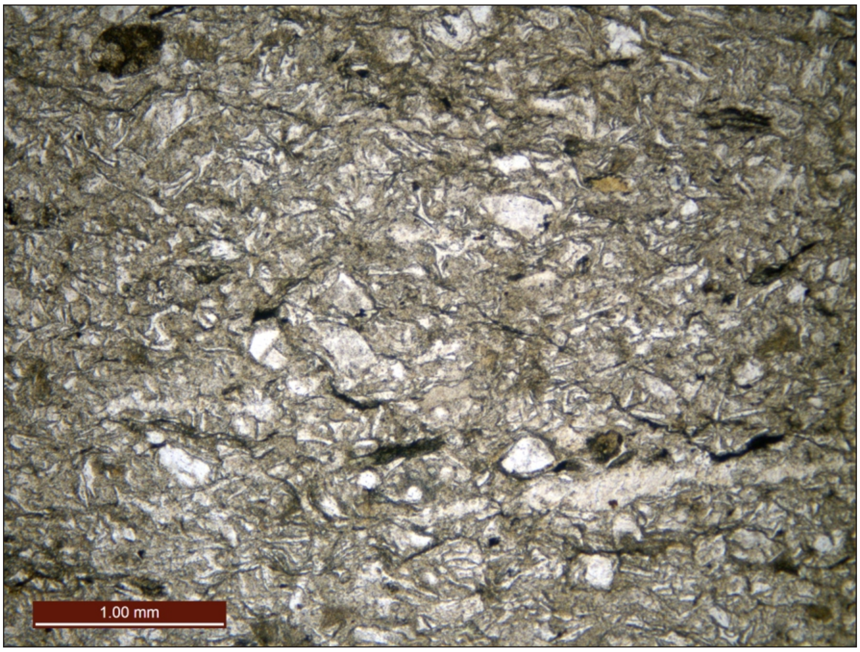
Mo421

Mylonitic granule conglomerate derived from mixed metamorphic and felsic volcanic terranes (Cvl).



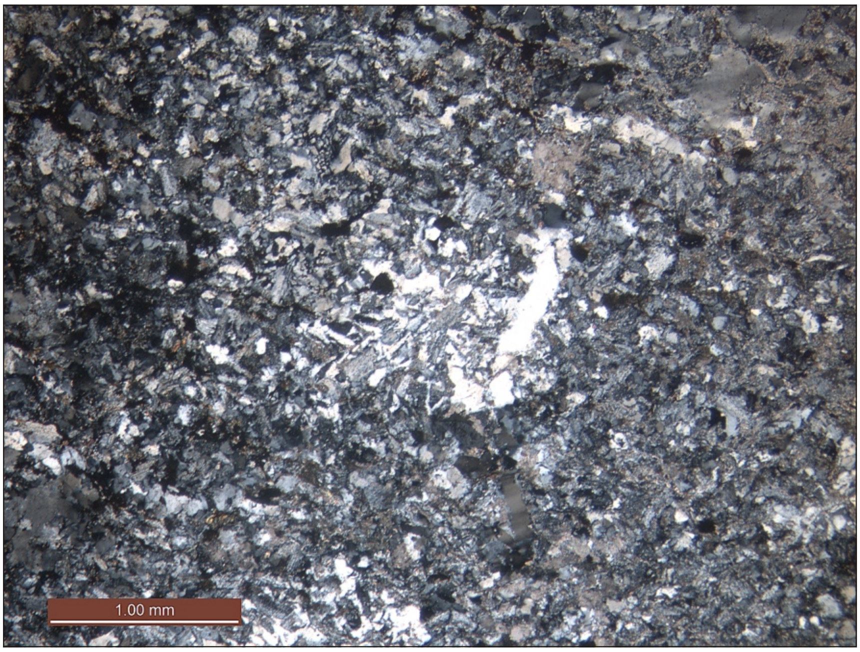
Mo453/1

Mixed felsic volcanic and metamorphic terrane granule conglomerate (Cvt).



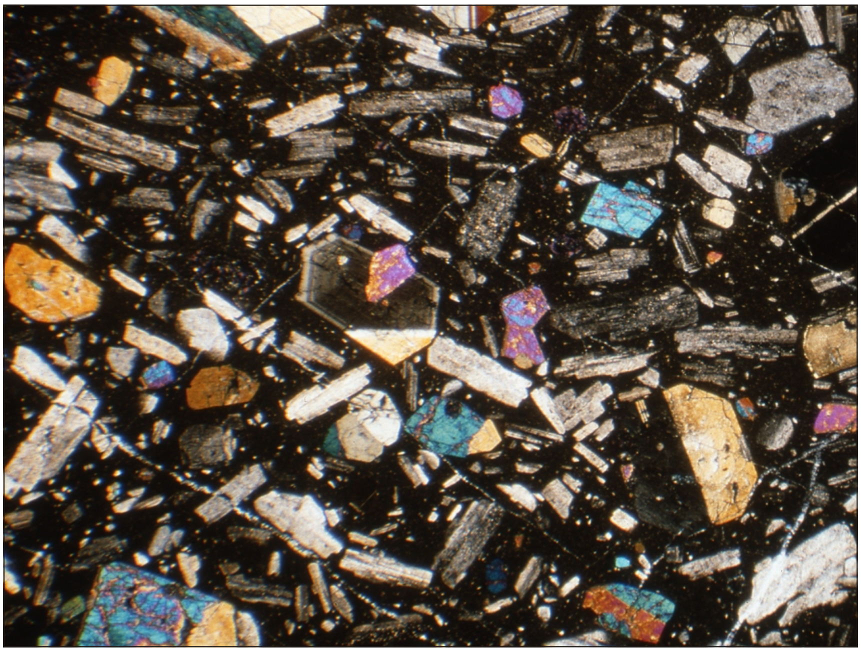
Mo453/2

Glass shard-rich siltstone interbedded with Mo453/1.



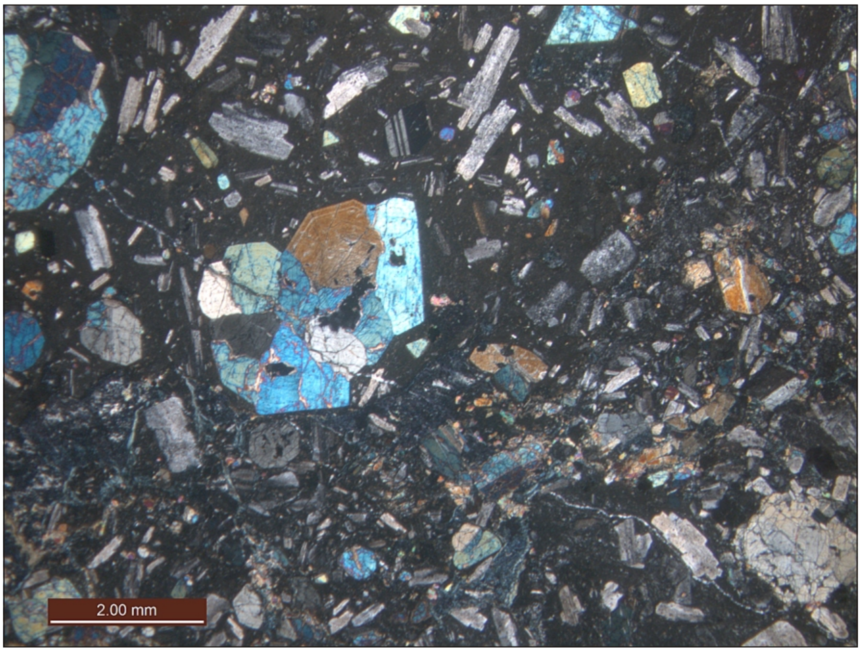
Mo471

Felsic lava with graphic intergrowth of quartz and feldspar (Cvt).



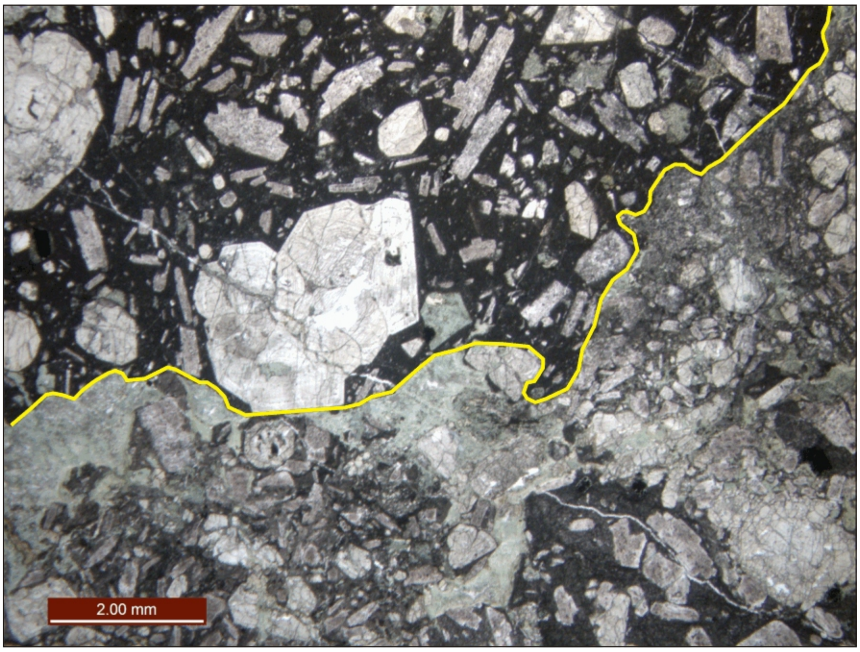
Mo495/1

Cpx-plagioclase breccia with fine-grained groundmass, fragmental, autobrecciated (Cvv).



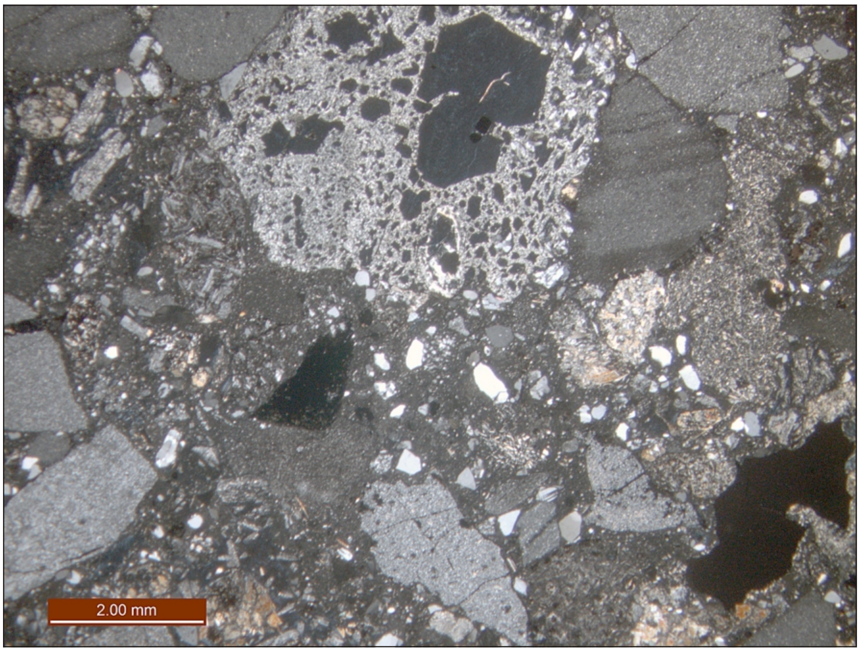
Mo495/3

Two lava mix; clinopyroxene phyric andesite and aphyric andesite (Cvv).



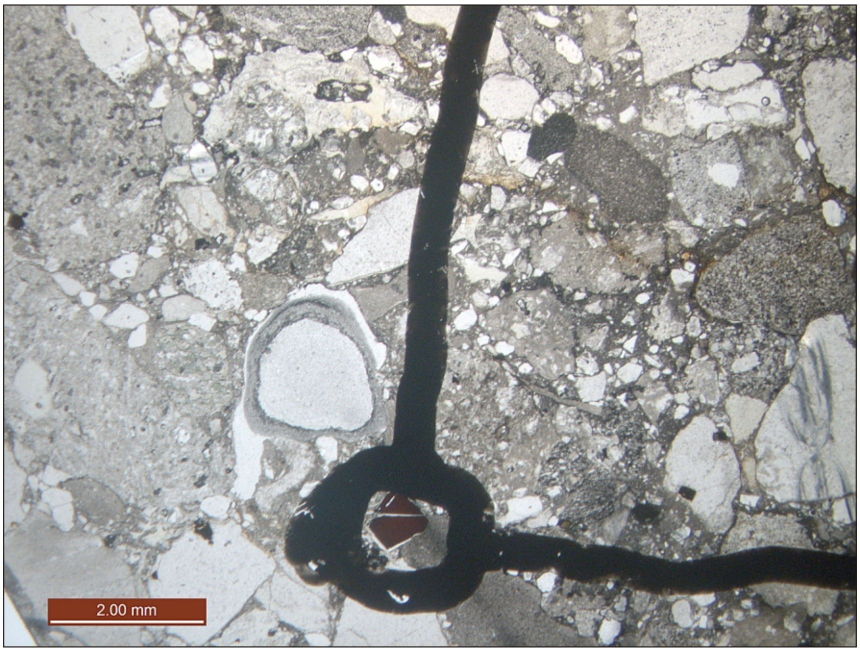
Mo495/3

As above, plain light.



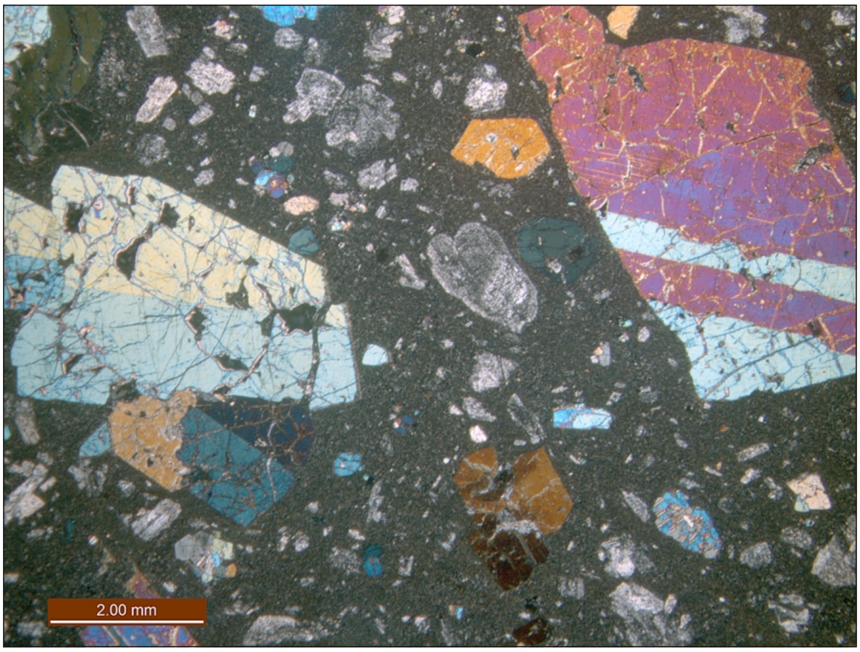
Mo513/2

Volcaniclastic coarse sandstone with boninite clast containing euhedral chrome spinel grains within pseudomorphed olivine (Cvt).



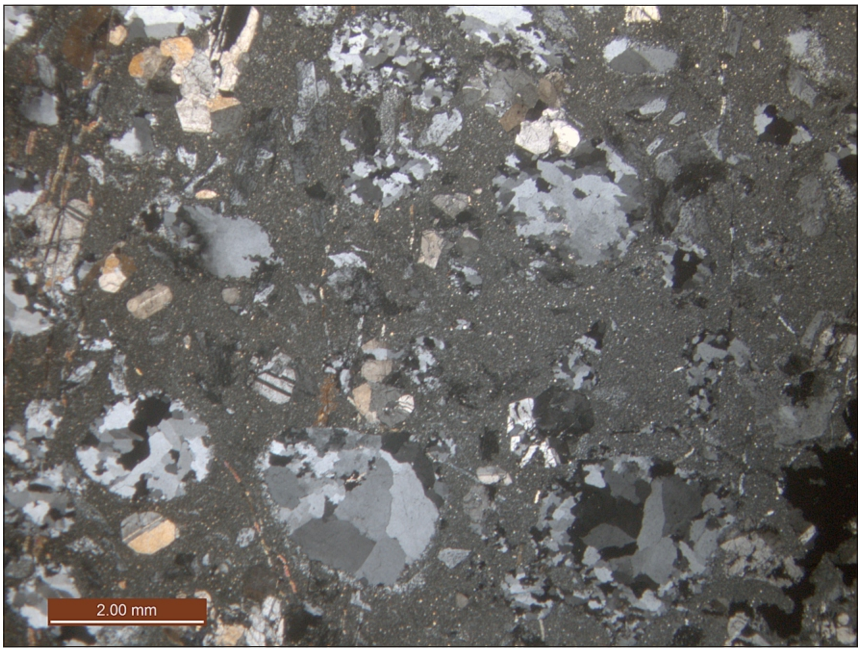
Mo513/2(b)

Volcaniclastic coarse sandstone with large, single euhedral chrome spinel grain (Cvt).



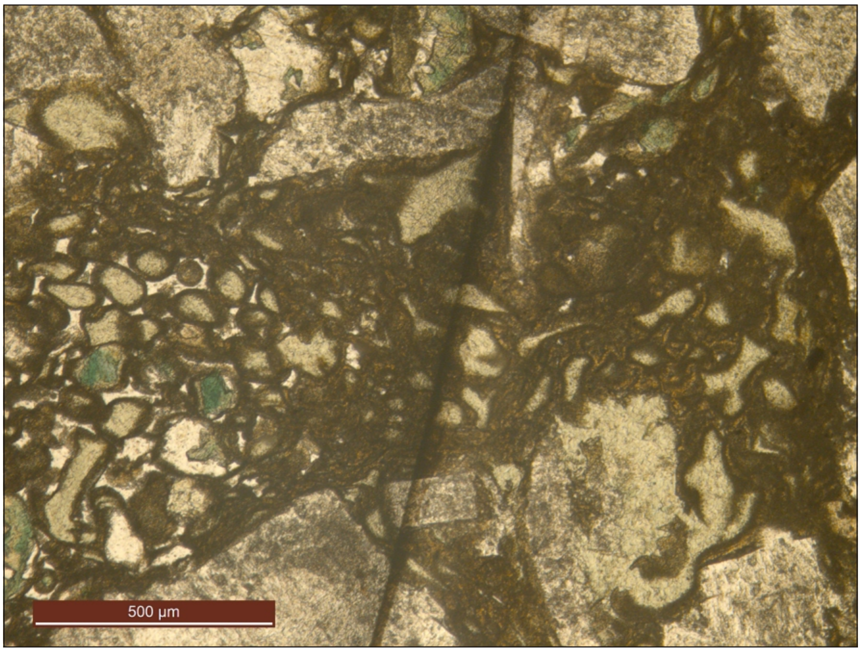
Mo530/1

Cpx (large and dominant) and plagioclase (smaller) phyric lava with a glassy groundmass (Cvs).



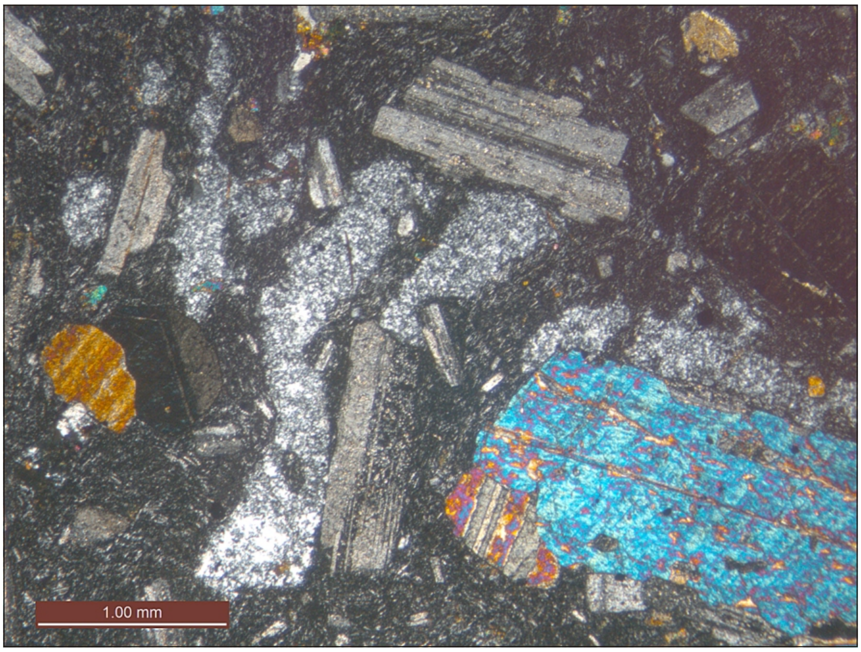
Mo530/4

Highly vesicular Cpx phyric lava with a fine-grained glassy matrix, from pillow lava (Cvs).



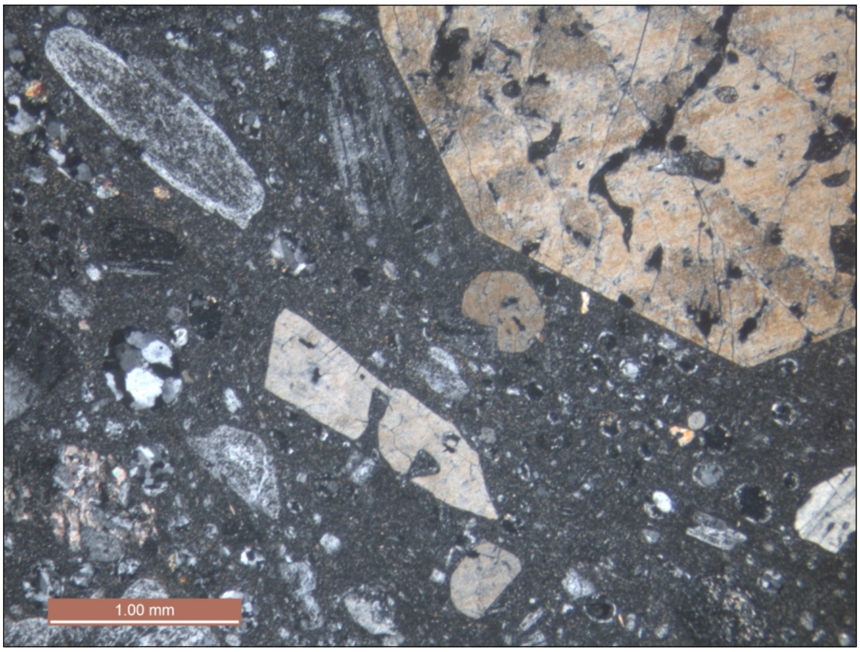
Mo534

Crystal vitric (tube and bubble pumice) lithic sandstone — breccia flow (Cvs).



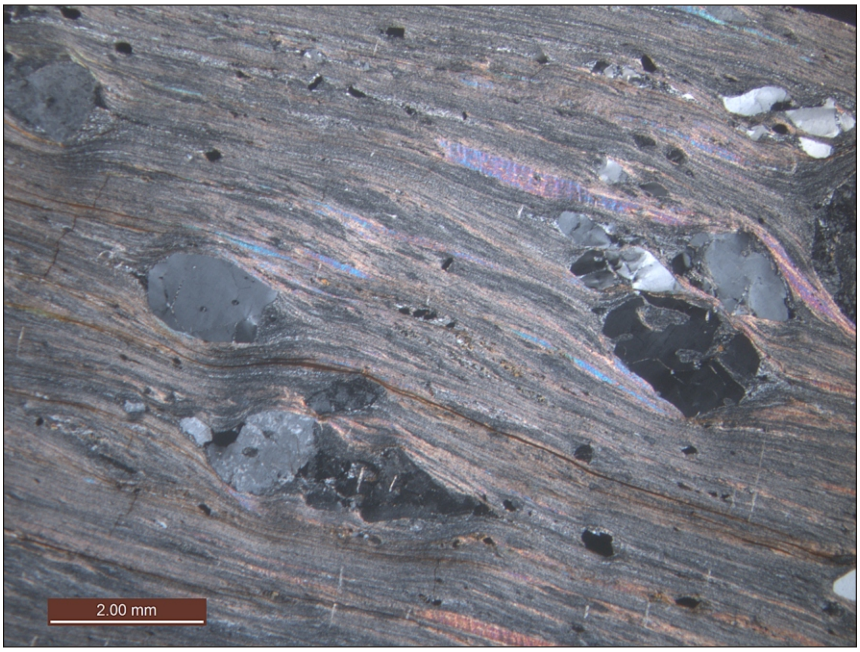
Mo538

Cpx > plagioclase phyric vesicular lava with devitrified glass matrix (Cvv).



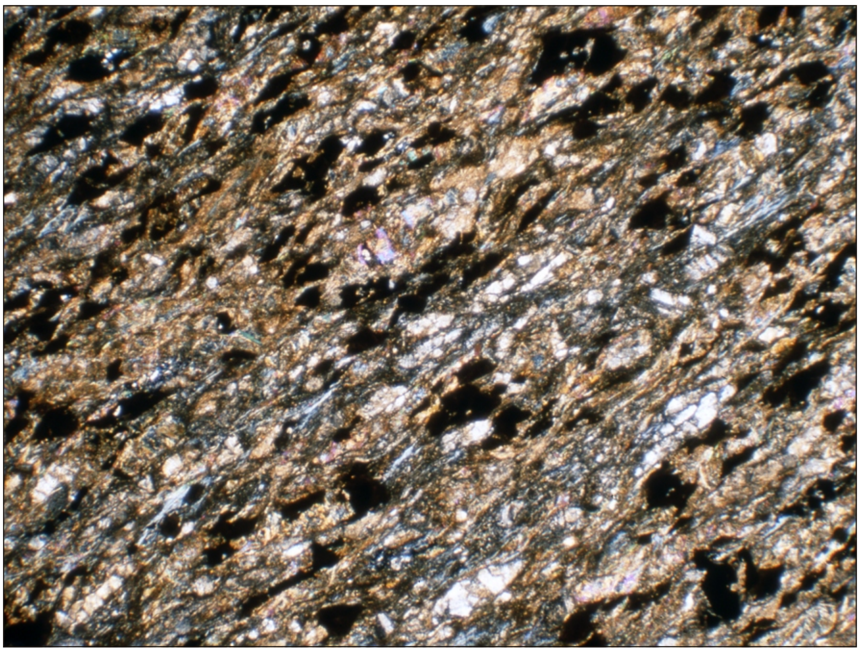
Mo539

Cpx >> plagioclase phyric vesicular lava with fine-grained devitrified glass groundmass and resorbed Cpx (Cvv).



Mo553

Schistose quartz-phyric volcanic rock (Cfv).



Mo559

Schistosed tholeiitic basalt from just west of the mylonite zone, upper Mainwaring River (Evv).