CHAPTER FOUR
LOCAL GEOLOGIC SETTING

4.1 INTRODUCTION

The first part of this study has established the regional geological setting of metalliferous mineral deposits in the Kuridala-Selwyn region, and reasonable constraints can now be placed on metallogenic studies. The remainder of this study documents in detail the characteristics of, and proposes a petrogenetic model for the Mount Dore breccia-hosted Cu±Ag deposit, one of a 70 km long chain of such deposits stretching southwards from Kuridala (Figure 1.2). The model can be tested and where appropriate modified to accommodate the entire family of deposits.

The Mount Dore deposit was a relatively minor prospect during the hey-day of mining in the early 1900's, yielding only a few tonnes of largely supergene Cu mineralization (Carter *et al.*, 1961). Two of its cousins were major producers in the past (*e.g.* Mount Elliott, Hampden group of mines), but little geological data of any sort remain from this past activity. A resurgence of interest in exploration for base metals in the last two decades has seen the re-evaluation of several of the known deposits, including that at Mount Dore. This deposit is herein chosen as the type deposit for the following reasons:

(i) Recent drilling has defined a resource of 40 million tonnes of ore, grading 1.08 percent Cu (using a 0.3% Cu cutoff) and 6.5 g/t Ag to a depth of 300 m (Nisbet, 1980). This makes the Mount Dore deposit a premiere example of this style.

(ii) The perceived geological setting is representative of the majority of these deposits.

(iii) Drillcore from forty diamond holes intersects the width and a significant length of the deposit, providing three dimensional control over the distribution and nature of the alteration and mineralization. This core is readily available on site.

(iv) Primary, polymetallic sulphide mineralization was intersected during drilling, providing a "window" through which prototypal metallogenic processes can be observed.

(v) Detailed, accurate mapping of the prospect at 1:2500 and 1:1000 scales by Leishman (1978, 1983) provides good surface geological control.

This wealth of information was far greater at the time of this study than existed for other, historically more productive deposits of this style. An opportunity was presented to examine this deposit, and work towards determining a model for its petrogenesis. Activities directed towards this endeavour were both field- and laboratory-based.

Field work involved logging and sampling of twelve of the forty available diamond drill holes[1]. Two hundred and twenty-five specimens were selected to obtain a representative collection of breccia types and mineral parageneses, for textural, fluid inclusion and isotope studies (Table B2, Appendices). Typical breccia and alteration textures in drill core were photographed. Examination and limited sampling of breccias in outcrop was also undertaken to determine macroscale geometry not readily apparent from drill core.

In the laboratory, 137 ordinary thin-sections, 37 polished sections (for sulphide parageneses and SEM analyses), 45 doubly polished blocks (for fluid inclusion analyses), and 34 mineral separates (for isotope studies) were prepared from selected drillcore samples (Table B2; Appendices). Transmitted and reflected light petrography

[1] Complete copies of drill logs are lodged with the curator at the Geology Department at James Cook University of North Queensland.

has defined alteration and mineralization parageneses. Fluid geochemistry is estimated in general terms from SEM determination of alteration and mineralization phase geochemistry, and more specifically using fluid inclusions. Oxygen, carbon and deuterium isotope studies of quartz, K-feldspar, carbonate and biotite have been used to constrain possible fluid provenance.

This chapter outlines the local geological setting of the Mount Dore Deposit, in particular documenting the characteristics of the different varieties of breccias occurring here, and proposing a model for their origin.

4.2 LOCAL GEOLOGY

4.2.1 Principal lithologies

The Mount Dore deposit occurs within metasediments immediately adjacent to the southwestern corner of the Mount Dore Granite pluton. Five variably brecciated and altered lithologies belonging to three formations crop out locally in and around the Mount Dore prospect (Figure 4.1). These lithologies are granite (Mount Dore Granite), carbonaceous slate and quartz-muscovite schist (Toole Creek Volcanics), meta-calcilutites/calcarenites (Staveley Formation), and massive to finely laminated quartzite, lying between the two metasedimentary formations. Surface outcrop is obscured by Recent alluvium, and is extensively weathered. Present erosion levels are probably only a few tens of metres below the Proterozoic-Mesozoic unconformity.

Granite is restricted to the eastern side of the prospect. Its contact with metasediments to the west is along a single east-dipping reverse fault. It is extensively altered and sporadically brecciated, and at the surface intensely weathered, for at least several hundred metres from its western margin. Unaltered granite was rarely observed, but where intersected during drilling proved to be a weakly foliated, medium- and even-grained (2 mm) biotite granite (*e.g.* JCU-27228, 27229 and 27231). Hornblende-

FIGURE 4.1a: Outcrop geology map of rock types in and around the Mount Dore Prospect (excerpt after the larger map of Leishman, 1983).

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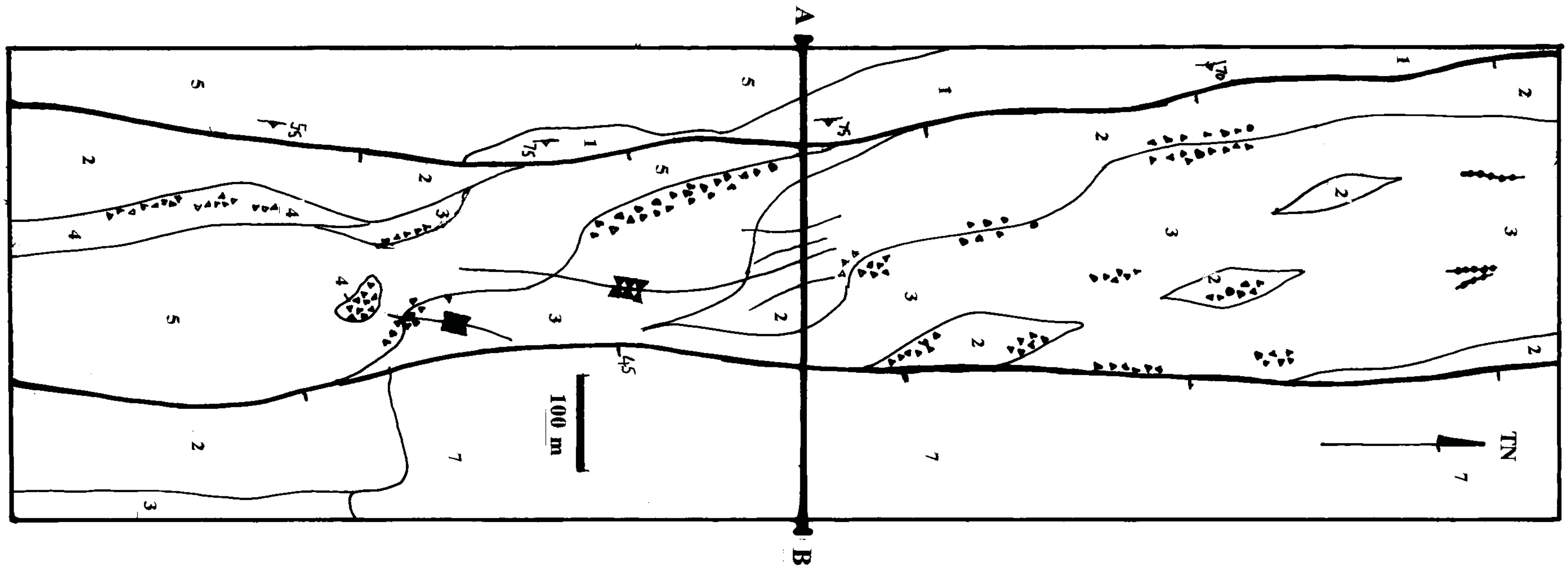


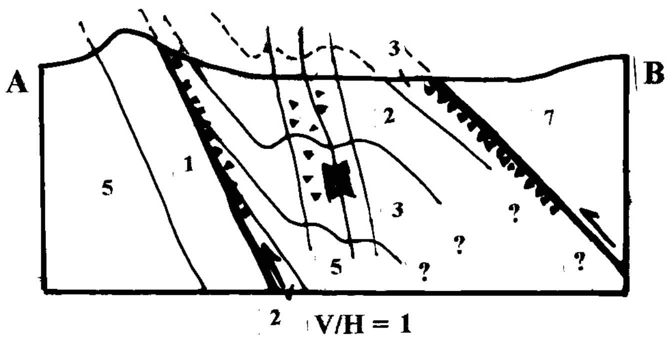


FIGURE 4.1b: Interpretive solid geology map and cross-section of the Mount Dore prospect. Variably altered carbonaceous slate occurs as relict lenses in similarly altered, mylonitic quartz-muscovite phyllite, in the Mount Dore Fault Zone. The fault zone marks the boundary between the uppermost Maronan Supergroup and the Staveley Formation, and a slice of the latter has been caught up in the faulting. Breccias are much more extensive than can be informatively illustrated, and the cross-section is rather schematic, as rock types are discontinuous at the scale of drill hole spacing (*ca.* 100 m). Legend is as for Figure 4.1a.

biotite granite reportedly crops out elsewhere in the pluton (Blake *et al.*, 1983). Fine-grained (≤ 0.5 mm), sub-horizontal aplite dykes up to a couple of metres thick intersect the granite, and have a similar mineralogy (*e.g.* JCU-27233). The foliation is sub-vertical and defined by preferred alignment of quartz grains showing deformation lamellae, subgrains and undulose extinction. Weak deformation of K-feldspar and biotite is also apparent, as kinking of crystal lattices and cleavage planes, *en echelon* cracks (filled with quartz or K-feldspar; JCU-27235) and undulose extinction (*e.g.* JCU-27230). Some recrystallization is also apparent along feldspar grain boundaries. The foliation intensity and orientation are consistent with S_3, and the granite is therefore interpreted to have been emplaced prior to or during D_3.

Lithologies of the Toole Creek Volcanics crop out immediately to the west of the granite, in a band 250 metres wide at the surface. This width increases with depth, but the complete interval was not intersected during drilling. Fresh carbonaceous slates are dark grey to black, extremely fine-grained, and strongly foliated. A thin (generally less 2 mm) banding defined by alternating paler and darker layers may be bedding. The foliation is slaty to spaced (but not noticeably differentiated), and usually at a measurable angle to the banding. Both generally dip moderately to steeply eastwards. In places the foliation is mylonitic, and the banding is absent, or only preserved in occasional rootless, isoclinal micro-folds (*e.g.* sample JCU-27198). A coarse (up to 3 mm) crenulation was occasionally observed to overprint the main foliation, at high angle. Randomly orientated chiastolite, of contact metamorphic origin, is common in the slate, usually within 100 metres of both the faulted and the intrusive contact with the granite.

Unaltered quartz-muscovite schists contain only minor proportions of other minerals, notably fine biotite and tourmaline. Bedding is absent. The foliation is phyllitic to schistose, and commonly differentiated into quartz-rich and phyllosilicate-rich domains up to 0.2 mm wide. The foliation generally dips steeply to the east, although in the central and southern part of the Mount Dore prospect it is locally flat-lying and overprinted by a coarse (5 mm), sub-vertical, north- to northwest-trending crenulation, equated with regional S_3. For this reason it is interpreted as S_2. Deformed veins and foliation-parallel lenses of possible regional metamorphic quartz were occasionally observed.

The relationship between the carbonaceous slates and quartz-muscovite schists is confused in the Mount Dore prospect by extensive brecciation and alteration. In the Metal Ridge area about five kilometres to the north, however, quartz-muscovite schist is interdigitated with carbonaceous slates, and becomes more abundant towards the quartzite to the west. This feature is also recognisable in drill core at Mount Dore. Contacts between the two lithologies are gradational over a few centimetres, and slate is commonly extensively silicified adjacent to schist (*e.g.* JCU-27199). S_2 foliations in both lithologies are parallel to each other, but S_3 is best developed in the schist. The quartz-muscovite schist is interpreted as a regional metasomatic unit related to the ductile deformation (Chapter 3).

Fine grained (<0.05 mm), massive to finely banded, white to grey quartzite forms the backbone of a north-striking ridge. and marks the western boundary of the Mount Dore Fault Zone. It can be traced in surface outcrop for several tens of kilometres to the north and south of Mount Dore, but its subsurface distribution is erratic. In the southern part of the prospect it can be correlated between drill holes at shallow levels. In deeper holes, however, it either disappears completely (is not present where predicted from surface geology), or silicified carbonaceous slate is present instead. The quartzite is essentially monomineralic and shows no sedimentary characteristics, and probably formed by silicification of other rock types, perhaps during regional ductile deformation (Chapter 3).

The bulk of the Staveley Formation crops out to the west of the quartzite, but small blocks occur within the Mount Dore Fault Zone in the southern part of the prospect. Best intersections are in drill-hole SHQ-79-23, but even here their relationship to other lithologies is obscured by extensive brecciation and alteration, and they were probably fault-emplaced. Fresh examples of the fine-grained quartz-plagioclase-carbonate calcilutites and calcarenites characteristic of the Staveley Formation are seldom observed within the Mount Dore Fault Zone. A fine-grained, brick-red-brown lithology comprising largely quartz and K-feldspar may once have been this lithology. Most abundant is a foliated, very fine-grained quartz-biotite phyllite (*e.g.* JCU-27139). Bedding is absent from this unit, and it could be analogous to the quartz-muscovite schists in the Toole Creek Volcanics, formed by regional metasomatism during D_2. It is commonly extensively altered.

Subsurface distribution is obscured by fault displacement and brecciation on scales less than the drill hole spacing. Lateral continuity of layering and structures is generally low. The only feature traceable over the length of the prospect is the fault contact between granite and metasediment.

4.2.2 Structure

The dominant structure passing through the Mount Dore prospect is the Mount Dore Fault Zone, comprising a series of north-striking, moderately (40 to 60^o) east-dipping reverse faults broadly parallel to the local trend of the dominant (S_2) foliation. The best-defined member of this series is that marking the western margin of the Mount Dore Granite. The minimum amount of reverse-slip along this fault is at least 700 m (determined from the maximum depth of intersection of the contact by drilling), and is probably much greater. Fault emplacement of the granite over the mineralized sequence was recognised by Carter *et al.* (1961) and Ophel (1980), but the most recent BMR geological maps (*e.g.* Selwyn Region 1:100 000 Geological Special) do not show this structure.

The eastern margin of the Mount Dore Fault zone is ill-defined, but bands of extensive grain-scale brecciation in the granite provide evidence for faults up to several hundred metres east of the metasediment contact. The western margin of fault zone is also poorly-defined, but is taken to be at the quartzite horizon separating the Toole Creek Volcanics and the Staveley Formation, because this horizon marks the lower boundary of base metal mineralization.

Metasediments at Mount Dore occur in the limb of a major F_2 fold, the axial plane of which passes close to or is coincident with, and is broadly parallel to the faulted contact with the Mount Dore Granite. Many small-scale D_2 folds can be found in outcrop. The prospect also lies within the D_1 mylonitic detachment zone containing the boundary between the Toole Creek Volcanics and Staveley Formation.

Several large folds with fold axes locally plunging up to 30° north or south are preserved in the larger blocks of Toole Creek Volcanics (Figure 4.1). The axial-plane-parallel foliation is a coarse (3 to 5 mm) crenulation, which overprints the pervasive S_2 schistosity. The style and orientation of the folds are consistent with regional F_3 structures.

4.3 BRECCIATION

4.3.1 Introduction

Restriction of breccias to the Mount Dore Fault Zone strongly implies fault-related processes, but the close spatial and temporal association with alteration implies that hydrothermal processes may also have been important. Breccias occur within and between large blocks of essentially unbroken rock. They occur mainly in tabular bodies parallel to the dominant foliation in the unbroken host, and it seems to have been this feature alone which led Ophel (1980) to interpret them to be of sedimentary or volcanic origin. The lithologies hosting the breccias have, however, experienced at least two episodes of intense regional ductile deformation, yet none of the breccias observed at Mount Dore have been ductilely deformed. Late tectonic origins are clearly indicated; sedimentary or volcanic processes cannot be responsible for breccia petrogenesis.

All lithologies within the Mount Dore Fault Zone have been brecciated to some degree. In outcrop, almost all breccias have a pale pink-orange colour, due largely to the presence of extensive K-feldspar and quartz alteration (*e.g.* Figure 4.2a,b).

Carbonate is only rarely preserved. Breccia textures may not be immediately apparent in outcrop, particularly where alteration has been pervasive. They can commonly be recognised, however, by the "knobbly" surfaces of outcrops containing them, produced by differential weathering of fragments and matrix. Recognition of intensely altered breccias in thin-section requires careful petrography.

In drill core, the gross geometry of the breccias is not evident, and breccia bands cannot be correlated between drillholes. Examples of fresh material are readily available, however, allowing determination of relationships between alteration parageneses and breccias not readily discernible from surface exposures. Where original lithologies are not completely replaced by alteration, fragments generally prove to be of the same material comprising the undisrupted host adjacent to breccia bands. Exceptions occur close to boundaries between different lithologies, particularly that between the granite and metasediments. All breccias show the effects of alteration (either hydrothermal or supergene), and some have formed in previously altered rock, implying contemporaneity of alteration and brecciation processes.

Breccias may be categorized into several textural end-members on the basis of fragment shape and composition, and on matrix proportion. Descriptions of breccias at Mount Dore follows the philosophy of Baker *et al.* (1986), who advocated that by carefully considering the combination of textures in a breccia while bearing in mind possible mechanisms of brecciation, one can formulate a model for breccia pipe formation. Their classification of hydrothermal breccia pipes contains four broad categories, of which two - hydrothermal breccia pipes and fault-related breccia pipes - are most relevant to my work. A petrogenetic model for breccias is discussed in Section 4.4.

FIGURE 4.2: Outcrop and drill core characteristics of Mount Dore breccias:

(a,b,) typical outcrop characteristics; fragments are poorly size-sorted in both examples, ranging up to several tens of centimetres in diameter, and are generally angular, although in (a) fragments are somewhat rounder; lens cap diameter is 55 mm;

(c) disruption of a strongly altered (K-feldspar and quartz) lithology showing transition from fractured rock (right) to angular breccia (centre), into highly comminuted breccia (left); carbonate infill (± replacement occurred after brecciation (location: SHQ-78-35; 313.5 m);

(d) fragment of crenulated quartz-mica schist in contact with a pervasively replaced (K-feldspar, quartz, tourmaline) fragment of the same (location: SHQ-77-16; 108.6 m);

(e) breccia containing angular to slightly rounded fragments of a strongly foliated lithology (schist?), replaced to different degrees by K-feldspar, quartz and tourmaline (location: SHQ-77-16; 91.35 m);

(f) example of highly rounded breccia; K-feldspathized fragments of mainly granite ranging up to 25 mm are set in a fine, dark (chloritic ± tourmaline) matrix; late carbonate veining is evident (location: SHQ-78-35; 267.9 m);

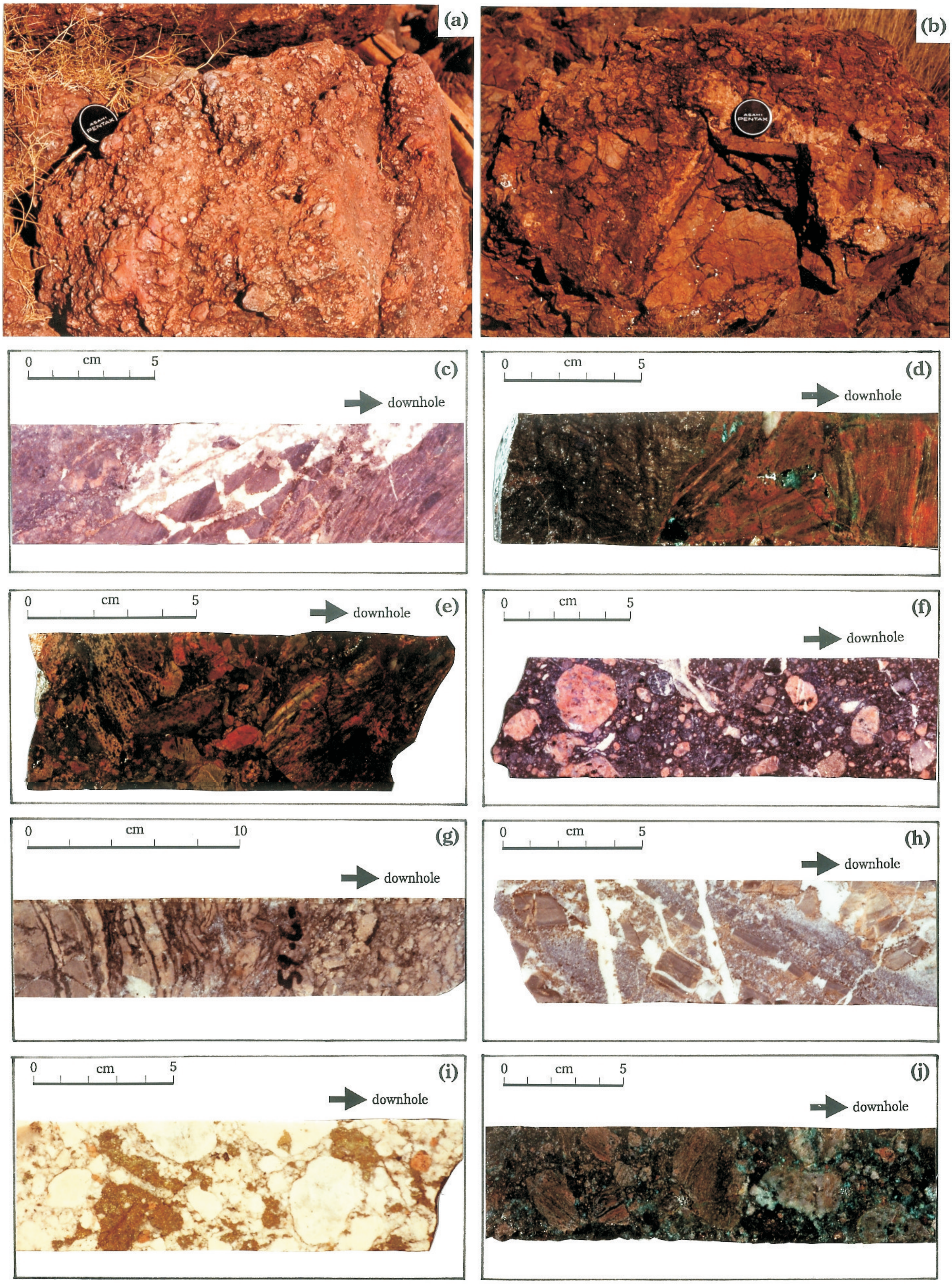
(g) transition (left to right) from relatively unbroken (though pervasively altered) rock into slabby, then angular, then comminuted, rounded breccias (location: SHQ-77-23; 58.95 m);

(h) breccias in strongly altered Staveley Formation calcilutites; mixed tabular fragments and very fine, carbonate-rich matrix, probably extensively replaced, finely milled breccia; carbonate alteration is later than brecciation (location: SHQ-77-27; 190.35 m);

(i) pervasive dolomite replacement after a rounded breccia; isolated pink-orange fragments attest to an earlier K-feldspathic alteration event; brassy interstitial material is mixed pyrite-chalcopyrite (location: SHQ-78-35; 327.15 m);

(j) rounded, mineralized breccia comprising pale silicified (after K-feldspar) fragments of schist or slate, in a fine, dark (chloritic?) matrix also containing abundant pyrite and chalcocite (location: SHQ-76-13; 54.1 m).

FIGURE 4.2:


(a)
(b)
0 cm 5
(c)
downhole
0 cm 5
(d)
downhole
0 cm 5
downhole
(e)
0 cm 5
(f)
downhole
0 cm 10
(g)
downhole
0 cm 5
(h)
downhole
0 cm 5
(i)
downhole
0 cm 5
(j)
downhole

4.3.2 Angular breccias

These breccias are best developed in the carbonaceous slates and quartz-muscovite schists. They have tabular to wedge-shaped, angular to only weakly subrounded fragments ranging up to tens of cm in size, but usually less than 5 cm in diameter. Size sorting is variable, but generally within a single order of magnitude in drill core. The transition to unbroken rock is generally marked by a zone of interlocking angular, little rotated fragments (Figure 4.2c), passing into a fractured zone, with abundant alteration infill (largely quartz and K-feldspar). This transition may occur over distances of up to several metres, but more commonly a few tens of centimetres.

Schist fragments are commonly crenulated by S_3, but there is no consistent orientation of this crenulation from clast to clast, indicating the breccias post-date or at the very earliest are very late syn-D_3 (Figure 4.2d). Fragments also appear to have been squeezed together, so that little interstitial space remains. Matrix is subordinate to clasts, and generally completely replaced by the alteration phases. Replacement of fragments is variable, from partial, along the margins, to complete (Figure 4.2e). Alteration infill is generally minor.

Angular breccias are also present in calcareous Staveley Formation rocks, but their textural characteristics are commonly obscured, because they were more susceptible to alteration. In places, one may observe irregular to tabular fragments less than two centimetres wide of fine-grained, pale pink-orange siliceous or feldspathic material, interpreted to be altered fine-grained calcilutites, highlighted by dark green to black interstitial material (biotite?; *e.g.* SHQ-77-23: 59 m).

Some of the intervals of angular breccias in drill core are wider than intervening intervals of apparently coherent host core. The latter may therefore be large blocks ("mega-fragments"), from the margins of which smaller fragments may have been spalled. Some of these blocks apparently exceed 20 metres in diameter.

4.3.3 Rounded breccias

These comprise the other main breccia type. Fragments are subangular to well-rounded, and are much reduced in size compared with the angular breccias, ranging from a couple of centimetres down to rock flour. The texture is clast- to matrix-supported. Fragments are commonly of feldspathized or silicified rock (Figure 4.2f), and in some instances early pyrite fragments are present (*e.g.* JCU-27277). Breccia bands are commonly replaced or veined by later phases (carbonate, chlorite), demonstrating that alteration was contemporaneous with brecciation. Fragment protoliths in these highly milled breccias are difficult to determine because of intense alteration. This is normally only a problem in distinguishing between the carbonaceous slates and the muscovite schist, but since the two are intimately related anyway, the need for distinction is lessened (Section 4.2.1).

Rounded breccias occur in bands rarely exceeding a few tens of centimetres wide, within intervals of angular breccias. These bands are generally parallel to main foliation and banding in coherent host rock. A complete gradation from incipiently brecciated rock through angular breccia into finely milled breccia may commonly be observed, with angular clasts "spalling" from breccia margins and becoming entrained into the band of rounded breccia (*e.g.* SHQ-77-23 58.85-59.12 m; Figure 4.2g). The textural relationships between angular and rounded breccias suggest that the latter are formed by comminution of the former, largely by physical abrasion, but possibly also by hydrothermal processes (*e.g.* Figure 4.2h).

Rounded breccias are less commonly observed in Staveley Formation rocks, again probably because these rocks have proved more reactive, and textures are consequently obscured by pervasive replacive alteration. In places, however, bands of rounded breccia generally less than 10 cm wide may be observed within angular breccias (*e.g.* SHQ-77-23: 178 m).

The most spectacular examples of sulphide mineralization are hosted by rounded breccias. Carbonate flooding, with subsequent replacement by chalcopyrite, is common in rounded breccias in the deep northern parts of the prospect, in some instances completely replacing the entire breccia. Fragments may still be discerned in most instances, however, picked out by slightly darker (chloritic) margins (*e.g.* JCU-27217; Figure 4.2i). In the shallower parts of the prospect, rounded breccias are carbonate-poor and much darker in colour, and the dominant copper sulphide is chalcocite (Figure 4.2j).

4.3.4 Granite breccia

Brecciation of granite increases progressively towards the faulted contact with metasediments. The random alignment of subgrains and deformation lamellae from fragment to fragment in breccias close to this contact demonstrate that brecciation is later than crystal-plastic deformation. Brecciation occurs initially by grain boundary disruption, producing fragments generally less than 3 mm in diameter (the original grainsize), consisting of deformed monocrystalline quartz or K-feldspar. In some instances, pyrite fragments are present (*e.g.* JCU-27211). Larger fragments are relatively rare, consist of polycrystalline quartz, K-feldspar or both, and formed by reworking of cemented earlier breccias. Fragments are angular to subrounded, depending on the degree of milling. The immediate contact between granite and metasediments is a very finely comminuted breccia, which is particularly porous and permeable, and filled with groundwater.

4.3.5 Ferruginous cataclasite

The contact between quartzite and overlying lithologies within the fault zone is commonly marked by a fine-grained, ferruginous breccia up to several tens of metres thick. The fine, ferruginous matrix is dominant, and supports an array of small, prominent, highly rounded and siliceous or feldspathic fragments usually less than 1 mm across. The lithology is weakly laminated in places, with laminae alternately richer and poorer in iron oxy-hydroxides.

4.4 BRECCIA PETROGENESIS, FAULT PROPAGATION AND HYDROTHERMAL FLUIDS

Any model describing breccia petrogenesis at Mount Dore must explain the following points:

(i) the range of breccia types;
(ii) the relationship between breccia types;
(iii) the overall geometry of the breccias;
(iv) the relationship between brecciation and tectonism;
(v) the contemporaneity of brecciation and hydrothermal alteration.

The close spatial and temporal association of brecciation with faulting begs a genetic relationship. The common coincidence of breccia bodies with zones of F_3 folding, and with signs of hydrothermal alteration within the fault zone, are probably also significant.

Ultimately, movement along faults in the zone was in response to the prevailing regional compressional stress field, with the maximum principal stress (σ_1) directed sub-horizontally in approximately an east-west to northeast-southwest direction at this time (D_3 and later). Importantly, however, constituent reverse faults are moderately to steeply (40^o to 80^o) east-dipping. This orientation is coincident with the contact between the Soldiers Cap Group and the Staveley Formation and is probably controlled by the regional grain of the rock, produced during earlier deformation events (Chapter 3).

Sibson *et al.* (1988) recognised that high angle reverse faults are anomalous structures, since the Coulomb failure theory predicts that faults should form along planes containing the intermediate principal stress (σ_2) and be orientated at 25 to 30^o to σ_1 - that is, have a shallow dip where σ_1 is subhorizontal. They calculated that reactivation of an existing high-angle structure as a reverse fault necessarily required fluid pressures in excess of the lithostatic load, to overcome the frictional shear strength of the pre-existing structure. The development of hydrothermal alteration during brecciation at Mount Dore is more direct evidence for the presence of a hydrothermal fluid at this time.

The mechanical role of a fluid in brecciation was considered by Phillips (1972). Under the conditions of low differential stress normally found at depth (less than a few tens of MPa; Etheridge, 1983), increasing the pore fluid pressure will decrease the effective stress acting on the rock. Fracturing can occur if the fluid pressure exceeds the minimum principal stress (σ_3) by an amount equal to the tensile strength of the rock. Fractures would ordinarily tend to open up in a direction parallel to σ_3; *i.e.,* vertically at Mount Dore. The greatest dilation occurs where fractures or planes of weakness are subhorizontal. F_3 fold hinges or fault jogs would be favourable sites at Mount Dore.

Brecciation is a likely natural consequence of the potentially large fluctuations in fluid pressure associated with fault rupture. The difference between lithostatic and hydrostatic pressures at any depth increases at about 17 $MPa.km^{-1}$. With each episode of failure, the sudden decrease of fluid pressure in dilatant zones along the fault would produce a fluid overpressure in the rocks adjacent to these zones. Hydraulic fracturing may occur, and fragments may burst from the fault walls or from larger fragments. These would initially be angular, and maybe tabular if the rock has a predominant fabric which could control fracture orientation. Fracturing without fragment movement may extend for some distance away from the original dilatancy.

Alteration and mineralization may cause temporary sealing of the fault, allowing fluid pressures to once more approach and exceed lithostatic conditions, until the rock is again disrupted. Rupture and movement along any particular fault plane is likely to be cyclic and incremental, occurring thousands of times during the active period of faulting. There is therefore ample opportunity for brecciation and alteration. There is comparatively little vein or vugh infill in the alteration zones, suggesting that dilatant zones were short lived and could not be supported at prevailing lithostatic loads. These may have been as high as several hundred MPa.

Milling of fragments may occur by hydrothermal reworking (dissolution or micro-hydraulic fracturing) or by physical abrasion. Abrasion can occur by friction during fault movement, or possibly hydrodynamically if fragments become entrained in a rapidly-moving fluid or vapour phase. As the system of faults and breccias approached the surface, movement became localized along progressively more discrete planes. The ferruginous cataclasite represents the stage in the faulting history, where movement was essentially along a single plane.

4.5 CONCLUSIONS

The Mount Dore copper deposit is largely hosted by a slice of slaty to schistose, probably mylonitic metasediments of the Toole Creek Volcanics, sandwiched between the Mount Dore Granite to the east and the Staveley Formation to the west. Ultimately, however, its localization has been in a structural trap, at the intersection of structures from several generations of deformation. Interaction of D_1 and D_2 ductile deformation produced a strong, steeply east-dipping grain to the rock (combination of bedding and near-parallel foliation). D_3 folding locally rotated this fabric to shallowly-dipping orientations. The Mount Dore Granite intruded the metasediments during D_3, at somewhat before about 1510 Ma (Nisbet *et al.*, 1983), but had solidified by the time of propagation of the late tectonic Mount Dore Fault Zone. Orientation of the fault zone was controlled by the regional grain, but zones of F_3 folds acted as fault jogs and became dilatant, and consequently sites of extensive brecciation and fault block shuffling. Textural varieties of breccias at Mount Dore mainly reflect the processes of hydraulic fragmentation and reworking (by physical abrasion or dissolution), and the fabrics of the rocks in which they have developed.

Hydrothermal fluids entering the highly permeable breccia zones interacted with large areas of rock, producing extensive alteration and base metal mineralization. Brecciation was continuous throughout hydrothermal alteration, and mechanical constraints on fault propagation show that a fluid must necessarily have been present for movement along the Mount Dore Fault Zone to have occurred (Sibson *et al.*, 1988).

There has been an intimate interaction between hydrothermal activity, faulting, and breccia formation.

The Mount Dore deposit is therefore constrained by observations of the timing and interrelationships between structures, brecciation, alteration and mineralization to have formed late in the compressional tectonic history, well after the peak of metamorphism. The Mount Dore Fault would appear to have been active for some considerable period of time. Fine-grained ferruginous breccias suggest movement along the Mount Dore Fault Zone up to at least the time of exposure of the Mount Dore deposit to the surface weathering environment.