Mount Read Volcanics: Host sequence to Cambrian massive sulphide deposits in western Tasmania

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INTRODUCTION

The Mount Read Volcanics of western Tasmania is famous worldwide for the abundance and richness of deposits of massive sulphides that they contain. Hellyer, Rosebery, Mount Lyell, Hercules and Que River all win ore from within the volcanics (fig. 1). Sea-floor volcanic-hosted massive sulphide (VHMS) mineralisation involves processes that partly depend on and affect the enclosing, contemporaneous host sequence. Therefore, understanding the genesis of known ore bodies, and successful exploration for new deposits, rely on a clear definition of the setting and character of the host volcanic rocks.

Although generally recognised as highly prospective for VHMS mineralisation, the Mount Read Volcanics present a formidable challenge in this regard. The volcanics have been affected by regional deformation and metamorphism, and locally hydrothermal alteration is intense. Useful exposures of the volcanics are very limited in extent and unevenly distributed, and some areas are enormously difficult to access. All these factors make geological mapping, the first step in exploration, a particularly difficult task.

In spite of the difficulties, a number of recent developments have paved the way for further major advances in understanding the Mount Read Volcanics. In particular, high-quality 1:25 000 scale geological maps which use consistent stratigraphic nomenclature are now available for the full extent of the volcanics. The maps are the outcome of systematic regional mapping by geologists of the Tasmania Department of Mines (Corbett, 1992), and provide a comprehensive database upon which other research projects can build. Secondly, progress in understanding the processes and products of sea-floor felsic volcanism has greatly accelerated in recent times. Deep-ocean volcanic environments are now accessible to direct observation by means of deep tow cameras, SEAMARC and GLORIA sonar technology, submersibles, and drilling. Field studies of submarine volcanic sequences that are now well-exposed on land are currently in vogue in physical volcanology. A particularly important recent discovery is the frequent occurrence of syn-sedimentary sills in deep-ocean extensional settings, and their potential to initiate and sustain hydrothermal circulation in unconsolidated host sediments (Einsele *et al.*, 1980; Einsele, 1986; ODP Leg 139, 1992). Finally, detailed research into the textural and mineralogical effects of hydrothermal alteration on volcanic host rocks to massive sulphide deposits suggest the power of alteration facies mapping as a tool in exploration. This paper briefly reviews recent achievements in these areas, and their implications for mineral exploration in the Mount Read Volcanics.

REGIONAL LITHOSTRATIGRAPHY IN THE MOUNT READ VOLCANICS

Systematic 1:25 000 scale regional mapping has led to the recognition of four main lithostratigraphic units (fig. 1; Corbett, 1992; Crawford *et al.*, 1992):

(i) the Central Volcanic Complex is dominated by feldspar-phyric rhyolitic lavas and very thick, pumiceous volcaniclastic units;

(ii) the Eastern quartz-phyric sequence comprises quartz and feldspar-bearing lavas, intrusions and volcaniclastic units;

(iii) the Western volcano-sedimentary sequences include packages dominated by well-bedded, volcaniclastic and Precambrian basement-derived sandstone and conglomerate which in places contain Cambrian marine fossils. There are three geographically-defined packages: the Yolande River sequence, the Dundas Group and the Mount Charter Group. The Yolande River sequence and the Mount Charter Group both locally contain significant thicknesses of andesitic and dacitic lavas and intrusions;

(iv) the Tyndall Group consists of quartz-bearing volcaniclastic units, minor rhyolitic lava, minor welded ignimbrite, and non-volcanic sandstone and mudstone.

Regional mapping has also established the importance of major faults, such as the Henty Fault and Rosebery Fault, and provides an invaluable framework for further detailed structural studies.

PHYSICAL VOLCANOLOGY OF THE MOUNT READ VOLCANICS

One of the most significant recent breakthroughs in understanding volcanic sequences has been the recognition of the control exerted by emplacement or depositional processes on facies geometry. Volcanic sequences typically contain the products of both effusive and explosive eruption styles. Each style has the potential to generate a variety of volcanic facies with markedly different internal textures, structures, geometry and extent. For example, extrusion of felsic lava onto the sea floor is normally accompanied by (fig. 2):

(1) genesis of autoclastic facies (especially quench-fragmented hyaloclastite);

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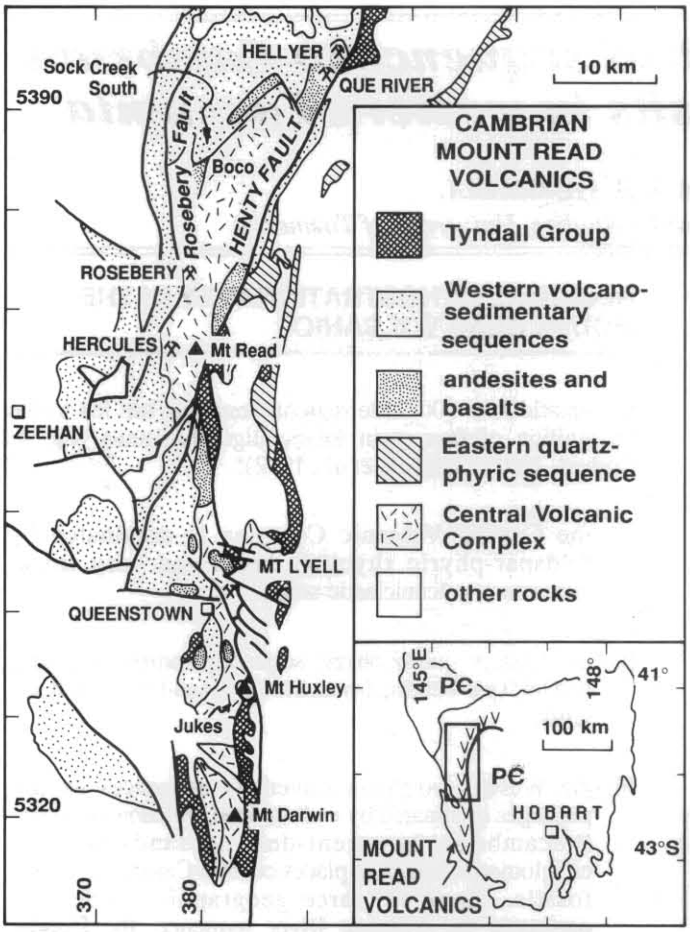

Figure 1

Distribution of the principal lithostratigraphic formations and major massive sulphide deposits in the Cambrian Mount Read Volcanics of western Tasmania (based on Corbett, 1992)

(2) complex mixing between the wet, poorly-consolidated sediment substrate and lava (producing peperite);

(3) resedimentation processes primarily derived from the growing autoclastic pile (resedimented hyaloclastite); and

(4) intrusion of magma pods and lodes into the lava pile.

Contemporaneous volcanic facies equivalents will be texturally diverse (fig. 2*b*), and correct correlation depends on recognition of genetically-related volcanic facies associations.

Submarine volcanic sequences also contain units which are laterally juxtaposed but which are not genetically related. For example, felsic lava domes are constructional and create topography which may be later infilled by pumiceous mass-flow deposits from an extrabasinal source (fig. 3). Correlation of drill-hole sections which include coherent lavas and mass-flow emplaced volcaniclastic units should consider such a facies relationship, among other possibilities.

Research using this approach has clarified the principal volcanic facies and facies architecture of the Mount Read Volcanics (fig. 4; McPhie and Allen, 1992):

(i) normal background sedimentation is recorded by pelagic mudstone and turbidite sandstone of mixed or Precambrian metamorphic basement provenance;

(ii) background sedimentation was episodically interrupted by emplacement of lavas and volcaniclastic mass-flow deposits;

(iii) lavas and related autoclastic deposits (autobreccia, hyaloclastite breccia, and re-deposited equivalents) occur separately or in clusters within more extensive volcano-sedimentary sequences;

(iv) in many cases, rising magma that encountered unconsolidated, relatively low density, water-saturated sediment remained embedded below the surface and/or mixed extensively with the host sediment; surface flows commonly foundered into the weak sediment substrate and advanced as shallow sills; and

(v) mass flows which deposited widespread pumiceous and/or crystal-rich sandstone-breccia units included some cases which correlated directly with explosive eruptions and other cases which were the results of resedimentation after temporary storage.

The volcanic facies in this architecture may include the products of both intrabasinal and basin margin or extrabasinal eruptions. Silicic lava and lava breccia sequences are likely to be from intrabasinal sources. Sources of extensive and voluminous pumiceous volcaniclastic mass-flow deposits are less easily constrained. The implied explosive eruption style is likely to have been restricted to volcanic centres in parts of the basin that were shallower than about 1000 m, or else in basin margin or nearby subaerial settings. The mass-flow packages generated from large explosive eruptions are likely to be widely distributed, rapidly emplaced, and readily distinguishable from enclosing facies. They therefore provide very good stratigraphic markers.

The relevance of understanding emplacement processes to mineral exploration in the Mount Read Volcanics was recently highlighted by the discovery of clasts of massive sulphide in volcanic breccia exposed by Hydro-Electric Commission excavations of the Newton Dam spillway (Gibson, 1991). The breccia contains a wealth of information on the source of the sulphide clasts, transportation and depositional processes, and setting. The clast assemblage reflects a dacite lava-dominated source. Some dacite clasts and clast clusters show jigsaw-fit texture, suggesting *in situ* dilation of prepared quench fractures. The breccia forms the basal part of a single sedimentation unit and is overlain sharply by diffusely bedded, crystal-rich sandstone that forms the top of the unit. This lithofacies organisation indicates deposition from a high-density, subaqueous, gravelly-sandy, volcaniclastic turbidity current in a below-wave-base environment (cf. Lowe, 1982). The unit may record collapse of an unstable part of an active dacite lava dome, on the flanks of which was a substantial massive sulphide deposit. The location of the source of the sulphide clasts cannot be determined from the exposure and remains a tantalising mystery.

Facies analysis reveals that the sea-floor hydrothermal systems responsible for the massive sulphide mineralisation in the Mount Read Volcanics operated in a variety of volcanic hosts and settings. In particular, the volcanic facies associations that dominate the Western volcano-sedimentary

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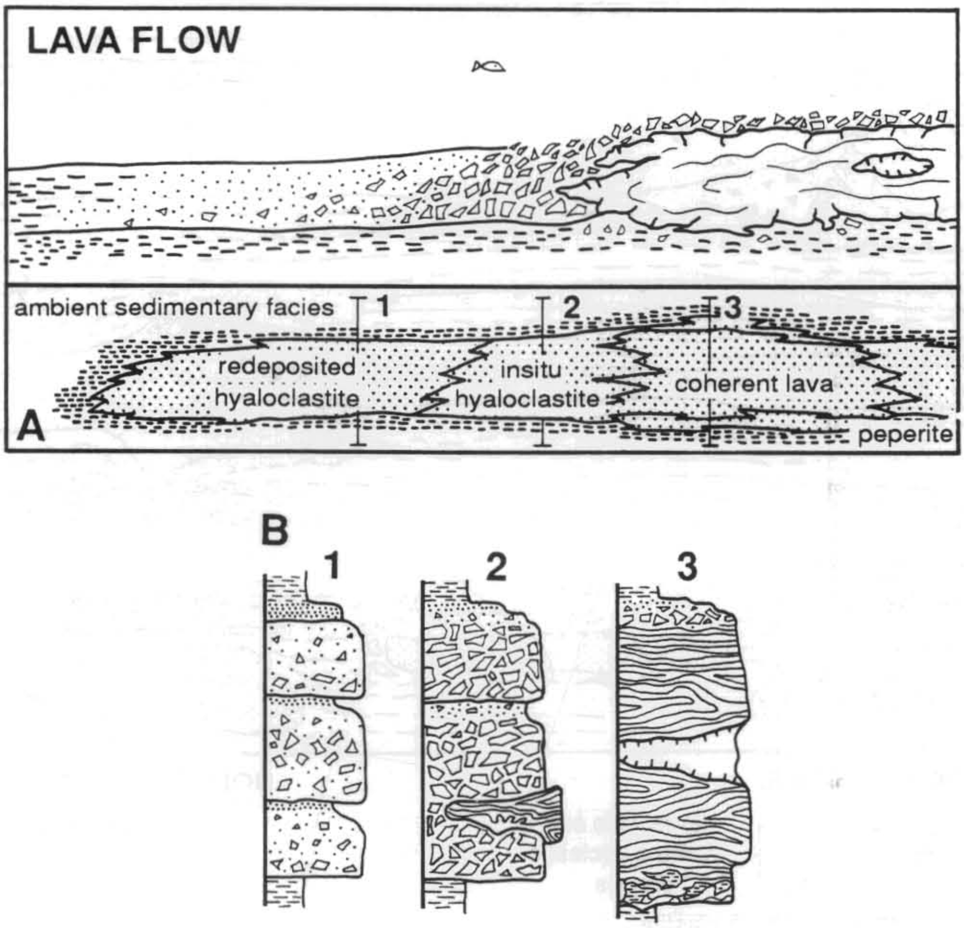

Figure 2

Character and arrangement of facies that develop in association with the emplacement of a felsic lava flow on the sea floor.
(a) The ideal genetically-related and contemporaneous volcanic facies association.
(b) Drill hole sections at different positions (1, 2, 3) in the ideal volcanic facies association.

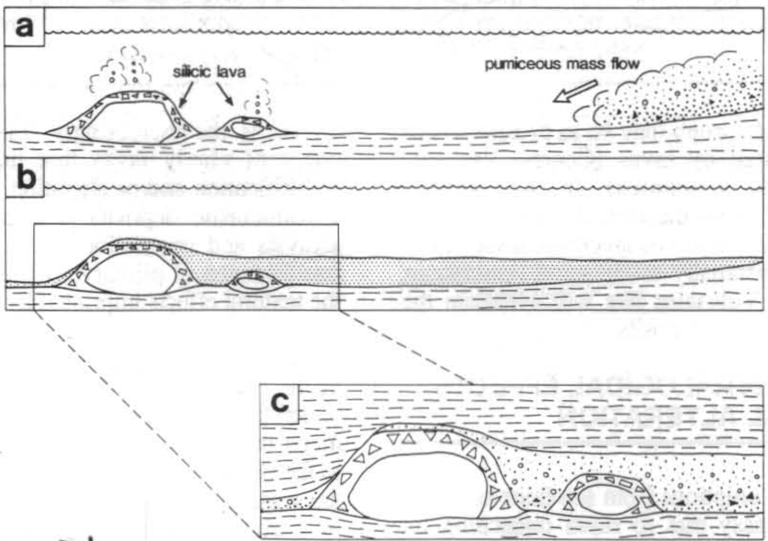

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Figure 3

Sketches illustrating a case of contemporaneous, laterally equivalent volcanic facies that are not genetically related. (a) A freshly emplaced silicic lava dome and breccia carapace has constructed considerable sea-floor topography. Pumiceous mass flows sourced elsewhere sweep into the basin. Such mass flows are sediment gravity flows that in general are constrained to flow downslope. Some may be generated directly by eruptions or else result from resedimentation of volcaniclastic debris after temporary storage. (b) The mass flows deposit a widespread, relatively thin volcaniclastic layer that fills in the topography created by the lava dome and breccia. (c) Final facies geometry in detail: the background sedimentary facies encloses two genetically distinct volcanic facies that are directly juxtaposed and that were emplaced essentially contemporaneously.

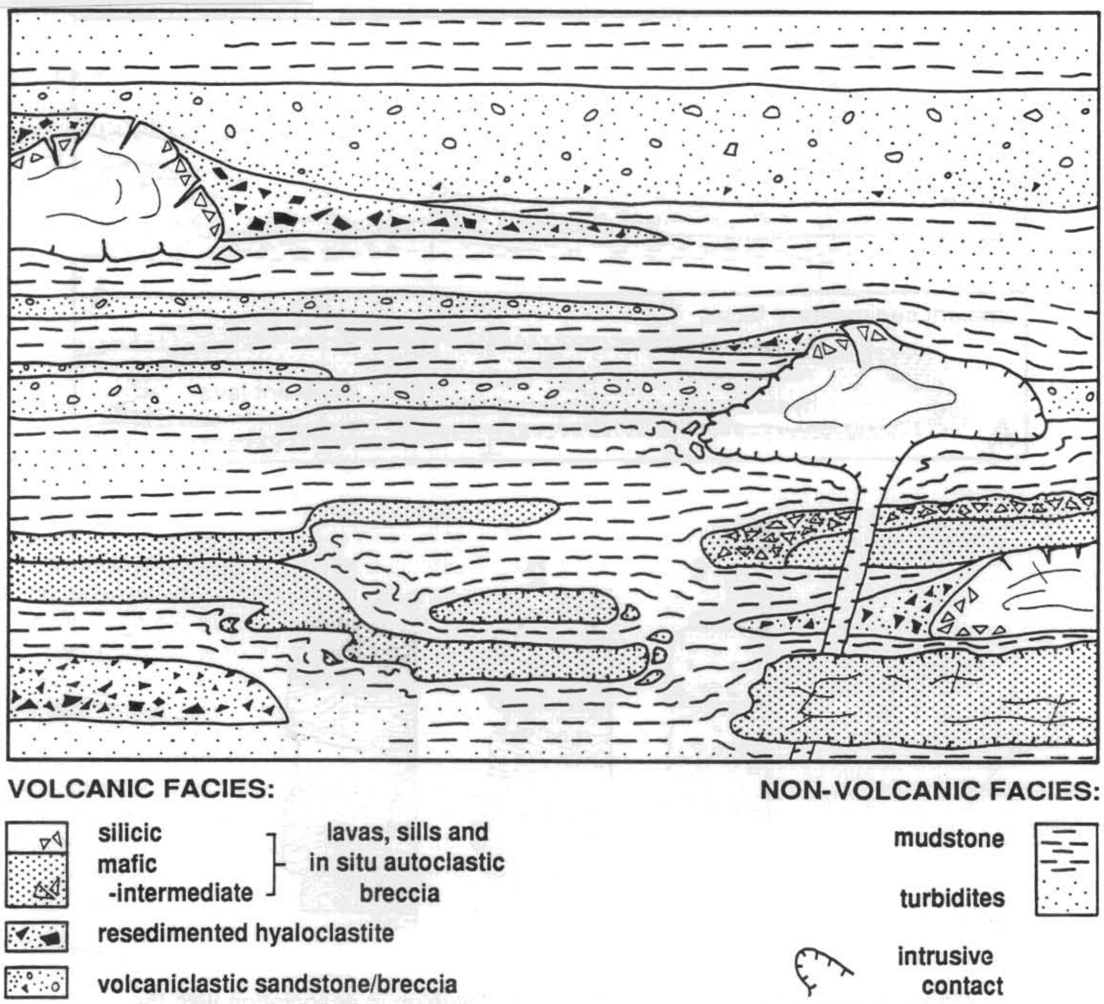

Figure 4

Principal elements in the facies architecture of the Mount Read Volcanics, western Tasmania. Sills are at least as important as surface flows. Volcaniclastic mass-flow deposits include resedimented hyaloclastite from intrabasinal lava flows and domes, and thick tabular units of pumice breccia that provide good markers for correlation. There are considerable regional variations in relative proportions of lava flows, sills and volcaniclastic units, and in volcanic versus non-volcanic facies.

sequences and the Tyndall Group may be as prospective as the formations dominated by lavas (Central Volcanic Complex, Que–Hellyer Volcanics). In fact, such a volcaniclastic association hosts the Hercules and Rosebery massive sulphide deposits. These volcaniclastic associations also offer a means of eventually establishing correlations within the Mount Read Volcanics that will constrain the relative ages of the known ore deposits.

TEXTURAL AND MINERALOGICAL EFFECTS OF HYDROTHERMAL ALTERATION

The products of volcanic eruptions from sea-floor vents are commonly originally glassy due to rapid quenching on contact with water. Volcanic glass is, however, a metastable solid which devitrifies during slow cooling, or else eventually crystallises in response to metamorphism or alteration. Volcanic glass readily hydrates, especially in subaqueous settings. Hydration involves a slight increase in volume that produces fine arcuate cracks (perlitic fractures) throughout the glass. The textural effects of hydration, devitrification and alteration of glassy volcanic rocks may be dramatic, and result in a potentially bewildering array of new textures, some of which closely resemble other primary volcanic textures (Allen, 1988). One of the most conspicuous effects is the increasingly "clastic" texture assumed by coherent glassy lavas that have undergone hydration, devitrification and/or alteration. Distinguishing lavas from volcaniclastic deposits is critically important in facies analysis and correlation studies, and depends on correct interpretation of primary textures, as well as recognition of the textural effects imprinted by alteration.

Awareness of the textural effects of hydrothermal alteration in the Mount Read Volcanics has greatly refined current understanding of the volcanic facies that host some of the major massive sulphide deposits. For example, the footwall to the Hercules and Rosebery massive sulphide ore deposits has a macroscopic texture comprising phyllosilicate lenses in a siliceous matrix that closely resembles a welded ignimbrite. However, detailed textural and lithofacies studies (Allen and Cas, 1990; Allen and Hunns, 1990) have shown that the texture is the result of domainal phyllosilicate and siliceous alteration. The primary texture is locally well preserved in siliceous domains, and comprises abundant, variably oriented, tube pumice clasts in which vesicles are uncollapsed, indicating that the deposit was non-welded. Deciphering the textural effects of alteration has allowed definition of the lithofacies characteristics. The footwall sequence in fact comprises very thick graded units of pumice

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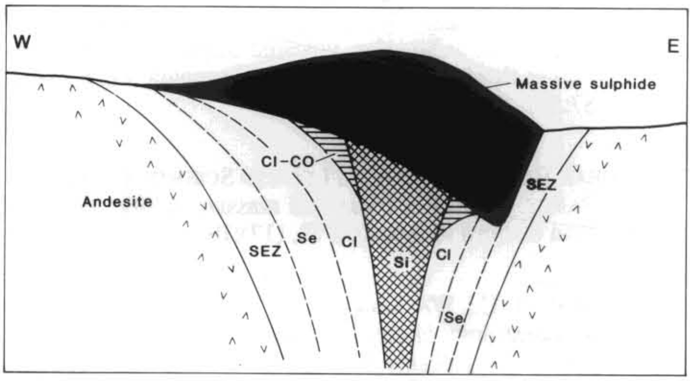

Figure 5

Schematic reconstruction of the alteration zones in the centre of the hydrothermal system below the Hellyer massive sulphide deposit. SEZ, stringer envelope zone; Cl, chlorite; CO, carbonate (primarily dolomite); Se, sericite; Si, quartz.

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breccia that were deposited from voluminous submarine mass flows (Allen and Cas, 1990).

Studies of the mineralogical and compositional changes that accompany hydrothermal alteration have enormous importance for the recognition of potentially mineralised sequences. The known ore deposits in the Mount Read Volcanics are associated with alteration styles that vary in extent, intensity and character. One of the most carefully documented is the footwall alteration to the Hellyer massive sulphide deposit (Gemmell and Large, 1992). The main feature is a vertically extensive alteration pipe, immediately below the ore body (fig. 5). The pipe has plan dimensions of 1500 × 350 m, and has been explored to 550 m into the footwall below the ore body. Elsewhere nearby, the less-altered footwall comprises massive and pillowed basaltic sheets overlain by a thick sequence of feldspar-phyric andesitic and dacitic lavas, sills and related clastic deposits (Waters and Wallace, 1992).

Within the pipe, hydrothermal alteration has almost entirely overprinted the original textures and mineralogy. Four well-defined alteration zones have been recognised (fig. 5):

(i) the siliceous core (silica ± sericite ± chlorite);

(ii) the chlorite zone (chlorite ± sericite ± carbonate);

(iii) the sericite zone (sericite ± chlorite);

(iv) the outermost, stringer envelope zone (silica ± sericite).

Within the siliceous core, a stronger system of syn-mineralising veins is well developed. Mineralisation in the core of the stringer system is Cu-rich, and grades outward to being more Pb + Zn-rich.

There are several aspects of the alteration associated with the Hellyer ore body which illustrate the influence exerted by the host volcanic sequence. In particular, the sharp definition of the alteration pipe reflects the relatively competent nature of the footwall volcanics, together with a syn-volcanic structural control, both of which had the effect of narrowly focusing the hydrothermal system. The ore body is overlain by volcaniclastic mass-flow deposits and sheets of basalt. Both these volcanic facies were rapidly emplaced, and were clearly important in the preservation of the massive sulphide mound. In fact, basalt above the central portion of the massive sulphide shows fuchsite + carbonate + barite alteration, indicating that the hydrothermal system was still vigorously active at the time of burial. Correct discrimination of hangingwall and footwall alteration styles thus requires an appreciation of the character and emplacement processes of the enclosing volcanic facies.

CONCLUSIONS

Regional 1:25 000 scale maps now available for the entire Mount Read Volcanics provide a framework for the application of other research techniques aimed at understanding the relationship between the Cambrian volcanism and mineralisation. Recognition of distinctive volcanic facies and facies associations in the Mount Read Volcanics is critical in reconstructing the original facies architecture, and in achieving correct correlations at a range of scales. This requires an appreciation of eruptive and emplacement processes, their influence on the character and geometry of volcanic facies, and the textural and mineralogical effects of hydrothermal alteration. The stage is set for accelerated progress in Mount Read Volcanics research, and the most useful investigations will be those that integrate volcanic facies analysis with alteration and mineralisation studies.

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