

Geochemistry and chrome spinel compositions of picritic lavas, breccias and associated cumulates from the Whyte River Complex, Waratah-Luina region, northwest Tasmania

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Front cover: View looking towards St. Valentines Peak from Mt Cleveland. Magnet Range is the flat, tabular-looking range visible beneath the skyline. The upper catchment of the Whyte River is visible directly below Magnet Range. In this area the Whyte river has incised through and exposed outcrops of picritic lavas, breccias and associated cumulates. Much of the area is obscured by dense vegetation.

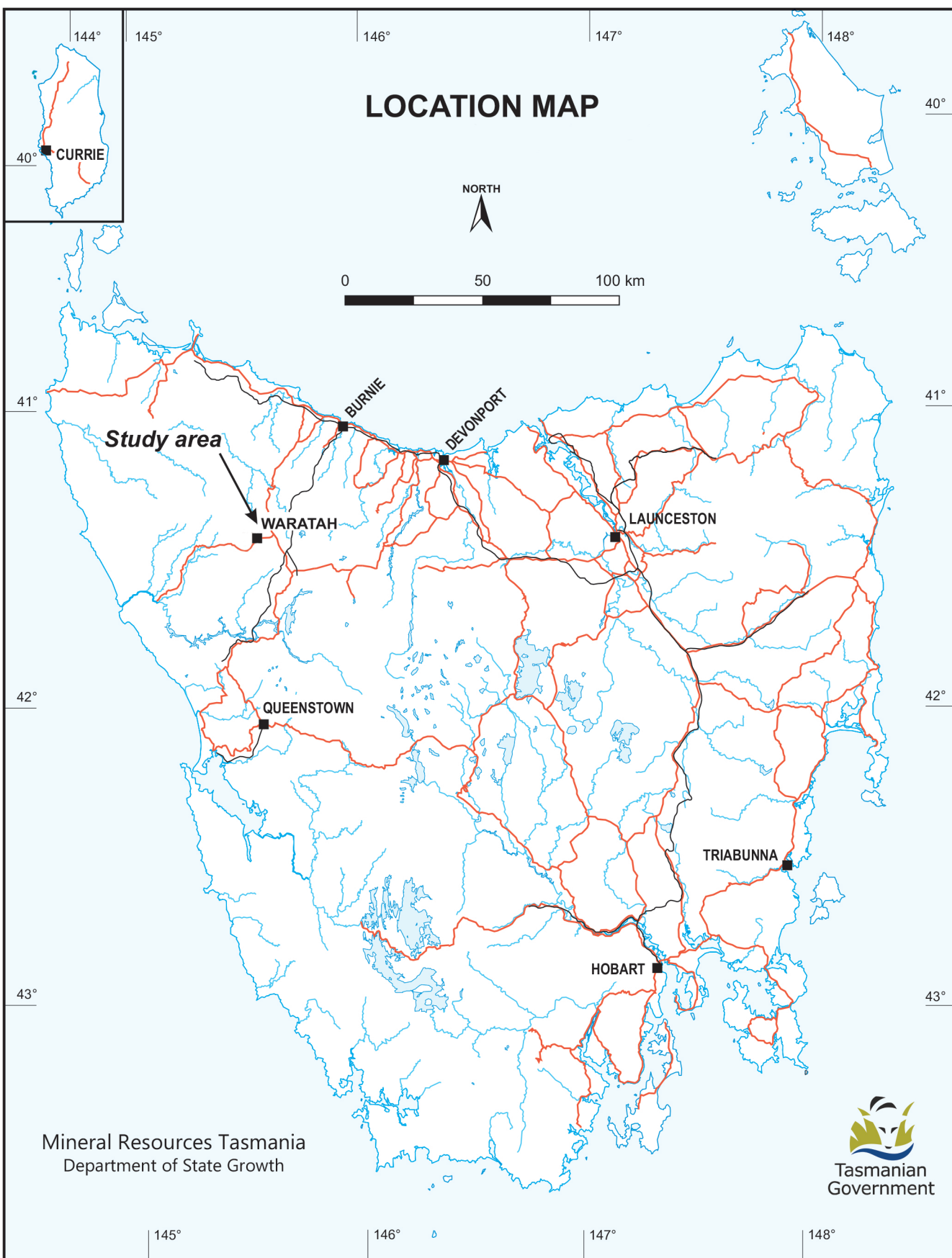
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LOCATION MAP



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ABSTRACT

Recent geological mapping in the Waratah-Luina region has identified several fault-bound blocks of picritic lavas, breccias and associated cumulates, enclosed within a thrust-emplaced Early Cambrian sequence of sedimentary and other igneous rocks. The picritic rocks extend for ~20 km, from Luina to Belmont Creek, and form part of the previously poorly known “Whyte River Complex.”

The lavas display well-preserved porphyritic textures, comprising abundant but usually altered euhedral olivine phenocrysts in a quenched, formerly glassy groundmass, locally bearing elongate to acicular prisms, laths and dendrites of clinopyroxene, olivine and plagioclase (“spinfex texture”). The cumulates are similar but contain a much lower proportion of groundmass, and olivine phenocrysts may be poikilitically included in platelets of clinopyroxene.

The cumulate rocks are higher in MgO, Ni, Co and Cr and lower in CaO, Al₂O₃, TiO₂ and most incompatible trace elements than the lavas. Both display strongly light rare-earth-element (LREE) depleted patterns, similar to those of the nearby low-titanium tholeiitic lavas, but at lower absolute levels.

Small grains of chrome spinel are abundant and ubiquitous, and have lower Cr# (100Cr/(Cr+Al)) than those from nearby boninites. They more closely resemble those from the Layered Pyroxenite and Dunite (LPD) and Layered Pyroxenite and Gabbro (LPG) suites of Tasmanian ultramafics, but those particularly from the lavas extend to higher Mg# (100Mg/(Mg+Fe^{II})). Spinel from the picritic lavas plot within the field for supra-subduction peridotites on tectonic discrimination diagrams, but some from the cumulate rocks plot ambiguously, spanning several fields, mainly because of their wide range of TiO₂ (0.07–4.94 wt%).

The picritic lavas are probably petrogenetically related to the low-titanium tholeiites, and possibly represent a higher degree of partial melting of a similar depleted mantle source. The cumulates are clearly derived from the picrites by crystal settling of olivine (± chrome spinel) and may simply represent the basal parts of flows.

Elsewhere in western Tasmania, somewhat similar picrites are known from the Guilfoyle Creek Basalt near Queenstown and the Mainwaring Group of the

Mainwaring River area, but these units are generally less depleted in LREE and high field-strength elements (HFSE). All, however, were probably produced in an oceanic forearc setting by a high degree partial melting of depleted oceanic lithosphere in the Early Cambrian, and shortly after their eruption were tectonically emplaced over continental crust during an arc-continent collision (Tyennan Orogeny).

INTRODUCTION

Chrome spinel compositions may record the petrogenetic history of their host magmas (e.g., Allan, 1992). Previous studies (e.g., Kamenetsky et al., 2001) have shown that spinel Mg# is largely controlled by melt composition, ion exchange, and rate of cooling. In order to better characterise newly recognised picritic rocks from the Waratah-Luina area, spinels from nine samples (three lavas, one breccia and four associated cumulates), from near the Whyte River and the Magnet Range, were analysed using the electron microprobe. The results are compared with spinels from mafic to ultramafic complexes elsewhere in Tasmania and plotted on discrimination diagrams for tectonic setting, developed by Kamenetsky et al. (2001).

GEOLOGICAL SETTING

The simplified geology of northwest Tasmania is shown in Figure 1. Most recent workers have interpreted the region as consisting of the dismembered fragments of an ophiolite, obducted westward over a passive margin, following an arc–continent collision in the early Middle Cambrian at ~510 Ma. This event is known as the Tyennan Orogeny (Berry and Crawford, 1988; Crawford and Berry, 1992; Berry et al., 2007; Meffre et al., 2000; Chmielowski and Berry, 2012; Mulder et al., 2016) and is broadly equivalent to the Delamerian Orogeny of South Australia and the Ross Orogeny of Antarctica (e.g., Corbett et al., 2014). The Waratah-Luina region is considered by Berry (2014) to lie in the “External Zone” or foreland zone of the obduction complex, in which “relatively intact ophiolites sit on top of a relatively unmetamorphosed (very low grade) continental shelf sequence dominated by thin skinned deformation.”

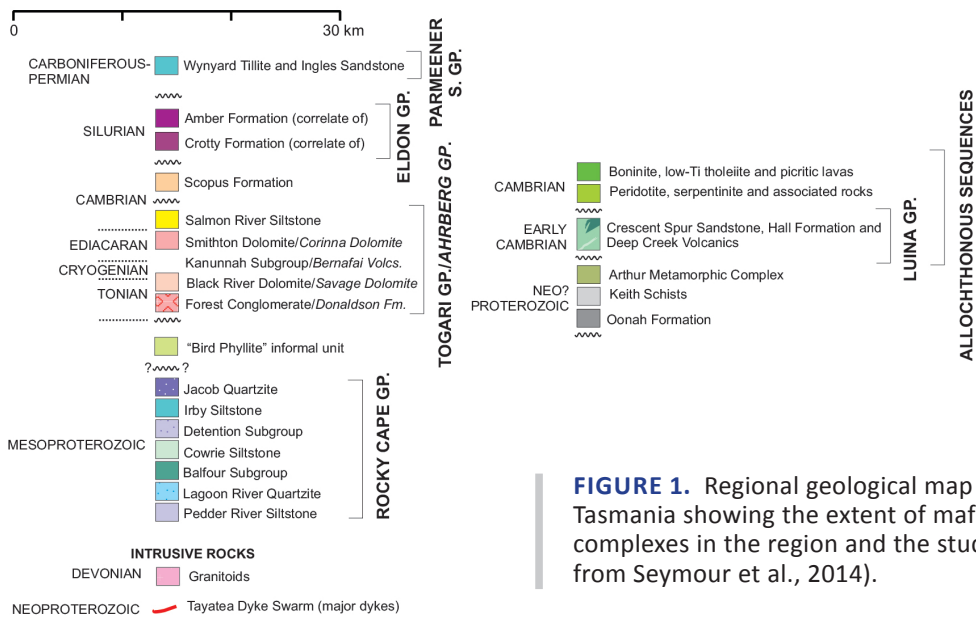
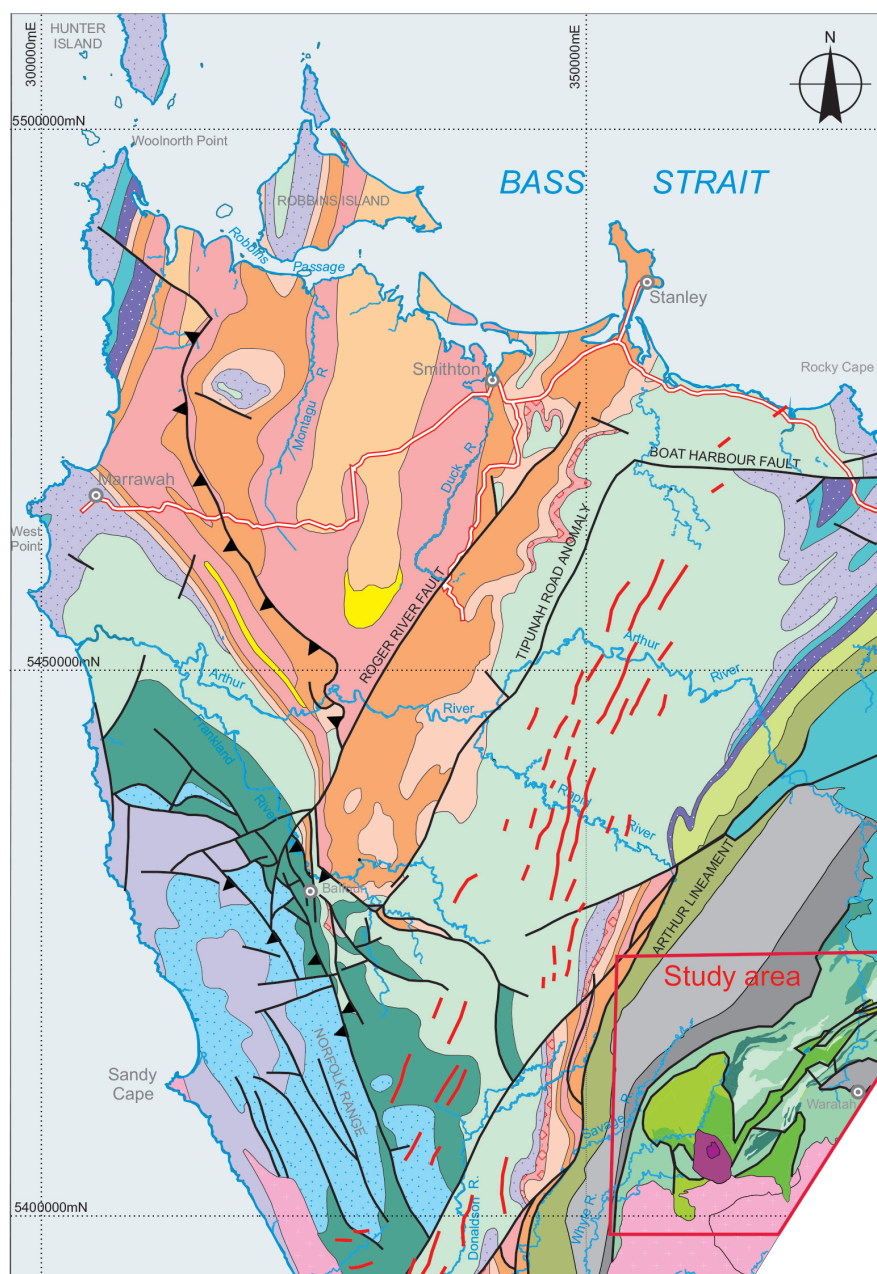


FIGURE 1. Regional geological map of far northwest Tasmania showing the extent of mafic-ultramafic complexes in the region and the study area (adapted from Seymour et al., 2014).

LOCAL GEOLOGY

The oldest rocks in the Waratah-Luina area comprise a quartz turbidite sequence with intercalated siltstone, mudstone and dolomite, which forms the fault-bounded Mt Bischoff inlier (Fig. 2A). Detrital zircon dating has shown that the Mt Bischoff inlier was deposited after ~1030 Ma and is thus probably Neoproterozoic (Cumming et al., 2016). These rocks are correlated with the Oonah Formation, which also occurs to the north-west of the area. The Oonah Formation and correlates are considered to have been part of the passive continental margin during the Tyennan Orogeny.

The most widespread unit in the area is the Luina Group, a deep-water volcanosedimentary sequence including volcanoclastic lithicwacke, maroon siltstone and mudstone, chert, argillite and minor dolomite, intercalated with MORB-like rift tholeiitic basalt. The Luina Group also includes continentally-derived micaceous quartzwacke turbidites, locally known as the Crescent Spur Sandstone (e.g., Calver and Everard, 2014). Recent dating of detrital zircons has shown that the Luina Group was deposited after ~536 Ma but probably before ~510 Ma (Cumming et al., 2016), and is thus Early Cambrian in age. It is considered to be allochthonous and part of the obduction complex, emplaced at ~510 Ma.

Enclosed within the Luina Group are several fault-bound blocks of a variety of mafic and ultramafic rocks, the largest of which are the Heazlewood River and Mt Stewart Ultramafic Complexes. Tonalite within the Heazlewood River Complex has been dated at 513.6 ± 5.0 Ma (Black et al., 1997). There are also large tracts of boninitic and low-titanium tholeiitic volcanic rocks, notably southeast of the Heazlewood town site, in the Betts Track area, and in the Magnet Complex (Fig. 2B, C). Brown (1986) showed that these volcanics have compositions characteristic of the fore-arc regions of intra-oceanic arcs on the modern Earth, and that the ultramafic complexes represent their complementary cumulates. Similar ultramafic complexes and associated arc-related volcanics are widespread in western Tasmania (e.g., Brown, 1986; Crawford et al., 2014), particularly near the western margin of the Dundas Trough, and are considered to be also part of the allochthon that was obducted in the early Middle Cambrian.

Recent geological mapping of these poorly known sequences has identified, also faulted within the Luina Group, large tracts of picritic lava flows (unit Cbbp on the Waratah 1:25 000 map sheet) and associated monomictic breccia (unit Cbbpb), grading to variably serpentinised wehrlite and plagioclase wehrlite cumulates (unit Cbsw on the Waratah and Luina map sheets). These extend from Luina, northeastward along the upper Whyte River and the eastern flank of the Magnet Range, to the upper Arthur River and Belmont Creek, beyond which they are obscured beneath Cainozoic cover (Everard and Cumming, 2016; Cumming and Everard, 2016). These picritic and ultramafic rocks were previously identified at Luina, where they were termed the Whyte River Complex (Collins, 1983; Brown, 1986) and described in more detail from the Arthur River-Wandle Road area (Williams and Brown, 1983). Their essential lateral continuity, for ~20 km between these areas, was however not previously recognised.

Field relationships

The area is densely vegetated, and mafic rocks are commonly deeply weathered, difficult to access and good outcrops are rare. Thus, despite the recent detailed geological mapping, the structural relationships and emplacement history of these mafic phases are poorly constrained by field relationships.

The Whyte River Complex is an elongate fault-bounded block up to 1 km wide. In the valley of the Whyte River, northeastward to about Pam Creek, the complex appears to comprise a central zone of wehrlitic cumulates, flanked on both sides by coarse-grained mafic volcanoclastics, probably derived from low-titanium tholeiite basalt. Near the source of the Whyte River, the strike extent appears to be offset beneath post-Devonian cover (Fig. 2B, C). East of the Magnet Range, the complex continues as two distinct northeast trending belts of lava and breccia, up to 700 m across. The westernmost unit is obscured by Cainozoic gravels at its northern end, whereas the easternmost unit trends and thins towards the Arthur River, where it is obscured beneath alluvium, but is quite likely transected by an inferred north-south trending fault. East of this structure, near Belmont Creek and Wandle Road, two belts of ultramafic rocks trend northeast and disappear beneath Cainozoic basalt cover (Fig. 2B).

Picritic cumulates predominate near the southwestern end of the Whyte River Complex, around Luina, whereas picritic lavas and breccias are the main facies in the Magnet Range area. This may indicate that deeper

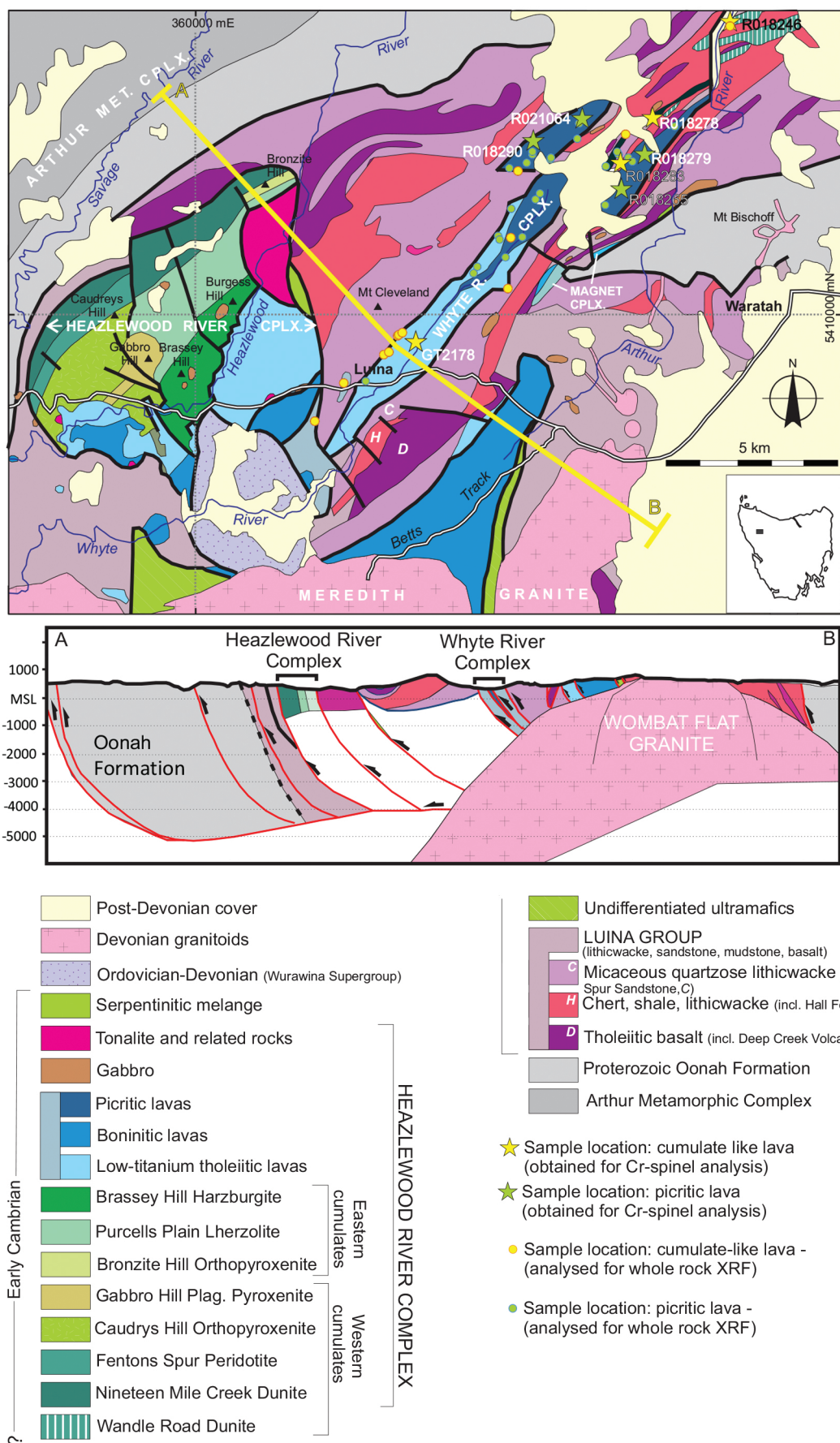


FIGURE 2A. Geological map and cross section of the Waratah-Luina area showing the extent of mafic-ultramafic complexes at Waratah and sample locations for both picrite and cumulate-like lavas from the Waratah/Luina areas.

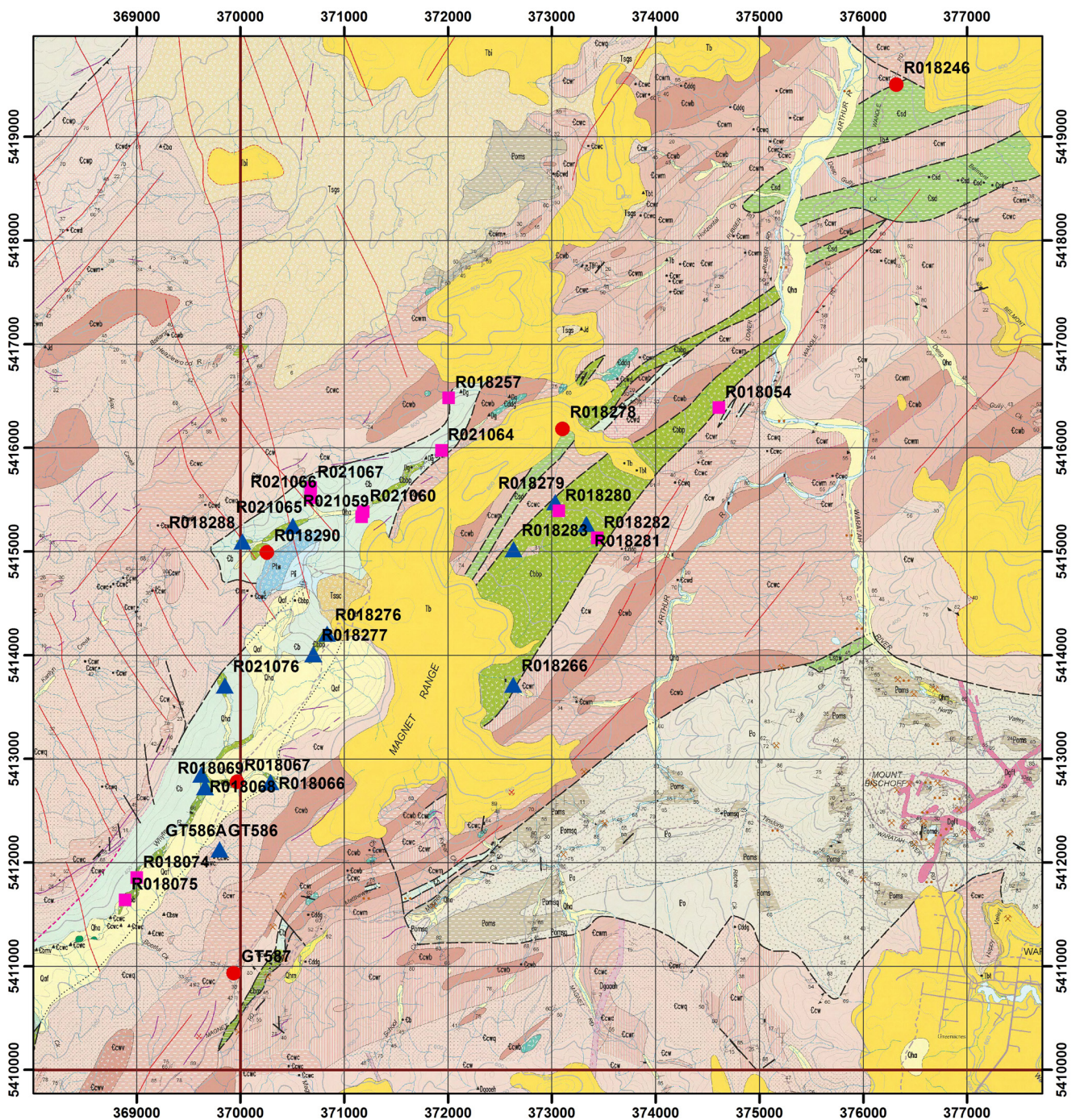


FIGURE 2B. Detailed 1:50,000 geological map of the Whyte River Complex, showing locations of samples collected from the northeast segment in Magnet Range area. Green units are mafic-ultramafic complexes including Whyte River Complex; maroon units are Luina Group; grey units are Oonah Formation correlates; khaki unit is Cainozoic basalt. See original maps for detailed legend. (Cumming and Everard, 2016; Everard and Cumming, 2016)

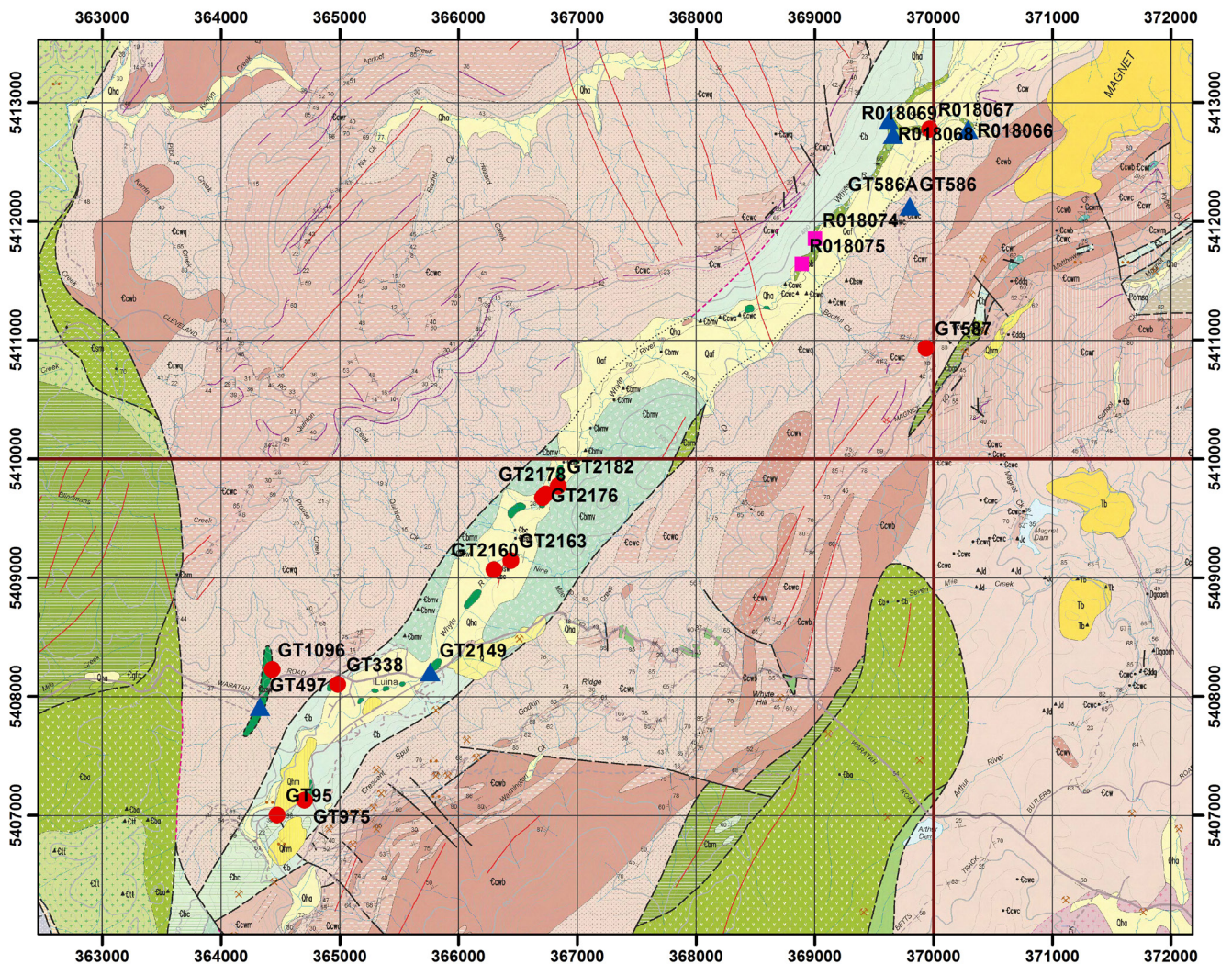


FIGURE 2C. Detailed 1:50,000 geological map of the southeast segment in the Luina area. Reduced from Waratah and Luina 1:25000 digital map sheets (Cumming and Everard, 2016; Everard and Cumming, 2016). Green units are mafic-ultramafic complexes including Whyte River Complex; maroon units are Luina Group; grey units are Oonah Formation correlates; khaki unit is Cainozoic basalt. See original maps for detailed legend.

levels of the Complex are exposed in the southwest. However, lavas and cumulates occur in both areas, and the extreme northeastern end of the Complex, in the upper Arthur River area, appears to consist mainly of dunitic cumulates.

Mafic-ultramafic rocks, now known to comprise similar picrites and associated cumulates, also crop out about 1 km west of Luina township (Collins, 1983), and are well exposed in an abandoned quarry just north of Waratah Road (364330mE, 5407915mN). Recent mapping suggests that they form a small NNE-trending fault-bound sliver, about 800 m long and 80 m wide, within the Luina Group (Everard and Cumming, 2016).

Exposures of both the picritic lavas and cumulate rocks close to contact zones (and fault structures) are generally highly fragmented, serpentinised and locally highly foliated. Cobbles of polymictic cataclasite were observed near the contact in the upper part of the Whyte River catchment (370281mN, 5414592mE). The internal parts of the units are massive, fractured and usually deeply weathered. In outcrop, the cumulate rocks are often massive, equigranular, black to dark green and are difficult to distinguish from the picritic lavas. The best exposures of cumulate rocks occur as large blocks near Lost Creek; these contain spaced, arcuate fractures (Fig. 3A) and have a clastic appearance. The lavas are generally highly weathered, pale green to lime-green, sparsely porphyritic and have a granular texture

(Fig. 3B). They often exhibit spheroidal weathering, especially the brecciated zones. Replaced dendritic to acicular pyroxene and olivine can be observed with a hand lens in rare outcrops. The cumulate rocks are also well exposed (and readily accessible) in a small tor at the Luina townsite (364980mE, 5408100mN; sample GT338). Relatively fresh kernels occur sporadically within deeply weathered exposures in drains near the Cleveland mine site (e.g., 364700mE, 5407130mN; sample GT975).

Volcaniclastic facies are not easily observed in outcrop but clastic textures are apparent in thin sections and cut slabs (Fig. 3C, D).

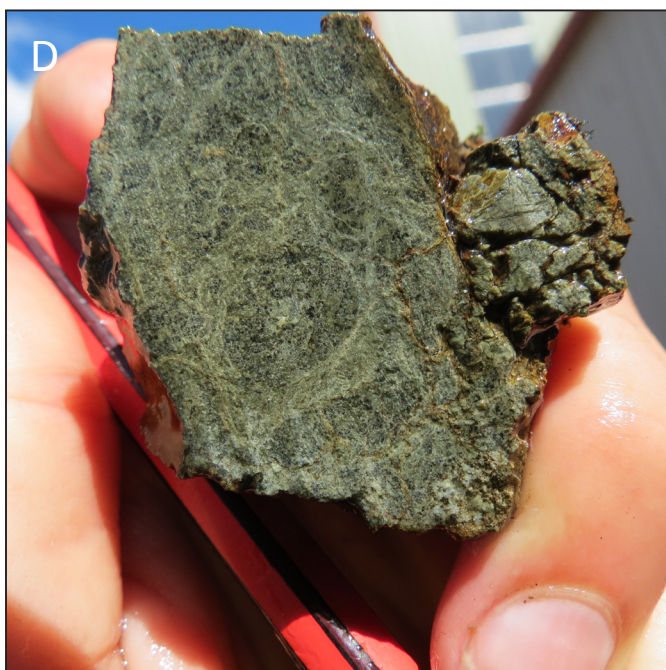
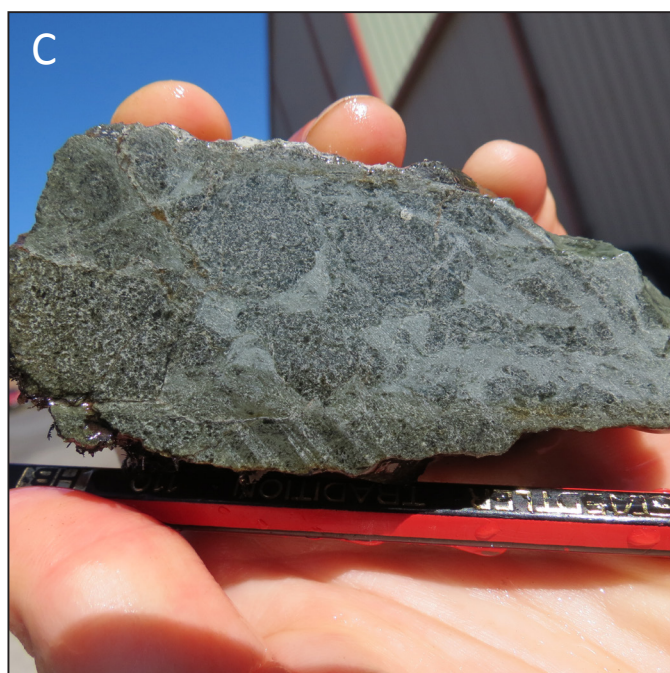
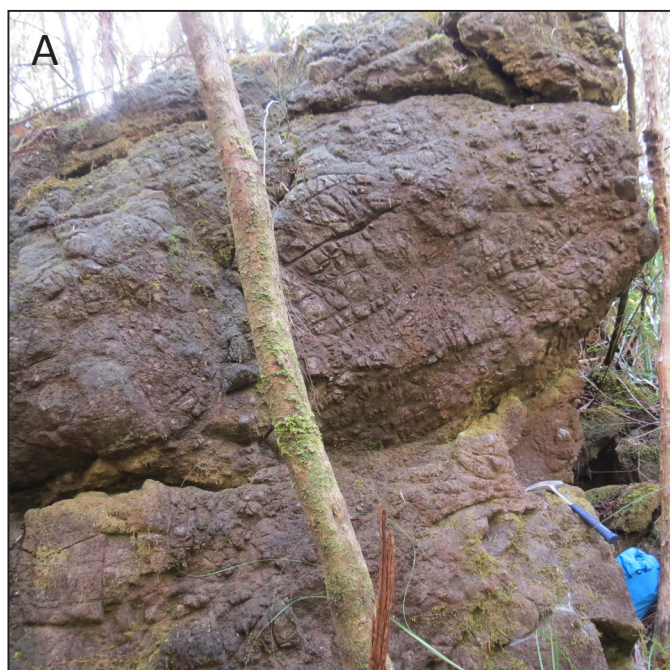


FIGURE 3. Hand specimen photographs of picritic lavas and breccias. **A** Cumulate lavas with arcuate fractures (sample R018265) in outcrop, weathered, fractured exposure of picritic lava in outcrop; **B** (sample R021064); and picritic breccia in hand sample, showing remnant clastic texture; **C** sample R018075; **D** sample R018066).

PETROGRAPHY

During mapping of the Waratah and Luina 1:25,000 geological map sheets (Cumming and Everard, 2016; Everard and Cumming, 2016) in 2012–2015, more than 40 samples of picritic rocks were collected from the Whyte River Complex and Magnet Range area for petrographic examination and geochemical analysis (Table 1). Field, petrographic and geochemical criteria were used to divide them into three groups.

Picritic lavas

The seventeen analysed samples identified as picritic lavas have broadly similar petrographic characteristics. The freshest sample, GT586, consists of abundant (~40 vol%) euhedral, equant to broadly elongate microphenocrysts of olivine (≤ 1 mm but mostly 150–400 μm long; aspect ratio up to ~2:1) in a turbid very fine-grained groundmass. Very elongate, narrow to acicular laths (200–800 μm long $\times$ ~20 μm wide) of altered plagioclase and sheaves and narrow microlites of clinopyroxene preserve the early stages of crystallisation in the quenched groundmass (Fig. 4A–D). Numerous tiny (~5–20 μm) equant grains of very dark red-brown chrome spinel occur both as inclusions in olivine phenocrysts and scattered throughout the groundmass (Fig. 5). The olivine microphenocrysts are partly altered (overall ~20 wt%), mainly along internal fractures, to serpentine ($\pm$ chlorite) and minor scaly magnetite; a few are completely serpentinised.

Other samples are similar with well-preserved microphyritic textures, but commonly primary igneous minerals (except chrome spinel) are largely or wholly altered. Olivine phenocrysts (some exceptionally well-preserved ≤ 2.5 mm in R018269) are replaced, usually by an aggregate of pale yellow-brown finely fibrous anthophyllite and serpentine, the latter tending to grow outward from internal fractures. In sample GT497, the larger olivine phenocrysts are replaced by carbonate. Sample R018277 contains, in addition to altered olivine, elongate prismatic microphenocrysts (≤ 600 μm long) of well-crystallised clinopyroxene. In many samples, elongate to acicular or dendritic microlites of incipiently crystallised clinopyroxene ($\pm$ altered olivine and plagioclase) are resolvable in the groundmass (which contain “spinifex texture”).

Picritic breccias

In thin section, the breccias (12 samples) typically consist of a jumble of subrounded to subangular,

poorly sorted, monomictic, clasts. The breccias are generally clast supported. Clasts are a few mm across and comprise altered picritic lava, between which is an altered, irregularly foliated, fine-grained comminuted matrix. Generally anhedral crystal fragments of clinopyroxene, together with chlorite and other secondary minerals, may be scattered throughout the matrix. Some of the clasts show well-preserved textures such as altered euhedral olivine microphenocrysts, prismatic clinopyroxene and a glassy groundmass with incipient spinifex textures, similar to those described in the lavas. Small equant grains of chrome spinel are dispersed throughout both the clasts and the matrix.

The proportion of clasts to matrix and intensity of foliation varies considerably between samples.

Picritic cumulates

The cumulates (14 analysed samples, of which 6 contain some fresh olivine) petrographically resemble the lavas, but contain a much smaller proportion of groundmass.

The freshest sample, R018067, contains abundant fresh, slightly rounded olivine euhedra and subhedra, mostly 300 μm to 1.1 mm across, with only slight alteration along their internal fractures (Fig. 5A). The groundmass, also little altered, consists of closely packed, parallel to radiating, prismatic to acicular crystals (up to ≤ 400 μm long but 5–20 μm wide) of clinopyroxene and subordinate serpentinised olivine (spinifex texture) as shown in Figure 5B. Small equant grains of chrome spinel are common throughout; elongate to dendritic aggregates of scaly magnetite are mainly associated with olivine. Minor patches of sea-green (chromian?) chlorite are present in the groundmass.

Other samples contain partly or wholly serpentinised olivine euhedra, in various proportions of a generally more quenched and altered groundmass. Invariably, small equant grains of chrome spinel are dispersed throughout, both within olivine or former olivine crystals and in the groundmass (Fig. 5C).

Several samples display a poikilitic texture. Sample GT587 from the Magnet Range consists of partly serpentinised olivine euhedra and subhedra (≤ 1 mm across, but commonly ≤ 500 μm), which may abut other olivine grains, or be partly or wholly enclosed in platelets of colourless to pale yellow clinopyroxene (≤ 3 mm across), some of which is replaced by well crystallised pale brown hornblende. Interstitial tremolite-actinolite and formless patches of indeterminate turbid fine-grained low-birefringence material are also present. Sample

TABLE 1. Sample locations.

Reg. No	Field No.	Analysis No.	mE (GDA94)	mN (GDA94)	Locality	Rock Type	EMPA
R017821	GT497	20130189	364328	5407917	1 km W of Luina	picritic lava	
R017835	GT586	20130196	369800	5412130	Small tributary of Whyte R	picritic lava	
R017836	GT586A	20130197	369800	5412130	Small tributary of Whyte R	picritic lava	
R020706	GT2149	20140361	365761	5408209	Whyte River above Luina	picritic lava	
R018068	R018068	20130107	369623	5412852	Upper Whyte River	picritic lava	
R018069	R018069	20130108	369659	5412731	Upper Whyte River	picritic lava	
R018265	R018265	20140062	370505	5415249	N end of Magnet Range	picritic lava	Y
R018266	R018266	20140063	372629	5413719	E flank of Magnet Range	picritic lava	
R018276	R018276	20140073	370834	5414210	Near Whyte R headwaters	picritic lava	
R018277	R018277	20140074	370704	5414013	Near Whyte R headwaters	picritic lava	
R018279	R018279	20140076	373033	5415478	NE of Magnet Range	picritic lava	Y
R018281	R018281	20140078	373332	5415267	NE of Magnet Range	picritic lava	
R018283	R018283	20140080	372630	5415024	NE of Magnet Range	picritic lava	Y
R018288	R018288	20140084	370020	5415099	N end of Magnet Range	picritic lava	
R021065	R021065	20140107	370505	5415249	N end of Magnet Range	picritic lava	
R018066	R018066	20130105	370289	5412778	Lost Creek	picritic lava	
R021076	R021076	20140153	369849	5413711	Near Whyte R headwaters	picritic lava	
R018054	R018054	20130098	374611	5416387	Near Whyte R headwaters	picritic breccia	
R021066	R021066	20140108	370677	5415519	N end of Magnet Range	picritic breccia	
R018074	R018074	20130111	369004	5411855	Whyte River near Bootful Ck	picritic breccia	
R018075	R018075	20130112	368892	5411641	Whyte River near Bootful Ck	picritic breccia	
R018257	R018257	20140054	372009	5416481	N of Magnet Range	picritic breccia	
R018280	R018280	20140077	373069	5415391	E of Magnet Range	picritic breccia	
R018282	R018282	20140079	373440	5415129	E of Magnet Range	picritic breccia	
R021059	R021059	20140101	371170	5415335	Valley at N end of Magnet Range	picritic breccia	
R021060	R021060	20140102	371186	5415384	Valley at N end of Magnet Range	picritic breccia	
R021064	R021064	20140106	371940	5415975	Valley at N end of Magnet Range	picritic breccia	Y
R021067	R021067	20140109	370681	5415614	N of Magnet Range	picritic breccia	
R011549	GT95	20030099	364472	5407003	Cleveland Mine area	picritic cumulate	
R011615	GT338	20030143	364982	5408103	Crag at Luina town site	picritic cumulate	
R017837	GT587	20130198	369937	5410934	Southern Magnet Range	picritic cumulate	
R017903	GT975	20130161	364704	5407128	Deep drain at Luina	picritic cumulate	
R017927	GT1096	20130167	364431	5408227	Disused quarry 1 km W of Luina	picritic cumulate	
R020710	GT2160	20140300	366299	5409068	Whyte River above Luina	picritic cumulate	
R020712	GT2163	20140301	366442	5409145	Whyte River above Luina	picritic cumulate	
R020717	GT2176	20140302	366707	5409675	Whyte River above Luina	picritic cumulate	
R020718	GT2178	20140362	366737	5409707	Whyte River above Luina	picritic cumulate	Y
R020720	GT2182	20140303	366841	5409773	Whyte River above Luina	picritic cumulate	
R018067	R018067	20130106	369968	5412778	Lost Creek	picritic cumulate	
R018246	R018246	20140043	376319	5419502	Wandle Road	picritic cumulate	Y
R018278	R018278	20140075	373104	5416182	SW of Lower Rubber Rd	picritic cumulate	Y
R018290	R018290	20140086	370255	5414991	N end of Magnet Range	picritic cumulate	Y
R017999	GT1429	-	366608	5417485	Upper Heazlewood River	very fine-grained lithicwacke	Y

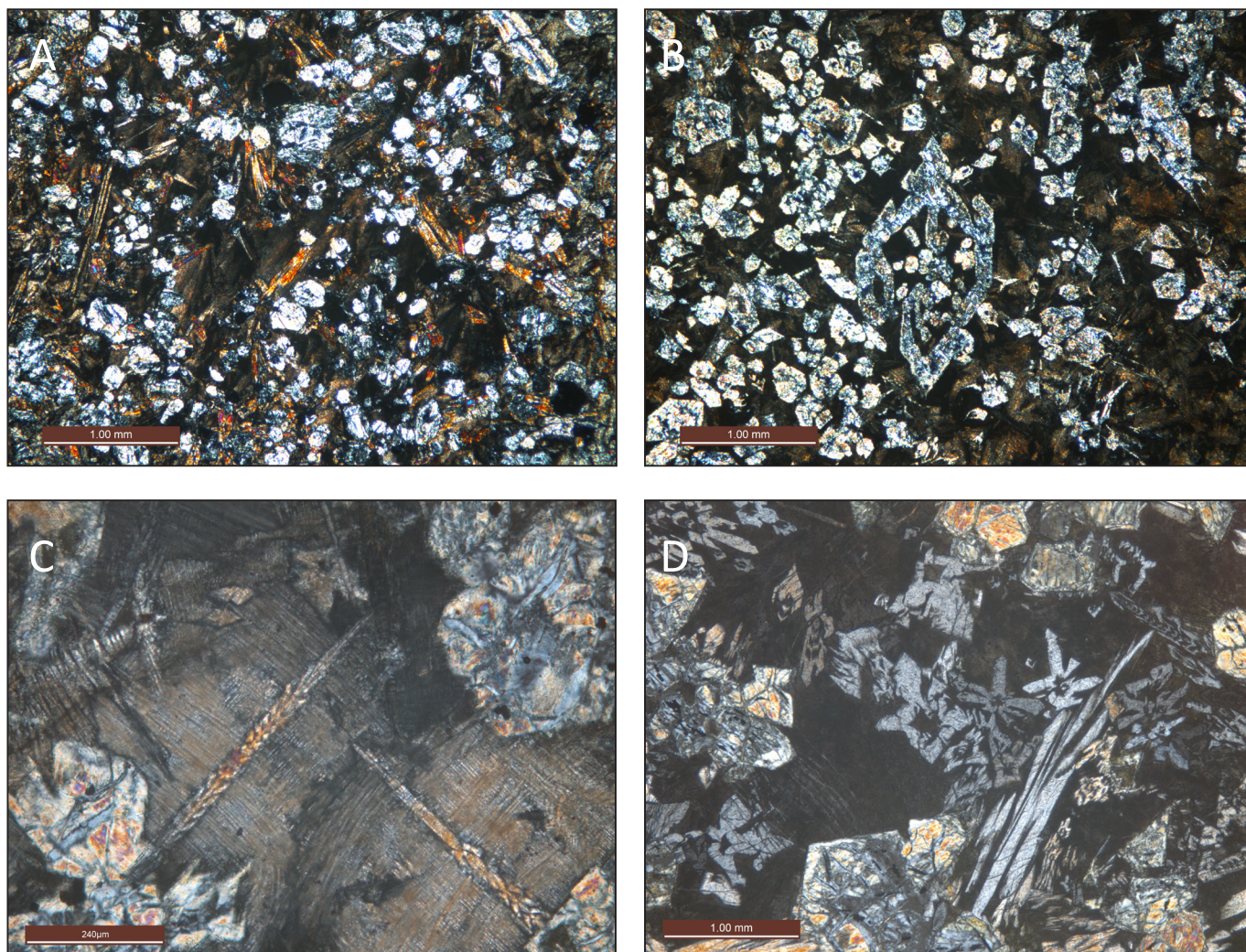


FIGURE 4. **A** Photomicrograph of picritic lava (sample R018066) with equant olivine and fine grained glassy groundmass with elongate, needle shaped pyroxene crystals; **B** Large quenched olivine crystal enclosing smaller (olivine and clinopyroxene) crystals in a glassy groundmass (sample R018068); **C** Dendritic clinopyroxene in glassy groundmass (sample R018265); and **D** Large euhedral olivine crystals (pale orange-cream) with skeletal grey clinopyroxene crystals (sample R018277). All images were taken in cross polarised light.

GT2176 is similar, with partly serpentinised olivine grains enclosed in platelets of fresh clinopyroxene, with interstitial chlorite. In samples GT338 and GT2178, poikilitic texture is less well-developed, and generally smaller and less abundant clinopyroxene platelets only partially enclose olivine.

A sub-group of five samples (GT975, GT2160, GT2163, GT2182 and R018246) consist of densely packed, wholly serpentinised olivine crystals, with relatively small amounts of a discontinuous interstitial groundmass consisting mainly of fine-grained dark turbid material, possibly altered glass, and only minor to trace amounts of clinopyroxene (photomicrograph of sample R018246 is shown in Fig. 5C). These samples are generally lower in CaO than the remainder of the cumulates (see Table 2).

WHOLE-ROCK GEOCHEMISTRY

Forty-two samples were analysed by x-ray fluorescence (XRF) for major and trace elements at the Mineral Resources Tasmania laboratories, using standard techniques and results are presented in Table 2. For four samples, trace elements were also determined by inductively coupled plasma mass spectroscopy (ICPMS) at the University of Tasmania (Table 3). This method allows certain trace elements, including rare-earth elements (REE), that are normally below XRF detection limits, to be determined at low levels with a high degree of precision.

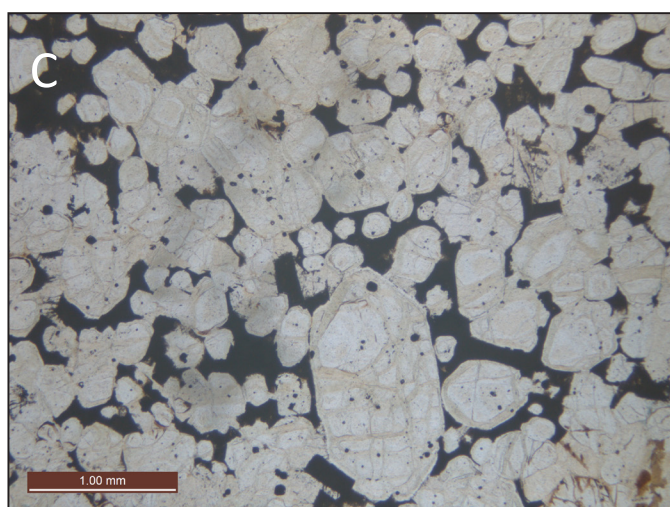
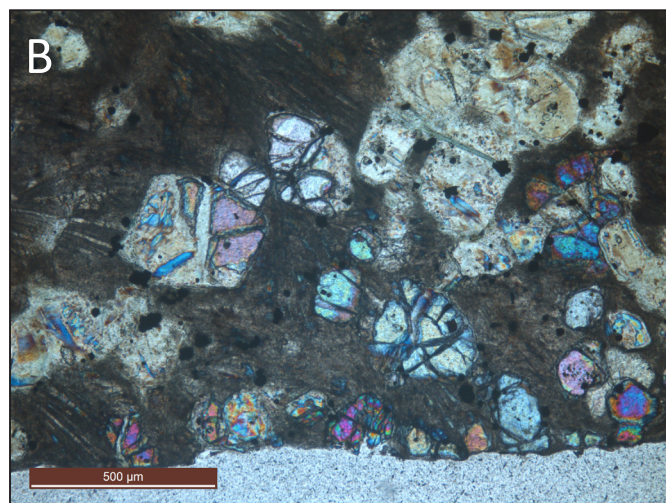
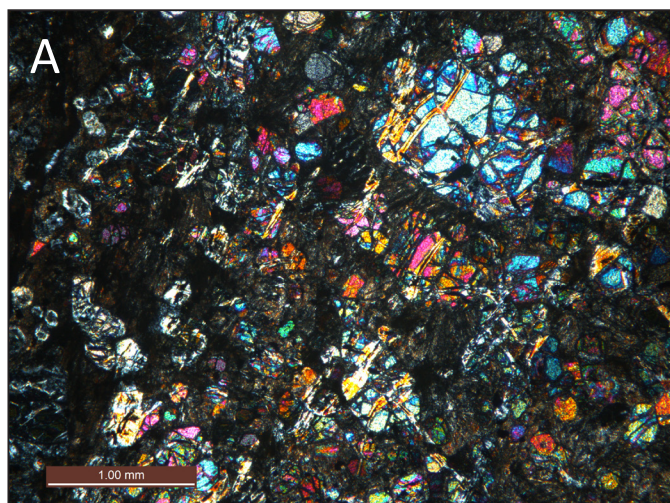


FIGURE 5. **A** Photomicrographs of picritic cumulates with relatively fresh (unserpentinised) olivine and very little groundmass (sample R018067); image taken under cross polarised light; **B** Large serpentinised and fresh olivine crystals set a glassy, quenched groundmass with abundant Cr-spinel and magnetite crystals distributed throughout (sample R018290), image taken under cross polarised light; and **C** Remnant serpentinised olivine crystals rimmed by magnetite (sample R018246), image taken under plane polarised light.

All the samples are characterised by high levels of MgO (generally >16 wt%), Ni (generally >700 ppm) and Cr (generally >1700 ppm), accompanied by low to extremely low levels of alkalis and incompatible minor and trace elements such as TiO_2 (<0.25 wt%), P_2O_5 (<0.05 wt%), Zr (≤ 12 ppm), Nb (≤ 4 ppm), Y, REE, Sr and Ba. They clearly fall in two groups which correspond to those identified petrographically (Fig. 6A–G). There are no consistent geochemical differences between the picritic lavas and breccias, but the cumulates have higher levels of MgO, Ni and Cr and lower levels of many other elements. Also plotted for comparative purposes are seventeen analyses of low-titanium tholeiites from the Waratah-Luina area. It is argued below that these have a petrogenetic relationship to the picritic lavas and associated cumulates.

Major elements

The three suites plot in separate well-defined fields of most binary major element plots (Fig. 6A–G). MgO is lowest in the low titanium tholeiites (5–11 wt%), higher in the picritic lavas (16–22 wt%), and highest in the cumulates (26–34 wt%). It is therefore used as the abscissa on the plots, although Mg# (molar $100\text{Mg}/(\text{Mg}+\text{Fe}^{11})$) could equally well be used. Al_2O_3 and TiO_2 correlate negatively with MgO (i.e., are highest in the low titanium tholeiites and lowest in the picritic cumulates). Total iron (expressed as Fe_2O_3) shows no consistent difference between the suites. CaO is distinctly lower in the cumulates (<6 wt%), relative to the picritic lavas (6–11 wt%), but the latter largely overlaps with levels in the low titanium tholeiites (mostly 7–11 wt%).

TABLE 2. XRF analyses of picritic rocks

Field No.	Picritic lavas																
	GT497	GT586	GT586A	GT2149	R018068	R018069	R018265	R018266	R018276	R018277	R018279	R018281	R018283	R018288	R021065	R021066	R021076
SiO ₂ (%)	51.12	45.29	44.35	44.92	44.40	45.29	43.45	44.15	43.31	46.23	44.04%	45.67	48.25	45.30	46.43	43.56	46.25
TiO ₂	0.18	0.16	0.16	0.19	0.17	0.16	0.19	0.17	0.18	0.20	0.15%	0.16	0.16	0.18	0.16	0.17	0.17
Al ₂ O ₃	10.89	9.86	9.78	10.82	10.26	9.84	10.76	10.47	10.08	11.30	9.72%	10.57	11.08	10.01	10.66	9.99	10.75
Fe ₂ O ₃ ¹	7.26	9.60	10.12	10.54	10.24	10.09	11.02	10.25	10.13	10.92	8.84%	9.93	8.93	10.10	10.46	10.04	10.09
MnO	0.12	0.16	0.15	0.12	0.17	0.22	0.15	0.18	0.18	0.14	0.19%	0.17	0.20	0.20	0.16	0.17	0.20
MgO	14.56	21.40	21.30	21.75	20.20	19.80	19.95	19.05	21.80	17.05	18.84%	19.10	16.80	20.30	18.60	21.25	18.41
CaO	9.05	7.85	7.65	2.48	7.72	7.56	7.10	7.74	6.32	8.23	11.81%	7.17	7.53	7.17	6.75	7.94	6.19
Na ₂ O	2.04	1.40	0.14	0.01	0.50	0.71	0.09	0.48	0.09	0.61	0.16%	0.93	1.42	0.40	1.10	0.08	1.42
K ₂ O	0.34	0.08	0.03	0.03	0.03	0.05	0.03	0.05	0.01	0.01	0.02%	0.04	0.06	0.04	0.05	0.02	0.07
P ₂ O ₅	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02%	0.02	0.02	0.02	0.02	0.02	0.02
L.O.I	3.78	3.71	5.87	8.42	5.73	5.74	6.92	6.67	7.26	4.89	5.71%	5.48	4.77	5.94	5.29	6.40	5.74
TOTAL	99.36	99.53	99.57	99.30	99.44	99.48	99.68	99.23	99.38	99.61	99.79%	99.24	99.22	99.66	99.68	99.64	99.31
CO ₂ ²	0.73	<0.4	<0.4	<0.4	0.37	0.37	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.37	<0.4
S ³	0.04	<0.02	<0.02	0.12	0.04	0.05	0.1	0.05	0.08	0.28	0.02	0.07	<0.02	0.08	0.15	0.16	0.18
H ₂ O ⁴	3.0	3.4	5.6		4.3	4.3	6.52	6.32	6.88	4.31	2.75	5.11	4.46	5.56	4.84	5.88	5.26
Cl (ppm)	500	400	100	100	300	300	600	600	600	2200		1700	8300	7800	1300	1100	1200
Sc	36	33	36	43	34	31	38	37	12	35	32	36	36	35	35	35	38
V	160	145	155	160	150	140	175	165	82	160	130	155	165	160	160	160	170
Cr	2600	2400	2500	3100	2700	2500	2800	2700	2800	3000	1458	2900	2700	2700	2700	2700	2600
Co	110	79	85	110	87	85	83	89	15	95	39	91	105	89	90	92	93
Ni	930	950	1000	1150	1100	1150	1150	1100	42	1400	878	1150	1000	1050	1150	1050	1050
Cu	88	49	46	61	56	55	47	57	8	62	59	55	76	47	57	65	56
Zn	45	59	56	65	58	65	135	84	89	73	70	63	52	58	61	54	64
Ga	7	7	8	8	9	8	9	8	20	9	8	8	8	8	8	7	8
As	<3	3	<3	<3	4	3	<3	<3	6	<3	<3	4	<3	<3	<3	<3	4
Rb	10	7	7	6	5	8	5	5	145	6	2	5	5	7	6	5	7
Sr	65	24	14	10	24	31	26	36	150	19	8	46	30	37	36	26	76
Y	10	8	7	9	7	9	9	8	42	13	8	8	8	9	7	8	9
Zr	9	8	7	9	8	10	10	8	290	12	5	8	10	9	7	9	9
Nb	1	2	3	3	3	4	3	2	16	2	0	3	3	3	2	3	1
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	4	<1	<1	<1	<1	<1	<1
Sn	<2	2	<2	<2	<2	<2	2	<2	3	2	3	2	<2	2	2	<2	<2
Sb	<2	<2	<2	<2	2	2	<2	<2	<2	<2	1	<2	<2	2	<2	<2	<2
Cs	9	6	10	20	4	9	<3	3	3	8	5	4	<3	5	3	5	8
Ba	150	25	14	7	24	45	51	95	660	46	24	19	28	73	54	28	66
La	<6	<6	6	11	8	<6	<6	<6	36	<6	7	6	<5	<5	<6	<6	<6
Ce	<5	<5	<5	<5	<5	<5	<5	<5	77	<5	14	<5	<5	<5	<5	<5	<5
Nd	<7	<7	<7	<7	<7	<7	<7	<7	42	<7	<7	<7	<7	<7	<7	<7	<7
W	<2	<2	<2	<2	<2	<2	<2	<2	5	<2	<2	<2	<2	<2	<2	<2	<2
Pb	<2	<2	2	2	2	<2	<2	<2	20	<2	3	<2	<2	<2	<2	<2	<2
Bi	1	2	2	2	2	1	2	2	<1	2	1	1	1	1	1	1	1
Th	<2	<2	<2	<2	<1	<1	<2	<2	15	<2	2	<2	<2	<2	<2	<2	<2
U	<1	<1	1	<1	<2	1	<1	<1	3	<1	2	<1	<1	<1	<1	<1	<1
Mg#(0.20) ⁵	82.4	83.9	83.1	82.8	82.2	82.1	80.9	81.3	83.4	78.5	83.0	81.8	81.5	82.5	80.6	83.2	81.0
Ti/Zr	120	120	137	127	127	96	114	127	-	100	40	120	96	120	137	113	113

¹ total iron as Fe₂O₃

² total carbon as CO₂

³ total sulphur as elemental S

⁴ minimum H₂O calculated from LOI, CO₂ and S

⁵ Mg# calculated at Fe₂O₃/FeO = 0.20

TABLE 2 - cont. XRF analyses of picritic rocks

Field No.	Picritic breccias											R021067
	R018054	R018066	R018074	R018075	R018257	R018280	R018282	R021059	R021060	R021064		
SiO2 (%)	46.35	46.78	45.27	47.86	44.91	45.05	46.61	45.02	44.61	44.21	43.83	
TiO2	0.16	0.19	0.13	0.12	0.14	0.16	0.14	0.14	0.16	0.15	0.15	
Al2O3	9.92	11.20	8.74	6.93	9.04	9.05	8.80	8.97	8.91	9.43	9.83	
Fe2O3 ¹	9.50	9.05	9.62	8.58	9.42	9.45	10.23	9.29	9.10	9.85	9.15	
MnO	0.21	0.17	0.16	0.28	0.18	0.17	0.29	0.20	0.18	0.18	0.16	
MgO	18.80	17.55	21.10	20.80	20.45	21.00	19.05	20.65	21.60	21.35	21.80	
CaO	8.35	8.08	8.96	10.37	9.92	9.39	7.13	9.92	8.96	8.41	7.72	
Na2O	0.13	1.53	0.19	0.13	0.06	0.09	0.13	0.13	0.10	0.08	0.05	
K2O	0.02	0.06	0.02	0.02	0.01	0.01	0.03	0.02	0.02	0.01	0.01	
P2O5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
L.O.I	5.92	4.94	5.38	4.56	5.60	5.66	6.90	5.40	6.01	6.00	7.06	
TOTAL	99.38	99.57	99.59	99.67	99.75	100.05	99.33	99.76	99.67	99.69	99.78	
CO2 ²	<0.4	1.10	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.37	
S ³	0.02	<0.02	<0.02	<0.02	na	0.03	0.06	0.13	0.15	0.12	0.14	
H2O ⁴	5.6	0.9	5.1	4.2	5.29	5.33	6.54	4.97	5.56	5.58	6.55	
Cl (ppm)	1100	100	200	200	5000	1500	2300	300	300	900	1000	
Sc	32	32	32	29	27	32	35	33	34	35	30	
V	125	150	130	110	115	135	145	135	145	150	145	
Cr	2200	1950	2200	1900	2300	2200	2400	2100	2300	2600	1750	
Co	72	67	72	72	78	69	105	74	77	89	68	
Ni	960	810	960	930	1000	980	1250	860	970	1000	760	
Cu	58	52	37	33	43	52	41	42	44	47	42	
Zn	61	54	57	60	54	58	80	52	56	59	53	
Ga	8	8	7	6	6	7	7	7	7	7	7	
As	4	3	4	<3	<3	<3	<3	<3	<3	<3	3	
Rb	3	3	4	4	4	4	5	4	4	5	4	
Sr	20	25	10	9	18	9	18	10	14	26	20	
Y	9	8	8	7	7	8	5	7	8	7	7	
Zr	9	10	7	6	7	9	11	7	7	7	7	
Nb	4	3	2	2	1	2	3	3	2	2	2	
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Sn	<2	<2	<2	<2	<2	2	<2	2	<2	2	<2	
Sb	<2	<2	<2	<2	<2	3	<2	<2	<2	<2	<2	
Cs	<3	<3	6	5	4	3	<3	<3	3	5	3	
Ba	17	62	10	50	20	28	61	27	37	30	19	
La	3	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	
Ce	<5	<5	<5	<5	<5	<5	7	<5	<5	<5	<5	
Nd	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	
W	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	
Pb	<2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2	
Bi	2	2	1	<1	1	1	2	1	1	1	1	
Th	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	
U	<2	<2	<2	<2	1	1	<1	<1	1	1	<1	
Mg#(0.20) ⁵	82.2	81.9	83.7	85.0	83.5	83.9	81.3	83.9	84.7	83.5	84.8	
Ti/Zr	107	114	111	120	120	107	76	120	137	128	128	

TABLE 2 - cont. XRF analyses of picritic rocks

Field No.	GT95	GT338	GT587	GT975	GT1096	GT2160	GT2163	Picritic cumulates				GT2178	GT2182	R018067	R018246	R018278	R018290
SiO ₂ (%)	42.26	41.12	39.30	39.45	41.34	38.74	39.45	39.68	38.85	38.19	42.92	37.74	41.80	42.18			
TiO ₂	0.08	0.09	0.25	0.07	0.12	0.10	0.09	0.06	0.07	0.08	0.12	0.05	0.10	0.11			
Al ₂ O ₃	5.52	6.22	6.87	4.22	8.41	5.50	4.84	5.06	5.56	4.78	7.07	3.79	6.25	6.80			
Fe ₂ O _{3t} ¹	10.02	9.62	12.71	10.89	10.12	10.85	9.39	10.52	10.57	9.95	9.80	9.72	10.15	9.91			
MnO	0.21	0.14	0.18	0.14	0.13	0.14	0.12	0.16	0.17	0.15	0.17	0.14	0.16	0.16			
MgO	28.75	28.83	28.50	31.20	26.00	30.80	32.60	31.70	30.60	33.30	27.60	33.00	29.20	27.75			
CaO	2.16	4.43	5.05	2.21	4.28	2.40	1.67	3.66	2.31	0.85	5.65	2.59	4.60	5.71			
Na ₂ O	0.35	0.43	0.14	0.12	0.17	<0.01	<0.01	<0.01	<0.01	<0.01	0.27	<0.01	0.08	0.14			
K ₂ O	0.10	0.04	0.03	0.03	0.03	0.01	0.01	0.02	0.04	0.01	0.03	0.01	0.03	0.03			
P ₂ O ₅	0.02	0.04	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02			
L.O.I	9.31	8.12	6.46	10.76	8.55	10.64	11.23	8.50	11.09	11.78	5.69	12.04	6.79	6.80			
TOTAL	98.88	98.57	99.52	99.10	99.16	99.20	99.41	99.37	99.27	99.10	99.34	99.09	99.17	99.61			
CO ₂ ²	-	-	<0.4	-	-	<0.4	0.40	<0.4	<0.4	<0.4	<0.4	<0.4	0.37	<0.4			
S ³	-	-	0.06	-	-	0.2	0.19	0.13	0.18	0.2	<0.02	0.03	0.11	0.11			
H ₂ O ⁴	-	-	6.10	-	-	10.10	10.70	8.10	11.3	11.3	5.40	11.71	6.31	6.39			
Cl (ppm)	na	na	300	400	200	1200	1000	1500	600	1500	300	3300	2600	7500			
Sc	23	24	23	20	26	22	19	19	19	18	23	19	26	26			
V	115	110	93	69	130	92	74	70	68	79	100	63	100	105			
Cr	4300	3900	2100	3600	3300	4000	3400	3400	3300	4200	3200	4000	4000	3300			
Co	89	89	130	105	110	100	105	110	115	110	97	115	105	94			
Ni	1700	1500	1500	2000	1300	2100	1650	1700	1750	2000	1500	2100	1600	1450			
Cu	<5	<5	72	22	72	25	<2	32	10	6	30	8	19	30			
Zn	36	44	74	53	61	52	53	55	53	47	55	60	89	60			
Ga	7	8	7	5	7	5	4	4	5	5	6	4	5	6			
As	<20	<20	4	3	6	<3	<3	<3	<3	<3	<3	<3	<3	<3			
Rb	20	13	7	5	6	5	4	7	9	3	5	3	5	6			
Sr	<5	<5	9	6	9	6	6	5	9	6	10	3	9	11			
Y	<5	<5	10	3	5	5	5	4	3	5	6	3	3	5			
Zr	7	8	12	4	7	6	6	5	5	6	7	5	5	6			
Nb	<3	<3	2	2	3	2	2	3	2	2	3	2	1	2			
Mo	<5	<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1			
Sn	<9	<9	<2	2	2	2	<2	2	<2	2	<2	2	2	2			
Sb	na	na	<2	2	2	3	<2	<2	2	2	<2	<2	<2	3			
Cs	na	na	21	12	20	5	7	8	17	5	6	3	5	9			
Ba	<23	<23	11	29	8	11	27	11	17	13	19	18	30	20			
La	25	<20	11	9	8	11	15	7	16	12	<6	7	<6	9			
Ce	<28	<28	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5			
Nd	<20	<20	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7			
W	<10	<10	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2			
Pb	<10	<10	<2	5	<2	2	3	<2	3	3	<2	2	<2	<2			
Bi	<5	<5	3	2	2	2	2	2	2	2	1	2	1	1			
Th	<10	<10	<2	<1	<1	<2	<2	<2	<2	<2	<1	<2	<2	<2			
U	<10	<10	<1	<2	<2	<1	<1	<1	<1	<1	<2	<1	<1	<1			
Mg#(0.20) ⁵	87.0	87.5	84.0	87.0	85.7	86.9	89.0	87.6	87.1	88.7	86.8	88.8	87.1	86.7			
Ti/Zr	70	69	125	105	103	100	90	72	84	80	103	60	120	110			

TABLE 3. ICPMS trace element analyses and comparison with XRF data

Field No	GT586		GT587		GT2178		R018290	
Reg No.	R017835		R017837		R020718		R018290	
Lab No	20130196		20130198		20140362		20140086	
Rock type	lava		cumulate		cumulate		cumulate	
(ppm)	ICPMS	XRF	ICPMS	XRF	ICPMS	XRF	ICPMS	XRF
Li	4.79	–	24.06	–	15.20	–	11.21	–
Be	0.031	–	0.040	–	0.016	–	0.014	–
Sc	38.40	33	28.89	23	17.99	19	27.90	26
Ti	864.0	[959]	1489.7	[1498]	362	[420]	587.1	[659]
V	139.4	145	105.1	93	71.82	68	100.9	105
Cr	–	2400	–	2100	3624	3300	–	3300
Mn	–	[1239]	–	[1394]	1180	[1316]	–	[1239]
Co	88.74	79	135.3	130	115.6	115	94.39	94
Ni	780.5	950	1433	1500	1464	1750	1284	1450
Cu(63)	53.18	49	86.60	72	14.39	10	32.89	30
Cu(65)	53.44	–	87.82	–	–	–	33.12	–
Zn	55.49	59	75.25	74	50.79	53	52.68	60
Ga	–	7	–	7	3.38	5	–	6
As	–	3	–	4	<2	<3	–	<3
Rb	3.81	7	2.98	7	5.36	9	3.26	6
Sr	24.65	24	9.03	9	8.44	9	10.12	11
Y	7.47	8	10.17	10	2.86	3	5.17	5
Zr	5.40	8	9.52	12	1.95	5	3.68	6
Nb	0.12	2	0.42	2	0.09	2	0.10	2
Mo	–	<1	–	<1	0.16	<1	–	<1
Ag	–	–	–	–	<0.05	–	–	–
Cd	–	–	–	–	<0.05	–	–	–
Sn	–	2	–	<2	0.02	<2	–	2
Sb	–	<2	–	<2	0.02	2	–	3
Cs	4.26	6	17.98	21	18.24	17	5.18	9
Ba	–	25	–	11	5.19	17	–	20
La	0.165	<6	0.393	11	0.047	16	0.096	9
Ce	0.442	<5	0.967	<5	0.133	<5	0.279	<5
Pr	0.075	–	0.152	–	0.026	–	0.043	–
Nd	0.466	<7	0.931	<7	0.180	<7	0.317	<7
Sm	0.287	–	0.520	–	0.095	–	0.171	–
Eu	0.138	–	0.249	–	0.047	–	0.093	–
Gd	0.594	–	0.990	–	0.230	–	0.418	–
Tb	0.142	–	0.212	–	0.053	–	0.095	–
Dy	1.064	–	1.511	–	0.408	–	0.769	–
Ho	0.282	–	0.365	–	0.107	–	0.187	–
Er	0.929	–	1.141	–	0.346	–	0.621	–
Tm	0.146	–	0.180	–	0.054	–	0.103	–
Yb	0.996	–	1.131	–	0.405	–	0.708	–
Lu	0.175	–	0.176	–	0.070	–	0.120	–
Hf	0.191	–	0.310	–	0.066	–	0.110	–
Ta	0.007	–	0.028	–	0.039	–	<0.006	–
W	–	<2	–	<2	–	<2	–	<2
Tl	–	–	–	–	0.032	–	–	–
Pb	0.072	<2	0.362	<2	0.004	3	0.672	<2
Bi	–	2	–	3	0.242	2	–	1
Th	0.032	<2	–0.060	<2	0.009	<2	0.012	<2
U	0.007	<1	0.014	<1	0.003	<1	0.005	<1

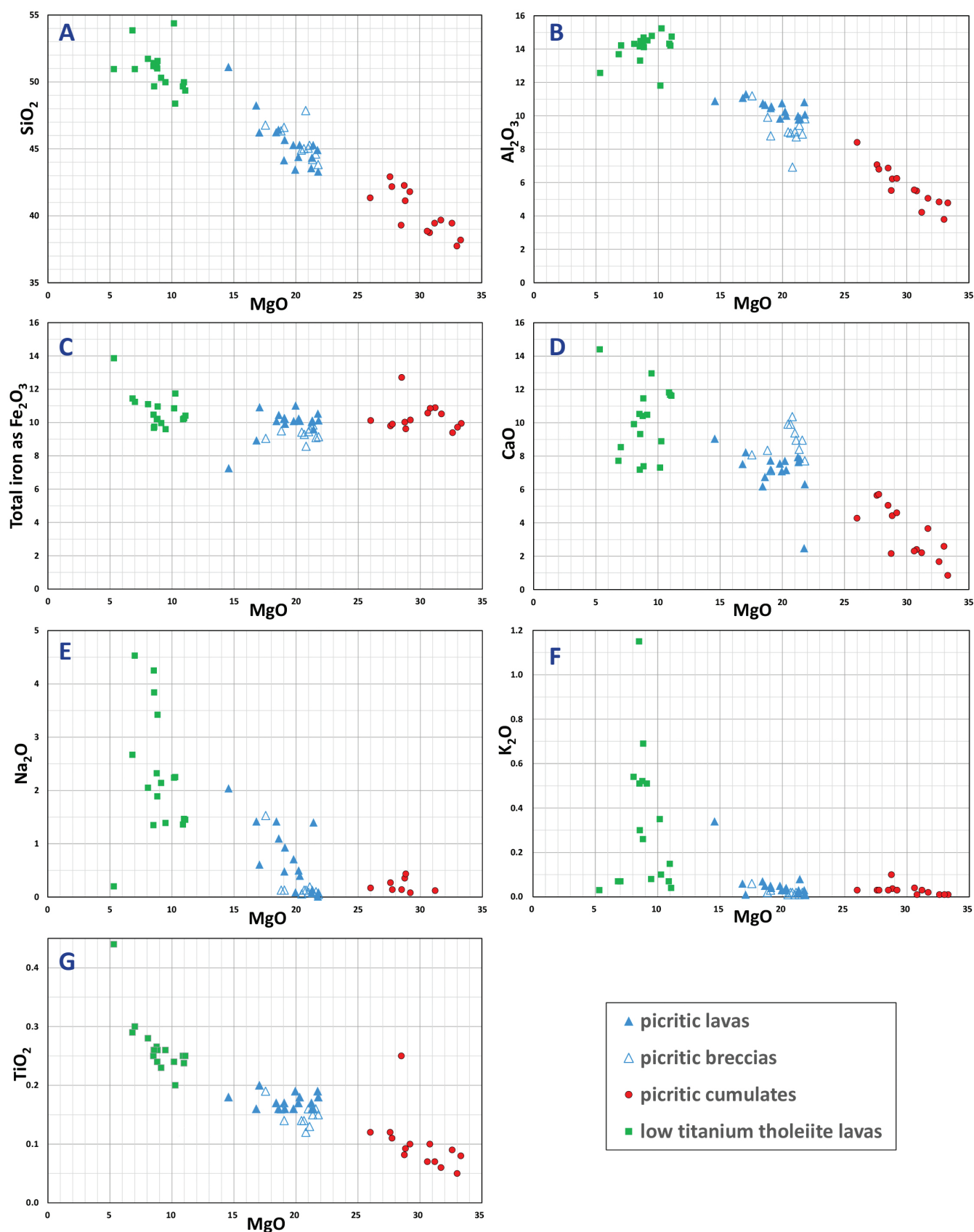


FIGURE 6. Major element geochemistry of picritic lavas, breccias and cumulates from the Whyte River Complex, plotted against MgO. Data from the low titanium tholeiite lavas of the Waratah-Luina area are also plotted for comparison.

A SiO₂; **B** Al₂O₃; **C** total iron as Fe₂O₃; and **D** CaO; **E** Na₂O; **F** K₂O; **G** TiO₂. All data by XRF, plotted as analysed.

Almost all the picritic lavas fit the definitions of komatiite of Kerr and Arndt (2001) and the IUGS classification scheme (Le Bas, 2000). For example, the latter scheme defines the composition of komatiite, after recalculation to 100 wt% on an anhydrous and CO₂-free basis, as 30 wt% < SiO₂ < 52 wt%, MgO > 18 wt%, (Na₂O + K₂O) < 2 wt% and TiO₂ < 1 wt%. A classification as komatiite is also supported by presence of olivine and clinopyroxene spinifex textures in some samples. However, as there is some debate regarding the use of the term komatiite in the literature (Kerr and Arndt, 2001), these rocks will be referred to as picritic lavas and breccias for the purposes of this study. Furthermore, these lavas have been subject to serpentinisation and alteration, probably resulting in addition or loss of some mobile components.

Trace elements

The compatible elements Ni and Cr are strongly correlated with MgO, reaching levels of 2100 ppm and 4300 ppm, respectively, in the cumulates. Co shows a similar but weaker correlation, and tends to be slightly higher in the cumulates (~90–130 ppm) relatively to the picritic lavas (~65–110 ppm). In contrast, Sc, V and Ga are negatively correlated with MgO and are at their lowest levels in the cumulates, suggesting that these trace elements were essentially incompatible in the fractionating assemblage (Fig. 7).

The high field strength elements Y and Zr, together with Ti, show a successive decline from the low titanium tholeiites to the picritic lavas and cumulates, also consistent with incompatible behaviour (Fig. 7K, L; Fig. 6G). The ratio Ti/Zr is ~100–140 for the picritic lavas and slightly lower (~70–120) for the cumulates. These values are comparable to those from the low titanium tholeiites of the Waratah-Luina area (~90–140) but much higher than values (≤40) from the “type 1” boninites (Brown and Jenner, 1989; Crawford et al., 2014; J. L. Everard unpublished data).

Data for Sr, Ba and the alkali elements are quite scattered (Fig. 7), probably due to the mobility of these elements during alteration and metamorphism, but for most their mean values also decrease from the low titanium tholeiites to the picritic cumulates. There is some suggestion that the picritic breccias tend to be even more depleted than the lavas in some alkali elements (Na, Rb and Cs), possibly because they were more prone to alteration. No consistent differences between the suites can be discerned for Cu and Zn, which are very scattered (Fig. 7F, G).

Rare-earth elements

In the picritic lavas and cumulates, these elements are generally close to or below XRF detection limits, and generally only the data obtained by the ICPMS method (from one lava sample and three cumulate samples) are useful. All these show strongly light rare-earth element (LREE) -depleted chondrite normalised patterns (Fig. 8A). The absence of Eu anomalies suggests that plagioclase fractionation and hydrothermal alteration have been weak or absent. In the Whyte River Complex, REE in the two cumulate samples (GT2178 and R018290) plot parallel to but at absolute levels well below (at about two-thirds and one-third, respectively) those in the picrite GT586. In contrast, a cumulate sample from the Magnet Range (GT587) plots at higher levels, particularly for the LREE.

For comparative purposes, REE data from other major mafic-ultramafic suites in the Waratah-Luina area and elsewhere in western Tasmania are plotted (Fig. 8B–D) along with other picritic rocks from western Tasmania. The patterns of the picritic lavas and cumulates from the Whyte River Complex are similar to, but at lower absolute levels than, those of the low titanium tholeiites, suggesting a petrogenetic relationship. In contrast, the Magnet Range cumulate (GT587) is much less depleted, particularly in the LREE, than the other cumulates, and the falls within the range displayed by the low titanium tholeiites.

MINERAL CHEMISTRY

Methods

Three relatively altered samples of picrite, one of a picritic breccia, and four samples of relatively unserpentinised wehrlitic to dunitic cumulates were selected for mineral analysis, primarily of chrome spinel. Chrome spinels from a sample of Luina Group lithicwacke (GT1429) were also analysed to help constrain its provenance. Samples are listed in Table 1 and their locations are shown in Figure 2.

The samples were prepared as polished thin sections, carbon-coated and their mineral analysed using the electron microprobe (Cameca SX-100) at the Central Science Laboratory, University of Tasmania, using wavelength-dispersive spectrometry at 15kV. Secondary standards were analysed before and after each run.

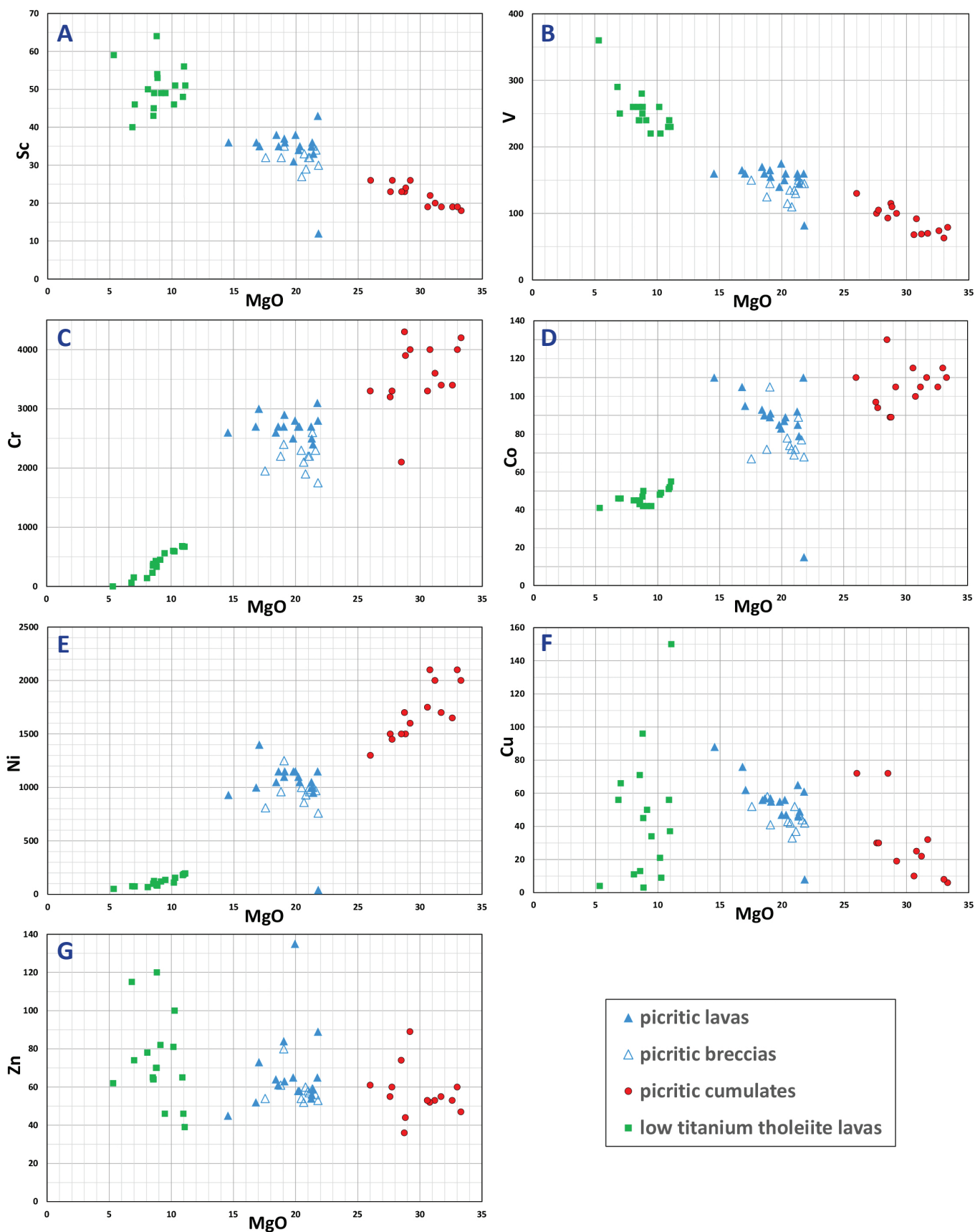


FIGURE 7. Trace-element geochemistry of picritic lavas, breccias and cumulates from the Whyte River Complex, plotted against MgO (wt%). Data from the low titanium tholeiite lavas of the Waratah-Luina area are also plotted for comparison. **A** Sc; **B** V; **C** Cr; **D** Co; **E** Ni; **F** Cu; **G** Zn. All data is in wt% by XRF, plotted as analysed.

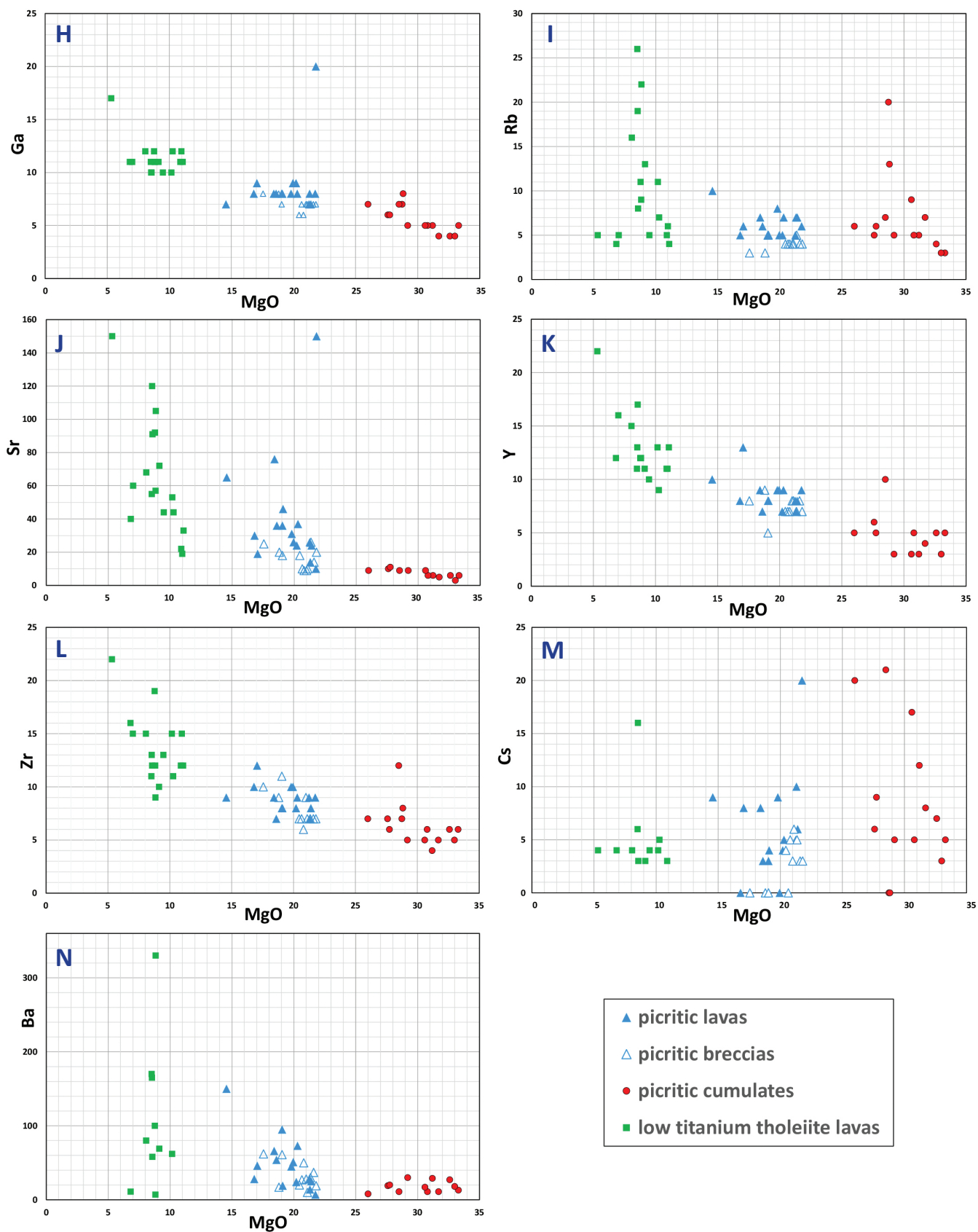


FIGURE 7 - CONT. Trace-element geochemistry of picritic lavas, breccias and cumulates from the Whyte River Complex, plotted against MgO (in wt%). Data from the low titanium tholeiite lavas of the Waratah-Luina area are also plotted for comparison. **H** Ga; **I** Rb; **J** Sr **K** Y; **L** Zr; **M** Cs; **N** Ba. All trace element data is in ppm. All data by XRF, plotted as analysed.

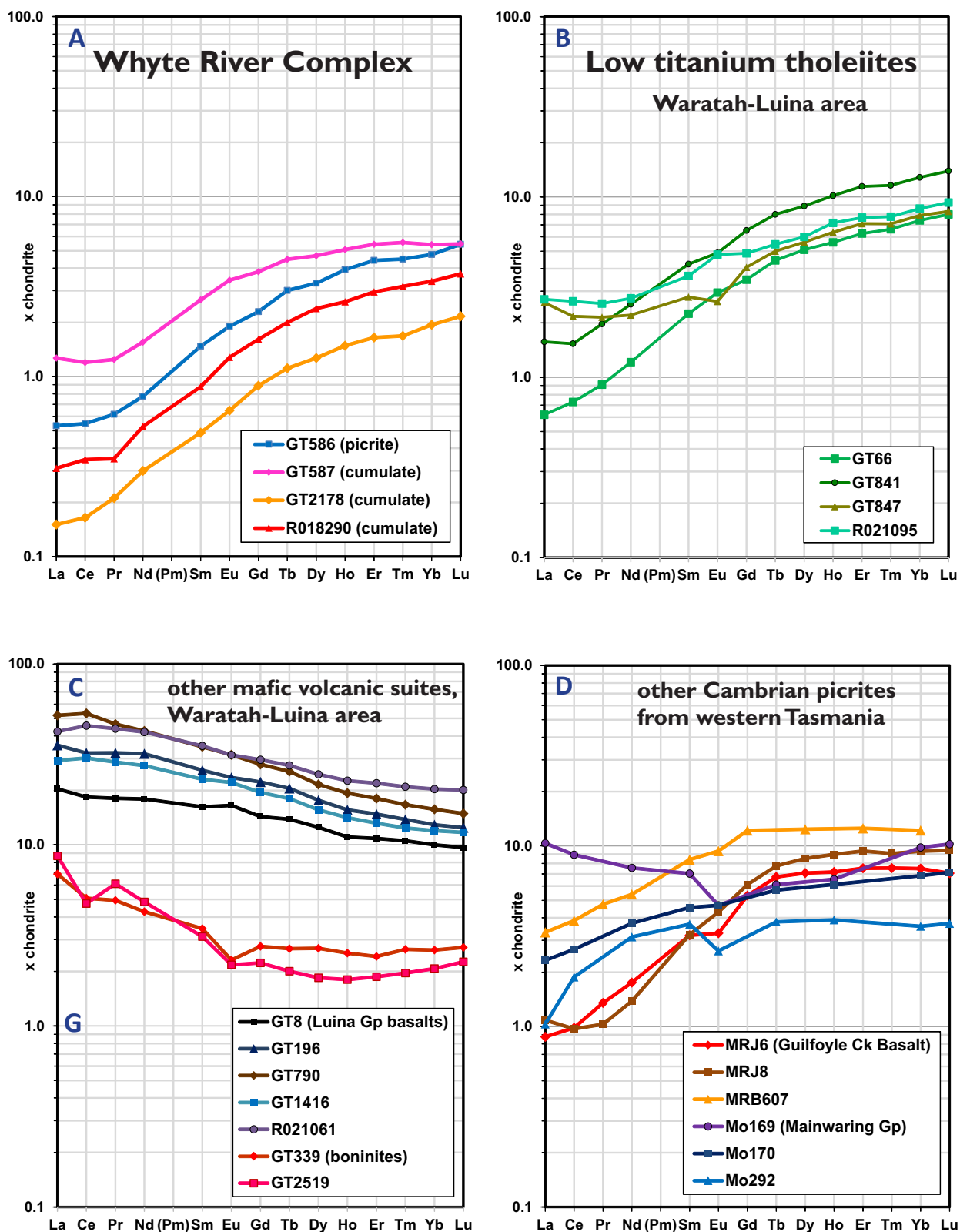


FIGURE 8. Chondrite-normalised rare earth element plots: **A** picritic lava and cumulates from the Whyte River Complex, compared with **B** low titanium tholeiite lavas from the Waratah-Luina area; **C** Luina Group basalts and boninites; **D** picrites from the Guilfoyle Creek Basalt and Mainwaring Group. Data sources: this report (Table 3), Dower (1991), Crawford et al. (2014), Brown (2011) and J. L. Everard (unpublished data).

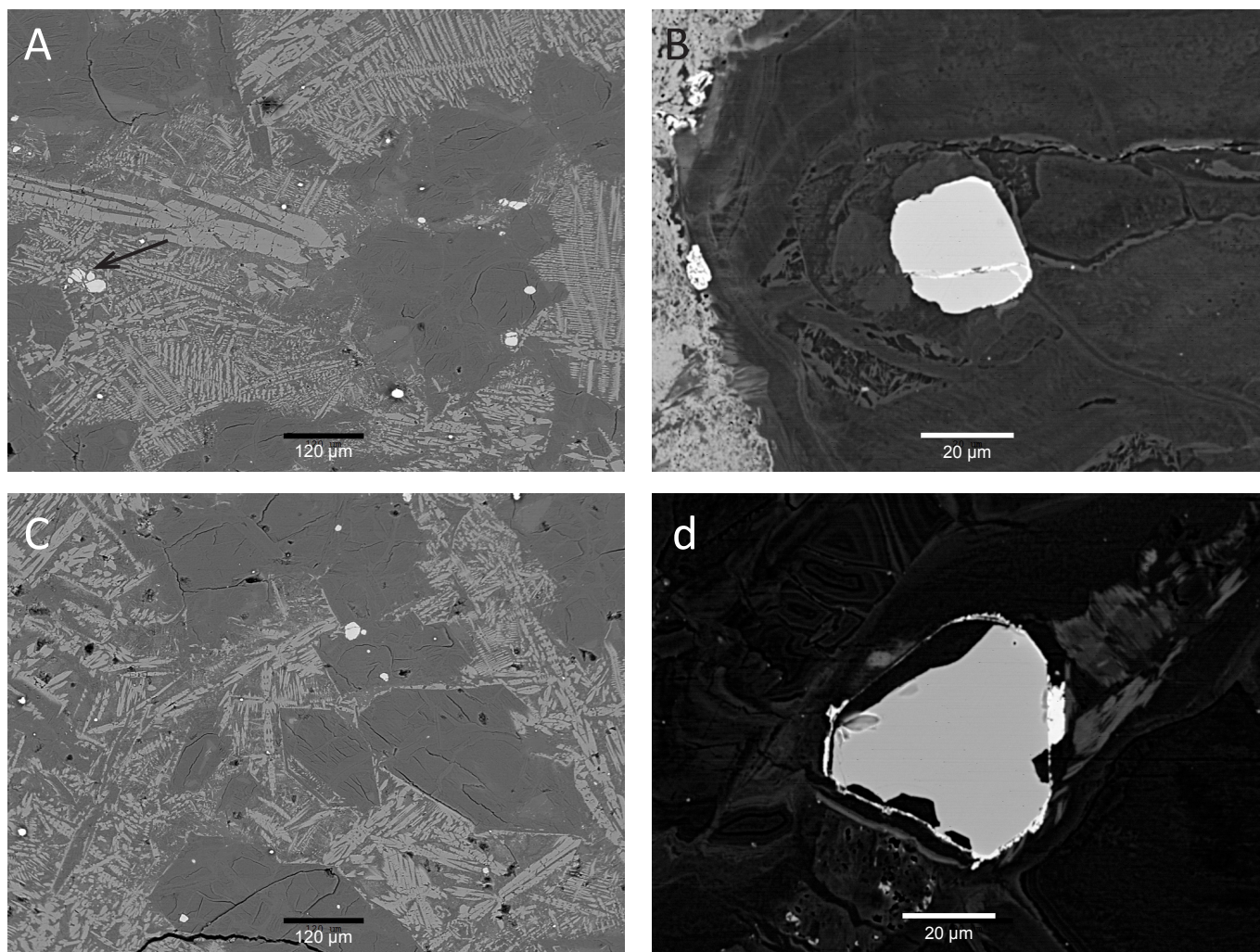


FIGURE 9. Images of spinel grains taken with the scanning electron microscope camera. **A** Clusters of spinel and free single spinels scattered in a groundmass of quenched dendritic clinopyroxene, as indicated with arrow (Sample R018265); **B** Large euhedral olivine crystals with tiny spinel inclusions (Sample R018265); **C** Slightly fractured but unzoned spinel enclosed within a serpentinised olivine phenocryst (Sample R018246); **D** Unzoned spinel with rim partly replaced by magnetite (Sample R018246).

Olivine and clinopyroxene phenocrysts from picrite samples contain sparse (1 or 2) spinel inclusions per phenocryst, and at least half are devoid of inclusions. Commonly, spinel crystals lie close to phenocryst margins (Fig. 9A, B). Isolated spinel grains, and less commonly clusters of 2–5 grains, also occur in the quenched glassy groundmass, together with clinopyroxene. Spinel crystals themselves show some variability. They may be fractured and rimmed by magnetite (Fig. 9C, D) or show a faintly visible compositional zonation.

Between five and ten Cr-spinel grains were analysed per sample. Preference was given to analysing spinel inclusions in olivine, but if these were not present then “free” spinels enclosed in the glassy groundmass were analysed. Core regions of each spinel, free of fractures,

magnetite replacement or zonation, were preferentially targeted. Attempts were also made to analyse primary silicate minerals, both olivine phenocrysts and ground-mass phases.

Olivine

Attempts to obtain analyses of fresh olivine from the selected samples were unsuccessful. About 13 analyses of altered olivine grains are interpreted as range of hydrous Fe-Mg-Al silicates including chromian chlorite, low-Ca amphibole (probably anthophyllite), serpentine-group minerals and mixtures thereof.

Fresh olivine is abundant in picritic lava GT586 and in several samples of picritic cumulates, and is a priority for further microprobe work.

TABLE 4. Electron microprobe analyses of clinopyroxenes

SAMPLE	GT2178	GT2178	GT2178	GT2178	GT2178	GT2178	GT2178	GT2178	R018265	R018265	R018265	R018265	R018265	R018265
Analysis	R1/2	R1/3	R2/3	R2/3	R3/1	R3/2	R4/2	R5/1	R1	R2	R6/1	R6/2	R7	R8/4
Collector	JLE	JLE	JLE	JLE	JLE	JLE	JLE	JLE	GVC	GVC	GVC	GVC	GVC	GVC
SiO ₂	51.806	50.963	52.665	52.504	52.897	51.265	52.540	52.561	47.196	45.488	47.793	47.508	47.596	47.644
TiO ₂	1.003	1.335	0.207	0.221	0.187	0.199	0.369	0.550	0.327	0.312	0.347	0.279	0.266	0.313
Al ₂ O ₃	2.498	2.716	2.102	2.087	2.248	4.800	2.153	2.430	11.723	12.361	11.125	11.007	10.688	10.355
V ₂ O ₃	0.087	0.092	0.038	0.037	0.026	0.034	0.052	0.073	0.063	0.049	0.063	0.061	0.053	0.059
Cr ₂ O ₃	0.883	0.865	0.865	0.888	0.950	0.020	0.902	0.978	0.206	0.145	0.215	0.230	0.126	0.340
FeO	4.335	4.371	4.752	4.617	4.777	4.990	4.604	4.619	7.254	10.074	7.871	7.842	7.848	7.293
MnO	0.125	0.104	0.139	0.135	0.107	0.125	0.150	0.143	0.161	0.183	0.182	0.186	0.172	0.406
ZnO	-	-	-	0.012	0.063	-	0.085	0.008	0.041	0.015	-	0.034	0.062	0.063
NiO	0.027	0.039	0.055	0.049	0.050	0.048	0.064	0.050	0.021	0.021	0.029	-	0.007	0.014
MgO	17.650	17.035	18.837	18.873	19.096	16.428	18.446	17.945	12.522	11.648	13.161	13.514	12.466	13.569
CaO	21.340	21.503	20.126	19.893	19.683	22.296	20.511	20.995	21.264	18.873	19.859	19.621	19.493	20.365
Na ₂ O	0.391	0.401	0.246	0.184	0.137	0.354	0.228	0.300	0.172	0.182	0.189	0.214	0.218	0.177
K ₂ O	0.009	0.006	0.005	-	-	0.007	-	-	-	-	0.004	0.006	0.000	0.002
TOTAL	100.152	99.431	100.037	99.499	100.221	100.567	100.107	100.653	100.950	99.352	100.837	100.503	98.993	100.600
<i>cations on the basis of Z = 4, (O) = 6</i>														
Si	1.884	1.872	1.910	1.915	1.916	1.856	1.908	1.902	1.724	1.701	1.747	1.739	1.776	1.744
Al	0.107	0.118	0.090	0.085	0.084	0.144	0.092	0.098	0.276	0.299	0.253	0.261	0.224	0.256
FeIII(iv)	0.009	0.011	-	-	-	-	-	-	-	-	-	-	-	-
Al	-	-	0.000	0.004	0.012	0.060	0.001	0.006	0.229	0.245	0.227	0.214	0.246	0.190
Fe	0.061	0.056	0.070	0.055	0.044	0.097	0.059	0.053	0.034	0.044	0.013	0.038	-	0.050
Ti	0.027	0.037	0.006	0.006	0.005	0.005	0.010	0.015	0.009	0.009	0.010	0.008	0.007	0.009
Cr	0.025	0.025	0.025	0.026	0.027	0.001	0.026	0.028	0.006	0.004	0.006	0.007	0.004	0.010
V	0.003	0.003	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002
Fe	0.062	0.068	0.074	0.086	0.100	0.054	0.081	0.087	0.188	0.271	0.228	0.202	0.245	0.173
Mn	0.004	0.003	0.004	0.004	0.003	0.004	0.005	0.004	0.005	0.006	0.006	0.006	0.005	0.013
Zn	-	-	-	0.000	0.002	-	0.002	0.000	0.001	0.000	-	0.001	0.002	0.002
Ni	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	-	0.000	0.000
Mg	0.957	0.933	1.019	1.026	1.031	0.886	0.999	0.968	0.682	0.649	0.717	0.738	0.694	0.740
Ca	0.832	0.846	0.782	0.777	0.764	0.865	0.798	0.814	0.832	0.756	0.778	0.770	0.779	0.799
Na	0.028	0.029	0.017	0.013	0.010	0.025	0.016	0.021	0.012	0.013	0.013	0.015	0.016	0.013
K	0.000	0.000	0.000	-	-	0.000	-	-	-	-	0.000	0.000	0.000	0.000
total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
charge	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.027	12.000
Fe	0.132	0.134	0.144	0.141	0.145	0.151	0.140	0.140	0.222	0.315	0.241	0.240	0.245	0.223
Mg#	93.9	93.2	93.2	92.3	91.1	94.2	92.5	91.8	78.4	70.6	75.9	78.5	73.9	81.0
<i>quadrilateral components</i>														
Ca'	0.434	0.444	0.401	0.399	0.393	0.454	0.411	0.423	0.478	0.438	0.447	0.439	0.452	0.450
Mg'	0.500	0.489	0.523	0.527	0.531	0.465	0.514	0.503	0.392	0.376	0.412	0.421	0.402	0.417
Fetot	0.066	0.066	0.076	0.074	0.076	0.081	0.074	0.075	0.130	0.186	0.141	0.140	0.145	0.133
classifi- cation	augite	augite	augite	augite	augite	diopside	augite	augite	diopside	augite	augite	augite	diopside	augite

Clinopyroxene

Clinopyroxene, of contrasting paragenesis and composition, was analysed in two samples (Table 4). Dendritic clinopyroxene in the groundmass of picrite R018265 is relatively iron-rich (Mg# 70.6–81.0) and very aluminous (Al_2O_3 10.3–12.4 wt%); Al is approximately equally partitioned between the tetrahedral and octahedral sites (Tschermak's substitution). In contrast, clinopyroxene, poikilitically enclosing altered olivine grains in a wehrlitic cumulate (GT2178) is much more magnesian (Mg# 91.8–94.2), with much lower Al_2O_3 (2.1–4.5 wt%) and minor Cr_2O_3 (≤ 0.9 wt%). Clinopyroxene from both samples mostly classifies as augite in the classification of Morimoto (1988), with a few slightly more calcic analyses falling marginally into the diopside field.

Spinel

Three of the 113 spinel analyses contain significant SiO_2 (≥ 0.4 wt%), probably due to the presence of silicate inclusions, and are rejected from further consideration. All the remaining analyses contain low CaO (≤ 0.39 wt%, usually much lower), Na_2O (≤ 0.13 wt%) and K_2O (≤ 0.02 wt%). Molar proportions of the other analysed elements (Ti, Al, Cr, V, Fe, Mn, Zn, Ni and Mg) were recalculated to 12 cations per formula unit and iron distributed to Fe^{II} and Fe^{III} to allow for 16 oxygens per formula unit (Table 5). Cr# (molar $100 \times \text{Cr}/(\text{Cr} + \text{Al})$), Mg# (molar $100 \times \text{Mg}/(\text{Mg} + \text{Fe}^{\text{II}})$) and $\text{Fe}^{\text{II}}/\text{Fe}^{\text{III}}$ were calculated for each analysis. Results are also presented as plots of Cr# against Mg# (Fig. 10), $\text{Fe}^{\text{II}}/\text{Fe}^{\text{III}}$ against Al_2O_3 (Fig. 11) and TiO_2 against Al_2O_3 (Fig. 12).

Spinel in the picritic lavas and breccias

Thirty-nine spinel analyses from three lava samples are characterised by a narrow range of Cr# (59.1–66.1), and those from two samples (R018265 and R018283) also show little variation in Mg# (66.8–73.1). Spinel from a third sample (R018279), however, show a lower and much wider range of Mg# (40.8–64.1). This may not reflect primary spinel compositions, as cations in the A sites (i.e., Mg and Fe^{II}) are more prone than those in the B sites to sub-solidus re-equilibration (e.g., Kamenetsky et al., 2001) and low temperature alteration (e.g., Brown, 1986, p. 85–86). The latter hypothesis may be supported by the anomalously high whole-rock SiO_2 content (67.2 wt%) of sample R018279, suggesting secondary silicification. Spinel from all three lava samples are low in TiO_2 (0.07–0.12 wt%) and also show a relatively restricted range of $\text{Fe}^{\text{II}}/\text{Fe}^{\text{III}}$ (2.1–4.1). There are no consistent compositional differences

between spinels enclosed in olivine and those “free” in the groundmass.

Seven spinel analyses from a picritic breccia sample (R021064) are similar to those from the lavas (except for one analysis with slightly lower Cr#), but show some dispersal of Mg# (56.4–77.2).

Spinel in the picritic cumulates

Fifty-three spinel analyses from the cumulates show a similar but slightly wider range of Cr# (56.0–70.3) compared to those from the lavas, but at lower Mg# (59.6–68.1) than most. Again, their lower Mg# may reflect slower crystallisation and partial re-equilibration of the A site cations. Spinel from three of the cumulates have slightly lower $\text{Fe}^{\text{II}}/\text{Fe}^{\text{III}}$ (1.8–2.5) than those from the lavas. Spinel from the cumulate sample from Wandle Road (R018290) have slightly lower Cr# and higher $\text{Fe}^{\text{II}}/\text{Fe}^{\text{III}}$ than the other three cumulate samples, and also low TiO_2 (0.09–0.11 wt%) similar to the lavas. Spinel from the three other samples of picritic cumulates, however, show a very wide range of TiO_2 (0.11–4.94 wt%), despite the very low whole-rock TiO_2 content of these rocks (0.05–0.10 wt%) (Fig. 12; Table 2).

Spinel in the Luina Group lithicwacke

Detrital spinels in sample GT1429, a lithicwacke from the Luina Group, are compositionally quite dispersed. Their Mg# (45.8–71.3) overlaps with that of spinels from the picritic rocks, but most are more aluminous (Al_2O_3 15.6–31.3 wt%, mostly >21 wt%) and thus they extend to lower Cr# (34.9–61.7). Their TiO_2 (0.17–0.95 wt%) is also higher than that of the picritic lavas, although similar to some of the picritic cumulates. These features may reflect a MORB-like source, although most also fall within the field of supra-subduction zone peridotites in Figure 12. Although chrome spinels have not been reported in the Luina Group basalts themselves, an oceanic setting is broadly consistent with a rift-related, ocean-floor-like setting for the Luina Group (at least in part), as suggested by Brown and Jenner (1988) and Brown (1989). Field relations suggest that the detrital spinels in the Luina Group are unlikely to have been derived from the picrites or boninites, as these arc-related volcanic units are tectonically interleaved within, and probably post-date, the Luina Group.

Comparison with spinels from other western Tasmanian mafic-ultramafic rocks

Chrome spinel compositions from the Cambrian mafic-ultramafic complexes of western Tasmania have been studied by numerous authors (e.g., Brown, 1986;

McClenaghan and Findlay, 1993; Olubas, 1989; Peck, 1990) and were recently compiled and reviewed by Crawford et al. (2014).

Spinel from these picritic rocks all have much lower Cr# than those from the western Tasmanian boninites (including those from the Waratah-Luina area) and the layered dunite and harzburgite (LDH) ultramafic successions, which are considered to be cumulates derived from the boninites (Brown, 1986). Their Cr# is, however, similar to spinels from the layered pyroxenite and dunite (LPD) and layered pyroxenite and gabbro (LPG) ultramafic successions identified by Brown (1986). Spinel from the picritic cumulates generally also have Mg# comparable to those from the LPD and LPG successions, whereas most of those from the picritic lavas have higher Mg#. However, spinels from the LPD and LPG successions are low in TiO₂ (≤ 0.78 wt% and commonly below detection limit; Brown, 1986, p. 212–213, 215) and dissimilar in this respect to some of those from the picritic cumulates.

The LPG succession was considered by Brown (1986) to represent cumulates derived from the low titanium tholeiites lavas which, however, do not contain chrome spinel.

Tectonomagmatic discrimination diagrams for spinel

On the Fe^{II}/Fe^{III} versus Al₂O₃ diagram developed by Kamenetsky et al. (2001), all the spinel analyses from the picritic lavas and cumulates (and most from the Luina Group lithicwacke GT1429) plot within the field of volcanic spinels. However, many analyses, particularly from the lavas and the Wandle Road cumulate R018290 also fall within the field defined for both MORB-type peridotites and supra-subduction zone peridotites, which overlap with volcanic spinel field on this diagram.

On the TiO₂ versus Al₂O₃ diagram (Kamenetsky et al., 2001), spinel analyses from the picritic lavas, breccias and cumulate R018290 plot tightly near the centre of the supra-subduction zone (SSZ) peridotite field, and between the volcanic arc field (at lower Al₂O₃) and MORB-type peridotite field (at higher Al₂O₃). Spinel from the other three picritic cumulates (R018246, R018278 and GT2178) form an array which spans, with increasing TiO₂, from the SSZ field through several volcanic fields, including boninite and island arc tholeiite, calc-alkaline and high K arc, OIB (ocean island tholeiite) and even LIP (large igneous provinces). In many cases, spinels from the same sample have diverse compositions and plot within different fields.

Although these diagrams do not unequivocally define the tectonic setting of the picrites, particularly for the cumulates, a volcanic supra-subduction setting seems most likely.

Although data are limited, detrital spinels from the Luina Group lithicwacke appear to have a volcanic source. This, however, was probably from an unrelated (and presumably older episode) of volcanism, as these spinels extend to markedly more aluminous compositions than those in the picrites or western Tasmanian ultramafics,

DISCUSSION

Petrogenetic and age relationships

Major-, trace- and rare-earth-element data broadly suggest that the picritic cumulates were derived from the lavas by crystal settling of olivine phenocrysts. The very high levels of Cr in the cumulates suggest that the fractionating assemblage also included chrome spinel, either as discrete grains or as inclusions in olivine, whereas low CaO suggests that clinopyroxene was not a cumulus phase. The reason for the less REE-depleted nature of the Magnet Range cumulate (GT587), relative to the other cumulates, is unclear, but it may have been derived from a less LREE-depleted parental magma, possibly transitional to the boninites.

The picritic lavas have similar incompatible element ratios (e.g., Ti/Zr) and rare-earth patterns to the nearby low titanium tholeiitic lavas, suggesting a similar petrogenesis. However, the picrites are unlikely to be related to the low-titanium tholeiites by crystal accumulation. The phenocryst assemblage in the latter suggests that clinopyroxene and plagioclase, in addition to olivine, would be the fractionating phases, but such an assemblage is inconsistent with major and trace element differences between the low titanium tholeiites and picrites. Both suites may have been generated by second stage partial melting of a similar source that had been depleted in LREE- and incompatible elements by previous extraction of melt. The picrites may represent a higher degree of partial melting of this depleted source than the low titanium tholeiites.

Brown and Jenner (1989) and Crawford and Berry (1992) have noted that volcanics similar to the western Tasmania boninites and low titanium tholeiites are rare on the modern Earth, and are restricted to supra-subduction zone settings, in the forearc of oceanic

TABLE 5. Electron microprobe analyses of spinel

Sample	Unit	Description	SiO2 ¹	TiO2	Al2O3	V2O3	Cr2O3	FeO	MnO	ZnO	NiO	MgO	CaO	Na2O	K2O	TOTAL	Ti ²	Al	V	Cr	Fe3	Fe2	Mn	Zn	Ni	Mg	Mg#	Cr#	Fe2/Fe3
R018265	lava	R018265-1 Cr spinel in glassy gmass	0.11	0.12	20.25	0.16	47.06	15.86	0.14	0.05	0.19	15.67	0.13	0.00	0.00	99.74	0.011	2.915	0.016	4.546	0.501	1.120	0.015	0.005	0.018	2.854	71.82	60.93	2.236
R018265	lava	R018265-1-2Cr-spinel-2	0.13	0.11	20.17	0.14	47.23	15.26	0.12	0.07	0.19	15.86	0.08	-0.02	-0.01	99.34	0.010	2.910	0.014	4.571	0.484	1.078	0.013	0.006	0.019	2.894	72.85	61.10	2.229
R018265	lava	R018265-2-CrSpinel-possibly enclosed in serp'd zone2	0.15	0.11	19.14	0.14	48.05	15.65	0.18	0.11	0.20	15.43	0.05	0.00	-0.01	99.20	0.010	2.785	0.013	4.689	0.492	1.124	0.019	0.010	0.019	2.839	71.64	62.74	2.284
R018265	lava	R018265-4-1 Cr-spinel-1	0.16	0.10	18.87	0.12	47.51	15.64	0.15	0.00	0.20	15.24	0.02	-0.01	-0.00	97.99	0.009	2.778	0.012	4.692	0.499	1.135	0.016	0.000	0.020	2.839	71.45	62.81	2.271
R018265	lava	R018265-4-3 Cr-spinel-core3	0.13	0.08	19.93	0.12	47.54	15.20	0.13	0.01	0.19	15.62	0.02	-0.05	0.01	98.92	0.007	2.891	0.012	4.626	0.456	1.108	0.014	0.001	0.019	2.866	72.12	61.54	2.427
R018265	lava	R018265-4-1 Cr-spinel-core1	0.14	0.11	21.28	0.13	45.80	15.16	0.17	0.06	0.20	15.94	0.03	0.04	-0.00	99.07	0.010	3.063	0.013	4.422	0.482	1.067	0.017	0.005	0.020	2.901	73.12	59.08	2.215
R018265	lava	R018265-4-2 Cr-spinel-core2	0.18	0.11	19.51	0.14	46.46	17.42	0.21	0.02	0.17	14.23	0.13	-0.01	0.02	98.60	0.010	2.873	0.014	4.590	0.503	1.317	0.023	0.002	0.017	2.651	66.80	61.51	2.621
R018265	lava	R018265-5-2 Cr-spinel2	0.13	0.09	18.52	0.11	49.06	15.40	0.17	0.09	0.17	15.62	0.03	-0.05	-0.00	99.35	0.009	2.692	0.011	4.785	0.495	1.093	0.018	0.008	0.017	2.872	72.43	64.00	2.210
R018265	lava	R018265-6-3 Cr-spinel-3	0.27	0.10	19.20	0.11	47.05	16.43	0.19	0.06	0.21	14.98	0.05	-0.05	-0.00	98.60	0.009	2.815	0.011	4.629	0.527	1.183	0.020	0.006	0.021	2.779	70.14	62.18	2.246
R018265	lava	R018265-6-4 Cr-spinel-4	0.16	0.12	20.34	0.11	46.91	15.19	0.17	0.05	0.21	15.87	0.03	-0.06	0.00	99.10	0.011	2.937	0.011	4.544	0.487	1.069	0.017	0.005	0.021	2.899	73.05	60.74	2.195
R018265	lava	R018265-7-3 Cr-spinel-3	0.14	0.09	19.21	0.10	47.81	15.66	0.15	0.11	0.20	15.19	0.07	0.03	0.01	98.79	0.009	2.810	0.010	4.690	0.473	1.152	0.016	0.010	0.020	2.810	70.92	62.54	2.438
R018265	lava	R018265-7-4 Cr-spinel-4	0.18	0.13	20.44	0.14	45.48	15.82	0.17	0.09	0.17	15.21	0.06	0.01	0.00	97.92	0.012	2.996	0.014	4.471	0.496	1.149	0.018	0.008	0.017	2.820	71.05	59.88	2.315
R018265	lava	R018265-8-1 Cr-spinel-core-1 not encl in ol	0.12	0.09	18.07	0.12	49.98	15.13	0.14	0.04	0.16	15.25	0.05	-0.05	-0.01	99.09	0.008	2.645	0.012	4.907	0.420	1.152	0.015	0.004	0.016	2.822	71.02	64.98	2.745
R018265	lava	R018265-8-2 Cr-spinel-core-2 enclosed in olivine	0.15	0.10	18.96	0.14	47.75	15.47	0.18	0.04	0.16	15.50	0.03	-0.09	-0.01	98.37	0.010	2.774	0.014	4.688	0.504	1.102	0.019	0.004	0.016	2.869	72.25	62.82	2.185
R018279	lava	18279-1-Cr_spinel-in gmass	0.08	0.11	19.52	0.14	46.31	19.63	0.20	0.04	0.14	13.12	0.11	-0.03	0.01	99.39	0.010	2.873	0.014	4.571	0.521	1.528	0.021	0.004	0.014	2.442	61.51	61.41	2.932
R018279	lava	18279-2-Cr_spinel-in gmass1	0.11	0.10	19.22	0.12	44.70	23.03	0.22	0.12	0.10	11.09	0.16	-0.00	-0.00	98.96	0.010	2.882	0.013	4.496	0.589	1.861	0.024	0.011	0.010	2.104	53.07	60.94	3.158
R018279	lava	18279-2-Cr_spinel-in gmass2-core	0.12	0.11	20.12	0.14	42.33	27.00	0.28	0.14	0.12	8.58	0.18	-0.04	0.00	99.08	0.011	3.054	0.014	4.310	0.600	2.307	0.030	0.014	0.012	1.648	41.66	58.52	3.846
R018279	lava	18279-2-Cr_spinel-in gmass3-core	0.13	0.11	18.84	0.14	46.17	19.18	0.20	0.11	0.13	12.77	0.24	0.04	0.00	98.05	0.010	2.824	0.014	4.644	0.498	1.543	0.022	0.010	0.013	2.422	61.09	62.18	3.099
R018279	lava	18279-2-Cr_spinel-in gmass4-core	0.39	0.11	19.72	0.12	41.06	27.59	0.26	0.12	0.11	8.27	0.21	0.02	0.01	97.98	0.011	3.042	0.012	4.249	0.675	2.346	0.029	0.011	0.012	1.613	40.75	58.28	3.476
R018279	lava	18279-2-Cr_spinel-in gmass5-core	0.28	0.11	19.19	0.17	42.65	24.19	0.28	0.11	0.09	10.36	0.39	0.09	-0.00	97.89	0.010	2.931	0.017	4.370	0.662	1.959	0.030	0.010	0.009	2.001	50.53	59.86	2.961
R018279	lava	18279-3-Cr_spinel-in gmass1-core or inclus rich spinel	0.14	0.10	17.16	0.13	46.94	22.61	0.29	0.10	0.14	10.70	0.20	-0.03	0.01	98.47	0.009	2.615	0.013	4.799	0.554	1.892	0.032	0.010	0.014	2.062	52.16	64.72	3.416
R018279	lava	18279-3-Cr_spinel-in gmass2-core fractured spinel	0.15	0.10	17.89	0.13	46.14	21.44	0.25	0.14	0.09	11.60	0.17	0.03	-0.01	98.12	0.010	2.710	0.013	4.690	0.568	1.736	0.028	0.013	0.010	2.223	56.15	63.38	3.054
R018279	lava	18279-3-Cr_spinel-in gmass3-core-in gmass	0.13	0.11	19.36	0.15	45.85	20.69	0.22	0.11	0.12	12.53	0.15	0.03	0.00	99.46	0.010	2.863	0.015	4.549	0.552	1.620	0.024	0.010	0.012	2.345	59.15	61.37	2.933
R018279	lava	18279-3-Cr-spinel-core-in gmass	0.13	0.11	19.62	0.13	43.80	21.30	0.22	0.08	0.11	12.16	0.23	-0.05	0.00	97.85	0.010	2.945	0.013	4.411	0.610	1.659	0.024	0.008	0.011	2.309	58.20	59.96	2.718
R018279	lava	18279-4-Cr-spinel-in-gmass	0.15	0.10	19.06	0.14	45.14	20.93	0.22	0.10	0.13	11.79	0.12	-0.00	0.00	97.88	0.010	2.875	0.015	4.566	0.525	1.715	0.023	0.010	0.013	2.248	56.72	61.37	3.270
R018279	lava	18279-4-Cr-spinel-in-gmass2	0.12	0.09	16.72	0.12	46.44	26.15	0.24	0.10	0.10	8.47	0.26	0.07	-0.00	98.88	0.009	2.586	0.012	4.819	0.565	2.305	0.027	0.009	0.011	1.657	41.83	65.08	4.079
R018279	lava	18279-4-Cr-spinel-in-ol-crystal3	0.13	0.11	18.78	0.14	46.03	20.06	0.26	0.07	0.12	12.52	0.15	0.13	0.01	98.51	0.011	2.809	0.015	4.620	0.535	1.595	0.028	0.006	0.012	2.370	59.78	62.18	2.979
R018279	lava	18279-5-Large cr spinel in gmass	0.16	0.09	18.96	0.10	47.24	18.70	0.20	0.05	0.15	13.68	0.14	0.03	0.00	99.49	0.009	2.788	0.010	4.659	0.526	1.425	0.021	0.005	0.015	2.543	64.10	62.56	2.710
R018279	lava	18279-5-Large cr spinel in gmass2	0.14	0.10	18.33	0.12	46.98	20.28	0.27	0.04	0.13	12.39	0.11	0.03	-0.00	98.93	0.010	2.737	0.012	4.706	0.525	1.623	0.029	0.004	0.013	2.340	59.04	63.23	3.090
R018283	lava	R018283-3-Cr-spinel-in-gmass	0.12	0.10	18.96	0.11	48.64	15.27	0.18	0.05	0.18	15.72	0.09	0.00	0.01	99.42	0.009	2.751	0.011	4.734	0.487	1.085	0.019	0.004	0.017	2.884	72.67	63.25	2.227
R018283	lava	R018283-3-Cr-spinel-in-gmass2	0.13	0.10	19.49	0.15	47.03	16.64	0.20	0.08	0.15	14.89	0.25	0.06	0.00	99.17	0.009	2.847	0.014	4.609	0.511	1.213	0.021	0.007	0.015	2.752	69.40	61.81	2.374
R018283	lava	R018283-3-Cr-spinel-in-gmass3	0.15	0.12	18.12	0.13	49.31	15.61	0.15	0.13	0.17	15.47	0.19	0.01	0.00	99.56	0.011	2.642	0.013	4.822	0.502	1.113	0.016	0.012	0.017	2.853	71.93	64.61	2.218
R018283	lava	R018283-3-Cr-spinel-in-gmass4	0.15	0.09	18.87	0.12	48.39	15.31	0.18	0.00	0.18	15.66	0.11	0.00	-0.01	99.03	0.008	2.748	0.012	4.728	0.496	1.086	0.019	0.000	0.017	2.885	72.65	63.24	2.190
R018283	lava	R018283-3-Cr-spinel-in-gmass5	0.14	0.08	18.20	0.11	48.65	16.11	0.18	0.04	0.17	15.07	0.11	0.03	-0.01	98.89	0.008	2.673	0.011	4.792	0.509	1.169	0.019	0.004	0.017	2.799	70.54	64.20	2.298
R018283	lava	R018283-2-Cr-spinel-in-gmass1	0.15	0.09	19.67	0.13	47.70	15.48	0.17	0.02	0.19	15.78	0.02	0.00	0.00	99.41	0.008	2.843	0.013	4.625	0.503	1.085	0.017	0.002	0.019	2.885	72.66	61.93	2.159
R018283	lava	R018283-4-Cr-spinel-in olivine	0.15	0.09	18.98	0.14	47.62	16.10	0.19	0.05	0.17	15.24	0.06	-0.02	-0.00	98.76	0.008	2.775	0.014	4.672	0.522	1.149	0.020	0.004	0.017	2.819	71.05	62.74	2.201
R018283	lava	R018283-4-Cr-spinel-in olivine2	0.12	0.08	19.25	0.12	47.18	15.95	0.16	0.06	0.17	15.26	0.09	0.02	-0.00	98.45	0.007	2.820	0.011	4.636	0.517	1.141	0.017	0.005	0.017	2.828	71.26	62.18	2.205
R018283	lava	R018283-4-Cr-spinel-in olivine4	0.13	0.07	19.61	0.16	47.33	15.64	0.19	-0.00	0.19	15.52	0.02	0.02	0.01	98.88	0.007	2.852	0.015	4.619	0.500	1.114	0.020	-0.000	0.018	2.855	71.93		

TABLE 5 - cont. Electron microprobe analyses of spinel

Sample	Unit	Description	SiO2 ¹	TiO2	Al2O3	V2O3	Cr2O3	FeO	MnO	ZnO	NiO	MgO	CaO	Na2O	K2O	TOTAL	Ti ²	Al	V	Cr	Fe3	Fe2	Mn	Zn	Ni	Mg	Mg#	Cr#	Fe2/Fe3
R018246	cumulate	RO211246-2-1-Cr-Sp-core	0.03	0.67	18.52	0.33	42.70	24.32	0.25	0.12	0.18	11.87	-0.00	-0.01	0.01	98.97	0.064	2.762	0.033	4.272	0.806	1.768	0.027	0.012	0.018	2.239	55.88	60.74	2.194
R018246	cumulate	RO211246-2-3-Crspinell2	0.06	0.50	16.90	0.31	44.23	25.14	0.25	0.07	0.16	11.26	0.03	-0.05	0.02	98.88	0.048	2.551	0.032	4.477	0.844	1.847	0.027	0.007	0.017	2.150	53.78	63.71	2.188
R018246	cumulate	RO211246-3-1-Crspinell1	0.03	0.15	18.61	0.29	42.72	24.36	0.24	0.10	0.16	11.95	0.00	0.01	0.00	98.62	0.014	2.781	0.029	4.283	0.878	1.705	0.025	0.009	0.016	2.260	57.00	60.63	1.941
R018246	cumulate	RO211246-3-2-Crspinell2	0.04	0.71	17.97	0.33	42.27	25.02	0.24	0.07	0.17	11.71	0.01	0.00	-0.01	98.54	0.068	2.698	0.034	4.259	0.872	1.793	0.026	0.007	0.017	2.225	55.37	61.22	2.056
R018246	cumulate	RO18246-4-1-Crspinell1-core	0.06	0.25	17.56	0.38	42.84	26.47	0.25	0.08	0.15	10.76	0.00	0.01	0.00	98.81	0.024	2.652	0.039	4.341	0.919	1.919	0.027	0.008	0.016	2.056	51.73	62.07	2.088
R018246	cumulate	RO18246-4-2-Crspinell2-core-inclusion-rich-spinell	0.05	0.35	17.08	0.28	44.36	24.34	0.23	0.10	0.18	11.38	-0.00	-0.00	-0.01	98.33	0.034	2.586	0.028	4.505	0.813	1.801	0.025	0.010	0.019	2.179	54.75	63.53	2.216
R018246	cumulate	RO18246-4-3-Crspinell3-core	0.05	0.47	17.84	0.33	42.67	24.97	0.20	0.07	0.18	12.13	0.00	0.02	0.00	98.95	0.045	2.664	0.034	4.274	0.939	1.707	0.022	0.007	0.018	2.291	57.31	61.60	1.819
R018246	cumulate	RO18246-5-2-Crspinell1-core	0.04	0.12	18.03	0.30	43.52	24.28	0.22	0.07	0.14	11.84	0.00	0.02	0.02	98.59	0.011	2.705	0.030	4.379	0.863	1.721	0.023	0.006	0.015	2.246	56.61	61.82	1.994
R018246	cumulate	RO18246-5-3-Crspinell2-core	0.07	0.13	15.74	0.35	44.63	25.32	0.26	0.10	0.13	10.19	-0.00	-0.00	0.01	96.93	0.013	2.447	0.036	4.654	0.837	1.956	0.029	0.010	0.014	2.004	50.62	65.54	2.336
R018246	cumulate	RO18246-6-1-Crspinell1-core	0.06	0.15	18.24	0.40	42.55	24.96	0.23	0.14	0.18	11.50	0.01	-0.02	-0.01	98.40	0.015	2.744	0.041	4.293	0.893	1.771	0.025	0.013	0.018	2.187	55.26	61.01	1.984
R018246	cumulate	RO18246-6-2-chrome spinell	0.03	1.65	15.55	0.55	42.40	27.35	0.25	0.05	0.19	11.13	0.00	0.02	0.01	99.19	0.159	2.354	0.057	4.307	0.963	1.975	0.027	0.005	0.020	2.133	51.92	64.66	2.050
R018246	cumulate	RO18246-6-2-chrome spinell	0.05	2.40	13.66	0.67	41.70	30.45	0.29	0.18	0.24	9.25	-0.01	-0.04	-0.01	98.83	0.237	2.118	0.070	4.337	1.001	2.349	0.032	0.018	0.025	1.813	43.56	67.19	2.347
R018246	cumulate	RO18246-7-2-chrome spinell bit spotty	0.05	1.16	15.75	0.43	42.85	26.96	0.26	0.10	0.17	10.98	0.01	0.01	0.02	98.76	0.113	2.395	0.045	4.371	0.963	1.946	0.029	0.009	0.018	2.111	52.03	64.60	2.022
R018246	cumulate	RO18246-1-CrSpinell1	0.06	0.16	18.18	0.32	42.36	24.57	0.22	0.07	0.15	11.92	0.02	0.02	-0.01	98.03	0.015	2.736	0.033	4.277	0.923	1.701	0.024	0.006	0.015	2.269	57.16	60.99	1.843
R018246	cumulate	RO18246-1-2-CrSpinell2	1.54 3	0.31	13.44	0.37	42.08	29.91	0.31	0.10	0.15	6.66	0.45	0.06	0.01	95.37													
R018246	cumulate	RO18246-2-1-CrSpinell1	0.08	1.68	15.54	0.55	41.91	28.52	0.25	0.14	0.18	10.22	0.00	-0.02	0.00	99.06	0.163	2.371	0.057	4.289	0.956	2.132	0.027	0.013	0.019	1.972	48.04	64.40	2.232
R018246	cumulate	RO18246-2-2-CrSpinell2	0.05	2.47	13.29	0.64	40.76	31.38	0.35	0.14	0.20	8.61	-0.01	-0.00	0.00	97.88	0.247	2.091	0.069	4.302	1.044	2.459	0.040	0.014	0.022	1.714	41.07	67.29	2.355
R018246	cumulate	RO18246-3-1-CrSpinell1	0.04	2.42	13.32	0.62	41.49	30.90	0.32	0.10	0.21	8.81	-0.01	-0.01	-0.00	98.20	0.242	2.086	0.066	4.359	1.005	2.429	0.036	0.010	0.022	1.745	41.81	67.63	2.418
R018246	cumulate	RO18246-3-2-CrSpinell2, mt alteration rim	0.83	0.23	12.99	0.37	41.77	27.15	0.34	0.15	0.17	8.75	0.06	-0.01	0.00	92.79													
R018246	cumulate	RO18246-4-1Cr-spinell	0.04	0.32	18.25	0.29	42.75	24.74	0.26	0.17	0.13	12.27	0.03	-0.01	-0.01	99.22	0.030	2.711	0.030	4.260	0.938	1.669	0.028	0.015	0.013	2.305	58.00	61.11	1.779
R018246	cumulate	RO18246-4-2Cr-Spinell-2	0.05	1.77	15.16	0.49	42.00	28.24	0.29	0.15	0.22	10.13	-0.01	0.00	0.02	98.51	0.174	2.329	0.052	4.329	0.942	2.136	0.032	0.014	0.023	1.968	47.95	65.02	2.267
R018246	cumulate	RO18246-5-1Cr-Spinell1	0.04	0.36	18.57	0.29	43.19	23.18	0.21	0.11	0.16	12.61	0.01	0.01	-0.01	98.73	0.034	2.761	0.029	4.309	0.833	1.613	0.023	0.010	0.016	2.373	59.54	60.95	1.936
R018246	cumulate	RO18246-5-2Cr-Spinell2-core	0.04	0.94	16.31	0.40	42.82	26.72	0.28	0.14	0.18	11.12	0.02	0.00	-0.00	98.96	0.090	2.466	0.041	4.344	0.968	1.900	0.030	0.013	0.019	2.128	52.83	63.79	1.963
R018246	cumulate	RO18246-6-1Cr-Spinell1-core	0.04	0.82	17.17	0.37	43.56	24.40	0.23	0.37	0.17	12.09	0.01	0.01	-0.01	99.24	0.078	2.566	0.038	4.368	0.872	1.716	0.025	0.035	0.017	2.285	57.11	62.99	1.969
R018246	cumulate	RO18246-6-2Cr-Spinell2-core	0.08	1.69	15.12	0.55	42.33	27.70	0.31	0.44	0.18	10.34	0.00	-0.02	0.01	98.74	0.166	2.316	0.058	4.351	0.944	2.067	0.034	0.042	0.019	2.004	49.23	65.26	2.190
R018278	cumulate	RO18278-1-CrSpinell-Not enclosed in Ol Possibly Px	0.07	0.12	19.99	0.14	46.77	18.52	0.20	0.11	0.14	14.13	0.02	0.02	-0.00	100.23	0.011	2.895	0.014	4.544	0.524	1.378	0.021	0.010	0.014	2.588	65.25	61.08	2.629
R018278	cumulate	RO18278-1-CrSpinell-Not-enclosed-in Ol Possibly Px 2	0.10	0.12	20.71	0.20	45.62	17.62	0.16	0.13	0.16	14.77	0.18	0.05	-0.01	99.80	0.011	2.994	0.019	4.424	0.540	1.267	0.016	0.012	0.016	2.700	68.06	59.63	2.345
R018278	cumulate	RO18278-1-CrSpinell-Not-enclosed-inOl- Possibly Px3	0.09	0.12	17.97	0.16	45.81	24.28	0.27	0.16	0.14	11.28	0.04	0.03	0.01	100.35	0.012	2.670	0.016	4.566	0.725	1.835	0.028	0.015	0.014	2.119	53.60	63.10	2.532
R018278	cumulate	RO18278-1-Cr-Spinell enclosed-in-fresh olivine4	0.14	0.36	18.46	0.26	41.55	26.22	0.23	0.13	0.17	11.37	0.06	0.05	-0.00	99.00	0.034	2.766	0.026	4.177	0.962	1.825	0.025	0.012	0.017	2.154	54.13	60.16	1.897
R018278	cumulate	RO18278-2-Cr-Spinell core-enclosed-in-fresh-ol	0.08	0.11	18.91	0.17	44.77	22.51	0.27	0.12	0.13	12.21	0.02	0.02	-0.02	99.28	0.010	2.805	0.017	4.455	0.703	1.666	0.029	0.011	0.013	2.291	57.90	61.37	2.369
R018278	cumulate	RO18278-2-Cr-Spinell-2	0.07	0.33	17.08	0.24	43.05	27.73	0.27	0.15	0.16	10.00	0.00	0.07	-0.01	99.15	0.032	2.593	0.025	4.384	0.934	2.053	0.029	0.014	0.017	1.919	48.32	62.84	2.197
R018278	cumulate	RO18278-4-Core-of-Cr-spinell	0.07	0.51	16.81	0.29	41.90	28.99	0.30	0.18	0.17	9.59	0.03	-0.00	0.00	98.83	0.050	2.567	0.030	4.292	1.011	2.130	0.032	0.018	0.017	1.852	46.50	62.58	2.106
R018278	cumulate	RO18278-5-Core-of-Cr-spinell-mottled-round	0.08	0.17	18.25	0.20	43.84	24.31	0.27	0.12	0.16	11.77	0.09	0.06	0.00	99.32	0.016	2.723	0.020	4.389	0.836	1.738	0.029	0.011	0.016	2.221	56.10	61.71	2.080
R018278	cumulate	RO18278-5-Core-of-Cr-spinell2	0.09	0.84	15.71	0.39	41.68	29.18	0.28	0.12	0.15	10.09	0.10	0.04	-0.00	98.66	0.082	2.407	0.041	4.284	1.104	2.069	0.030	0.012	0.016	1.956	48.60	64.03	1.874
R018290	cumulate	RO18290-1-Cr-sp-encl in-fresh-ol-close-to-fracture1	0.11	0.09	21.61	0.14	43.10	20.24	0.20	0.16	0.17	13.47	0.03	0.02	0.01	99.35	0.008	3.146	0.014	4.209	0.615	1.476	0.021	0.014	0.017	2.480	62.69	57.23	2.401
R018290	cumulate	RO18290-2-Cr-Spinell at rim of fresh olivine	0.12	0.11	19.59	0.15	40.99	26.41	0.28	0.36	0.11	9.79	0.06	-0.05	-0.00	97.91	0.011	2.980	0.016	4.183	0.799	2.052	0.030	0.034	0.012	1.883	47.86	58.40	2.570
R018290	cumulate	RO18290-2-CrSpinellinCoreOfOlivine2-3	0.11	0.10	21.02	0.15	42.47	21.68	0.21	0.25	0.14	12.25	0.03	0.03	-0.00	98.43	0.009	3.115	0.015	4.223	0.628	1.653	0.022	0.023	0.014	2.297	58.16	57.55	2.632
R018290	cumulate	RO18290-2-Cr-spinell-partly enclosed-by-fractured-ol	0.09	0.10	20.03	0.14	42.95	24.80	0.27	0.21	0.14	10.39	0.03	-0.00	0.00	99.14	0.010	2.998	0.014	4.314	0.655	1.979	0.029	0.020	0.014	1.968	49.85 </		

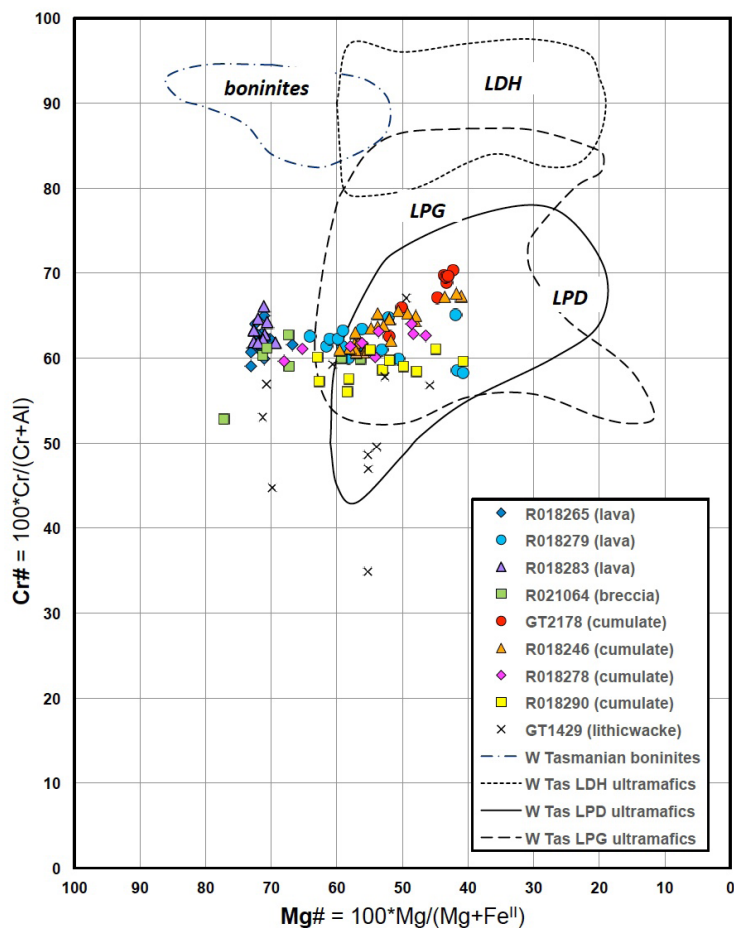


FIGURE 10. Plot of Cr# against Mg# for chrome spinels from the Whyte River Complex, and a Luina Group lithicwacke (data from Table 5). Fields shown for chrome spinel from Tasmanian Cambrian boninites, layered dunite and harzburgite (LDH), layered pyroxenite and dunite (LPG) and layered pyroxenite and gabbro (LPD) ultramafic successions (Brown 1986).

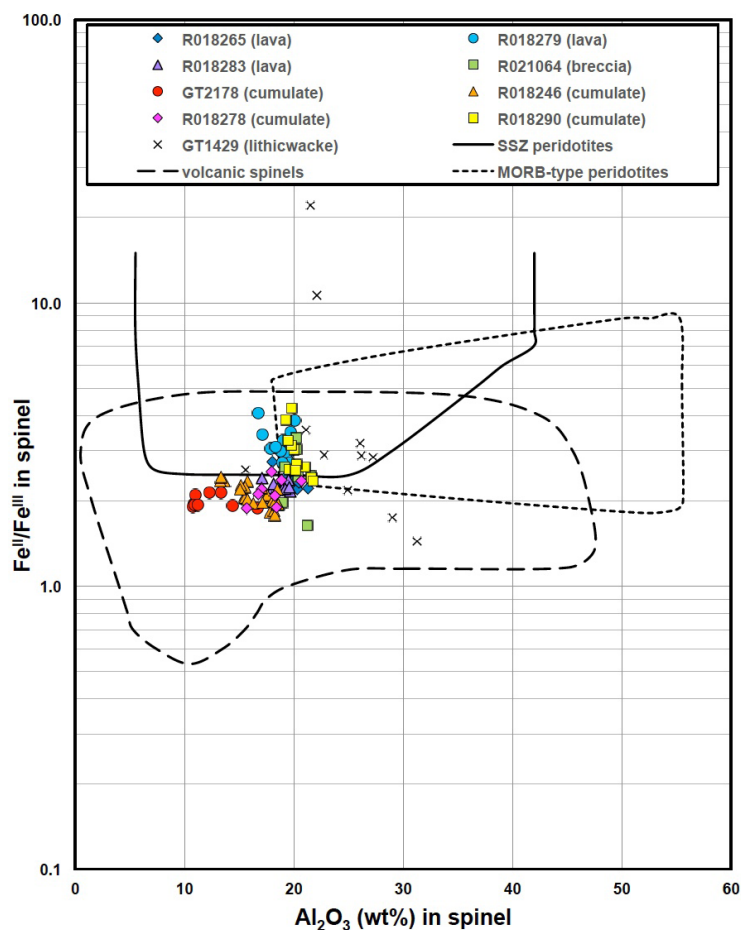


FIGURE 11. Plot of Fe^{II}/Fe^{III} against Al_2O_3 (wt%) for chrome spinels from the Whyte River Complex, and a Luina Group lithicwacke (data from Table 5). Fields shown for supra-subduction zone (SSZ) peridotites, mid ocean ridge basalt (MORB)-type peridotites and volcanic spinels as defined by Kamenetsky et al. (2001).

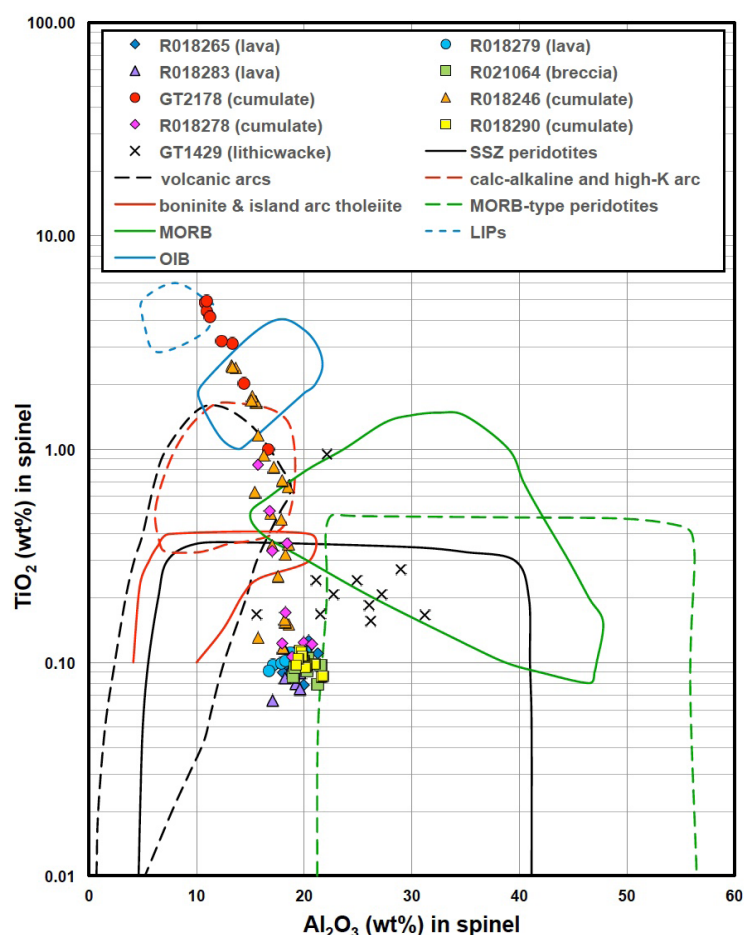


FIGURE 12. Plot of TiO_2 (wt%) against Al_2O_3 (wt%) for chrome spinels from the Whyte River Complex, and a Luina Group lithicwacke (data from Table 5). Fields shown for chrome spinel from various tectonic environments, as defined by Kamenetsky et al. (2001).

island arcs built on thin crust (such as the Mariana and northern Tongan arcs). Both are considered to be derived from a depleted mantle source, with the boninites in addition requiring the influx of SiO_2 -, LILE- and LREE-enriched hydrous fluids derived from dehydration of the down-going slab (e.g., Umino and Kushiro, 1989). The picrites of the Whyte River Complex, together with the low titanium tholeiites, lack this LREE-enrichment, and were thus probably not affected by slab-derived fluids. The picrites may have been generated by a higher degree of partial melting, at higher temperatures, than the low titanium tholeiites.

Age relationships between the Tasmanian picrites and the low titanium tholeiites and boninites are uncertain. Brown (pers. comm., 2017) also observed picritic dykes cross-cutting boninitic lavas, suggesting that at least some picritic intrusions are younger. However, no similar relationships were confidently observed during the 2012–2016 mapping campaign.

Possible correlates in Tasmania

Picritic lavas of inferred Early Cambrian age are known elsewhere in western Tasmania, associated with generally more voluminous tholeiitic basalts. The main occurrences are within the Guilfoyle Creek Basalt (formerly Miners Ridge Basalt), which apparently forms the substrate of the Mt Read Volcanics in the core of an anticline just south of Queenstown (Corbett, 1979; Dower, 1991), and within the Mainwaring Volcanics, south of Macquarie Harbour (Brown, 2011). Both sequences are considered to have island arc affinities and to have been emplaced during the Early Middle Cambrian Tyennan Orogeny.

The Guilfoyle Creek Basalt contains picrites with up to 26.8 wt% MgO and strongly LREE-depleted rare-earth patterns (Crawford et al., 1992; Dower, 1991, Everard and Calver, 2014 and unpublished data) similar to these from the Waratah-Luina area (Whyte River Complex). However, the TiO_2 content of even the most magnesian samples (~0.35 wt%) is much higher than otherwise comparable samples from the Whyte River Complex. Furthermore, levels of other HFSE (e.g., P_2O_5 , Zr and Y) are also generally higher in the Guilfoyle Creek Basalt.

The Mainwaring Volcanics contain picrites with up to 20.8 wt% MgO, but they are also generally higher in TiO₂, Zr and other HFSE than the picrites from the Whyte River Complex. Their REE patterns range from weakly LREE-depleted, to V-shaped patterns comparable to western Tasmanian boninites (Brown, 2011). The Birch Inlet Volcanics were considered, on the basis of similar geochemistry (including REE), to be correlates of the Mainwaring Group (McClenaghan and Findlay, 1993), but available analyses are all basaltic (≤ 9.2 wt% MgO).

On the southeast coast of King Island, the picrites of the Shower Droplet Volcanics are strongly LREE-depleted like the Whyte River Complex, but also generally higher in TiO₂ and other HFSE (Waldron and Brown, 1993; Meffre et al., 2004). Picritic lavas and shallow intrusions are a rare component of Togari Group in the Smithton Synclinorium of far northwest Tasmania, but these are LREE-enriched with possible alkalic affinities (Everard et al., 2007). Picritic lavas occur toward the top of the Lucas Creek Volcanics to the south of Macquarie Harbour, notably at Double Cove (Crawford and Berry, 1992; McClenaghan and Findlay, 1993), but they lack the strong LREE-depletion of the Whyte River Complex. All these units, however, have been shown or inferred to be of Ediacaran age (~580 Ma) (Calver et al., 2004; Calver and Walter, 2000; Meffre et al., 2004) and are thus unlikely correlates of the Whyte River Complex and related picritic rocks in the Waratah-Luina area.

CONCLUSIONS

A newly recognised suite of picritic lavas, breccias and cumulates in the Waratah-Luina area (Whyte River Complex) has no clear correlates elsewhere in western Tasmania. Although there are some similarities to picrites within the predominantly basaltic Guilfoyle Creek Basalt and Mainwaring Group, the Whyte River Complex picrites are more depleted in LREE and HFSE.

Chrome spinel compositions from the Whyte River Complex picrites discount a direct link with western Tasmanian boninites and associated LDH ultramafics but, together with major, trace and REE geochemistry, a genetic relationship with the low-titanium tholeiite basalt suite and associated LPG and/or LPD ultramafics seems likely.

Although their chrome spinel compositions plot rather ambiguously on tectonomagmatic discrimination diagrams (Kamenetsky et al., 2001), the picrites probably formed by a high degree of partial melting of depleted oceanic lithosphere, and were subsequently obducted on to continental crust, along with the boninites, low-titanium tholeiites and ultramafic cumulates, during an arc-continent collision in the Early Cambrian.

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