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Map of Altered Facies in the Mount Read Volcanics, Tasmania

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Introduction

These notes explain the background, compilation and format of a GIS map of altered facies in the Mount Read Volcanics, Tasmania.

Researchers at the Centre for Ore Deposit Research produced the altered facies map under contract agreement with Mineral Resources Tasmania (MRT). It is a component of the three-dimensional mineralisation and structural model of Tasmania's prospective ground being created by the Predictive Mineral Discovery Cooperative Research Centre (pmd*CRC) at the University of Melbourne. The 3-D model aims to provide a rigorous framework that will identify gaps in geoscientific knowledge, offering new opportunities for mineral deposit discoveries and an immediate stimulus to mineral exploration and research in Tasmania.

The altered facies map covers the area of Mount Read Volcanics from Elliott Bay to Sheffield. It has been compiled from all publicly available data including published papers, unpublished research and company mineral exploration reports on open-file at MRT.

The map was delivered as GIS digital data, spatially registered to the standard 1:25,000 digital topographic base (AGD66) created in ArcInfo v. 8.2 and ArcView v. 3.2a software, plus paper copies at 1:250,000 and 1:100,000 scale.
It has two main components, represented as separate *themes:*

1. *Polygons* that delineate 175 altered zones in plan. They are linked to a table of 39 *attributes*, which systematically describe the altered facies (Table 1).
2. Wholerock geochemical data, and alteration indices derived from them, for several thousand spatially located samples.

Table 2 summarises the contents, relationships and folder locations of the computer files related to GIS data.

Altered facies data sources and search methods

Exploration company reports and academic research theses provided data for most of the altered facies. Published journal articles provided relatively few data but these, where available, were generally of high reliability.

We took several approaches to search for altered facies information:

- Scanning the list of titles for research theses at the School of Earth Sciences & CODES, University of Tasmania produced a short list of all titles that referred to "alteration" or/and Mount Read Volcanics. These theses were then superficially examined, by reading abstracts, tables of contents and lists of plans, to identify promising works, which were subsequently investigated in detail.
- Searches of on-line databases including GeoRef, Geobase, AESIS and MRT's Technical Reports for various combinations of the keywords "alteration, hydrothermal, Mount Read Volcanics and Tasmania". Reading

the abstracts and annotations of the resultant multitude narrowed down the field for detailed follow-ups of the actual journal papers and exploration reports, which were mostly available at UTAS and MRT libraries.
- Spatial representation in ArcView of MRT's borehole database (DORIS) enabled us to identify holes drilled in likely parts of the Mount Read Volcanics. Interrogation of the database revealed the names of interestingly located drill holes, the exploration groups and relevant reports. Those reports were briefly reviewed using MRT's Technical Reports on-line search facility and all favourable leads were followed up at the MRT library.
- Local knowledge assisted by poring over geological maps, particularly the 1:25,000 series produced by the Mount Read Volcanics Project (1986-93), prompted some recollections of exploration programs and discoveries of altered facies, which were followed up by searching for relevant reports by authors, companies, and exploration licence numbers.

We believe that it is an almost complete compilation of currently available *documented* altered facies in the Mount Read Volcanics. There are some notable omissions of altered zones, which are known and even well-described, but have evidently never been delineated in plan; e.g. altered facies around the Henty Mine and Burns Peak — Pinnacles prospects. There are also some altered areas, which have been explored and presumably described and delineated in recent years but the data remain confidential in exploration reports; e.g. Goldfields' exploration at White Spur.

A significant number of recent research theses and exploration reports have reported detailed studies of altered facies in a few drill holes on one or two cross-sections. It is not possible to convincingly represent these altered facies in plan view and unfortunately, some of those fine details could not be included in the GIS compilation as separate facies. This is not easily overcome in western Tasmania where weathering and poor outcrop seriously limit potential for surface mapping of altered facies. Sub-surface data sufficient to construct detailed altered facies plans is largely restricted to around the major mines and although such plans may exist in mine-offices, they are not generally published or publicly available.
There are many cases of detailed descriptions of altered facies, with no accompanying delineation on maps. Que River is an example. Offler and Whitford (1992) described ten assemblages in great detail (including X-ray diffraction, electron microprobe mineral analyses and micro-textural studies) but did not (and perhaps could not because of complexity) separately delineate the zones in plan. Such cases have necessitated simplification of the altered facies to outlines, which envelope entire altered zones. We have attempted to indicate the internal complexities in them by recording all the main minerals and/or noting the existence of diverse assemblages as comments in the attributes table.

There are several cases where single drill holes intersect altered facies but there is insufficient information to interpret and delineate their full extent; e.g. High Point, Cattley Range. However, since the locations of the intercepts are well defined, we have included these altered facies as arbitrary 10 x 10 metre square polygons and assumed they have local distributions.

In some cases, we used different sources for delineation and descriptive details. The 1:25,000 Mount Read Volcanics Project maps nicely delineate many altered zones at appropriate scale, but provide only the barest mineralogic information. By combining those outlines with descriptive data from other sources, we were able to interpret simplified altered facies; e.g. Rosebery and Hercules. This process also involved the loss of detail by forcing variable assemblages into one facies, because they had not been separately delineated by the observers.

Another problem, frequently encountered in research theses, was the 'reductionist' approach to describing occurrence and textures of individual mineral species, rather than as alteration assemblages or facies. Too often, authors delineate zones on plans (e.g. chloritic and sericitic) but in the accompanying texts separately describe the individual species, such as chlorite, sericite, quartz, carbonate and pyrite, in ways that are not clearly linked to the zones.

Our objective in mentioning these deficiencies in the existing data, is to encourage universal adoption of a system of defining and mapping *altered facies* in terms of intensity, distribution, texture and mineralogy (following the method of Gifkins et al., in prep.), rather than individual minerals or assemblages that do not adequately characterise facies.

Nevertheless, the altered facies GIS map is a comprehensive summary of previously *observed* and *documented* altered facies. Some colleagues have suggested that we could include *potentially* altered zones *interpreted* from regional data such as magnetic intensity, radiometric and spectral data. However, we have resisted this temptation because the regionally interpreted altered facies would spatially overwhelm the observed facies, thereby tending to suppress the real data and over-emphasise the potential altered zones. Furthermore, integration of the diverse geologic and geophysical data into the three-dimensional mineralisation and structural model currently under construction will greatly facilitate such further interpretation in the near future. Stimulation of such future research is one of the principal aims of the 3-D model and we did not wish to pre-empt it.

Representation of altered facies

The GIS map *(AltZone.apr)* presents the altered facies polygons as three separate themes, which are coloured or formatted according to the three attributes which combine to form the Alt Facies name: association, intensity and assemblage (as defined in Table 1). Assemblages, being the most variable but least interpretative of these attributes, are represented by 24 solid colours, in colour tones grouped according to 11 major assemblage groups. Association and intensity are formatted with symbols on transparent backgrounds, which when overlaid, enable recognition of assemblage and geologic association, or assemblage and intensity of alteration.

We have not attempted to display the full complexity of *Alt Facies* names because there are over sixty combinations of association, intensity and assemblage sub-groups represented in the data. However, the GIS format enables future users to add new themes graded by any desired attribute.

Wholerock geochemical data

The wholerock geochemical data is based on 7689 analyses recorded in MRT□s Tasmania-wide database, as at February 2003. Weeding out the duplicates and spurious analyses (e.g. 141% Al_2O_3) and pruning off all those east of the Tamar River left 5143 analyses, of which the majority are of Mount Read Volcanics. To that we added 102 analyses generated by the recent Industry-ARC SPIRT isotopic study of Mount Read Volcanics (Davidson et al., 2002) and some more gleaned from research theses to arrive at a total of 5331 analyses for western Tasmania. Some of the SPIRT data are under confidentiality agreement until April 2004, but the industry project sponsors have granted permission for alteration indices calculated from those data to be used in this GIS product.

We encountered, during this project, at least several hundred additional wholerock major and trace element analyses, mainly in research theses, which unfortunately have not been included because of the lack of adequate location details. Scanning tables of analyses and converting to them to digital data via optical character recognition software is a time consuming task, considerably aggravated by the small fonts, gridlines in tables and inconsistent formats typically found in research works. Sample catalogues or lists in some research theses provide AMG co-ordinates separately from the analytical data tables. Retrieval and matching of such data by scanning and conversion of different tables and careful cutting and pasting or use of VLOOKUP functions in spreadsheets, is not trivial. However, drill hole samples located only as borehole numbers and depths present the greatest and too frequent difficulties. Translations to AMG map co-ordinates require accurate details of collar locations and borehole orientation, which may be troublesome to obtain years after closure of mines and exploration offices.
Clearly, in this era of large spatial datasets, all reports of analytical data should now include accurate 3-D (x, y, z) digital location data in widely compatible formats; e.g. as text files (.txt) on CD-ROM.

Alteration Indices

The GIS map *(mrv alteration indices.apr)* includes seven alteration indices, SiO_2 and Na_2O weight percent data and Ti/Zr ratios, presented in themes as colour-graded contours for the area between Hellyer Mine and Mount Darwin. ArcView project *AltZone.apr* displays Ishikawa AI as colour graded dots for all available data in western Tasmania. The alteration indices were calculated from the whole-rock composition data, according to formulas stated below, to highlight compositional changes associated with various styles of alteration.

Index name	Formula	Reference	No. of Hellyer-Darwin[1] data	Percentage of Hellyer-Darwin data (n = 4177)
	(components in weight %)			
Ishikawa AI	$100(MgO+K_2O)/(MgO+K_2O+CaO+Na_2O)$	(Ishikawa et al., 1976)	3442	84.2
CCPI	$100(FeOtotal+MgO)/(FeOtotal+MgO+Na_2O+K_2O)$	(Large et al., 2001b)	3505	83.9
S/Na	$100S/(S+Na_2O)$	(modified from Large et al., 2001a)	1500	35.9
HSAI	$100(SiO_2)/(SiO_2+10MgO+10CaO+10Na_2O)$	(Williams, 2000)	3453	82.7
$MnCO_3$	$100(MnO+CO_2)/(MnO+CO_2+Na_2O)$		969	23.2
MnO_d	30.41(MnO/CaO)	(Large et al., 2000)	3787	90.7
Na_2O%	Na_2O		4168	99.8
SiO_2%	SiO_2		4168	99.8
	(components in ppm)			
Ba/Sr	Ba/Sr	(Large et al., 2001a)	2826	67.7
Ti/Zr	Ti/Zr		3289	78.7

[1] Hellyer-Darwin area refers to the rectangle limited by 370000-395000 E and 5310000-5400000 N.

The formulas (in the calculation spreadsheet) included conditional “IF” statements so that the index values were calculated only if analyses of all components of the index were available, in order to avoid spurious values. The distribution and usefulness of some indices is thus limited because some components were not routinely analysed. For example, Na_2O is almost universal in the Hellyer-Darwin data (99.8%) but the S/Na index is less applicable because only 35.9% of the data include analyses for both sulfur and Na_2O.

The highly selective sampling and irregular distribution of these data are not conducive to contouring. Nevertheless, the colour-contoured maps improve visual appreciation of compositional variations. The contoured plans for all indices and ratios were created in Surfer 7™ software (Anonymous, 1999) using the following parameters:

Grid density	100 x 100 m
Gridding method	inverse distance squared
Search ellipse	300 m E-W and 600 m N-S
Number of sectors searched	4
Maximum number of data in each sector	20
Minimum number of data in each sector	2
Number of empty sectors to produce blank node	2
Contour smoothing	high

This produced coloured maps that provide a fair indication of rock compositions where there are sample data and leave blank areas where no data are available. These maps were delivered as paper copies covering the Hellyer-Darwin area at 1:100,000 scale. They are also included in the GIS package *(mrv alteration indices.apr)* to enable spatial interrogation and displays of the geochem data in other colour schemes, if required. The *Surfer* maps of the alteration indices, plus the associated data grids and legends, are included in the folder *Surfer_geochem*.

Ishikawa AI

This well-known and useful index works well in the MRV data highlighting zones of intense alteration around the major base metal mines and significant anomalies at Mt Charter, Chester, east of Sterling Valley, Selina, Red Hills, Bradshaw Road, Jukes Road and Prince Darwin. It does not show an anomaly at Boco because a large number of analyses in the Boco data lacked MgO.

Na_2O%

Na_2O% shows a very similar pattern to Ishikawa AI confirming that sodium depletion associated with plagioclase destructive alteration is the major influence on AI values. Na_2O% shows strong depletion anomalies at Boco and Mount Darwin, which are not evident in Ishikawa AI, because of the lack of MgO or CaO data in some analyses.

CCPI

The CCPI values are highest in areas of mafic volcanics around Hellyer, Sterling Valley, Henty River and Lynchford. Because of this effect of primary composition on CCPI (Large et al., 2001b) it is not effective, in isolation, as an indicator of alteration intensity in the MRV. It is best used in combination with Na_2O% or Ishikawa AI, as in the CCPI-AI box plot, as a discriminator of alteration style.

S/Na

The applicability of this index is limited by the available data distribution: only 35.9% of the Hellyer-Darwin analyses include both sulfur and Na_2O. Nevertheless, it shows high contrast anomalies at Hercules, Rosebery, Chester and Boco that are clearly related to coincidental increases in sulfide content and degrees of plagioclase destruction. Steep gradients from background values (<10) suggest that values of >20 are likely to indicate rocks that are significantly hydrothermally altered.

HSAI

This “High-Sulfidation Alteration Index” (Williams, 2000) was devised to quantify silicification, destruction of feldspar and absence of carbonate and chlorite, which are characteristics of altered zones associated with high-sulfidation epithermal gold deposits. HSAI’s major limitations are its dependence on SiO_2 which is strongly affected by the phenomenon of closure in composition data (Rollinson, 1993), and the potential negative effect of alunite (hydrous K-Na-Al sulfate) in high-sulfidation assemblages (Herrmann, 2001). AI-HSAI box plots, however, may overcome the ambiguity between chlorite and pyrite inherent in AI-CCPI box plots.

Similarly to Ishikawa AI data, HSAI values are available for about 82% of the analyses in the Hellyer-Darwin block. There are strong HSAI responses around the major base metal deposits and anomalies at Mt Charter, Chester, east of Sterling Valley, Selina, Red Hills, Bradshaw Road, Jukes Road and Prince Darwin, in patterns that are remarkably similar to Ishikawa AI. This co-incidence suggests that the main control on high HSAI is Na_2O depletion, as in the Ishikawa AI. Potential gains of other components in the numerators of these indices (SiO_2 in HSAI, and MgO and K_2O in Ishikawa AI) seem to be less important. The HSAI anomaly at the Chester deposit, arguably the best-represented high sulfidation system in this dataset, is overshadowed by the pre-eminent anomaly at Rosebery. In that sense, HSAI does not effectively discriminate the VHMS-type and high-sulfidation associated hydrothermal systems. It is a measure of intensity of plagioclase destruction, but no more effective than Ishikawa AI or Na_2O%.

MnO_d

The MnO_d index was devised as an indicator of broad scale manganese enrichment in dolomitic host rocks surrounding Zn+Pb SEDEX-type deposits in northern Australian Proterozoic sedimentary basins (Large et al., 2000). It has been experimentally applied to the MRV data to test its response to the Rosebery and Hercules type altered zones, which include Mn-rich carbonate facies. MnO_d indices are available for 90.7% of the Hellyer-Darwin data. They show strong anomalies of MnO_d >80 around Rosebery and Hercules, and effectively discriminate them from the Hellyer-Charter area where MnO_d values are generally below 40. These levels are one to two orders of magnitude higher than in the SEDEX environments where MnO_d values >0.5 are significant. Surprisingly, MnO_d is also anomalous around Chester, Lake Selina, Red Hills, Bradshaws Road and Jukes Road. This generally reflects strong CaO depletion associated with plagioclase destruction, but some of the high MnO_d values at those sites are also associated with high MnO.

$MnCO_3$

The “Manganese Carbonate Index” is an invention of this project, aimed at discriminating the Mn-carbonate rich facies at Rosebery and Hercules from the MnO_d-anomalous but generally carbonate-poor facies of Chester, and other advanced argillic altered facies. The data are limited, by of the paucity of CO_2 analyses, to 23.2% of the samples in the Hellyer-Darwin area and the distribution is fragmental. Nevertheless, $MnCO_3$ appears to fail as a discriminator. Rosebery and Hercules show the strongest responses in $MnCO_3$ but slightly subdued anomalies persist at Chester, Lake Selina, Red Hills, Bradshaws Road and Jukes Road. The Hellyer-Que River altered facies show a slightly enhanced response in $MnCO_3$ relative to MnO_d.

Ba/Sr compositions

The Ba/Sr ratio is an effective medial to proximal geochemical indicator at values >10 around the Rosebery K-lens, due to Ba enrichment of white-micas and Sr depletion associated with plagioclase destruction (Large et al., 2001a). The ratio shows strong anomalies of >40 in the whole-rock geochemical data around the major deposits at Rosebery, Hercules and Hellyer-Que River and some other altered facies including Red Hills, Bradshaws Road and Jukes Road. The high sulfidation type advanced argillic altered facies at Chester and Boco have lower Ba/Sr ratios of 5-40. The Chester zone appears to be partly encircled by a halo of Ba/Sr >40. It suggests that Ba/Sr has potential as a prospect-scale medial to distal geochemical vector for this type of deposit.

Ti/Zr

Ti/Zr, being a ratio of hydrothermally immobile compatible and incompatible elements, has found wide chemostratigraphic usage as a discriminator of volcanic compositions, even in highly altered rocks (Winchester and Floyd, 1977). The MRV Ti/Zr data are arbitrarily divided into five classes: rhyolite <10, dacite 10-20, andesite 20-40, basalt 40-80 and tholeiitic basalts >80. The first four correspond approximately to the subdivisions of Winchester & Floyd (1977) and the last to the western Tasmanian mafic tholeiitic Suites IV and V, of Crawford et al. (1992).

The Ti/Zr distribution in the GIS map is generally faithful to the mapped geology (Corbett, 2002), highlighting the dominance of felsic volcanics in the MRV, partly delineating mafic volcanics at Que-Hellyer, Sock Creek, Hollway Rivulet, Anthony Road and Lynchford, and mafic tholeiites in the Henty Fault dyke swarm, Henty Fault Wedge and Miners Ridge. One minor surprise is in the existence of several samples of high-Ti basalts from near the western margin of the Murchison “granite”. These are possibly analogues of Suite IV dykes, which are not common east of the Henty Fault.

The reasonably high availability of Ti/Zr data (78.7% of the analyses in the Hellyer-Darwin area) suggests an application for Ti/Zr as a filter for CCPI, as a discriminator between high CCPI samples that had non-altered-mafic, and altered-felsic origins.

SiO_2%

The SiO_2% map shows a broadly similar pattern to Ti/Zr, reflecting the dominance of felsic rocks and picking out the areas of mafic rocks mentioned above. Some of the altered mafic rock areas, such as Que-Hellyer and Hollway andesite, include high-SiO_2 patches, which confirm (what everybody should already know) that SiO_2 is highly mobile in hydrothermal systems. Because of its mobility, and its high susceptibility to effects of closure in composition data, SiO_2% is not on its own a useful indicator of alteration intensity or of primary rock composition in altered volcanics.

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References

Anonymous, 1999, Surfer 7, Golden Software Inc. Golden, Colorado, 80401-1866, USA.

Corbett, K. D., 2002, Bedrock geological map of the Mt Read Volcanics belt and adjacent areas - South Darwin Peak to Hellyer; 1:100,000 scale: Hobart, Mineral Resources Tasmania, Department of Infrastructure, Energy & Resources.

Crawford, A. J., Corbett, K. D., and Everard, J. L., 1992, Geochemistry of the Cambrian volcanic-hosted massive sulfide rich Mount Read Volcanics, Tasmania, and some tectonic implications: Economic Geology, v. 90, p. 597-619.

Davidson, G. J., Herrmann, W., Green, D. G., Green, G. R., Blake, M., Solomon, M., and Bassano, K., 2002, Isotopic response of fluid flow in submarine volcanic-hosted hydrothermal systems and its implications for prospectivity: Mount Read Volcanics case study: Industry-ARC SPIRT project, final report, Centre for Ore Deposit Research, University of Tasmania, October, 2002.

Gifkins, C. C., Herrmann, W., and Large, R. R., in prep., Altered volcanic rocks - a guide to description and interpretation, Centre for Ore Deposit Research, University of Tasmania.

Herrmann, W., 2001, Boco prospect: major element, sulfur isotope and oxygen isotope geochemistry: Progress Report 3, Industry-ARC SPIRT Project: Stable and radiogenic isotope applications to ranking prospects in volcanic and volcanosedimentary terrains: Mt Read Volcanics study, Centre for Ore Deposit Research, University of Tasmania.

Ishikawa, Y., Sawaguchi, T., Iwaya, S., and Horiuchi, M., 1976, Delineation of prospecting targets for Kuroko deposits based on modes of volcanism of underlying dacite and alteration halos: Mining Geology, v. 26, p. 105 —117, (in Japanese with English abstract).

Large, R. R., Allen, R. L., Blake, M. D., and Herrmann, W., 2001a, Hydrothermal alteration and volatile element halos for the Rosebery K lens volcanic-hosted massive sulfide deposit, western Tasmania: Economic Geology, v. 96, p. 1055-1072.

Large, R. R., Bull, S. W., and McGoldrick, P. J., 2000, Lithogeochemical halos and geochemical vectors to stratiform sediment hosted Zn-Pb-Ag deposits Part 2. HYC deposit, McArthur River, Northern Territory: Journal of Geochemical Exploration, v. 68, p. 105-126.

Large, R. R., Gemmell, J. B., Paulick, H., and Huston David, L., 2001b, The Alteration Box Plot: a simple approach to understanding the relationship between alteration mineralogy and lithogeochemistry associated with volcanic-hosted massive sulfide deposits.: Economic Geology, v. 96, p. 957-971.

Offler, R., and Whitford, D. J., 1992, Wall-rock alteration and metamorphism of a volcanic-hosted massive sulfide deposit at Que River, Tasmania: petrology and Mineralogy: Economic Geology, v. 87, p. 686-705.

Rollinson, H. R., 1993, Using geochemical data: evaluation, presentation, interpretation, Longman, 352 p.

Williams, N. C., 2000, The Basin Lake high sulfidation alteration system, western Tasmania: Unpub. B.Sc. Honours thesis, University of Tasmania, 102 p.

Winchester, J. A., and Floyd, P. A., 1977, Geochemical discrimination of different magma series and their differentiation products using immobile elements: Chemical Geology, v. 20, p. 325-343.

<u>Table 1</u> **Altered facies attributes**

No.	Attribute name	Explanation
01	Shape	*ArcInfo*-derived attribute i.e. polygon
02	Area	Area in square metres as calculated by *ArcInfo*
03	Perimeter	Perimeter in metres as calculated by *ArcInfo*
04	Arcinfo_a	Extraneous *ArcInfo*-assigned number
05	Arcinfo_b	Extraneous *ArcInfo*-assigned number
06	Altzone_id	Unique number which identifies each altered zone on the map
07	Geogarea	Name of the geographic area; e.g. name of nearby mineral prospect, mine, river, mountain etc.
08	Map_sheet	Name of 1:25,000 scale map sheet on which the altered zone is located.
09	Amg_e	AMG easting of approximate centre of the altered zone
10	Amg_n	AMG northing of approximate centre of the altered zone
11	Depth	Numeric code indicating subsurface or vertical extent, classified into four categories: • 50 denoting shallow zones <50 m deep • 250 denoting depth range 0-250 m • 500 denoting depth range 250-500 m • 999 denoting depth >500 m.
12	Distrib	Qualitative indication of the area extent of altered zone according to four categories: • unknown • local: up to several hundred metres lateral extent • kilometers: 1-3 kilometers extent • district: >3 kilometers extent
13	Morphology	Indication of the three dimensional shape of the altered zone and/or structural relationships: • contact aureole • fault zone • fracture controlled intra granitoid • halo around felsic stock • intrusive margin • pipe • pod • sill margin • stockwork • stratiform • stratiform adjacent to fault • stratiform and/or stockwork • stratiform in fault zone • stratiform stacked • unknown • vein related
14	Relmindep	Relationship to mineral deposit, if any: • along strike from minor vein & disseminated sulfides • enveloping low grade gold mineralized zone • enveloping minor disseminated and vein-type pyrite/chalcopyrite/magnetite mineralized zones • enveloping minor polymetallic sulfide +/- carbonate veins • enveloping sparse massive sulfide clasts • footwall • medial footwall of sulfide lens • medial halo • medial to lateral footwall • nil • proximal footwall • proximal halo

- proximal hangingwall
- structural repetition of footwall
- unknown

15	Del_rel	A subjective assessment of the accuracy of the delineation of the mapped altered zone. Expressed as an alphabetic code: L low reliability M moderate reliability H high reliability
16	Texture	Description of textures produced by alteration, particularly if significant in terms of process. It is highly variable, in both form and descriptive terminology, and we have tried to retain much of the primary descriptive detail in the following classification: • disseminated and/or veiny • foliated • massive CH and spotty CB in CH matrix • massive pervasive • massive pervasive & vein related • massive pervasive or breccia matrix fill and wispy • massive to veined typically overprinted by CH veins • patchy • patchy disseminated to semi-pervasive • patchy pervasive • patchy semi pervasive • patchy to pervasive • pervasive • pervasive & brecciated • pervasive and foliated • pervasive and primary fabrics obliterated • pervasive and sheared • pervasive but primary fabrics preserved • pervasive foliated • pervasive massive • pervasive massive to foliated • pervasive massive to spotty and spheroidal • pervasive mottled or with CH in veins & breccia fill • pervasive or veiny and disseminated overprinting K-feldspar alteration • pervasive typically associated with cb vein stockwork; primary fabrics preserved • pervasive; siliceous augen defined by sericite foliae • pervasive; siliceous augen defined by sericite foliae; spotty-nodular CB in massive CH • selective pervasive • selective to pervasive • semi pervasive • semi pervasive breccia fill • semi pervasive foliated • semi pervasive patchy • stockwork to semi-pervasive • stringer veinlets • unknown • vein associated • veins & breccia matrix • veins and nodules
17	Intensity	Indication of the intensity of alteration. It has been interpreted where the original source did not describe intensity, or had used other terms such as slight, minor or major. Expressed as floating point numeric codes on a scale of one to four: 1 weak 1.5 weak-moderate 2 moderate 2.5 moderate-strong 3 strong 3.5 strong-intense 4 intense

18	Assemblage			Floating-point numeric code related to dominant mineralogy classified into eleven major groups and twenty-four sub-groups. The corresponding alphanumeric codes (at left) are used in the “Alt Facies” name.
	1	QZ	1	Siliceous assemblage with low phyllosilicate content, – sulfides
	2	PR/KA	2	Assemblage containing pyrophyllite or kaolinite; usually with quartz, sulfide and minor sericite but no carbonate or chlorite
	3	QZ+SE+PY	3	Quartz, sericite and pyrite; no carbonate
	3.1	QZ+SE+PY1	3.1	Quartz, sericite, pyrite and carbonate
	4	SE	4	Essentially sericite without major quartz; – chlorite & carbonate
	4.1	SE1	4.1	Sericite coexisting with K-feldspar; – carbonate and sulfides
	4.2	SE2	4.2	Sericite – quartz & carbonate but no sulfides or magnetite etc.
	4.3	SE3	4.3	Sericite – quartz, carbonate & chlorite but no sulfides, magnetite.
	4.4	SE4	4.4	Sericite + chlorite assemblage – quartz & sulfides; no CB
	4.5	SE5	4.5	Sericite + chlorite assemblage – quartz, sulfides & carbonate
	5	CH	5	Chlorite – minor sulfides, magnetite, carbonate etc.
	5.1	CH1	5.1	Chlorite and quartz – minor sulfides, magnetite, carbonate etc.
	5.2	CH2	5.2	Chlorite, quartz and sericite – minor sulfides, magnetite, carbonate.
	6	CH+CB	6	Chlorite and carbonate – sulfides
	7	CH+FE	7	Chlorite with Mt/Hm – sulfides, quartz, sericite, carbonate etc.
	7.1	CH+FE1	7.1	Chlorite & hematite – sulfides, qtz, sericite, carbonate etc.
	8	KS	8	K-feldspar – quartz, chlorite and sericite
	8.1	KS1	8.1	K-feldspar – quartz, chlorite and sericite with minor pyrite, Mt/Hm.
	9	HM	9	Hematite
	9.1	HM1	9.1	Hematite and carbonate
	9.2	HM2	9.2	Hematite and sericite, quartz and pyrite
	10	EP	10	Quartz and epidote
	10.1	EP1	10.1	Quartz, epidote and chlorite
	11	TM	11	Tourmaline bearing assemblages
19	Major_min			Major mineral constituents, restricted to 5 or less, expressed as two-character capitalised & abbreviated codes separated by spaces in a 25-character field. The mineral codes used are listed in Table 3. Many are similar to codes used by the MRT ISOTAS database. The MRT codes allow up to three characters (e.g. CCP for chalcopyrite) and two-letter codes that have full stops for the third character (e.g. AB. for albite and PY. for pyrite). To save space and for consistency, we have opted for two-character mineral codes. They will be simple to translate for any subsequent users who prefer the MRT codes.
20	Minor_min			Minor mineral constituents, restricted to 5 or less, expressed as two-character capitalised & abbreviated codes separated by spaces in a 25-character field.
21	Major_elem			Major associated metallic or potentially economic elements, expressed as two-character abbreviated codes based on chemical symbols, separated by spaces in a 25-character field; e.g. Cu Zn Ba Si S.
22	Minor_elem			Minor associated metallic or other elements of interest, expressed as two-character abbreviated codes based on chemical symbols, separated by spaces in a 25-character field; e.g. Mo Au Sb.
23	Geoch_data			Indication of the type of existing whole-rock geochemical data as reported by the observer/s of the altered zone; e.g. nil, unknown, major elements, P, Ti, Zr, S, CO_2, trace elements (listed by chemical symbol if only a few). This generally relates to data reported in the primary source and may omit geochemical data from other sources. However, some other geochemical data may be included in the associated geochemical database.
24	Isotop_data			Indication of the type of existing isotopic analyses as reported by the observer/s of the altered zone, expressed as self-explanatory alphabetic codes: • carbonate C & O • Pb • S • Sr • wholerock O

25	Min_det	Indication of the observation methods used to determine mineralogy of the altered zone, which contributes to the assessment of Desc Rel (below). Expressed as an alphabetic code for the following categories: A XRD B electron microprobe analysis C SWIR D microscopic E megascopic
26	Desc_rel	A subjective indication of the reliability of the original observations and description. Expressed as an alphabetic code: L low reliability M moderate reliability H high reliability
27	Associat	The general geologic setting of the altered zone, expressed as a 3-character alphabetic code. These codes are leading components of the 'Alt Facies' names. FIR felsic intrusion related, including Cambrian granitoids MIR mafic-intermediate intrusion related FVH felsic volcanic hosted, including coherent and volcaniclastic facies MVH mafic-intermediate volcanic hosted, including coherent and volcaniclastic facies SIC hosted by Cambro-Ordovician siliciclastic rocks
28	Host_litho	150-character field for a brief lithologic description, generally retaining the descriptive terminology used in the primary source.
29	Spgrp	2-letter code consistent with MRT's existing database authority table for stratigraphic supergroups: CD Cambrian mafic intrusive rocks CF Cambrian felsic volcanic rocks CG Cambrian granitoids and intrusive porphyries CM Cambrian mixed derivation sequences CS Cambrian sedimentary sequences CV Cambrian felsic volcano-sedimentary sequences
30	Alt_facies	Codified descriptive altered facies names, which are based on the attributes of association, intensity and assemblage, in that sequence, following the methodology of Gifkins et al. (in prep.). The Alt Facies names were constructed by stringing together the component codes to produce over sixty combinations. For example, FVH 2 QZ+SE+PY1 means "felsic volcanic hosted, moderate intensity, quartz + sericite + pyrite + carbonate altered facies". This is a slight departure from the intensity + distribution + texture + mineralogy nomenclature recommended by Gifkins et al. (in prep.). It is justified by the distributions being self-evident in the map format, and the highly variable, non-systematic terminology used for textural descriptions.
31	Altprocess	Broadest classification of alteration type; e.g. diagenetic, contact metamorphic, hydrothermal or unknown. Classification is partly interpretative, and partly based on recorded attributes and conclusions reported in the source data.
32	Refno	Number linking the sources of altered zone data to the REFERENCE table in MRT's databases, e.g. ISOTAS. The six attributes of the reference (below) have been recorded for all altered zones, whether or not their REFNOs are known.
33	Year	Year of publication or reporting of the principal source data.
34	Orig	2 or 3-letter code for the observer or organisation that mapped and reported the altered zone; based on MRT's existing authority table used in the ISOTAS database.
35	Authors	List of Authors.
36	Title	Title of the reference.
37	Source	Name of journal or organisation that produced the reference, including volume and page numbers where appropriate.
38	Tcrn	Catalogue number of open-file company exploration report in MRT library.
39	Comments	Additional descriptive data, references for additional sources of data and so on.

Table 2 **Description of computer files related to GIS Map of Altered Facies.**

NB: The GIS related files were created in ArcInfo version 8.2 and ArcView version 3.2a software.

File name	Folder	Description
5331Analy.txt	*geochem_shapefile and alt_shapefile*	Text file containing analyses, alteration indices and location data for 5331 whole-rock geochemical samples from western Tasmania. Duplicates of this file are linked to the ArcView projects: *mrv alteration indices.apr* and *AltZone.apr.*
.avl	*geochem_shapefile*	ArcView *legends* used to classify and display alteration indices data in *mrv alteration indices.apr.* Note that CCPI, S/Na, HSAI, $MnCO_3$ all have similar legends, from 0-100 in steps of 10.
AltAttrib.xls	*files_MRT*	Microsoft Excel“ version of attribute table for *mrv_alt.shp* in condensed and codified form
AltZone.apr	*alt_shapefile*	ArcView *project* file that displays a *view* of the altered zones, classified according to alteration intensity, assemblages and geological settings (Associat). The project contains additional *themes* showing the locations of wholerock geochemical samples (colour graded by Ishikawa AI), borehole locations (DORIS), and topographic contours and streams (1:250,000 data).
mrv alteration indices.apr	*geochem_shapefile*	ArcView *project* file that displays a *view* containing various *themes* of alteration indices, calculated from existing whole-rock geochemical data, graded by colours. The *spatial analyst extension* in ArcView must be checked (switched on) in order to open this *project*.
mrv_alt.e00	*infofile*	File that can be imported directly into ArcInfo to obtain access to the ArcInfo files used in construction of the altered facies polygons. This facilitates export of GIS altered facies data into other spatial information software, e.g. MapInfo.
mrv_alt.shp *mrv_alt.dbf* *mrv_alt.sbn* *mrv_alt.sbx* *mrv_alt.shx*	*alt_shapefile*	ArcView shapefiles that delineate and describe altered facies in the Mount Read Volcanics
RawAltAttrib.xls	*files_MRT*	Microsoft Excel“ version of the attribute table in its raw form, before codification. This version largely retains descriptions of the altered facies as reported in the original source data.

Table 3 **Mineral Abbreviation Codes**

Mineral	Code	Mineral	Code	Mineral	Code
actinolite	AC	fluorite	FL	pyroxene	PX
albite	AB	fuchsite	FU	pyrrhotite	PO
alunite	AL	galena	GN	quartz	QZ
amphibole	AM	garnet	GR	rhodochrosite	RD
ankerite	AK	goethite	GT	sericite	SE
apatite	AP	hematite	HM	siderite	SD
arsenopyrite	AS	illite	IL	smectite	SM
barite	BA	ilmenite	IM	sphalerite	SP
biotite	BI	iron oxides & sulfides	FE	sulfide	SF
bornite	BN	jasper	JA	talc	TC
calcite	CA	kaolinite	KA	tetrahedrite	TE
carbonate	CB	K-feldspar	KS	topaz	TO
cassiterite	CS	limonite	LM	tourmaline	TM
chalcopyrite	CP	magnetite	MT	tremolite	TR
chlorite	CH	mica	MI	unknown	U
clay	CL	montmorillonite	MM	white mica	WM
corundum	CO	muscovite	MS	wolframite	WF
dickite	DK	paragonite	PG	wollastonite	WO

dolomite	DO	plagioclase	PL	zeolite	ZE
epidote	EP	pyrite	PY		
feldspar	FS	pyrophyllite	PR		