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GEOLOGY AND STRUCTURAL DEVELOPMENT OF THE CERBEREAN CAULDRON, CENTRAL VICTORIA

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Abstract

The Cerberean Cauldron, in Central Victoria, is a classic example of the cauldron subsidence phenomenon. The ring and radial fracture patterns and the interbedded volcanic and sedimentary units preserved enable the history of the cauldron's development to be traced in detail. Three cycles of acid magma represented by rhyolite-rhyodacite ash flows with associated tuffaceous sediments were interspersed with periods of sedimentation or eruptions of basic lavas. The earliest formations, constituting the pre-collapse phase, show variable thickness and distribution within the cauldron, whereas the thick Cerberean Volcanics, representing the major subsidence event overlap all other formations. The rhyolites and rhyodacites respectively from the three acid volcanic formations show similar petrographic features.

Igneous activity in the region may have commenced with basining and ash-flow eruptions from along early formed faults or isolated vents. The ring and radial fractures were probably initiated by a point explosion at depth in the chamber providing magma for the Cerberean Volcanics. Eventual collapse of the central block was one of foundering under gravity, following removal of magmatic support due to substantial ash-flow eruptions. Activity culminated in high level intrusions of granodioritic magma.

Introduction

Upper Devonian vulcanism in Central Victoria is represented by a number of well-exposed subsidence complexes, occupied by part or all of a remarkably similar rhyolite-dacite sequence. The total volume of acid-intermediate magma preserved is of the order of several thousand cubic kilometres. (A general outline of the geology of the Central Victorian province is given by Marsden, 1976.)

The Cerberean Cauldron is the most spectacular complex, being a classical example of cauldron subsidence (in the sense of Smith and Bailey, 1948). Its importance lies in that its three cycles of acid volcanism may reflect rhythmic crustal movements and magmatism in the prevailing tectonic regime.

The geometric centre of the Cerberean Cauldron complex lies 96 km northeast of Melbourne. The volcanic rocks within the structure now comprise the Cerberean Ranges, the high-level, roughly elliptical plateau forming part of Victoria's Eastern Highlands.

The area was mapped in detail by Birch *et al.* (1970) and covers an area of about 1 150 square kilometres (Fig. 1). Earlier mapping work on parts of the cauldron had been carried out by Bell (1959), Thomas (1947), Hills (1929, 1932) and Whitelaw (1913). Additional mapping of the Acheron Cauldron, which adjoins the Cerberean along the latter's southern edge, was carried out by Dudley *et al.* (1971) and Howard (1972). Mapping of the basement sediments, in particular the Cathedral and Koala Creek Sandstone, was carried out by Vandenberg (1977).

This paper outlines the general geology of the Cerberean cauldron and its structural development, and provides a brief petrography of the main rock types. The chemistry and petrogenesis will be discussed in more detail in further papers, although these have been alluded to by Birch and Gleadow (1974).

Tectonic Setting

The Central Victorian Trough was apparently a localized basin of sedimentation, possibly representing a marginal sea within the Lachlan Geosyncline, at the southern end of the Palaeozoic Tasman Mobile Belt. The Trough is geologically bounded on east and west by complex up-faulted axial structures consisting of Cambrian sediments and greenstones with tholeiitic affinities—the Mt Wellington and Heathcote axes respectively. Within this trough, marine geosynclinal conditions

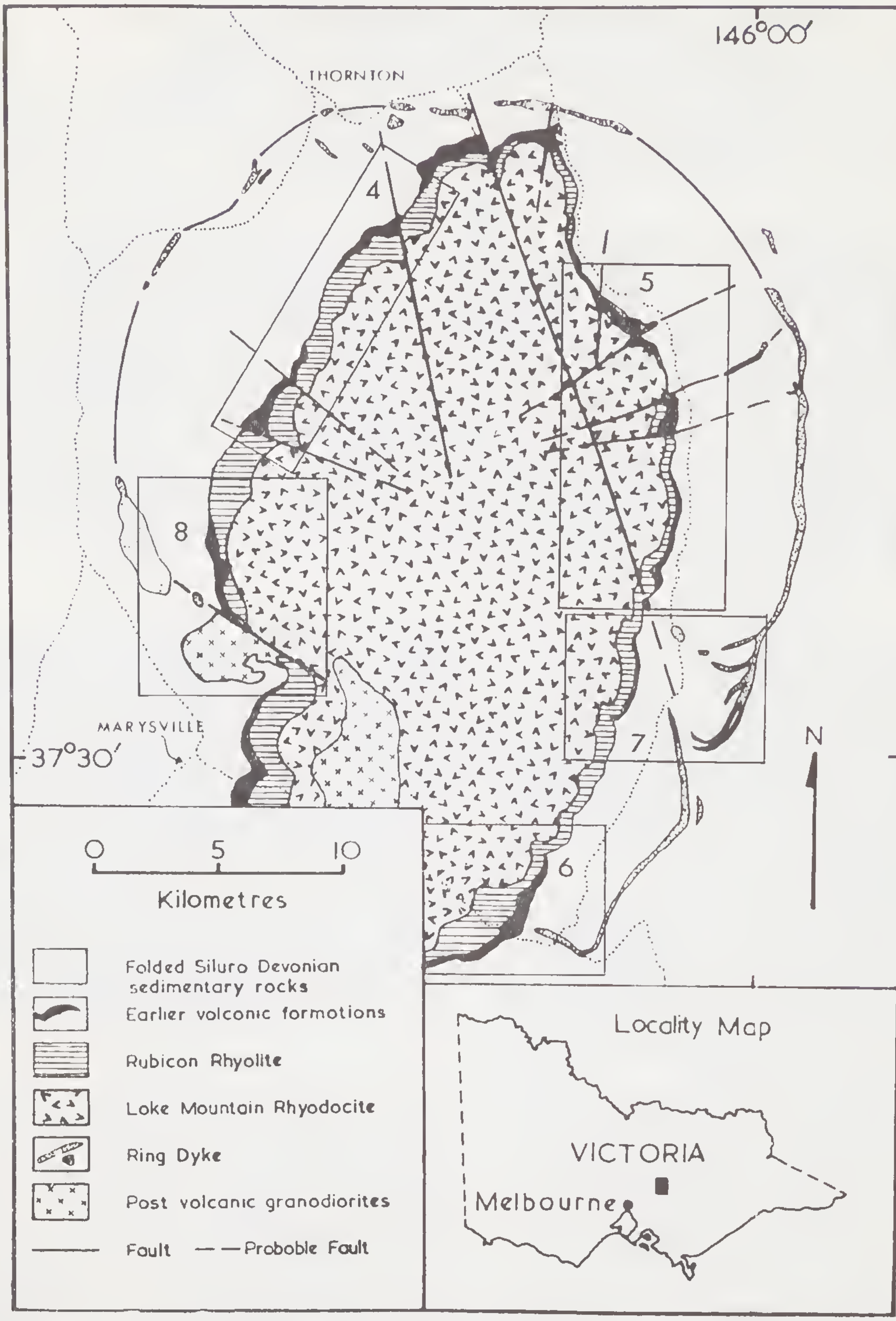


Figure 1—The Cerberean Cauldon, showing its location and the positions of the larger scale maps of the sequence along the margin of the volcanic pile shown in Figs. 4 to 8.

were operative from at least the Lower Ordovician, but possibly as early as Lower-Middle Cambrian, up until Lower-Middle Devonian times.

In the late Middle to early Upper Devonian, the sedimentary fill was folded on a NNW-SSE trend, and intruded by a dyke swarm with mainly lamprophyric and quartz dioritic rock types (the Woods Point Dyke swarm) whilst orogenic forces were still operative (Hills, 1959). Following deformation, large amounts of acid-intermediate magma were emplaced at high levels within the crust, forming a batholith-volcanic province fairly typical of circum-Pacific (Andean) magmatism.

General Geology

The Cerberean Cauldron is circumscribed by a circular, near vertical, partly dyke-filled ring fracture of 27 km diameter, in combination with a radial fracture pattern focussing at the geometric centre. (See Figs. 1 and 2). The complex has been emplaced through the thick Lower Silurian-Lower or Middle Devonian bedrock of folded sandstones, siltstones and shales. The youngest basement rocks are the Cathedral Range and Koala Creek Sandstones, which outcrop on the western and southeastern sides of the cauldron volcanics respectively, in what appears to have been a northwest to southeast trending structural basin. They are apparently continuous beneath the volcanics (Clarke *et al.,* 1970). Both units form prominent strike ridges within and subparallel to the ring fracture, but are apparently conformable with underlying basement sediments (Dale, 1964; Bell, 1959; Hills, 1929). The units as a whole behaved competently during cauldron formation and have locally influenced the fracture pattern (Fig. 2).

The sequence within the Cerberean Cauldron can be divided into a number of alternating volcanic and sedimentary formations, which have a general inward dip at relatively shallow angles (Fig. 3). These are shown in Table 1 and are based on the subdivision of Thomas (1947) and on more detailed mapping of Birch *et al.* (1970).

The five formations within the Taggerty Subgroup represent the pre-collapse phase in the cauldron's development.

Wightmans Hill Conglomerate

This is a terriginous formation comprised mainly of a high-energy, fluviatile conglomerate, with well rounded pebbles of indurated quartz sandstone derived from the Palaeozoic bedrock. The pebbles range up to about 30 cm in diameter, but average 3-8 cm.

The formation overlies an irregular basement topography and hence outcrop distribution and thickness are variable. In some places, quartzite pebbles on the surface are its only expression. It is thickest in the northeast (30 m) and most continuous in the Blue Range, east of Taggerty (Fig. 4).

Snobs Creek Volcanics

Volcanic activity in the cauldron began with the emplacement of rhyolitic ash flow tuffs, of relatively small extent. The formation is best developed west of Snobs Creek in the northwest, where it reaches a maximum exposed thickness of 300 m (Thomas, 1947). Its outcrop elsewhere on the western side of the cauldron is fairly continuous but it is generally less than 60 m thick (Fig. 4). Near Snobs Creek, the basal ignimbritic rhyolite, containing carbonized plant remains, grades upwards into a rhyodacite. Overlying this is a band of poorly, or non-welded tuffaceous rocks, with more compact bands of biotite-rich rhyodacite. Tuffs rich in phenocrysts occur at the top of the formation (Thomas, 1947).

The formation is restricted to the west or downthrown side of the Snobs Creek Fault apart from a small exposure on the eastern side of the cauldron (Fig. 5).

Blue Range Formation

This formation consists of sedimentary units of various types, some probably tuffaceous, and represents a definite break in the extrusive activity. The most significant unit is the 'Fish Beds' (Hills, 1929), which reaches a maximum development (about 130 m thick) in the Blue Range, north of Little River (Fig. 4). Here, well-bedded, red and yellow fine-grained, lacustrine sandstones, and brown and greenish

TABLE 1

Generalized sequence within the Cerberean Cauldron

Group	Subgroup / phase	Unit	Description	*
		INTRUSIVE PHASE	CENTRAL INTRUSIONS Granodiorite Porphyritic microgranodiorite RING DYKES, RADIAL DYKES Porphyritic granodiorite (equivalent to the Lake Mountain Rhyodacite). Porphyritic granite (equivalent to the Rubicon Rhyolite).	
MARYSVILLE GROUP	(collapse phase)	ACHERON VOLCANICS Donna Buang Hypersthene Rhyodacite Warburton Quartz Rhyodacite	NOT REPRESENTED	
MARYSVILLE GROUP	(collapse phase)	CERBEREAN VOLCANICS Lake Mountain Rhyodacite	Ignimbritic rhyodacite (uppermost unit in cauldron).	900 m
MARYSVILLE GROUP	(collapse phase)	Rubicon Rhyolite	Ignimbritic rhyolite, grading to rhyodacite at top. Lenticulite at the base.	390 m
MARYSVILLE GROUP	TAGGERTY SUBGROUP (pre collapse phase)	ROBLEYS SPUR VOLCANICS	Porphyritic andesite, andesitic basalt, minor basalt in south, some intercalated with underlying Ignimbritic rhyodacite flows. Interbedded non-welded tuff, tuffaceous sediments. Minor agglomerate. Ignimbritic rhyolite flows, associated tuff.	150 m
MARYSVILLE GROUP	TAGGERTY SUBGROUP (pre collapse phase)	TORBRECK RANGE ANDESITES	Andesite basalt, andesite, minor basalt, basic and intermediate tuff, minor agglomerate.	360 m
MARYSVILLE GROUP	TAGGERTY SUBGROUP (pre collapse phase)	BLUE RANGE FORMATION	Shale and fine sandstone, with fish and plant remains. Some tuffaceous sediments, minor quartzite and hornfels.	120 m
MARYSVILLE GROUP	TAGGERTY SUBGROUP (pre collapse phase)	SNOBS CREEK VOLCANICS	Phenocryst-rich tuff. Non-welded biotite-rich tuff, bands of welded rhyodacite. Ignimbritic rhyodacite with biotite apparently grading into Basal ignimbritic rhyolite.	285 m
MARYSVILLE GROUP	TAGGERTY SUBGROUP (pre collapse phase)	WIGHTMANS HILL CONGLOMERATE	Basal quartzose conglomerate, minor quartzite, unconformable with basement.	30 m

* Approximate maximum thickness in metres.

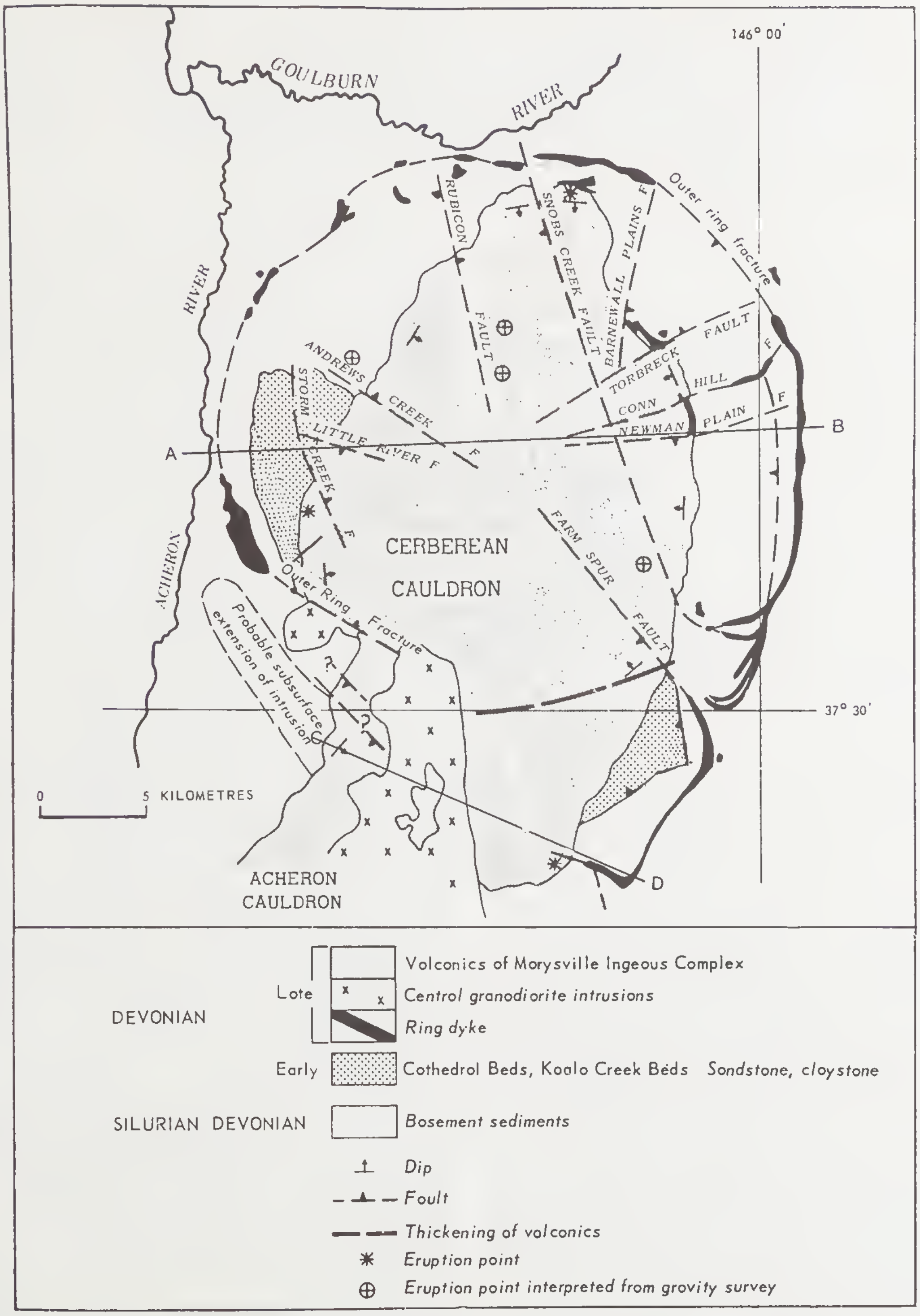


Figure 2—Structural Map of the Cerberean Cauldron. A-B and C-D arc cross section lines for Fig. 3.

shales have yielded a fish fauna and plant remains of Upper Devonian age. (Hills, 1929, 1931). The formation is not well developed at Snobs Creek and only thin conglomerates are recorded by Thomas (1947). On the eastern side of the Cauldron, the stratigraphic position is occasionally represented by thin, compact brown or greenish shales containing mud pellets.

Torbreck Range Andesites

This is the most extensive of the formations in the Taggerty subgroup, and is the only known occurrence of basic vulcanism (apart from that of the Robleys Spur Volcanics) in any of the Victorian cauldron structures. The formation consists of uniform, dark fine-grained basaltic andesites with minor basic tuffs of various types and occasional agglomerates. The greatest variety of rock types occurs at Snobs Creek (Thomas, 1947).

The formation reaches its maximum thickness and continuity along the eastern side of the cauldron, and the outcrop pattern between the Conn Hill and Newman Plain Faults indicates a thickness of at least 380 m (Fig. 5).

Robleys Spur Volcanics

Two easily recognized and fairly persistent members characterize this formation. The older consists of dark, phenocryst-poor ash flow rhyolites (the Middle Rhyolite of Thomas, 1947) and the younger is of dark, fragmental rhyodacites (the Fragmental Toscanites of Hills, 1932). There is a wide variety of other rock types in the formation, including tuffs and tuffaceous sediments, particularly on the western side of the cauldron. On the eastern side, the formation is generally less than 20 m thick and the rhyolitic member predominates.

In the south of the Cerberean Cauldron, close to its junction with the Acheron Cauldron, porphyritic andesites are interbedded with acid volcanics, e.g. in the cuttings of the Marysville-Cumberland Road up Robleys Spur and near Cumberland in the southeast of the cauldron (Fig. 6).

Cerberean Volcanics

This formation represents the catastrophic collapse phase of the central block and contributes about 80% of the volcanic rocks in the cauldron. The formation has been subdivided into two mappable units but these have no definite structural boundary and represent almost continuous ash flow emplacement (Birch, in prep.).

(1) Rubicon Rhyolite. The Rubicon Rhyolite (Nevadite of Hills, 1932 and Thomas, 1947) is a thick, phenocryst-rich, rhyolitic ash flow averaging 250 m in thickness and with an areal extent of about 400 km² in the Cerberean Cauldron. It is thicker on the western side (up to 390 m near Little River, Fig. 4), than on the east, where it may be absent (Fig. 5).

In the north, near Snobs Creek, the Rubicon Rhyolite forms a prominent cliff-forming horizon. A lenticulite horizon occurs at the base, with the vitroclastic texture best developed in the Blue Ranges (Fig. 4). At Snobs Creek, a second lenticulite horizon occurs about half way up the rhyolite indicating at least two cooling units in this particular area. Xenoliths of hornfels, representing country rock, occur most commonly in the lenticulite horizons.

(2) Lake Mountain Rhyodacite. The Lake Mountain Rhyodacite is the uppermost unit in the cauldron, and forms the high-level, dissected plateau of the Cerberean Ranges. It probably reaches the order of 1000 m in thickness at the centre of the cauldron (Fig. 3). There was no apparent gap in extrusive history between the rhyodacite and the Rubicon Rhyolite and textural evidence in general suggests that the two rock types comprised the one cooling unit.

The rhyodacite shows only minor mineralogical and textural variations. The most significant is the presence of lighter-coloured, flattened lenses or schlieren (with similar mineralogy to the host rhyodacite) which may occur at all levels and over its entire areal extent. The term 'Snobite' (Hills, 1932) was applied to the most heterogeneous ('hybrid') varieties of the rhyodacite.

At one locality in the southeast, near the settlement of Cambarville (Fig. 6), the base of the rhyodacite contains small, greenish, rhyolitic, lens-like inclusions. Xenoliths with-

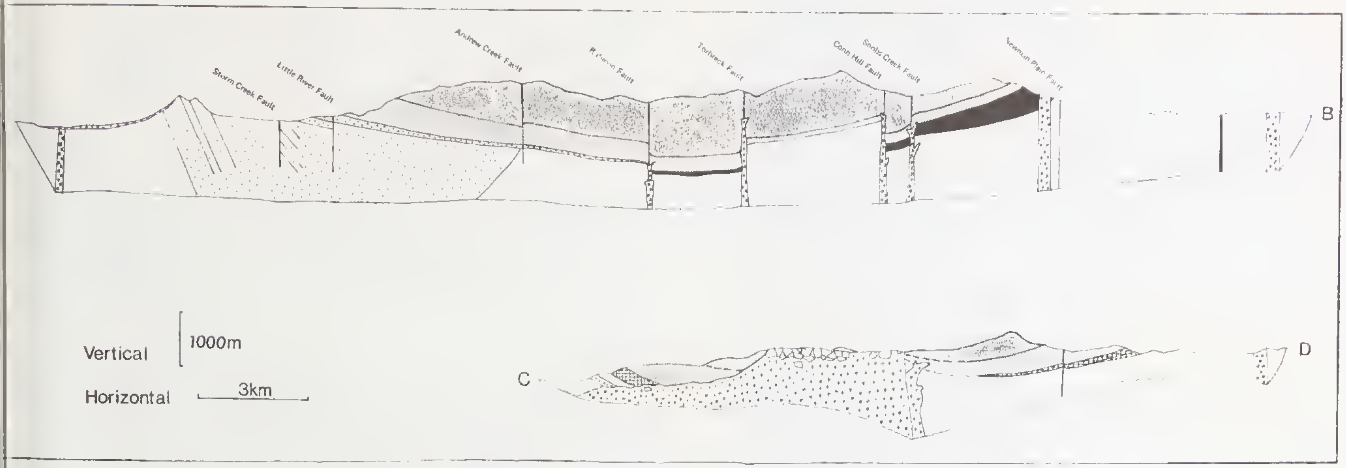
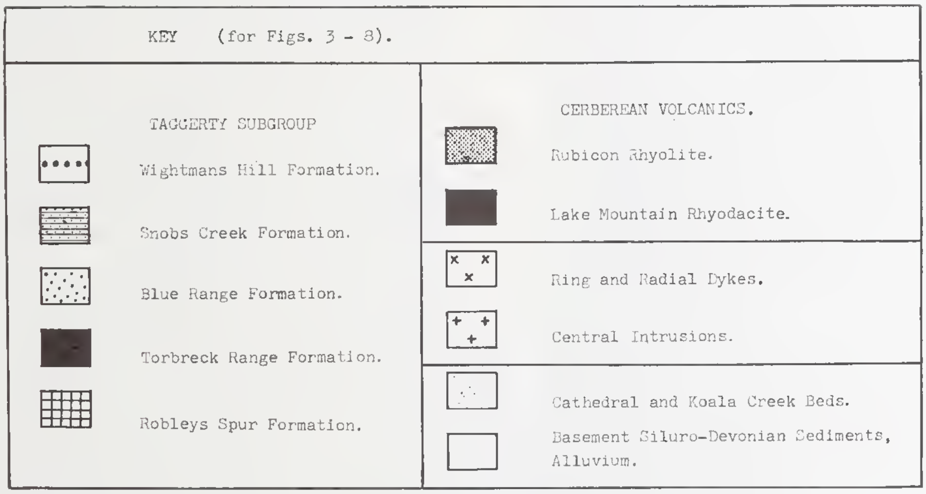


Figure 3—Cross sections of the complex.



in the rhyodacite include hornfels and the Rubicon Rhyolite. One piece of graphite was recorded and probably represents carbonized wood (by analogy with the Snobs Creek Rhyolite).

Ring and Radial Dykes, Satellite Intrusions

The circular, outer ring fracture is filled for about 70% of its extent, with the dyke ranging from garnetiferous porphyritic granodiorite (which is the more common) to porphyritic granite. In the north-east, the main ring dyke is complicated by several small satellite intrusions in which both rock types may occur, e.g. Christie's Hill.

In the southeast, the dyke undergoes a complex branching (Fig. 7) with fractures curving inwards or backwards on themselves. Further south, the dyke is a continuous body, trending sub-parallel to the strike ridges of the Koala Creek Sandstone. The fracture finally bends westward to cut the volcanics without dyke fill (or significant vertical and horizontal displacement) near Cumberland (Fig. 6). This contrasts with the situation in the southwest, where the ring fracture cuts the volcanics and offsets them by 3000 m horizontally and 500 m vertically (Fig. 8).

Detailed mapping on the northeastern side of the complex revealed an inner ring dyke actually cutting the volcanic pile. In the best exposure, on the Barnewall Plains Road, the

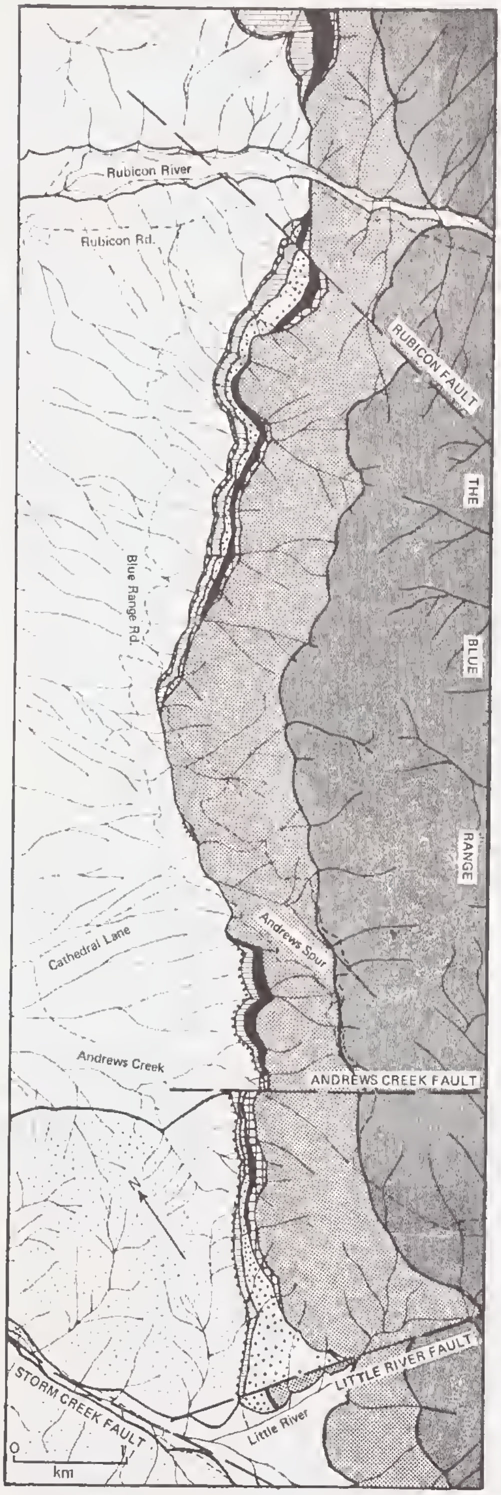


Figure 4—The geology in the Blue Range.

chilled margin is of porphyritic granite, but the bulk of the dyke is of porphyritic granodiorite (Fig. 5). In the extreme north, Thomas (1947) mapped thin branching porphyry dykes intruding the volcanics.

Of the radial faults, only two definitely contain dyke fill. These are the Torbreck and Conn Hill Faults (Fig. 5). Opposite the Newman Plains Fault, Whitelaw (1913) mapped a small, radial, protrusion from the outer ring dyke.

Central Intrusions

Intrusion of two texturally-distinct, high-level granodiorites, marked the final stages in the evolution of the Cerberean Cauldron.

(1) Porphyritic Microgranodiorite. The older and less-developed is a fine-grained granodiorite with occasional large orthoclase phenocrysts. It forms a stock, intruding and metamorphosing basement sediments and volcanics, southeast of Buxton (Fig. 8). The intrusion has a small extension to the southeast along the continuation of the outer ring fracture, and within the fault zone the Rubicon Rhyolite has been dragged down and incorporated within the intrusion (Fig. 8). The microgranodiorite also occurs as thin dyke-like bodies intruding the Lake Mountain Rhyodacite in the Keppels Falls area.

(2) Granodiorite. The final high-level granodiorite intrusion was emplaced into the base of the volcanic pile in the Junction region between the Cerberean and Acheron Cauldron. The mass is elongated north-south in outcrop, and its eastern contact with the Lake Mountain Rhyodacite appears fault-controlled (Fig. 6). On the western side, the contact between granodiorite and volcanics is not well exposed, but a shallow westerly dip under the volcanics is suggested.

A significant feature of the intrusion is a complex and not easily interpreted zone ('Hybrid' zone of Hills, 1932), exposed in cuttings on the highest part of the Marysville-Cumberland road, and extending south and west. Large blocks of hornfels, partially granitized, with less common andesite and rhyodacite, are veined by granodiorite and in places the rock Biotite is abundant in the Lake Mountain Rhyodacite, but less common in the Snobs

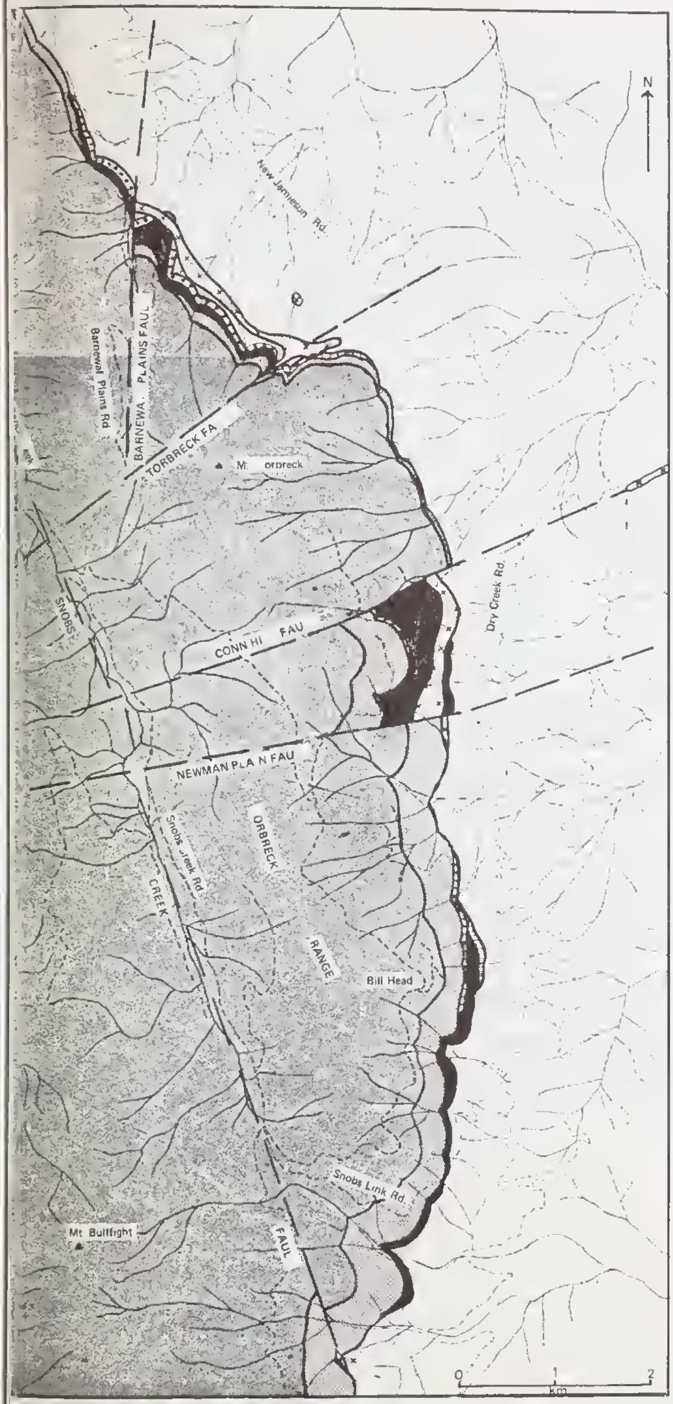


Figure 5—The geology in the Barnewall Plain—Snobs Link Road area.

types are strongly sheared. Bedding preserved in some of the hornfels blocks suggests that little movement relative to the basement has occurred. This hornfels region is at a much higher level than the original surface on which the volcanic rocks in the Cerberean Cauldron to the north were deposited (Fig. 3).

A few thin dykes of late-stage hornblende porphyrite have been described in the Snobs Creek area by Thomas (1947) and Birch *et al.* (1970).

Petrography of the Major Igneous Rocks

Rhyolites

Quartz (euhedral to subhedral and embayed) and potassium feldspar (orthoclase to intermediate microcline) are the dominant phenocrysts in the rhyolitic rocks, with less common plagioclase (oligoclase-basic andesine) and biotite. A small proportion (up to 5 modal per cent) of iron cordierite crystals and rare almandine garnets characterize the Rubicon Rhyolite (see Birch and Gleadow, 1974), but these two minerals are absent in the Snobs Creek and Robleys Spur Rhyolites.

All three rhyolites show remnant eutaxitic and vitroclastic textures, as evidence for an ash flow origin. These are best developed in the basal, phenocryst-poor region of the Rubicon Rhyolite. Dense welding, followed by devitrification and recrystallization has tended to obliterate original ignimbritic textures in the quartzo-feldspathic groundmass in all three rhyolites. Both the Snobs Creek and Rubicon Rhyolites are pale grey in colour, but the latter is distinctive due to its high phenocryst content or prominent eutaxitic textures in the low phenocryst varieties. The Robleys Spur Rhyolites are dark and aphanitic, the dark colour being due to finely-divided magnetite in the groundmass.

The Rubicon Rhyolite grades into the overlying Lake Mountain Rhyodacite with increase in phenocryst content and modal proportion of biotite and plagioclase.

Rhyodacites

Quartz and plagioclase are the dominant phenocryst phases in the rhyodacitic rocks.

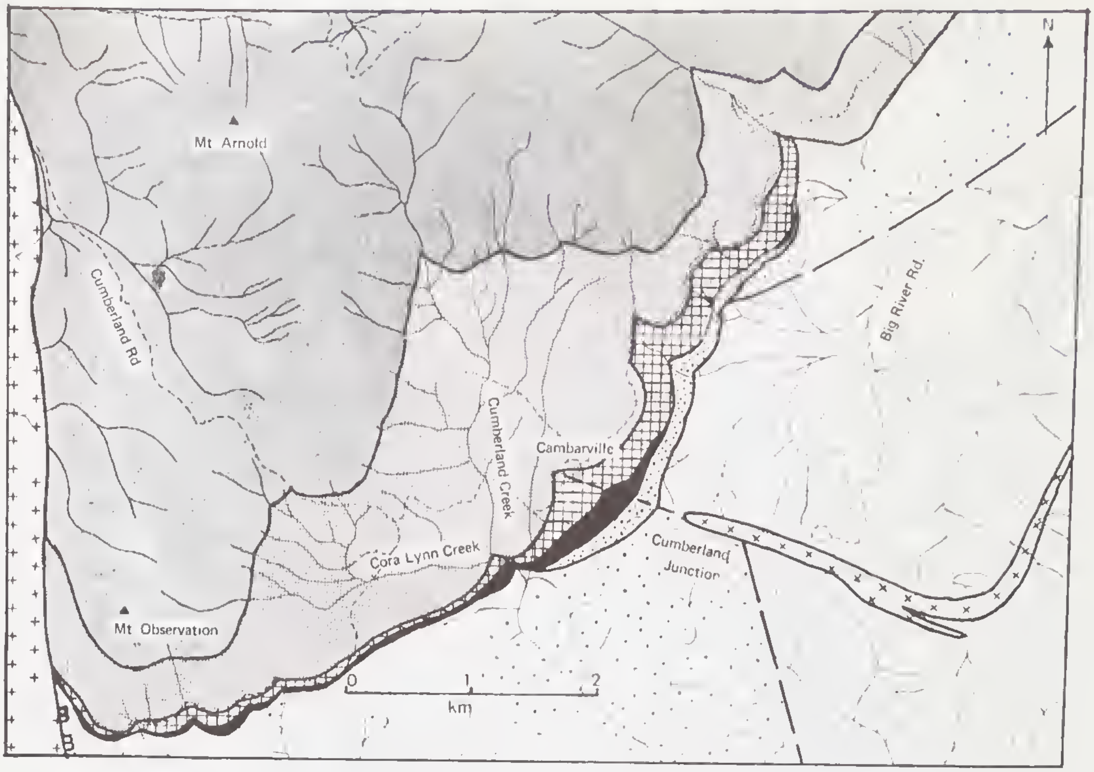


Figure 6—The geology in the Cumberland region.

Creek and Robleys Spur Rhyodacite. Orthoclase is uncommon in all three rhyodacites. Small quantities of hypersthene and almandine characterize the Lake Mountain Rhyodacite.

The groundmass in all three rhyodacites is microcrystalline, and only in the Robleys Spur Rhyodacite are remnant vitroclastic textures preserved. However, the continuity of the Snobs Creek and Lake Mountain Rhyodacites with their underlying ignimbritic rhyolites implies ash flow origins for both. Recrystallization has occurred to the greatest extent in the Lake Mountain Rhyodacite due to autometamorphic effects resulting from its considerable thickness.

The three rhyodacites differ considerably in appearance, with the Snobs Creek Rhyodacite being pale in colour, the Robleys Spur Rhyodacite dark with abundant small phenocrysts, and the Lake Mountain Rhyodacite dark grey and biotite-rich.

Basaltic Andesites

The basaltic andesites of the Torbreck Range Andesites are dark bluish-grey, uniform and finegrained. Prismatic phenocrysts of augite and occasional labradorite occur in a groundmass of small plagioclase lathes, prisms of augite and iron ore grains. Groundmass alteration is widespread however, producing chlorite, actinolite, carbonate and iron oxides.

The basaltic andesites interbedded with the rhyodacites of the Robleys Spur Volcanics near Marysville are dark grey, compact rocks with abundant sub-rectangular phenocrysts of plagioclase showing oscillatory zoning and less common augite, the latter usually altered to a pale green amphibole. The groundmass is similar to that in the Torbreck Range Andesites, although secondary biotite has developed in the sequence near Marysville, due probably to contact metamorphism from the effect of the nearby ring dyke mass.

Intrusive rocks

The porphyritic granite and granodiorite in the ring dykes are the intrusive equivalents of the Rubicon Rhyolite and Lake Mountain Rhyodacite respectively. The granite contains large phenocrysts of quartz, white to pink intermediate microcline perthites and less common saussuritized plagioclase and biotite in a fine-grained, greenish, sericitized, quartzofeldspathic groundmass. Pinitized cordierite is rare. The granodiorite consists of quartz, plagioclase, biotite and orthoclase in a medium grained groundmass. It is characterized by reddish garnets, usually partly altered to biotite, up to 1·5 cm across.

The two rock types forming the central intrusions have normal granodioritic mineralogy. However, the porphyritic microgranodiorite contains large, conspicuous orthoclase phenocrysts up to 3 cm long, and sillimanite and almandine are unusual, if rare, constituents and are probably xenocrystic. The granodiorite forming the larger intrusion is generally medium-grained and sub-equigranular, although it tends to be more porphyritic in the veins within the complex hornfelsic zone at the junction between the Cerberean and Acheron cauldrons.

Structural Development

Structural pattern

The Cerberean Cauldron subsidence area is basically a cylindrical block which has subsided along an integrated pattern of circular and radial faults (Fig. 2). Greater subsidence at the centre of the block has led to basining of the volcanic pile, i.e. all formations dip inwards (Fig. 3). Differential movement has also occurred on the radial faults.

Where the Cerberean Cauldron adjoins the Acheron Cauldron there is no clearly defined structural break. The volcanic sequence on the western side is apparently continuous between the two cauldrons.

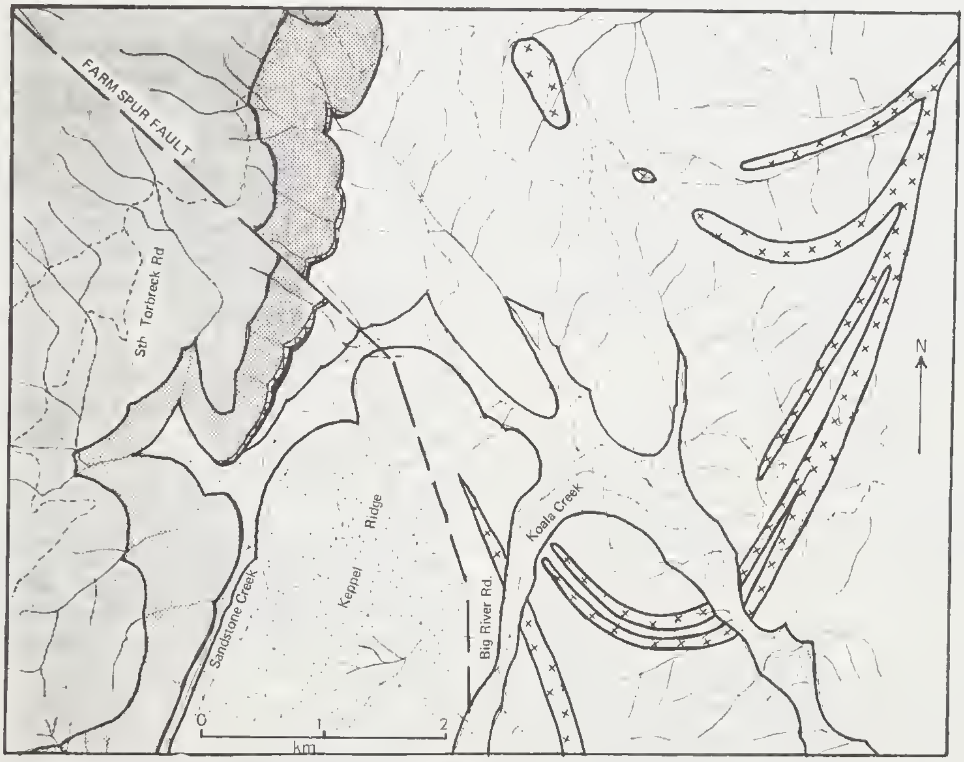


Figure 7—The geology in the region of the complex branching of the ring fracture in the south-east of the Cerberean Cauldron.

Early faulting

The earliest known fault associated with the cauldron structure is Snobs Creek Fault, which is parallel to and probably controlled by the regional basement trends (Fig. 2). The fault was operative at least as early as the extrusion of the Snobs Creek Formation, since these rocks are restricted to the downthrown, or western side of the fault in the northwest. Of the overlying formations, only the Torbreck Range Formation changes in thickness across the fault. The much greater subsidence on the fault line in the northwest, compared to the southeast, where the vertical displacement is apparently reversed, indicates a hinging effect (Fig. 5).

The inner ring dyke, exposed between pairs of radial faults in the northeast, represents an early-formed fracture. The interpretation of the geology between the Conn Hill and Newman Plain Faults (Fig. 9) requires this fracture being present as a scarp during emplacement of the Torbreck Range Andesites, since thick accumulations of basaltic andesites occur against it (Fig. 5). This scarp was apparently not present at the time between the Barnewall Plains and Torbreck Faults further north. Although interpretation of this ring fracture's history is complicated, it may represent part of the margin of a caldera, of about 9 km diameter, dipping inwards at 50°-60°, and centred on Snobs Creek Fault. The gravity survey by Clarke *et al.* (1970) indicates a probable thickening of the volcanic sequence in this area.

Later faulting

(1) Ring Fractures. The outer and most continuous ring fracture is almost perfectly circular, with a 27 km diameter. Minor branching is caused by radial and other faults, but only Snobs Creek Fault offsets it.

The complex zone of arcuate fractures developed in the southeast has probably been caused by the intersection of the southeastern end of the Snobs Creek Fault with the outer ring fracture, and influenced by the northwest-southeast regional basement trends. Further to the south, the fracture pattern has been shaped by the rigid block of Koala Creek Sandstones (Fig. 7).

Minor fractures paralleling the main fracture occur inside it, but are only detectable where dyke-filled. These include the dykes intruding the volcanics in the north (Thomas, 1947) and a partly dyke-filled fracture concentric with the outer ring dyke in the east.

A gravity survey by Clarke *et al.* (1970) near Taggerty, shows an outward dip of 70° for the ring dyke, confirming earlier observations by Hills (1959) and Thomas (1947). The offset of the ring fracture by Snobs Creek Fault in the north also indicates an outward dip. A further gravity and magnetic survey (Clarke *et al.* 1970) near Buxton, indicates an anomalous body dipping outwards at 50°. If this is the sub-surface extension of the ring dyke, its shallow dip could explain the marked thickening of the dyke near Buxton (Fig. 8).

In the southeast, where the ring fracture intersects the volcanic sequence with considerable horizontal and vertical displacement (see Fig. 8), the Rubicon Rhyolite does not change markedly in thickness but has been dragged down across it. Thus, the major subsidence on the ring fracture must have postdated extrusion of the Rubicon Rhyolite.

(2) Radial Fractures. The mapping by Birch *et al.* (1970) disclosed a set of eight radial fractures, which focus at the geometric centre of the outer ring fractures (Fig. 2), implying a close relationship between all fractures. Movement on the radial fractures occurred late in the eruptive history of the Lake Mountain Rhyodacite, as they may offset its base (Figs. 5 and 8). Stream lineaments follow fault lines in the rhyodacite, across the top of the Cerberean Ranges.

The Torbreck Fault (Fig. 5) was probably active at an earlier time, as the volcanic sequence changes across it. Considerable drag on early formations is evident on this fault, and is also shown by the magnetic survey of Clarke *et al.* (1970) near the Barnewall Plain Fault.

Source Vents

The feeder vents for the Snobs Creek Volcanic were probably associated with Snobs

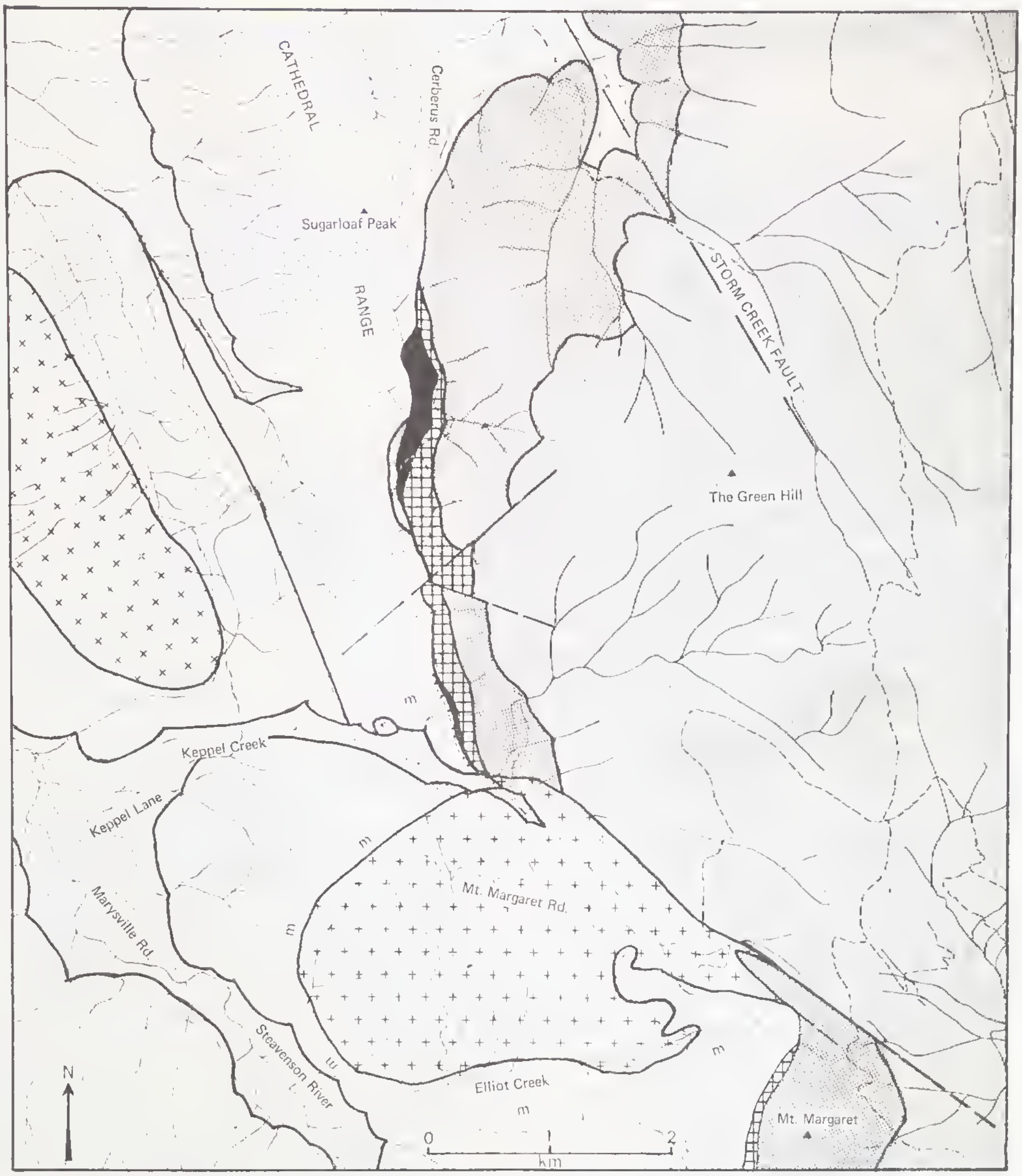


Figure 8—The geology in the Mt Margaret-Little River area.

Creek Fault, as the formation is thickest close to the fault, which was active at the time of emplacement. The suspected caldera now represented by the inner ring dyke may have been a feeder for the thick Torbreck Range Andesites. A coarse, basic agglomerate in the southwest of the cauldron (Fig. 8) with which a magnetic anomaly is associated (Clarke *et al.* 1970), indicates a likely eruption point of a more minor character. Because of the widespread occurrence of the basaltic andesites, it is likely that more vents such as this existed, but have been hidden by later volcanic eruptions.

Eruption points for the Robleys Spur Formation are probably in part represented by agglomerates, for example, one at Barkers Gully in the north (Thomas, 1947) and one near Cumberland Junction in the southeast (Fig. 6).

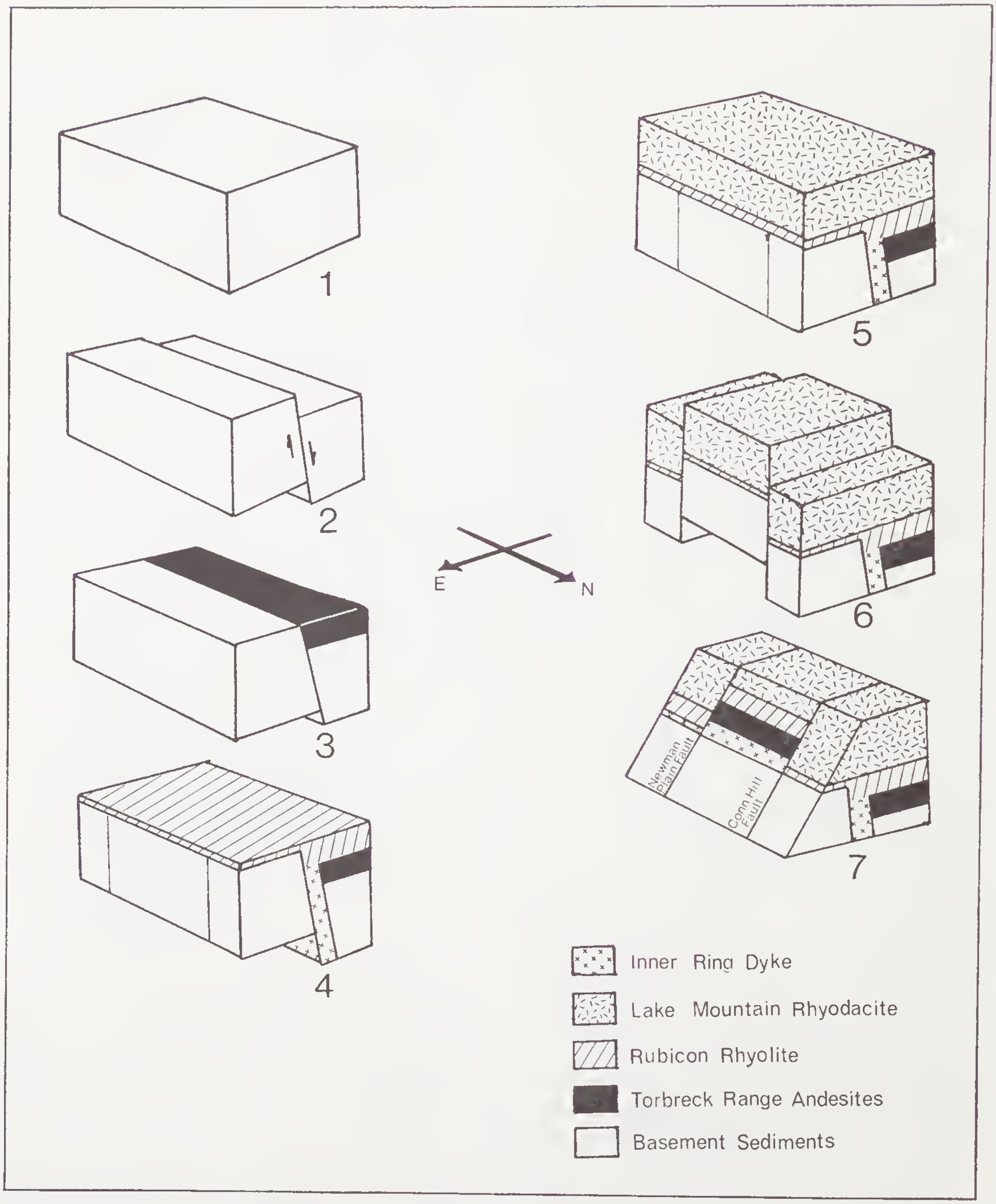


Figure 9—Block diagram illustrating the origin of the outcrop pattern between the Conn Hill and Newman Plain Faults.

Large scale ignimbritic eruptions generally take place from fissures associated with volcanic subsidence structures (Branch, 1967; Roberts, 1967; Ross and Smith, 1961). In the case of the Cereberean Volcanics, the most likely source of the ash flow eruptions is the ring fracture, as it contains intrusive equivalents of both the Rubicon Rhyolite and the Lake Mountain Rhyodacite. Tuffs with rhyolitic fragments are included in the ring dyke at Cumberland Junction. The inner ring dyke may also have been a feeder as it contains intrusive equivalents of both these rock types. Source vents may also have been situated along radial faults. The gravity survey by Clarke *et al.* (1970) indicated several anomalies which may represent buried vents (Fig. 2). A large early-formed central vent may also have developed, evidenced by the focussing of the radial faults.

Nature of the subsidence

The subsidence of the Cerberean Cauldron can be divided into two components—a basining and a ring fracture subsidence. Early basining is suggested by decreasing inward dip of the volcanics progressively up the sequence (Thomas, 1947) and by the deposition of the Blue Range Formation under lacustrine conditions. Across the southeast, gravity data (Clarke *et al.* 1970) indicates a line of thickening of the volcanics (Fig. 2), suggesting a warp marking the edge of the main cauldron basin. To the south and east of this line, the volcanics are relatively flat lying (Clarke *et al.* 1970).

By restoring the downwarped basin to its original state, a diameter of about 31 km is obtained for the circular block, compared to the present ring dyke of 27 km diameter. The well documented outward dip of the ring dyke means that the 4 km difference between these diameters represents stretching of the central block. Most of this stretching must have occurred before the tensile stress was relieved by failure along the ring fracture. The major subsidence along the ring fracture postdates the Rubicon Rhyolite, but may have taken place progressively throughout emplacement of the Cerberean volcanics. A certain amount of basining occurred after emplacement of the Lake Mountain Rhyodacite as the base shows some inward dip.

Mechanism of the subsidence

The mechanism of subsidence of the Cerberean Cauldron has undoubtedly been one of foundering under gravity, following withdrawal of magmatic support due to the extrusion of the Cerberean Volcanics. The relatively coherent subsidence of the downthrown block indicates very rapid evacuation of the magma chamber, as discussed by Williams (1941), and is borne out by the ash flow emplacement of the Cerberean Volcanics as one or two large cooling units. The fracture pattern and stretching of the foundered block suggest that the roof of the magma chamber behaved as a circular plate with a thickness considerably less than its diameter.

The timing and cause of formation of the ring and radial fractures are problematical, but there are two possibilities.

1. Eruption of magma for the Cerberean Volcanics was initiated through central vents in the cauldron area, until enough magma had been withdrawn to enable gravitational collapse of the central block along ring and radial faults.
2. Pressure build-up in the magma chamber led to explosive failure of the roof rocks along ring and radial faults. These would relieve the pressure and act as feeders for the eruption of the Cerberean Volcanics. Subsidence would then occur as the magma chamber was emptied.

In evaluating these possibilities, the following evidence must be considered:

1. The geometry of the fracture pattern is highly regular and is apparently little influenced by regional basement trends.
2. The region was apparently under tension.
3. Chemical evidence (Birch, 1975) suggests that a volatile phase could have been generated at the top of the Rubicon Rhyolite magma at some interval prior to eruption.
4. The ring fracture dips steeply outwards (at the surface).

The first three lines of evidence suggest that a 'point' explosion at depth was responsible for the fracture pattern. It is difficult to imagine purely gravitational collapse producing a perfectly circular ring fracture through a lineated crustal plate. A fracture pattern produced by an explosion at depth would be extended and enlarged by a rebound effect. Eruptions from those fractures which extended through to the surface could then permit the wedge-shaped fragments to subside into the magma chamber, at the same time initiating or increasing eruptions along the ring fracture.

The evidence from the dip of the ring fracture is inconclusive. While inward dips have been ascribed to pressure build-up by a number of workers (Anderson, 1936; Williams, 1941; Robson and Barr, 1964; Roberts, 1967; Smith and Bailey, 1968), the theoretical treatment of the problem of the fracture patterns derived from either withdrawal of magmatic support or upward magmatic pressure is by no means rigorous. For example, Robson and Barr (1964) suggest that steeply outward dipping ring fractures may result from either mechanism.

Emplacement of high level intrusions

Following the volcanic episode, with its associated dyke intrusions, came a culminating period of intrusion into the base of the volcanic pile. Such high-level extrusive activity is typically the final magmatic event in similar complexes throughout the world (c.f. Branch, 1966; Kingsley, 1931; Oftedahl, 1952; Jacobson *et al.*, 1958).

The intrusion proceeded in two stages and was largely controlled by pre-existing lines of weakness. The first phase is represented by the porphyritic microgranodiorite. While its intrusion along the main Cerberean ring fracture in the southwest was permissive, its emplacement in the Keppels Falls area, along the continuation of the main boundary fault of the Acheron Cauldron may have produced localized gneissic textures in the Lake Mountain Rhyodacite.

The second-phase granodiorite is more extensive, forming a relatively flat-roofed intrusion. The fault controlling the intrusion's eastern boundary is continuous to the south with the main boundary fracture of the Acheron Cauldron (Dudley *et al.* 1971). The apparent shallow westerly dip of the western margin of the intrusion may explain the high degree of contact metamorphism of the sequence on Robleys Spur, east of Marysville.

Intrusion probably occurred by quiet stoping, as the magma apparently caused no resurgent vulcanism, yet cooled within a kilometre of the surface. The region of granitized hornfels described previously was probably a structural high at the time of cauldron formation both to the north (Cerberean) and south (Acheron). That thin volcanic sequences may have been deposited on it is suggested by the occurrence of isolated, flat-lying, metamorphosed remnants of the Lake Mountain Rhyodacite, forming the highest part of the topography (Mt Stinton and Mt Grant, Figs. 2 and 3).

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