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CHAPTER 1

INTRODUCTION

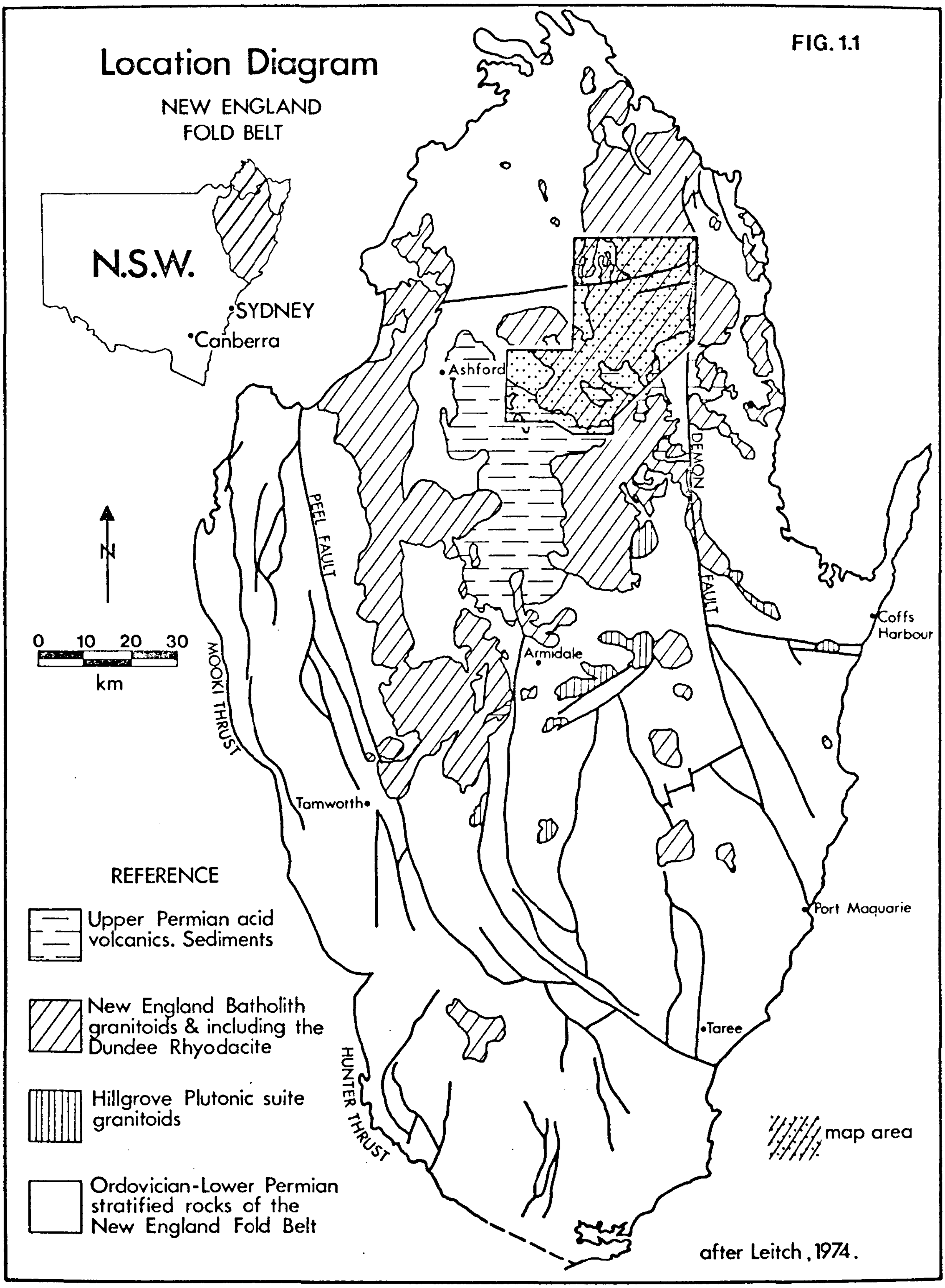
The Emmaville district in northeastern New South Wales has been of interest to geologists since the first reports of tin-bearing granitoids in the area by the Rev. W.B. Clarke in 1853 (Carne, 1911). Since then detailed accounts of the geology of the region have focussed on the Late Permian calc-alkaline intrusive rocks or on the documentation of orebody occurrences. To date little progress has been made towards an understanding of the physical and compositional relationships of the rocks or the genesis of the associated ores. Perhaps the main reason for this stems from a restricted knowledge of the Late Permian acid volcanic rocks in the area, until recently only superficially documented. This thesis represents the first attempt to relate the associated calc-alkaline volcanic and intrusive rocks and the various types of mineralization.

Although a detailed account of the field relations and petrography of the Permian igneous rocks was an important objective of this study, the principal aims have been to relate the composition of orebodies to those of the assumed parental magmas and to determine the position of such magmas within an evolutionary sequence. The approach has involved an assessment of the emplacement and volcanic histories of the calc-alkaline rocks and a knowledge of the processes of magma evolution which ultimately result in orebody formation. However, the discussions and conclusions presented in this thesis on magma processes and ore genesis in evolved calc-alkaline granitoids are not restricted only to the Emmaville district. Analogous geological environments have been documented from several continents and it will be established that the scope of the principles outlined herein may have wider application.

LOCATION OF THE AREA

The area is situated in the extreme northeast of New South Wales and extends into southern Queensland. An area of almost 2000 km^2 was mapped, about central co-ordinates - lat. 29°17'S, long. 151°50'E. The region lies to the south and east of the Mole Tableland and is covered by the Warwick, Grafton and Inverell 1:250,000 scale sheets issued by the Geological Survey of New South Wales.

FIG. 1.1


Location Diagram

NEW ENGLAND FOLD BELT

after Leitch, 1974.

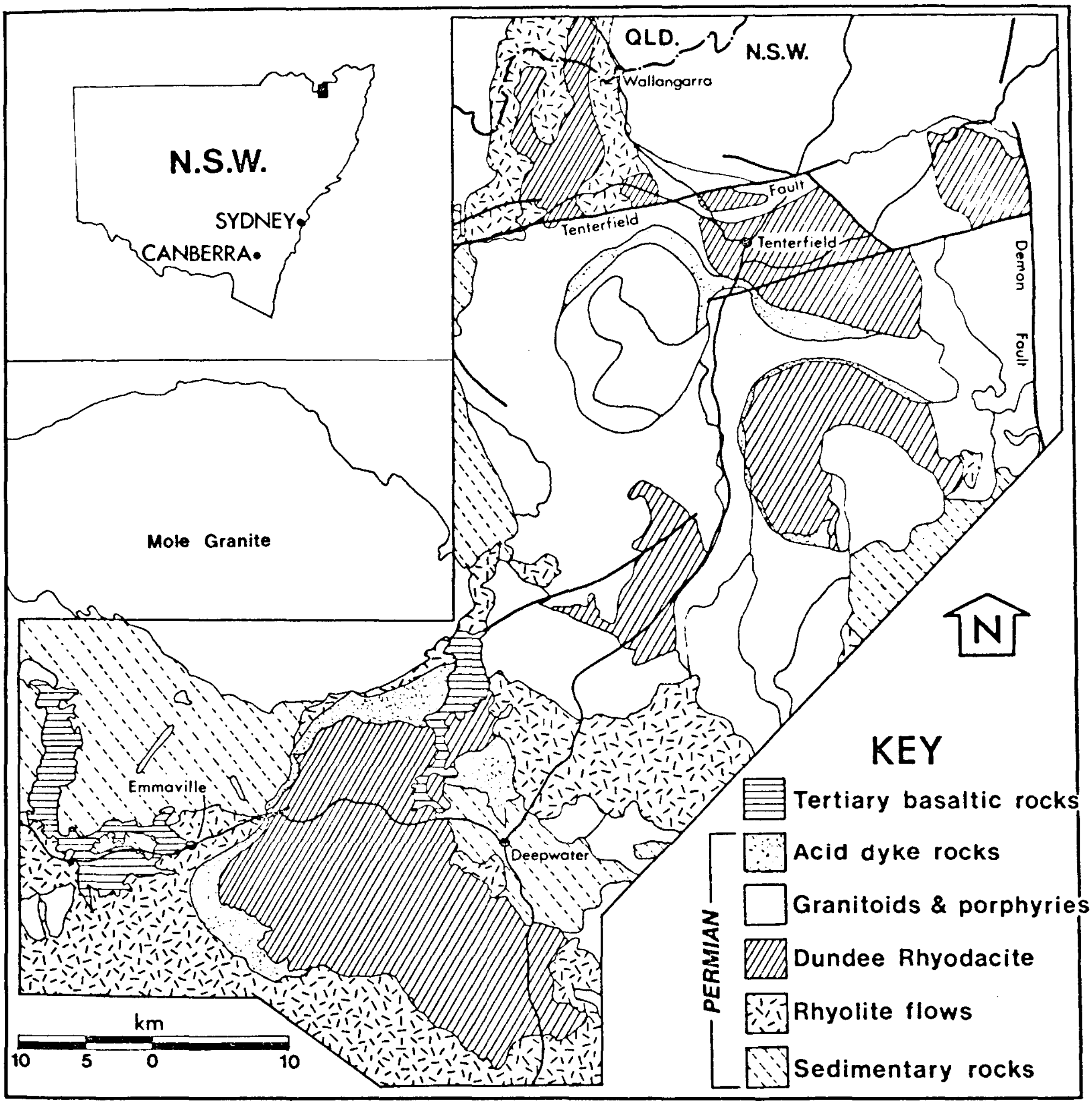


FIG. 1.2 SIMPLIFIED GEOLOGICAL MAP OF STUDY AREA

PHYSIOGRAPHY

Much of the topography is rugged, including the dissected mountain country of the Great Dividing Range in the eastern parts, the Mole Granite highland in the southwest and the Bolivia Range which trends east-west in the central region. Volcanic rocks form gently sloping hills dissected by intermittent and permanent streams, in contrast to the sedimentary units which form the foothills of the Mole Granite and other plutons, and which may be deeply incised by the tributory and main stream drainage channels. Acid porphyries and rhyolites outcrop as prominent ring structures which border individual masses of the Dundee Rhyodacite in the central portions of the area. Andrews (1903, 1904) recognized three peneplain levels in the region, including the Stanifer Peneplain developed on the Stanthorpe Adamellite north of Tenterfield, the Bolivia Peneplain and the Mole Peneplain around Emmaville and Deepwater. Most of the area is more than 1000 m above sea level.

REGIONAL GEOLOGICAL SETTING

The Emmaville-Tenterfield region is situated in the north-central portion of the southern part of the New England Geosyncline or Fold Belt. The New England Geosyncline, as defined by Harrington (1974), comprises the stratified Palaeozoic and accompanying intrusive rocks that occur east of the Eungella-Cracow Mobile Belt and the Great Artesian Basin in Queensland, and east of the Hunter-Mooki Fault System in New South Wales (Fig. 1.3). The Geosyncline is thus readily divided into three "provinces"; the Yarrol Province in the north, Gympie Province in the southeast and the New England Province which is synonymous with the southern part of the Geosyncline (Day et al., 1978).

The southern part of the Geosyncline has been divided into two major zones, termed the Tablelands Complex to the east of the Peel Fault System and the Tamworth Belt to the west (Korsch, 1977). The Tablelands Complex, of which the Emmaville-Tenterfield region represents the northern part, has been sub-divided by previous workers using mainly structural criteria (e.g. Scheibner, 1973), or combined lithological, stratigraphic and structural criteria (e.g. Leitch, 1974; Runnegar, 1974). Korsch (1977) recognized seven lithostratigraphic sedimentary associations within the Tablelands Complex, two of which - the Sandon and Nambucca Associations - are represented in the Tenterfield area (see Fig. 1.4).

PREVIOUS INVESTIGATIONS

The earliest published reports of the Emmaville-Tenterfield region concerned the discovery and later development of tin and tungsten mining fields (e.g. David, 1887). In the early part of the century Andrews (1905, 1905a, 1907, 1907a) and Saint-Smith (1913) studied the petrography and chemistry of the granitoids of northern New England and Southern Queensland. More recent studies of selected aspects of the igneous petrology have been carried out by Vernon (1959), Shaw (1964), Wilkinson et al. (1964) and Flood et al. (1977, 1980) and by several graduate students of the Universities of New England and New South Wales. Although many individual aspects of the igneous geology and mineralization have been covered by previous investigations, this study represents the first attempt to correlate the spatial and magmatic relationships of the volcanic and subvolcanic rocks in any detail.

SUMMARY OF GEOLOGY

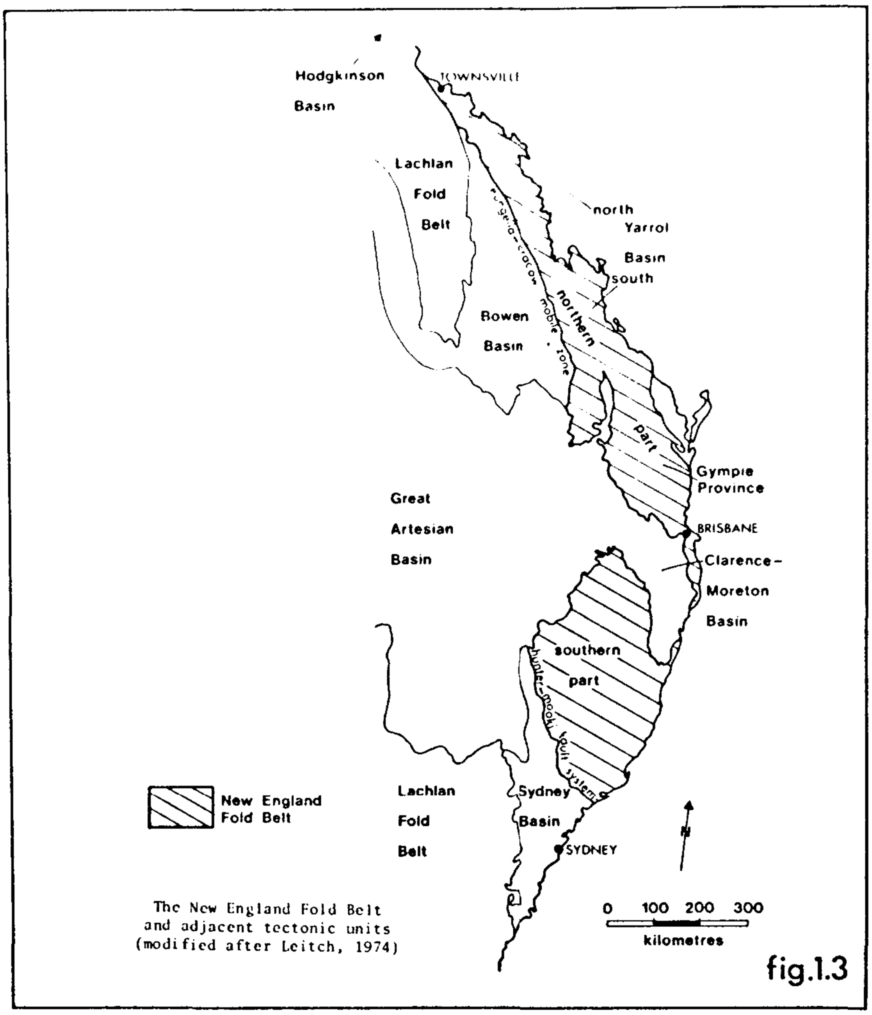
In Late Permian times, ignimbritic acid calc-alkaline volcanics were extruded onto Early Permian turbiditic rocks which comprise the sedimentary basement in the Emmaville-Tenterfield region. There is evidence to suggest that the eruption of large volumes of fluidized acid magma resulted in the partial depletion of high-level magma chambers, which triggered cauldron collapse at several volcanic centres. Caldera formation culminated in the eruption of enormous volumes of ignimbritic rhyodacite (242 Ma) which filled and partly breached the confines of the calderas. Ignimbritic volcanism therefore occurred during two major episodes -

(a) ash-flow eruptions of (dominantly) rhyolitic magma which initiated caldera formation; and

(b) eruption of fluidized rhyodacitic magma which modified the pre-existing calderas.

The time interval separating the two volcanic episodes is not known.

Shortly after the second volcanic episode, calc-alkaline magmas were emplaced at high crustal levels, forming plutons dominantly adamellitic in composition. These intruded and contact metamorphosed the earlier eruptives. The form of several calderas near Tenterfield was substantially modified during this



The New England Fold Belt
and adjacent tectonic units
(modified after Leitch, 1974)

fig.1.3

modified from Korsch, 1977.

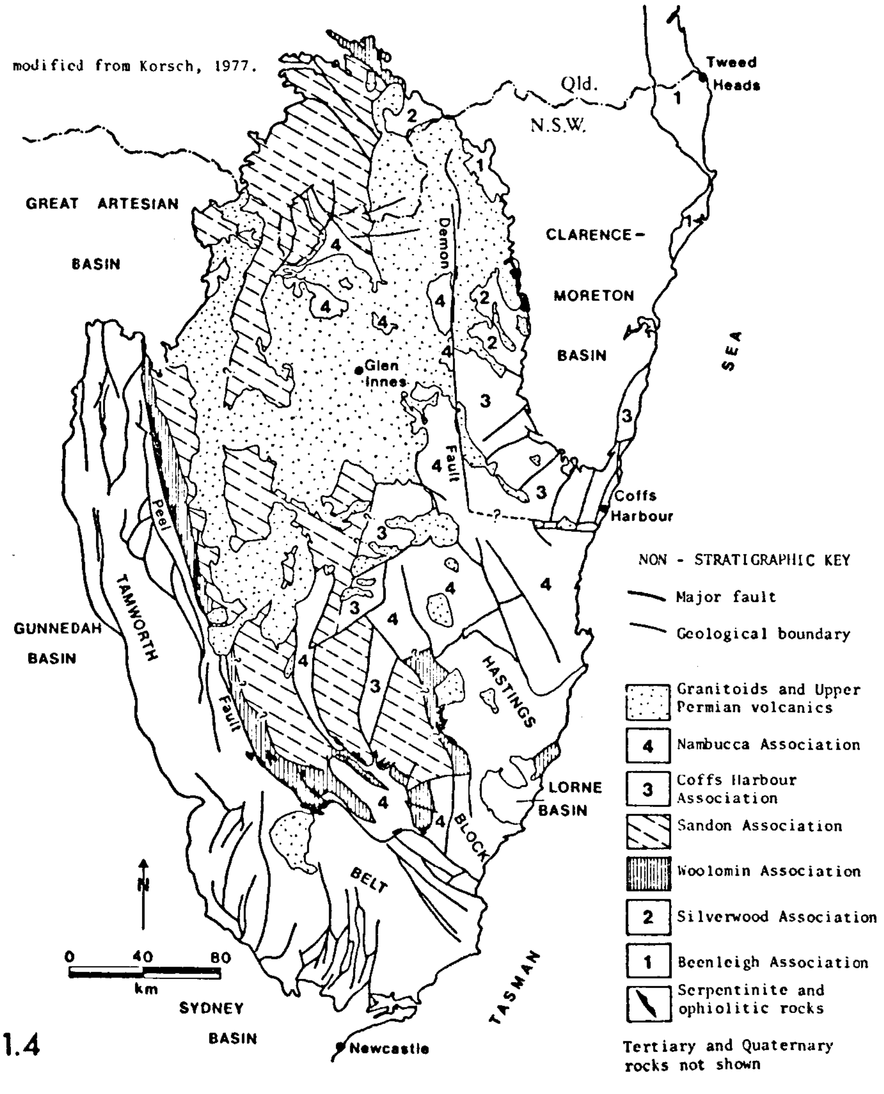


fig.1.4

period of subvolcanic plutonism (~237 Ma). In the Early Triassic (222 Ma) a second episode of calc-alkaline magmatism was marked by high-level emplacement of adamellite and leucoadamellite plutons in the region north of Tenterfield.

1. SEDIMENTARY ROCKS

The early Permian sedimentary rocks forming the basement have not been extensively studied and little is known in detail of their stratigraphy, petrology and structural relations. Siltstones and conglomerates intruded by the Mole Granite and the silicified argillites and sandstones west of the Demon Fault (Fig. 1.4) are part of Korsch's (1977) Nambucca Association. West of Tenterfield, Sandon Association sediments are partly in faulted contact with undifferentiated adamellites and leucoadamellites such as the Clive Adamellite (see map). Greywacke and siltstones are dominant in both associations, but the Nambucca Association is characterized by the presence of paraconglomerates. The bulk of the material constituting the sediments of the Nambucca and Sandon Associations was derived from an acid to intermediate source and was largely deposited by turbidity currents (Korsch, loc.cit.).

Vickery (1972) correlated sandstones, mudstones and conglomerates north of the Mole Granite with turbiditic Texas Beds sediments in southern Queensland (Lucas, 1958; Olgers and Flood, 1970). These sediments are overlain by volcanoclastic para- and orthoconglomerates of the Bondonga Beds or Silver Spur Beds (Lucas, 1958). Rose (1960) and Olgers and Flood (loc.cit) proposed an unconformable contact between the Carboniferous Texas Beds and "Upper Permian" Silver Spur Beds, but this unconformity was disputed by Vickery (loc.cit). North of the Mole Granite paraconglomerates of the Mosman Formation of probably Late Permian age unconformably overlie the Bondonga Beds which are in turn overlain by an acid pyroclastic unit terms the Gibralter Ignimbrite (Vickery, loc.cit). Vickery also recognizes muddy and sandy sedimentary rocks which apparently overlie the Bondonga Beds but which are stratigraphically beneath the Late Permian Mosman Formation and Gibralter Ignimbrite. He was able to subdivide these fine-grained sedimentary rocks into two units - the Silent Grove Beds and the Riverton Beds. A detailed correlation of these units with those exposed south of the Mole Granite was not attempted in this study, but at the present level of erosion the Granite appears to have intruded the Silent Grove Beds and the paraconglomerates of the Bondonga Beds have been preserved as a roof pendant. South of the Mole Granite the sedimentary rocks are vertically dipping and in places are complexly folded.

Nambucca Association sediments near Deepwater are very poorly exposed and appear to consist mainly of massive and thinly laminated siltstones with fine-grained tuffaceous interbeds. Interbeds of this type are also observed in the Emmaville and Webbs Consols Mine areas where ignimbritic volcanics overlie fine-grained sandstones and silty sediments.

2. BASIC INTRUSIVES

Metadolerites or "epidiorites" intrude the sedimentary rocks south of the Mole Granite in the vicinities of the Ottery, Reids and Collisons Mines, and bordering Glen Greek (Lawrence, 1969). Dolerites also intrude the sediments north of the Mole Granite (Vickery, 1972). The dolerites occur as plug-like masses, small sills and dykes. Although they have been metamorphosed by and are therefore older than the Mole Granite, the age of the metadolerites relative to the majority of the granitoids in the region cannot be ascertained from field evidence.

Petrographic studies of the intrusive at Reids Copper Mine reveal mineralogical and textural variation consistent with low-pressure fractionation of a basic magma. Plagioclase-rich and clinopyroxene-rich cumulate facies occur in the quartz-bearing microgabbro now contact metamorphosed to hornblende hornfels facies. The grade of contact metamorphism is atypically high in this region and is apparently related to a very high-level granitic intrusive (possibly part of the Mole Granite) which outcrops in a shallow shaft adjacent to the metagabbro.

3. CALC-ALKALINE VOLCANIC ROCKS

The dominantly rhyolitic welded ash-flow tuffs which comprise the Emmaville Volcanics in the southern portion of the area and the presumably equivalent Wallangarra Volcanics in the northwest, are products of the first volcanic episode in the region. Evidence of a conformable contact between the Emmaville Volcanics and basement sedimentary rocks is restricted to the Webbs Consols Mine area (see map).

The most common rock types are quartz-two feldspar rhyolites with variable phenocryst feldspar ratios and well developed eutaxitic textures. Minor flow-banded rhyolite outcrops in the Webbs Consols Mine region and lavas of similar composition are also reported to occur near Wellingrove, 24 km south of Emmaville (McKay, 1975). Ignimbritic biotite rhyolites and hornblende-bearing rhyodacites are common south of the Bolivia Range, and rare dacites and andesite occur east of Dundee. Ash-fall tuffs are very minor components of the Emmaville Volcanics and the only known occurrences of these rocks are those noted by McKay (1975) near Wellingrove, and a poorly exposed sequence 5 km due south of Dundee. Poor exposures, the large number of individual flow units, and the rarity of any units with megascopically recognizable and distinctive characteristics, have prevented a detailed evaluation of the volcanic stratigraphy.

There is evidence to suggest that granitic plutons have been emplaced at high levels within the Permian volcanic pile. Within and south of the area the Emmaville Volcanics have been contact metamorphosed, are frequently hydrothermally altered and may contain base-metal sulfide veinlets. The sporadic distribution of granitic inliers (e.g. Webbs Consols Mine and west of Locarno Homestead) suggests that plutons are now in the process of being unroofed.

The ignimbritic Tent Hill Volcanics and Dundee Rhyodacite are considered to belong to the second episode of volcanism. The Tent Hill Volcanics border the western margin of the Dundee volcanic mass, and appear to conformably overlie the Emmaville Volcanics. The Tent Hill Volcanics range in composition from rhyodacites which are virtually identical to the Dundee Rhyodacite, to dacite lithic tuffs. These Volcanics are black, glassy rocks readily distinguishable from the cream to buff-coloured outcrops of the Dundee Rhyodacite.

The Dundee Rhyodacite is a pyroxene-hornblende-bearing ignimbrite with a distinctive microgranular "recrystallized" groundmass. It is remarkably uniform in modal and chemical composition and is distributed throughout the area as several discrete masses, the largest of which (the Brassington, Tenterfield, Dundee and Bolivia masses) are interpreted to be cauldron structures related to the formation of the older Emmaville Volcanics. The contacts of most masses of the Rhyodacite are either faulted or intruded by high-level adamellite plutons. However, the Wyberba and Sunnyside Rhyodacite masses overlie the Wallangarra Volcanics and they may represent the outflow volcanics from a nearby caldera. Rhyodacite of the Dundee mass grades almost imperceptibly into units of the Tent Hill or Emmaville Volcanics. Near the contact the distinctive microgranular groundmass textures of the Rhyodacite gradually merge into finely devitrified and ultimately glassy textures which display abundant evidence of an ash-flow origin. Because the texture, size and modal abundance of phenocryst minerals, and hence chemical composition of these rocks differ from typical Dundee Rhyodacite, early workers (e.g. Shaw, 1964; Wilkinson et al., 1964) failed to recognize these rocks as being part of the Dundee mass. For this reason, these authors did not consider the possibility of an ignimbritic origin for the Dundee Rhyodacite.

4. CALC-ALKALINE GRANITOIDS

Closely following the second episode of volcanism plutons of adamellite and leucoadamellite composition were emplaced at high crustal levels. Plutons of the first intrusive phase, dated at 238-236 Ma, outcrop south of the Tenterfield Fault (Leitch, 1975) in the central-northern part of the area. O'Neil et al. (1977) considered that the intrusives are I-type granitoids (as defined by Chappell and White, 1974).

Adamellite and leucoadamellite porphyries intrude more coarsely crystalline granitoids in north-south trending belts situated east and west of Tenterfield. Intrusive acid porphyries are also a component of the arcuate dykes which partly surround the Tenterfield and Brassington masses of the Dundee Rhyodacite, and the Mackenzie Adamellite. Those granitoids which intrude the Emmaville Volcanics characteristically develop broad contact aureoles. The subvolcanic Bolivia Range, Sandy Flat, Petries Sugarloaf and Mount Jonblee Leucoadamellites, are examples.

Emplacement of the leucocratic Stanthorpe and Ruby Creek Adamellites (222 Ma) mark the second and final major intrusive episode in the region. Like the Mole Granite (the youngest pluton of the first major intrusive episode), the Ruby Creek Adamellite is cassiterite-bearing, and it is the younger granitoid of the second intrusive episode.

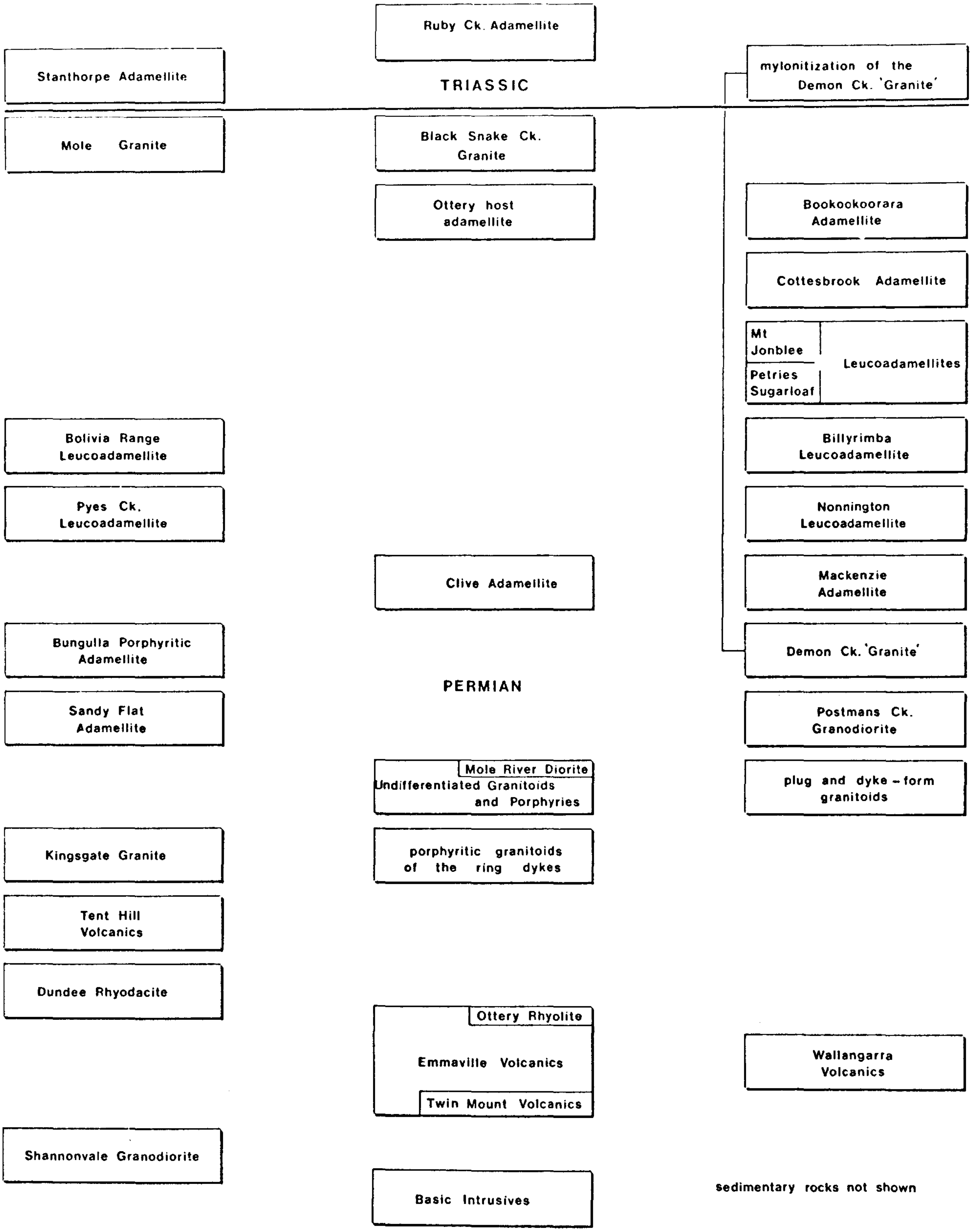
High-level plutons were largely unroofed by Middle Triassic times (Bourke et al., 1977), and many in the southern portion of the area are capped by flows of Lower Oligocene-Miocene alkali-olivine basalts and related alkaline volcanics (Wilkinson et al., 1964)

5. CONTACT METAMORPHISM

Because of very high-level intrusion by subvolcanic granitoids, the volcanics in the region display effects of biotite-grade metamorphism, increasing locally to hornblende-grade immediately adjacent to granite contacts. The wide (up to 5 km) thermal aureole surrounding the Mole Granite suggests that a very low-angle contact exists between the Granite and the sedimentary country rocks (Kleeman et al., in prep.). There is no evidence of any regional metamorphism in the area, even at grades as low as the zeolite facies.

More detailed accounts of metamorphism are provided in the description of individual rock units presented in Chapter 2.

SEQUENCE OF INTRUSION



sedimentary rocks not shown

Fig. 1.5

6. MAJOR FAULTS

The Demon Fault is a prominent major linear feature in the eastern part of the Tablelands Complex. Shaw (1969) proposed a dextral strike-slip movement of 30 km along the Fault in the Tenterfield region, but McConachy (1975) observed only a 17 km displacement of granitoids in the same area. These estimates relate to movement since emplacement of the granitoids (238-223 Ma), but Leitch (1975) and Runnegar (1974) inferred a total dextral strike-slip movement of about 150-200 km. Day et al. (1978) also proposed large movements along the fault in the Late Palaeozoic. Korsch et al. (1978, p.104) proved a dextral strike-slip movement of "at least 17 km", but suggested there have been no large-scale movements. They considered that the fault may have bounded the emplacement of several plutons which abut the fault but appear to lack a conjugate displaced portion on the other side. Emplacement of the Mount Mitchell Adamellite and Newton Boyd Granodiorite plutons located 75 km south of Billyrimba Homestead and the Stanthorpe Adamellite north of this homestead, was strongly influenced by the Demon Fault. Korsch et al. (loc.cit.) also suggest that upward movement of the eastern block on the Demon Fault may have "lead to the development of a trough in which the sediments of the Nambucca Association were deposited". This proposal refers to Nambucca Association sediments located at the southern end of the Fault and may not be applicable to the rocks of this association outcropping near Billyrimba.

The east-northeast-trending Tenterfield Fault (see Fig. 1.2) is the dominant member of the group of similarly oriented faults in the region of Tenterfield. The Tenterfield Fault played a major role in the emplacement of intrusions such as the Bungulla Porphyritic Adamellite, Stanthorpe Adamellite and the porphyritic granitoids west of Tenterfield. Plutons of these rock types are apparently truncated by the Fault but lack a conjugate portion on the other side.

The magnitude, direction and time of movement on the Tenterfield Fault are not known. However, Leitch (1975) proposed major dextral movement on the Fault during the Late Devonian, and a reversal of this movement in the Late Carboniferous. Leitch apparently exaggerated the western limits of the Fault (see Fig. 1.1) and his tectonic model depends on poorly substantiated large movements on the Fault, a proposal regarded by Harrington (pers.comm.) as suspect.

GRANITOIDS OF THE TABLELANDS COMPLEX - CLASSIFICATION

The Palaeozoic New England Batholith s.l., which has been termed the "Core of New England" (Wilkinson, 1974), has an outcrop area of some 16,500 km^2, with an additional 3,500 km^2 covered by Tertiary basalts (Chappell, 1978). Plutons of the Batholith intrude (almost exclusively) the sedimentary rocks and Permian acid volcanics of the Tablelands Complex. Depending on the classification followed, the Batholith may be subdivided into four or five distinct groups or associations.

Korsch (1977) recognized the Bundarra, Hillgrove and Stanthorpe Plutonic Suites, and assigned the remaining intrusions to a group termed the New England Batholith s.s. (see Fig. 1.6A). O'Neil et al., (1977) accepted the associations defining the Bundarra and Hillgrove Plutonic Suites, but they classified the remainder into the Uralla, Moonbi and Leucoadamellite Suites (see Fig. 1.6B). The Leucoadamellite Suite includes all of the intrusions belonging to the Stanthorpe Plutonic Suite as defined by Korsch (1977), as well as the older leucogranitoids in the Tenterfield region. O'Neil et al. (1977) elected to exclude the Mount Jonblee and Petries Sugarloaf Leucoadamellites from the Leucoadamellite Suite and assigned them to the Moonbi Plutonic Suite. Because the age difference between the Stanthorpe granitoids (222 Ma) and those south of the Tenterfield Fault ($\sim$ 237 Ma) is as significant as those categorizing other suites of the Batholith, Korsch's Stanthorpe Plutonic Suite which includes the granitoids of the second intrusive episode, has been accepted for this thesis. However, regarding the chemical characteristics of leucogranitoids belonging to both the first and second intrusive episodes, all may be assigned to a single suite (cf. O'Neil et al., 1977).

The Bundarra Plutonic Suite consists of a number of massive, coarse-grained leucoadamellites which form a 220 km long, meridianally-trending belt east of the Peel Fault System. According to Flood and Shaw (1975), the rocks are cordierite-bearing biotite-muscovite granites derived from a pelitic sedimentary parent (i.e. they are S-type granitoids). Radiometric data indicate a Late Carboniferous to Early Permian age for the Suite (Wilkinson, 1974; Korsch, 1977).

The Hillgrove Plutonic Suite consists of syntectonic and late tectonic plutons of granodiorite and adamellite (Leitch, 1974). Individual members often display a primary foliation (produced during emplacement of the partly crystalline magmas) which is overprinted by a tectonically induced secondary foliation (Wilkinson, 1974). The rocks have the characteristics of S-type granitoids with an initial $^{87}Sr/^{86}Sr$ ratio of 0.706, and have been allegedly derived by partial melting of ". . . deformed sediments marginal to a continental region" (Flood and Shaw, 1977). They are similar in age to the Bundarra Plutonic Suite (295 ± 25 Ma).

An inspection of Figures 1.6A and B reveals a lack of agreement between the classifications of O'Neil et al. (1977) and Korsch (1977) concerning the assigning of

GRANITES & PERMIAN VOLCANICS OF THE SOUTHERN PART OF THE NEW ENGLAND GEOSYNCLINE

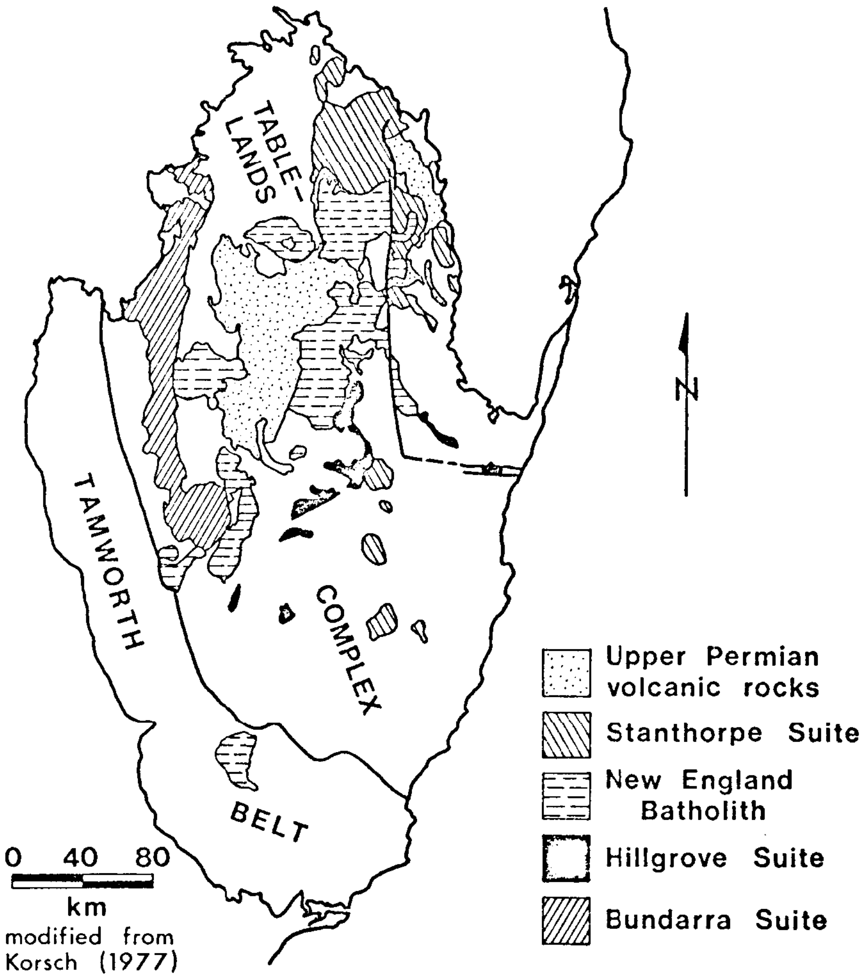
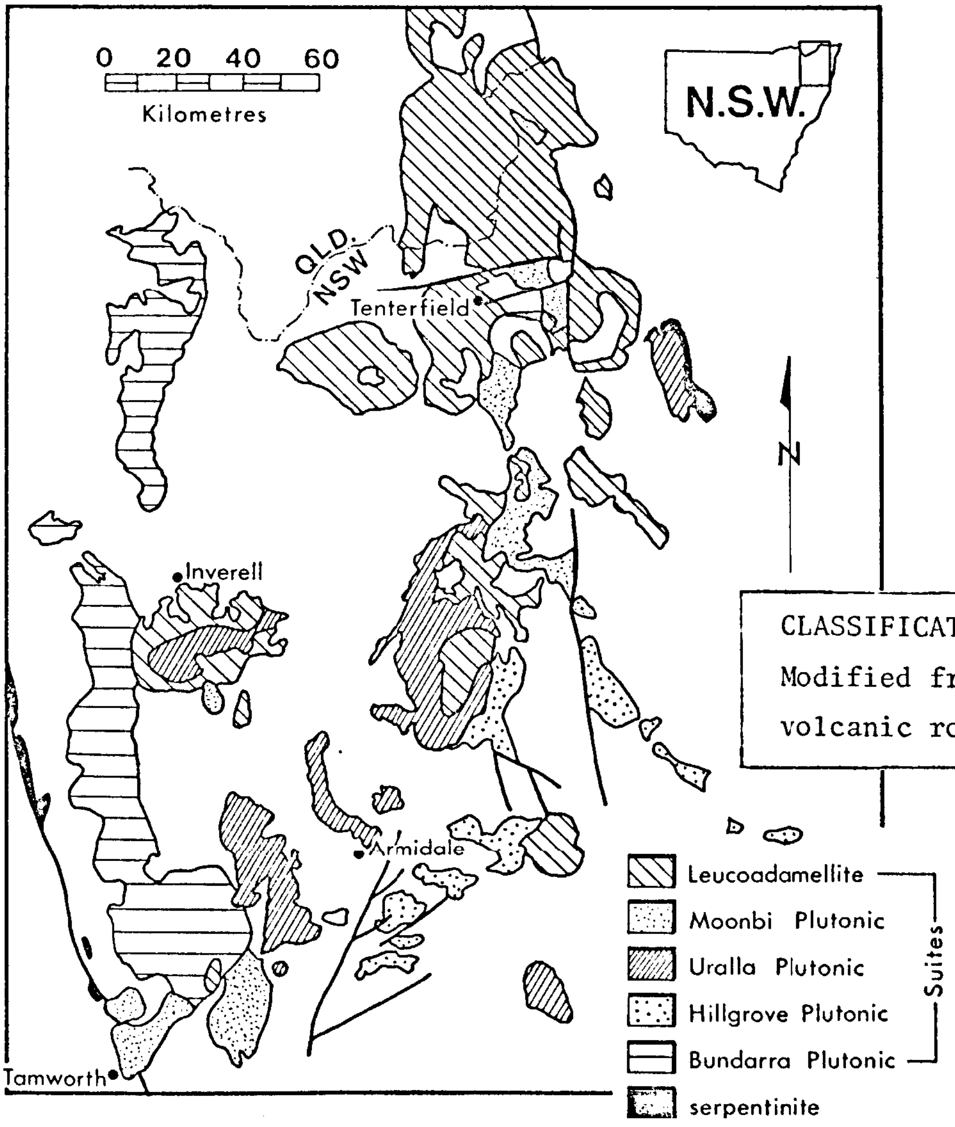


fig.1.6A modified from Korsch (1977)



CLASSIFICATION OF GRANITOIDS
Modified from O'Neil et al.,1977.
volcanic rocks not shown

fig.1.6B

the Chaelundi Adamellite (Brunker and Chesnut, 1976) to the Hillgrove Plutonic Suite.

The Moonbi Plutonic Suite consists of widely spaced plutons whose average composition approaches adamellite. O'Neil et al. (1977) quote an unusually low initial $^{87}Sr/^{86}Sr$ ratio for the plutons of 0.7074 and consider that the Suite possesses a very marked I-type character. The sphene-bearing Bungulla Porphyritic Adamellite (and similar Undercliff Falls Adamellite) are included in this suite.

Plutons in the Uralla Plutonic Suite range in composition from gabbro to diorite, granodiorite and granite. All are approximately the same age as the Moonbi Suite (240-255 Ma). Because they have comparatively low hornblende/biotite ratios, a sub-aluminous amphibole and lack magnetite as the principal opaque phase, plutons of this suite are considered to have rather less pronounced I-type features, compared with the Moonbi Suite rocks (O'Neil et al., 1977).

Korsch's Stanthorpe Plutonic Suite consists of leucocratic adamellites ranging in age from 225-222 m.y.. The I-type Stanthorpe Adamellite is the dominant member of this suite. It has been intruded by the Ruby Creek Adamellite which has some S-type characteristics (O'Neil et al., 1977; Thomson, 1976). The plutons of the Stanthorpe Plutonic Suite were emplaced during the second episode of intrusion in the study area.

The remaining leucoadamellites and adamellites, located mainly in the Tenterfield region, are of Late Permian age (236-238 Ma; Evernden and Richards, 1962; Shaw, 1964). These rocks are part of the New England Batholith s.s. according to Korsch (1977), and are considered to represent an earlier intrusive episode than that which produced the Stanthorpe Plutonic Suite.

With few exceptions, the granitoids within the New England Geosyncline in northeastern New South Wales are unstressed and may be surrounded by metamorphic aureoles (Wilkinson, 1974). Most appear to have been emplaced at high crustal levels and results from this study indicate that specific acid volcanics and high-level plutons may be comagmatic, at least in the northern regions of the New England Tableland.

CHAPTER 2

CALC-ALKALINE ROCKS: PETROGRAPHY

CHAPTER 2

CALC-ALKALINE ROCKS: PETROGRAPHY

The major units of calc-alkaline igneous rocks in the area will be described within the framework of a two-fold division, namely volcanic and intrusive types. Many of the intrusive masses have been described by Shaw (1964) but only brief accounts of seven plutons have appeared in print (Shaw, 1969). Thomson (1976a) provided descriptions of five intrusive rock types that occur in the northern portions of the area. For brevity, the granitoids will be described under the general headings:

(a) adamellites and granodiorites;
(b) diorites; and
(c) silicic granitoids.

Accounts of the ring dykes and undifferentiated granitoids are more detailed than those offered by Shaw (1969).

Volcanic rocks are divided into three distinct groups:

(a) the Dundee Rhyodacite;
(b) the Tent Hill Volcanics; and
(c) the Emmaville Volcanics (including the Twin Mount and Wallangarra Volcanics).

Detailed petrographic accounts of Groups (b) and (c) have not been published. Although descriptions of the Dundee Rhyodacite have been published (Wilkinson *et al.*, 1964; Flood *et al.*, 1977), no convincing petrographic data supporting its volcanic origin have been presented, and a detailed discussion of its genesis is therefore warranted.

Mineral compositions were determined by electron microprobe or wet chemical techniques. Potassium feldspar compositions (in wt.% Or Ab An) are based on the data of Shaw (1964). Amphiboles are classified according to the scheme of Leake (1968), biotites according to Foster (1960) and iron-titanium oxides have been calculated on an ulvospinel or ilmenite basis, as outlined by Carmichael (1967). Ilmenite analyses are quoted in terms of mol% ilmenite and hematite end-members, where the hematite component includes all the trivalent cations appropriate to the general formula R_2O_3. The term Mg number or mg = atomic 100 Mg/(Mg + Σ Fe), where Fe = total iron as Fe^{2+}.

NOMENCLATURE OF THE IGNEOUS ROCKS

Granitoids have been classified (Fig. 2.1) according to the scheme proposed by Chappell (1978). To avoid further confusion, rock types named by previous workers have been retained. Previously undocumented rocks have been named in accordance with the classification adopted here.

The Emmaville and Tent Hill Volcanics display a wide variation in phenocryst content and abundance of cognate and accidental volcanoclastic material. Classification schemes based on modal pheoncryst contents (e.g. Streckeisen, 1967, 1978) or abundance of clastic material (O'Brien, 1963) are therefore unsuitable. Similarly, the chemical classification devised by Church (1973) which employs the three-axis orthogonal plot $Na_2O + K_2O$ vs. $FeO + Fe_2O_3 + \frac{1}{2}(MgO + CaO)$ vs. Al_2O_3/SiO_2 in weight percent, does not adequately discriminate between dacites, rhyodacites and rhyolites. A simple chemical classification, similar to that employed by Ewart (1979), has therefore been adopted.

% SiO_2	Name	Common Phenocryst Phases
> 70	rhyolite	quartz, K-feldspar, oligoclase, biotite
64-70	rhyodacite	quartz, K-feldspar, andesine, biotite, hornblende, (± clinopyroxene)
61-64	dacite	calcic andesine, biotite, hornblende, clinopyroxene, (± quartz, K-feldspar)
< 61	andesite	calcic andesine, (± biotite), hornblende, clinopyroxene.

Following the suggestion of Healy (1972), the term ignimbrite refers to deposits of pyroclastic flow origin, regardless of the degree and amount of welding. The terms cauldron and caldera are employed following the definitions offered by

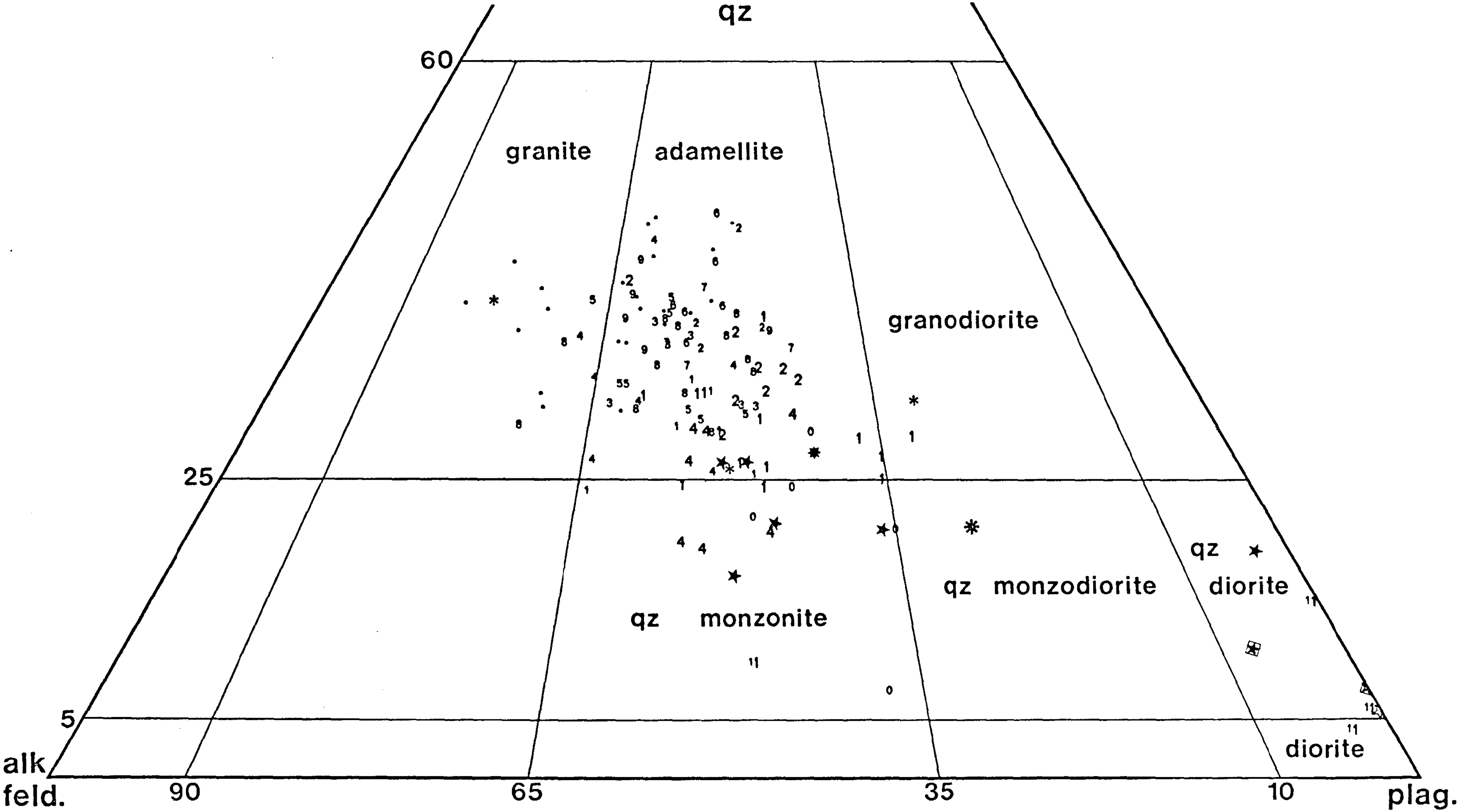
Fig. 2.1. Classification of Calc-Alkaline Intrusive Rocks in the Tenterfield Region

The modification of Streckeisen's (1973) classification used by Chappell (1978), has been adopted

0	Cottesbrook Adamellite
1	Bungulla and Undercliff Falls Porphyritic Adamellites
$^{1}1$	Bungulla and Undercliff Falls Porphyritic Adamellites--xenoliths
1	Mackenzie Adamellite
2	Nonnington Leucoadamellite
3	Billyrimba Leucoadamellite
4	Stanthorpe Adamellite
4	Stanthorpe Adamellite--hornblende-bearing
5	Bolivia Range Leucoadamellite
6	Sandy Flat Adamellite
7	Clive Adamellite
8	Mt Jonblee Leucoadamellite
9	Pyes Creek Leucoadamellite
•	Mole Granite
2	Ruby Creek Adamellite
★	Undifferentiated granitoids
◈	Undifferentiated granitoids--xenoliths
*	Bookookoorara Adamellite
❋	Postmans Creek Granodiorite
✸	Shannonvale Granodiorite
☆	Mole River Diorite

Classification of Intrusive Rocks

Tenterfield Region



Oftedahl (1978). "A caldera is the topographic depression formed by the subsidence of a round to oval caldera block, and the term also includes the geologic structure and its rocks, whereas the cauldron is the present-day surface and subsurface structure as well as its rocks." (Oftedahl, 1978, p.347).

A. CALC-ALKALINE INTRUSIVES

ADAMELLITES AND GRANODIORITES

Granodiorites and hornblende-bearing adamellites which form individual plutons displaying a limited range of textural and chemical composition are discussed in this section. These include the Mackenzie, Cottesbrook, Bookookoorara and Bungulla Porphyritic Adamellites, and the Shannonvale and Postman's Creek Granodiorites.* The adamellites which outcrop in the two broad belts designated on the map as "undifferentiated granitoids and porphyries" do not occur as sizeable plutons and are therefore discussed as a separate group in a later section.

The adamellites and granodiorites are massive rocks outcropping as moderately jointed large tors or platform sheets. Contact zones of the Bungulla Porphyritic Adamellite exhibit an intrusive foliation formed by the orientation of elongate diorite xenoliths and the sub-parallel alignment of K-feldspar megacrysts. Diorite or mafic granodiorite xenoliths and mafic clots occur in most of these plutons, but with the exception of the Bungulla Porphyritic Adamellite, such xenoliths and clots are isolated and rare.

Excluding the hornblende-rich Postman's Creek Granodiorite (which merges locally into quartz-dioritic facies) the adamellites and the Shannonvale Granodiorite are related members of a petrographic (and chemical) series. The rocks have seriate hypidiomorphic or distinctly porphyritic textures. In the porphyritic types plagioclase, amphibole and K-feldspar are frequently euhedral or occur as monomineralic aggregates. Interstitial quartzo-feldspathic material contains ferromagnesians and the common accessory minerals apatite, zircon, titanomagnetite and sphene. Ilmenite and pyrite may be present in small amounts but magnetite with low Fe_2TiO_4 contents is the principal opaque phase, ranging from $Mt_{97.2}$ $Usp_{2.8}$ in the Shannonvale Granodiorite, to $Mt_{99.7}$ $Usp_{0.3}$ in the Bungulla

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* The Postman's Creek Granodiorite (Thomson, 1976) plots in the quartz monzodiorite field in Fig. 2.1.

Porphyritic Adamellite. The siliceous Mackenzie Adamellite and the more leucocratic variants of the Shannonvale Granodiorite contain rare metamict allanite.

Magnesio-hornblende is commonly associated with biotite and magnetite in mafic clusters (3 mm), but also occurs as euhedral crystals. Minor actinolite and actinolitic hornblende are late-stage amphiboles mantling magnesio-hornblende and minor relict clinopyroxene in the Bungulla Porphyritic Adamellite. Biotite occurs as coarsely crystalline (> 3 mm) and fine-grained clusters, or as discrete flakes. The highly siliceous adamellites have Fe biotites, whereas biotite in the more mafic rocks is more Mg-rich.

Plagioclase and K-feldspars in the adamellites can be assigned to at least two distinct episodes of crystallization. The plagioclase typically consists of a variably epidotized and sericitized calcic core which is mantled by clear, more Ab-rich plagioclase displaying intense normal and minor oscillatory zoning. Shaw (1964) recognized three generations of K-feldspar in the Bungulla Porphyritic Adamellite - i.e. "porphyroblasts" at the margins of dioritic xenoliths (up to 3 cm), giant phenocrysts (up to 15 cm - Or_{77} Ab_{22} An_{1}) and groundmass K-feldspar (Or_{85} Ab_{14} An_{1}). Shaw (1964) proposed that each generation of K-feldspar was accompanied by a complementary generation of plagioclase crystallization.

DIORITES

Diorites are comparatively rare rocks in the study area. Two dioritic intrusions occur within the western belt of undifferentiated granitoids and porphyries near the northern contact of the Clive Adamellite.

The Mole River Diorite (new name) forms a small lensoidal outcrop (elongate in a northwest direction) approximately 10 m wide and a few tens of metres in length, outcropping in the bed of the Mole Rive immediately north of the Clive Adamellite. The Diorite is compact and massive with broadly spaced joints that are accentuated by koalinization of the abundant plagioclase. In hand specimen it closely resembles the dioritic xenoliths that occur in the hornblende adamellites which the Mole Rive Diorite intrudes.

The Diorite is medium-grained (1.5 mm) and has a classic intergranular texture. Plagioclase and hornblende, which comprise 90% of the rock, range from <0.8 mm to 3 mm. The plagioclase is very strongly zoned (An_{82}-An_{23}) and shows evidence of a protracted magmatic history. Sericitized, patchy-zoned cores are

Table 1 ADAMELLITES, GRANODIORITES AND DIORITES - GENERAL PETROGRAPHIC CHARACTERISTICS

	TEXTURE	AMPHIBOLE	BIOTITE	K-FELDSPAR	PLAGIOCLASE	ACCESSORY MINERALS
BUNGULLA PORPHYRITIC ADAMELLITE	coarse porphyritic	Actinolite actinolitic hornblende Magnesio-hornblende X = pale brown Y = brown-green Z = grass green	Mg biotite X = straw yellow Y = Z = greenish-brown	phenocryst $Or_{77}Ab_{22}An_1$ groundmass $Or_{85}Ab_{14}An_1$	An_{32}-An_{28} An_{35}-An_{19} sodic rims	sphene magnetite apatite zircon epidote
MACKENZIE ADAMELLITE	Seriate hypidiomorphic granular to porphyritic (3 mm)	X = pale brown Y = olive green Z = apple green	Fe biotite X = pale brown Y = Z = dark grey-brown	microperthite $Or_{74}Ab_{25}An_1$	An_{37}-An_{13} Av . An_{16}	allanite zircon ilmenite apatite, sphene
COTTESBROOK ADAMELLITE	medium-(2 mm) and fine-grained (1 mm) semi-porphyritic	X = pale yellow Y = pale green Z = green	X = pale brown Y = Z = dark brown	microcline microperthite and sympletic Qz-K-feld	An_{37}-An_{29}	apatite magnetite sphene
BOOKOOKOORARA ADAMELLITE	coarse porphyritic	X = pale green Y = green Z = dark green	Mg/Mg + Fe = 43.7 X = straw yellow Y = Z = brown	megacrysts perthitic orthoclase	An_{30}-An_{15} albitic rims	sphene, epidote, zircon pyroxene cores in amphiboles
SHANNONVALE GRANODIORITE	hypidiomorphic granular 2 mm	Magnesio-hornblende X = pale brown Y = olive green Z = pale blue-green	Fe biotite X = pale brown Y = Z = rich brown	perthitic microcline	An_{43}-An_{23} An_{53}-An_9	Opx, allanite magnetite sphene, apatite zircon
POSTMAN S CREEK GRANODIORITE	semi-porphyritic 2-3 mm	Magnesio-hornblende X = yellow Y = pale green Z = green	Mg/Mg + Fe = 43.7 X = straw yellow Y = Z = dark brown	Carlsbad-twinned orthoclase	An_{50}-An_{40}	zircon magnetite
MOLE RIVER DIORITE	intergranular 1.5-2 mm	Actinolite actinolitic hornblende Magnesio-hornblende X = pale brown Y = olive green Z = pale green	Mg biotite mostly replacement of hornblende	trace microcline	An_{82}-An_{23}	apatite sphene Fe-Ti oxide
QUARTZ DIORITE 451	seriate hypidiomorphic granular 0.5-1.5 mm	magnesio-hornblende X = pale brown Y = green-brown Z = pale brown	Mg/Mg + Fe = 46.5 X = pale brown Y = Z = foxy brown	minor perthite	An_{48}-An_{23}	epidote sphene ilmenite

surrounded by corroded rims which are further mantled by a more Ab-rich plagioclase.

The abundant pleochroic magnesio-hornblende, commonly showing polysynthetic twinning, is sometimes rimmed by a pale green actinolitic hornblende. Decussate biotite occurs chiefly as a replacement of hornblende, where it may be rimmed by granular sphene. Mg biotite also forms crystalline clots and discrete flakes (1 mm). The thermal recrystallization of biotite dates to the intrusion of the Clive Adamellite.

Virtually all the accessory minerals sphene, pyrite and chalcopyrite occur as inclusions in the amphiboles. Very minor K-feldspar, traces of apatite and minor quartz ($\sim$3%) are interstitial to the plagioclase and amphibole.

It is not proposed to formally name the quartz diorite which outcrops midway along the northern contact of the Clive Adamellite. This diorite intrudes and is intruded by hornblende-bearing adamellites. The total outcrop area of the quartz diorite is only a few tens of square metres. The rock has a seriate hypidiomorphic to intergranular texture, with an average grain size of 0.5 mm.

Plagioclase is of two types. The large (3 mm) crystals are moderately zoned (andesine-oligoclase) and rarely contain a distinct core. Plagioclase of the second type forms subhedral crystals usually <1 mm, but sometimes up to 2 mm in length. A distinct, partly sericitized and weakly zoned calcic core is mantled by a clear rim (An_{48}-An_{23}). Pleochroic magnesio-hornblende (0.4 - 0.2 mm) forms clusters in association with partly chloritized biotite. Sphene, titanomagnetite, pyrite and ilmenite (av. $Ilm_{99.4}$ $Hem_{0.6}$) are common inclusions in hornblende and biotite. Quartz (15%) and perthitic K-feldspar (2%) were the last phases to crystallize.

SILCIC GRANITOIDS

The general petrographic characteristics of the following intrusives will be described in this section.

Stanthorpe Adamellite
Ruby Creek Adamellite
Black Snake Creek Granite
Clive Adamellite
Mole Granite
Kingsgate Granite

Pyes Creek Leucoadamellite
Nonnington Leucoadamellite
Sandy Flat Adamellite
Billyrimba Leucoadamellite
Bolivia Range Leucoadamellite
Mt Jonblee and
Petries Sugarloaf Leucoadamellites

TABLE 2: LEUCO-GRANITOIDS GENERAL PETROGRAPHIC CHARACTERISTICS

	MAJOR TEXTURAL TYPE	TEXTURAL VARIANTS	COMPOSITIONAL VARIANTS	AMPHIBOLE	BIOTITE	K-FELDSPAR	PLAGIOCLASE	ACCESSORY MINERALS*
STANTHORPE ADAMELLITE	hypidiomorphic equigranular 5 mm	medium equigranular porphyritic	biotite only types hornblende + biotite types	mostly Ferro-hornblende X = straw yellow Y = green or brown Z = dark green or brown	Fe biotite X = straw yellow Y = Z = foxy brown	patch perthite $Or_{78}Ab_{21}An_1$	An_{40}-An_{28} albitic rims An_{12}	allanite ilmenite
RUBY CREEK ADAMELLITE	hypidiomorphic equigranular 2-3 mm	xenomorphic granular 0.1-0.15 mm	aplites		Fe biotite X = straw yellow Y = Z = dark brown	microcline perthite	An_{20}-An_{10}	pyrite, muscovite cassiterite, molybdenite wolframite
BLACK SNAKE CREEK GRANITE	xenomorphic equigranular 3 mm	saccharoidal near margins 1 mm			Fe biotite X = straw yellow Y = Z = brown	microperthite	An_{26}-An_{10}	sphene
CLIVE ADAMELLITE	xenomorphic granular 3 mm	evidence of shearing	accessory hornblende (unsheared types)		Fe biotite X = straw yellow Y = Z = dark brown	microcline microperthite $Or_{76}Ab_{23}An_1$	An_{15} An_{13}	hornblende
MOLE GRANITE	seriate xenomorphic granular 2-3 mm	porphyry	topaz-quartz rocks (silexite), aplites 1 mm		Fe biotite X = straw yellow Y = Z = dark brown	perthite	An_7	allanite, fluorite tourmaline
NONNINGTON LEUCOADAMELLITE	xenomorphic granular 1.5 mm	rare megacryst antiperthite			Fe biotite X = straw yellow Y = Z = foxy red	microperthite	An_{28}-An_9 An_{16}	allanite, epidote ilmenite magnetite
SANDY FLAT ADAMELLITE	hypidiomorphic to xenomorphic granular 5 mm			polysynthetic twins X = pale green Y = brown-green Z = blue-green	Ferro-hornblende-edenite Fe biotite X = pale brown Y = Z = brown-green	microcline microperthite $Or_{77}Ab_{22}An_1$	An_{38}-An_{18} An_{17}	sphene, allanite epidote, ilmenite magnetite, pyrite
BILLYRIMBA LEUCOADAMELLITE	hypidiomorphic inequigranular 1-2 mm	saccharoidal contact rock 0.8 mm			Fe biotite X = straw yellow Y = Z = dark foxy red	microcline microperthite $Or_{84}Ab_{15}An_1$	An_{12}	magnetite
BOLIVIA RANGE LEUCOADAMELLITE	seriate xenomorphic granular 0.5-5 mm	rapakivi porphyritic			Fe biotite X = pale brown Y = Z = green-brown	microperthite Or_{84}	An_{36}-An_{14} An_{15}-An_{10} Av . An_{16}	allanite calcite, fluorite ilmenite, magnetite
PYRES CREEK LEUCOADAMELLITE	xenomorphic granular 2 mm	fine-grained porphyry contact rock			Fe biotite X = pale brown Y = Z = foxy red	perthite $Or_{76}Ab_{23}An_1$	An_{11}	fluorite
KINGSGATE GRANITE	hypidiomorphic granular 4 mm				Fe biotite X = pale brown Y = Z = dark brown	microperthite	An_{20}-An_{10}	allanite muscovite
Mt. JONBLEE and PETRIES SUGARLOAF LEUCOADAMELLITES	xenomorphic equigranular 2.5 mm	saccharoidal inequigranular 1.5 mm			chloritized	microperthite	An_{15}	epidote

Data Sources: Thomson (1976), Brett (1972), Shaw (1964), Juniper (1974), Jones (1976), this study.

* Zircon and apatite are common to all rocks

Selected modal analyses of the most typical facies of these intrusions are presented in Table 3.

The granitoids listed above have a colour index of ≤ 5.0, where colour index equals the sum of modal ferromagnesian minerals only. By this definition the prefix leuco is an appropriate qualifier to all rock types.

The leucogranitoids are massive, coarse- to medium-grained high-level types. Most occur as discrete plutons which commonly exhibit a major northeast-trending joint set and a less well developed orthogonal conjugate set of close-spaced joints. The Clive Adamellite is exceptional because its western margin is in faulted contact with sedimentary country rocks, and there is evidence of shearing on a microscopic scale.

Although these intrusions tend to be texturally uniform, porphyritic or finer-grained variants are represented in virtually all plutons. Significant mineralogical variation, usually indicated by the appearance of modal amphibole, is restricted to the Clive and Stanthorpe Adamellites. Pegmatites are associated with the Mole Granite and some portions of the Ruby Creek Adamellite but are notably absent from the other leucogranitoids. Miarolitic cavities are present in the Billyrimba Leucoadamellite (see also Shaw, 1964), and the Stanthorpe Adamellite contains aplite dykes with narrow cores of pegmatite (Thomson, 1976a). A few aplite veins occur at the margins of the Billyrimba, Nonnington and Mt Jonblee Leucoadamellites.

Very rare microgranodiorite microxenoliths (1 cm) are present in the Nonnington Leucoadamellite. The leucocratic Mackenzie Adamellite (average colour index = 5.1) also contains ". . . rare xenoliths of microdiorite . . . " (Shaw, 1964, p.54). Mafic xenoliths are absent from leucogranitoids of similar age and the rocks of the Mount Mackenzie area are therefore unique in this respect. Thomson (1976a) reports xenoliths (up to 60 mm) of epidiorite in the Stanthorpe Adamellite and mafic adamellite inclusions of similar size and abundance in the Ruby Creek Adamellite. North of the study area the Stanthorpe Adamellite also contains blocks of sedimentary and volcanic country rocks, and is intruded by diorite dykes (Thomson loc.cit., p.77).

Mineralogy: The major phases are quartz, K-feldspar, biotite and weakly zoned plagioclase occasionally with small sericitized cores. The principal accessory mineral is titanomagnetite. Biotite is always the dominant mafic mineral. Although both hornblende and biotite may occur as discrete euhedra, they are frequently associated in mafic clusters. Titanomagnetite, sphene, and occasionally epidote and ilmenite are associated with these mafic clots, and apatite and zircon occur as inclusions in the ferromagnesians. The Mole Granite, Ruby Creek Adamellite, Pyes Creek and Bolivia Range Leucoadamellites contain minor fluorite. Rare allanite is present in most of the leucogranitoids.

Perthitic K-feldspar, commonly with incipient or well developed crosshatched twinning, is invariably coarse grained (4-7 mm in equigranular rocks and up to 20 mm in the porphyritic varieties). Similarly, euhedral to anhedral plagioclase and quartz are coarse grained (up to 6 mm) and frequently form 8-10 mm aggregates. The same felsic minerals comprise the bulk of the anhedral interstitial material.

Porphyritic variants of the Bolivia Range Leucoadamellite display rapakivi texture with ovoid phenocrysts of perthitic K-feldspar mantled by optically continuous or granular oligoclase (An_{12}: Shaw, 1964).

The interesting topaz-bearing silexites which occur as dykes and sills mainly in the roof pendant of the Mole Granite, have recently been investigated by Eadington and Nashar (1978). The so-called topazites contain 18-27% topaz, but in hydrothermally altered samples the topaz is replaced by white mica, the quartz is recrystallized and wolframite is often present in economic concentrations. Eadington and Nashar (loc.cit.) favour a magmatic origin for these rocks.

A summary of petrographic characteristics and mineral compositions of the leucogranitoids is presented in Table 2.

OTTERY HOST ADAMELLITE

Adamellite porphyry is host for the mineralized fissures which comprise the Ottery cassiterite and arsenopyrite lodes. The adamellite has intruded silty sedimentary basement rocks and a siliceous unit of the Emmaville Volcanics. The contact with the Ottery Rhyolite (see later) is ill-defined owing to extensive sericitization of both rock types, the development of quartz veins, and post-intrusive shearing parallel to the contact. The shearing has resulted in the formation of quartz augen and the granulation of many masses of vein quartz. Like the intruded sedimentary rocks, the adamellite is strongly jointed, the dominant joint sets having the following orientations - 040/058 NW, 300/070 SW, 020/065 W.

Phenocryst phases are embayed, bipyramidal quartz ($< 2\%$), plagioclase ($\sim 30\%$), hornblende ($<3\%$), biotite ($< 5\%$) and K-feldspar ($<1\%$). The groundmass is a fine- to moderately coarse-textured granophyric intergrowth of quartz, albitic plagioclase and cloudy K-feldspar peppered with magnetite and ilmenite. Plagioclase (0.5 mm - 5 mm) is strongly zoned, sometimes with a distinct sericitized core, and fequently forms 3 mm glomeroporphyritic aggregates. Euhedral hornblende (X = pale brown, Y = mid brown, Z = greenish brown) is partly replaced by pale green actinolitic amphibole, biotite or chlorite. Biotite phenocrysts (< 3 mm) contain abundant inclusions of zircon and sphene.

The Ottery host adamellite has been extensively sericitized and silicified by the invading hydrothermal fluids which transported the ore metals. Cassiterite and much of the arsenopyrite were deposited only in quartz veins but the adamellite adjacent to the veins was also mineralized. The disseminated sulfide assemblage includes arsenopyrite, pyrite, pyrrhotite, marcasite, sphalerite, and very minor bismuth-bismuthinite. Pyrrhotite-rich masses contain ilmenite and secondary goethite-limonite in fractures.

UNDIFFERENTIATED GRANITOIDS

Undifferentiated granitoids occur in a north-south trending belt linking the Tenterfield and Brassington masses of the Dundee Rhyodacite southeast of Tenterfield, and form a large complex extending from the Bolivia Range northwards to the Tenterfied Fault. Numerous bodies of granitic and adamellitic porphyry (described in a later section) have intruded and metamorphosed the granitoids. As four or more individual rock types frequently comprise a single outcrop, detailed mapping of these granitoids was not attempted.

The granitoids vary in composition from pink-feldspar leucogranites and leucoadamellites to hornblende-bearing adamellites and quartz monzonites, the more acid types being only of minor importance.

Contact metamorphosed leucogranites outcrop adjacent to and south of the Tenterfield Fault northwest of Mount Mackenzie. They contain unzoned albitized plagioclase (2-4 mm), quartz, microperthite, granular titanomagnetite and minor epidotized biotite. Leucoadamellites with a similar mineralogy occur as rare microxenoliths in hornblende-bearing adamellites in the same area.

Hornblende-bearing granitoids range from mafic adamellites and quartz monzonites with seriate hypidiomorphic granular textures to equigranular, medium- to fine-grained leucoadamellites. These rocks belong to the same petrogenetic lineage as the adamellites and leucoadamellites which occur as major plutons. The adamellites and quartz monzonites may contain quartz diorite and (more rarely) granodiorite xenoliths up to 15 cm in diameter.

A typical specimen contains quartz, plagioclase, perthitic K-feldspar with some cross-hatched twinning, amphibole accompanied by sphene, magnetite ($Mt_{99.5}$ $Usp_{0.5}$) and exsolved ilmenite ($Ilm_{99.6}$ $Hem_{0.4}$), and biotite with inclusions of zircon and apatite. Rare allanite is confined to the leucoadamellites. The average grain size is 2-3 mm, but plagioclase and K-feldspar range to 12 mm. Hornblende and biotite are finer grained (1 mm) in the more leucocratic adamellites where they commonly occur as aggregates.

Plagioclase invariably has a sericitized and epidotized core (as calcic as An_{60} in the more mafic adamellites) surrounded by a thick rim (zoned to An_{16} -An_{11} at the periphery). The bulk of the plagioclase has the composition An_{47} -An_{20}. Hornblende (X = pale green, Y = olive green or dark green, Z = apple green) varies considerably in composition, i.e. actinolitic hornblende, magnesio-hornblende (most common), and ferro-hornblende. The hornblende-rich adamellites typically contain Mg biotite (1-3 mm), with Fe biotites restricted to the more leucocratic adamellites.

Pseudo-porphyritic Adamellites

Three adamellites with very pronounced seriate textures were examined in the Mole River Valley, north of the Clive Adamellite. All have unusually low amounts of phenocryst and groundmass K-feldspar. Hornblende compositions range from magnesio-hornblende (sample No. 446) to ferro-hornblende (447), and 448 is a biotite adamellite which lacks hornblende. These rocks also contain above-normal concentrations of apatite and zircon. In all the adamellites studied, decussate biotite, minor chlorite and epidotized plagioclase suggest low-grade metamorphism.

Adamellite and Granite Porphyries

Adamellite and (more rarely) granite porphyries are intimately associated with the undifferentiated massive granitoids which outcrop west of the New England Highway from Bolivia to north of Tenterfield. The porphyries are highly variable in texture, grain size and phenocryst mineralogy and can be assigned to three major groups.

(a) Hornblende-bearing adamellite porphyries are similar to those of the ring dyke which abuts the Mackenzie Adamellite. They contain phenocrysts of zoned plagioclase (An_{42} -An_{11}), perthitic orthoclase, magnesio-hornblende and minor ferroan pargasitic hornblende, Mg biotite and minor quartz in a fine-grained (0.03 mm) felsic groundmass. Modal data are presented in Table 2. Orthoclase and plagioclase frequently form monomineralic and bimineralic glomeroporphyritic aggregates in synneusis relationship (Vance, 1969). Hornblende phenocrysts (X = pale brown, Y = green brown, Z = green) are infrequently euhedral and may contain inclusions of biotite, titanomagnetite, sphene and zircon. Pyrite and ilmenite (av. $Ilm_{99.8}$ $Hem_{0.2}$) are common. Hornblende-bearing adamellite porphyries that were contact metamorphosed by the Stanthorpe Adamellite occur west of the Wyberba (Dundee Rhyodacite) mass.

(b) Contact metamorphosed leucoadamellite and leucogranite porphyries are abundant north and west of Mount Mackenzie. Leucoadamellites are dominant. Perthitic K-feldspar with patchy cross-hatched twinning, albitic plagioclase and small clusters of partly chloritized decussate biotite (0.5 - 3 mm) are set in a fine-grained (0.03 - 0.1 mm) quartzo-feldspathic groundmass containing the dominant accessory phase, titanomagnetite. The modal abundance of phenocrysts varies widely, from 25% to as high as 75%. The leucogranites have a saccharoidal texture whereas leucoadamellites are strongly porphyritic and sometimes contain megacrysts of K-feldspar (up to 12 mm). Accessory allanite is rare. Hornblende-bearing leucoadamellite porphyries, abundant northwest of Mount Mackenzie, contain a relatively calcic plagioclase (An_{51} -An_{25}) which may form clusters up to 5 mm in diameter.

(c) Contact metamorphosed foliated porphyries are restricted to the region southwest of Mount Mackenzie and marginal to the Clive Adamellite contact near the Mole River. In common with some of the Group (b) porphyries, the foliated types are not obviously intrusive and many may be metarhyolites with a relict volcanic foliation. This interpretation is consistent with the proposed model of sub-volcanic emplacement of the granitoids in the region (see Chapter 4).

The foliated porphyries are all fine-grained, siliceous types with biotite as the dominant mafic phase. Where present, amphibole is confined to the groundmass. Tha alignment of chloritized phenocryst biotite or decussate masses of that mineral, imparts a delicate foliation reminiscent of fluidal flow patterns or eutaxitic textures in rhyolites. Near the Clive Adamellite contact, porphyries contain abundant plastically-deformed pelitic xenoliths and at this locality they are clearly intrusive.

TABLE 3 : Modal Data for Calc-Alkaline Intrusive Rocks

	ADAMELLITES																	GRANODIORITES	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Quartz	30.0	22.2	27.2	27.3	22.2	18.8	18.7	30.0	21.4	24.1	6.9	15.7	19.5	23.8	31.6	32.6	32.1	22.9	14.0
K-feldspar	37.9	32.3	30.4	36.9	29.8	24.6	29.4	20.0	39.4	34.1	4.2	38.7	33.4	35.3	35.3	25.9	37.9	25.2	15.8
Plagioclase	25.5	36.6	34.8	30.2	37.7	45.5	42.1	44.7	30.8	32.4	52.0	38.7	39.2	33.0	29.3	36.9	25.8	35.1	40.8
Biotite	1.7	5.8	4.7	3.9	5.9	7.7	7.3	1.7	4.6	1.7	5.8	4.0	5.4	5.4	3.1	4.6	3.4	10.2	8.0
Hornblende	3.7	1.8	2.0	1.2	3.9	2.9	2.1	3.4	12.1	5.5	29.8	2.6	1.4	2.1	0.3	-	0.7	6.5	16.9
Sphene	0.5	0.4	0.3	0.2	tr.	-	-	-	-	-	0.8	tr.	0.4	-	-	-	tr.	-	-
Opaque Oxide	0.6	0.9	0.5	0.3	0.5	0.5	0.4	0.2	1.7	1.9	0.5	0.3	0.7	0.2	0.1	tr.	0.1		
Accessory Minerals	0.1	-	0.1	tr.	tr.	-	-	-	tr.	tr.	tr.	tr.	tr.	0.2	0.3	-	tr.	0.1	4.5
Colour Index	5.4	7.6	6.7	5.1	9.8	10.6	9.4	5.1	16.7	7.2	35.6	6.6	6.8	7.5	3.4	4.6	4.1	16.7	24.9

	LEUCOCRATIC GRANITOIDS														DIORITES		IGNEOUS XENOLITHS			
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Quartz	19.8	31.2	32.9	33.8	39.1	38.1	35.4	38.0	34.5	45.4	39.5	35.6	1.7	2.2	2.9	14.6	3.4	8.4	3.0	5.2
K-feldspar	27.4	30.6	35.0	34.8	30.6	30.0	31.6	34.5	36.2	37.2	34.0	41.8	19.6	8.4	tr.	1.9	0.3	37.4	6.0	-
Plagioclase	47.8	34.4	28.5	28.1	25.9	28.6	28.7	24.7	26.6	12.7	23.0	17.4	23.9	29.0	47.9	59.9	55.2	40.6	54.1	64.2
Biotite	3.2	3.7	3.6	3.2	4.0	2.9	4.3	2.6	2.6	4.6	3.5	3.2	2.9	4.1	5.4	12.1	15.8	5.4	11.5	18.8
Hornblende	1.9	-	-	-	0.2	tr.	-	-	tr.	-	-	-	1.9	1.3	42.7	8.0	24.6	5.4	24.1	9.2
Sphene	0.4	-	-	tr.	0.1	tr.	-	-	-	-	-	-	tr.	-	tr.	1.0	0.1	1.4	0·3	0·5
Opaque Oxides	0.4	0.1	tr.	0.1	0.1	0.4	tr.	0.2	0.1	-	-	-	0.9	0.9	tr.	1.5	0.2	1.2	1.0	2.1
Accessory Minerals	tr.	tr.	tr.	-	tr.	tr.	-	-	-	tr.	-	-	49.2#	54.1#	0.9	tr.	0.4	0.2	—	—
Colour Index	4.2	3.7	3.6	3.2	4.2	2.9	4.3	2.6	2.6	4.6	3.5	3.2	4.8	5.4	48.1	20.1	45.4	10.8	35.6	28.0

1	S	Bungulla Porphyritic Adamellite
2	S	"
3	S*	"
4	S*	Mackenzie Adamellite
5	S	Cottesbrook Adamellite-coarse phase
6	S	Cottesbrook Adamellite-fine phase
7	S*	Cottesbrook Adamellite
8	T	Bookookoorara Adamellite
9	433D	Undifferentiated Adamellites and Quartz Monzonites
10	446	"
11	445A	"
12	447C	"
13	457A	"
14	T*	Stanthorpe Adamellite - >0.5% Hornblende
15	T*	Stanthorpe Adamellite - <0.5% Hornblende
16	T	Stanthorpe Adamellite - Biotite only
17	S*	Stanthorpe Adamellite
18	J	Shannonvale Granodiorite
19	T	Postman s Creek Granodiorite
20	427A	Leucoadamellite-unnamed
21	T*	Ruby Creek Adamellite
22	S*	Billyrimba Leucoadamellite
23	S*	Bolivia Range Leucoadamellite
24	S*	Sandy Flat Adamellite
25	S*	Nonnington Leucoadamellite
26	S*	Clive Adamellite
27	S*	Pyes Creek Leucoadamellite
28	S*	Mt Jonblee Leucoadamellite
29	S*	Mole Granite
30	L*	"
31	J*	Kingsgate Granite
32	391B	Adamellite Porphyry
33	399A	"
34	445C	Mole River Diorite
35	451	Unnamed quartz diorite
36	S	Bungulla Porphyritic Adamellite
37	S	"
38	X370A	"
39	X433A	Adamellite-unnamed

* Average mode from several determinations

\# Groundmass

References: S Shaw, 1964
T Thomson 1976
J Jones, 1976
L Lonergan, 1971
Numbered specimens - this study

Associated porphyries host a variety of angular microxenoliths of biotite-adamellite porphyry and equigranular granite. The xenoliths were probably incorporated into the melt during high-level emplacement, but some xenoliths may represent fragments of foundered volcanic rocks from the roof zone - field relations are inconclusive.

MAFIC XENOLITHS

Igneous xenoliths ranging in composition from biotite granodiorite to quartz diorite occur in quartz monzonites, hornblende-bearing adamellites and the Nonnington Leucoadamellite. Representatives of each xenolith type will be briefly described.

Biotite microgranodiorites and microtonalites occur as very rare microxenoliths (1 - 3 cm) in the Nonnington Leucoadamellite and Bungulla Porphyritic Adamellite. They have hypidiomorphic to intergranular textures, with an average grain size of 0.5 - 0.8 mm. Chloritized biotite is the sole ferromagnesian and contains all the accessory minerals as inclusions. Subhedral plagioclases (up to 3 mm) have large, partly sericitized cores and thin, zoned rims. Quartz and K-feldspar are interstitial.

Hornblende microgranodiorite xenoliths (up to 10 cm) are occasionally found in the Shannonvale Granodiorite. These xenoliths have a hypidiomorphic texture and an average grain size of 0.5 mm. Euhedral hornblende (< 1 mm), blocky laths of zoned plagioclase (0.2 - 0.4 mm) and chloritized biotite mantled by granular sphene, form an interlocking network supported by anhedral quartz and K-feldspar.

Mafic xenoliths in the hornblende-bearing adamellites and quartz monzonites of the western belt of undifferentiated granitoids and porphyries fall into two major categories.

(a) Medium-grained tonalites have hypidiomorphic textures and are characterized by plagioclase showing a distinctly bimodal size distribution. The euhedral plagioclase (up to 4 mm) has a large, weakly zoned and corroded core surrounded by a narrow andesine-oligoclase rim. The smaller (1 mm) subhedral plagioclases are very strongly zoned (An_{74} -An_{19}). Magnesio-hornblende, partly replaced by biotite and green actinolitic hornblende, occurs as discrete subhedral phenocrysts (< 3 mm) and is also associated with decussate biotite in mafic clusters. Included minerals are quartz, apatite, sphene and ilmenite ($Ilm_{97.5}$ $Hem_{2.5}$ -$Ilm_{99.8}$ $Hem_{0.2}$).

Ferromagnesian-rich tonalite xenoliths abound in hornblende-adamellites intruded by the Mole River Diorite. The xenoliths very closely resemble the intrusive Diorite, differing only in the modal abundance of quartz and K-feldspar. Tiny cores of highly calcic plagioclase (sericitized) are mantled by a rim zoned outwards from An_{68} to An_{18}. Hornblende ranges in composition from magnesio-hornblende to actinolitic hornblende. The opaques include magnetite ($Mt_{99.5}$ $Usp_{0.5}$) and pyrite.

(b) Quartz diorite xenoliths (see Table 3 for modal analysis) occur in medium-grained hornblende adamellites west of the Mackenzie Adamellite pluton. The xenoliths have seriate hypidiomorphic to intergranular textures. Magnesio-hornblende, actinolitic hornblende (X = pale brown, Y = green, Z = pale green) and Mg biotite are intimately associated. These minerals contain inclusions of magnetite ($Mt_{99.1}$ $Usp_{0.9}$), exsolved ilmenite ($Ilm_{99.5}$ $Hem_{0.5}$), sphene and epidote. Crystals of apatite accompany quartz. Like the tonalitic xenoliths described above, the quartz diorites contain two varieties of plagioclase. The larger (3 mm) crystals are moderately zoned and have no distinct core. In contrast, the smaller plagioclases (<1 mm) display a thick rim (An_{45} -An_{20}) enclosing a strongly sericitized core.

Mafic xenoliths in the Bungulla Porphyritic Adamellite are of two main types. Quartz diorite xenoliths up to 30 cm in diameter are the most common type and locally may be abundant. Prismatic magnesio-hornblende (3 mm) partly replaced by decussate biotite and chlorite; shreds of biotite, and tiny plagioclase laths are set in a matrix of poikilitic granular quartz and K-feldspar. Randomly distributed coarse-grained plagioclase (5 mm), granular masses of quartz and megacrysts of perthitic K-feldspar (up to 3 cm) produce a distinctly porphyritic texture. The principal accessory minerals are magnetite ($Mt_{99.5}$ $Usp_{0.5}$) with exsolved ilmenite, pyrite, sphene, apatite and interstitial calcite.

The Bungulla Porphyritic Adamellite may also contain "porphyritic" granodiorite xenoliths (<8 cm). These xenoliths display a more pronounced porphyritic texture than the quartz diorite xenoliths and may contain K-feldspar megacrysts. Clusters of coarse-grained plagioclase (3 - 8 mm); monomineralic aggregates of K-feldspar and quartz (<10 mm), and crystals of zoned plagioclase (4 mm) are set in a matrix of poikilitic quartz and late-stage K-feldspar. Abundant, tiny crystals of hornblende, biotite, plagioclase and apatite (0.05 mm) and shapeless masses of granular hornblende and titanomagnetite (1 - 2.5 mm) are inclusions in the coarse-grained K-feldspar and quartz of the matrix. Relict euhedral clinopyroxene (<1 mm) is largely replaced by hornblende.

GRANITIC PORPHYRIES OF THE RING DYKES

Granitic porphyries form a prominent ridge along the southern contact of the Tenterfield (Dundee Rhyodacite) mass, and extend in a broad arc along the northern margin of the Mackenzie Adamellite west of Tenterfield. Porphyries also define the perimeter of the Brassington mass, outcropping as a sinuous ridge which is locally offset by east-west trending faults. The porphyries are considered to be ring fracture-fill dyke rocks associated with caldera formation in the Tenterfield area (see Chapter 4).

Porphyries bordering the Tenderfield mass are two-feldspar quartz rhyolites and rhyodacites that have been contact metamorphosed by the Bungulla Porphyritic Adamellite. The metarhyolites have 1 - 3 mm phenocrysts of altered perthitic K-feldspar, poorly zoned plagioclase (An_{19}-An_{11}) and embayed quartz, set in a microgranular quartzo-feldspathic groundmass. Biotite occurs as an occasional phenocryst phase and is a ubiquitous groundmass component, forming clusters in association with titanomagnetite. Recrystallization of the groundmass increases towards the contact with the Bungulla Porphyritic Adamellite, but original eutaxitic textures are still partly preserved.

The metarhyodacites are texturally similar to the metarhyolites but contain comparatively larger (2 - 4 mm) and modally more abundant phenocrysts of K-feldspar, weakly zoned sodic plagioclase and quartz. Fragments of these phenocryst phases are scattered throughout the groundmass. Apple green metamorphic amphibole, and decussate biotite with associated ilmenite, magnetite (av. $Mt_{99.6}$ $Usp_{0.4}$) and sphene are present as phenocrysts and as small grains in the microgranular groundmass. Flow-aligned mafic minerals impart a delicate foliation. At the Bungulla Porphyritic Adamellite contact, all original volcanic textures have been obliterated by contact metamorphism, and the grain size of groundmass components reaches 0.04 mm. In places the contact has been intruded by small bodies of leucogranite and adamellite.

The granitic rocks which abut the Mackenzie Adamellite are coarse-grained porphyries with an intrusive foliation. A very poorly defined contact separates these rocks from metavolcanic porphyries displaying vestigial eutaxitic textures, which define the northern margin of the ring dyke. The coarse-grained porphyries typically contain phenocrysts of perthitic orthoclase (<3 mm), zoned plagioclase (An_{49} -An_{17}) as discrete crystals and in clusters, quartz (< 3 mm), coarsely crystalline and decussate Mg biotite, and minor green amphibole, in a microgranular groundmass. Magnetite ($Mt_{99.8}$ $Usp_{0.2}$), exsolved ilmenite, sphene, chlorite and zircon are always present.

The granite porphyries surrounding the Brassington mass are metamorphosed by the Bungulla Porphyritic Adamellite in the north and south, and partly by the Sandy Flat Adamellite in the west. Metarhyodacites were observed only near the Cottesbrook Adamellite contact. All other porphyries are typically intrusive, and include the following types:

(a) leucogranite, leucoadamellite and hornblende-bearing adamellite porphyries with microgranular groundmass textures

(b) pink leucogranites with allotriomorphic granular (1 mm) or granophyric textures

(c) leucogranite porphyries with very fine-grained granophyric groundmass textures.

The relationships of the ring dyke porphyries to associated volcanic and intrusive rocks are discussed in more general terms in Chapter 4, where selected aspects of the association have been incorporated in a model for magma emplacement in the entire region.

B. VOLCANIC ROCKS

DUNDEE RHYODACITE

The Dundee Rhyodacite outcrops over approximately 720 km^2 in seven discrete masses in the study area (see map). Originally termed the "Blue Granite" by Andrews (1905), the rock was renamed the Dundee Adamellite Porphyrite (Wilkinson et al., 1964; Shaw, 1964) to convey some of its compositional and textural features. Shaw and Vernon were among the first to recognize features characteristic of an extrusive origin and proposed the name Dundee Rhyodacite (Flood et al., 1977).

The Dundee Rhyodacite erodes to form large boulders and platform sheets more typical of intrusive granitoids. The Wyberba, Sunnyside and Dundee masses of the Rhyodacite are almost totally enclosed by Late Permian volcanic rocks. The Timbarra, Tenterfield, Brassington and Bolivia masses are either intruded by high-level granitoids, or their margins are partly defined by linear or arcuate faults along which acid porphyries have been intruded.

The Dundee Rhyodacite is strongly porphyritic, with euhedral to anhedral phenocrysts (av. 2 mm) of quartz, zoned plagioclase (av. An_{37}), biotite, hornblende, clinopyroxene and minor K-feldspar and orthopyroxene, set in a microgranular quartz-feldspar groundmass (0.02 mm). The presence of fragments of all the major phenocryst phases is particularly characteristic, and large quartz and especially plagioclase crystals frequently display evidence of arrested micro-brecciation (Wilkinson et al., 1964).

Approaching the margins of the Dundee mass the Rhyodacite becomes distinctly foliated due to the alignment of biotite flakes, and the groundmass becomes progressively more finely devitrified. Near the contact this fine devitrification gives way to a glassy groundmass that exhibits eutaxitic texture. Similar textures were observed in finely devitrified specimens from the Brassington mass, but here the structures are imperfectly preserved and somewhat equivocal. Modal variation is more pronounced in these contact rocks and the decrease in phenocryst grain size is paralleled by an increase in the abundance of crystal fragments. The Wyberba and Sunnyside masses probably once comprised a single, continuous ignimbrite sheet. Rhyodacite from these masses is darker in hand specimen (i.e. finer-grained) than that forming the masses further south, and eutaxitic textures are well preserved.

Quartz phenocrysts (< 3 mm) are typically embayed and show varying degrees of fracturing, but rare euhedral crystals have the outline of the inverted bipyramidal variety. Plagioclase (An$_{53}$-An$_{33}$, av. An$_{44}$-An$_{36}$) occurs as individual laths, forms glomeroporphyritic aggregates, and is a common component of mafic clusters. Magnesio-hornblende occurs as twinned euhedra, forms monomineralic aggregates (1-3 mm) and is associated with plagioclase, pyroxene and titanomagnetite in mafic clots. Hornblende also pervasively replaces clinopyroxene and orthopyroxene (rarely), or forms incomplete rims around those minerals. Euhedral or fractured clinopyroxene phenocrysts are generally twinned and unzoned and have a uniform composition (av. $Ca_{44.6}$ $Mg_{36.5}$ $Fe_{19.9}$). Clinopyroxene in the mafic clots is generally only slightly more magnesian (Flood et al., 1977) but a range from highly calcic augite to endiopside ($Ca_{48.2}$ $Mg_{41.9}$ $Fe_{9.9}$) was determined in this study. Hypersthene occurs as discrete euhedra, as cores to clinopyroxene, hornblende or biotite and as a rare component of mafic clusters. Although generally of quite uniform composition ($Ca_{2.0-3.3}$ $Mg_{57.1-58.2}$ $Fe_{39.6-39.7}$: Flood et al., 1977), a range from $Mg_{64.5}$ to $Mg_{51.4}$ was noted in a single specimen, and Flood et al. reported strong zoning in one crystal (Mg_{83} -Mg_{51}).

Mg biotite is an essential mineral in the Dundee Rhyodacite. It forms 2 mm phenocrysts which, although frequently kinked or bent, have resisted the process of attrition which abraded the more brittle phenocryst phases. Distorted biotites are more prevalent in samples from the margins of the Dundee mass where shredding and ultimate disaggregation of phenocrysts is demonstrated.

Common accessory phases are titanomagnetite, magnetite ($Mt_{99.4-99.2}$ $Usp_{0.6-0.8}$) with blebs and lamellae of exsolved ilmenite, pyrite, chalcopyrite, zircon and apatite, all of which occur in the groundmass and as inclusions in the phenocrysts. Alteration minerals are marcasite (after pyrite), bornite and covellite (chalcopyrite), hematite (magnetite), chlorite (biotite) and traces of epidote in plagioclase.

Xenoliths and Mafic Aggregates

(a) Mafic Aggregates:

Reference has been made to mafic aggregates consisting of zoned andesine (av.), hornblende, clinopyroxene and occasional orthopyroxene. Approximately two of these aggregates (from 2 mm to 6 mm in diameter) appear in each thin section (Shaw, 1964). The "gabbro or anorthositic gabbro xenoliths" (Vernon, 1959) "most(ly) show partial to extensive replacement of pyroxene by hornblende and/or biotite of the same composition as the equivalent phenocrysts" (Flood et al., 1977, pp.300-301). The latter authors failed to acknowledge that occasionally hornblende appears to be a primary constituent of the aggregates. Wilkinson et al. (1964) termed the aggregates "dioritic xenoliths" which implies their acceptance of hornblende as a primary mineral constituent. The term "dioritic" is also consistent with the estimated bulk chemistry of the aggregates.

Wilkinson et al. (loc.cit.) considered the "dioritic xenoliths" to be remnant fragments of a biotite-diorite that had been extensively disaggregated during assimilation by an acid liquid. The Dundee Adamellite Porphyrite was thus thought to be a large-scale hybrid. Flood et. al. (1977) abandoned the hybrid model in favour of a partial melting origin. They suggested that the coarse-grained aggregates of plagioclase and pyroxene are either refractory residuals that have equilibrated with the melt, or are fragments of cumulate material which represent the first products of crystallization from the magma.

(b) Felsic Cognate Xenoliths

Pale-coloured xenoliths which range in size from 60 cm to 1 mm (av. 8 cm) are found in all masses of the Rhyodacite but are more common in the finer-grained rocks of the Wyberba and Sunnyside masses, and near the margins of the Dundee mass. Variously termed "coarse-phase xenoliths" (Vernon, 1959) or "early phase xenoliths" (Wilkinson et al., 1964), these inclusions have a mineral assemblage identical to the host. Many are elongate or "stretched" parallel to the foliation of the host, indicating that they were plastic at the time of eruption.

The phenocrysts tend to be larger and more frequently euhedral than those in the host Rhyodacite. The groundmass is often virtually devoid of phenocryst fragmenta which indicates that the xenoliths were coherent during the period when the crystals in the host were being abraded. The quartz-feldspar groundmass has devitrified to produce a mozaic texture (0.03 - 0.05 mm) which is identical to the devitrification observed in pumice lenticles from the Tent Hill Volcanics. Individual units of the mozaic are composed of microscopic subgrains of, presumably, quartz and alkali feldspars. In plane polarized light, fluidal structures in the groundmass are faintly visible. These structures could be vestigial evidence of flow in the viscous liquid prior to crystallization. Equally possible is that they represent flattened shards whose outlines have been largely destroyed during devitrification.

Because the felsic xenoliths are obviously cognate and formed prior (or possibly during) eruption of the Dundee Rhyodacite, they are best described as autoliths. Although many have rounded margins, some autoliths show evidence of disaggregation and many of the smaller specimens may be products of this disaggregation. The origin of the autoliths is not clear. They may represent fragments from the chilled carapace of the magma chamber or vent which were incorporated into the magma during eruption. Another possibility is that they are fragments of quenched magma which were re-incorporated into the main flow while it was still fluidized.

(c) Mafic Xenoliths:

Two types of porphyritic microgranodiorite xenoliths (<15 cm) occur mainly near the margins of the Dundee mass. The more common variety contains microphenocrysts of zoned plagioclase, altered clinopyroxene, hornblende and biotite in a microgranular groundmass similar to that of the host Rhyodacite. Some xenoliths have ragged or diffuse margins, depending on the degree of "invasion" by the groundmass of the host. Infrequently xenoliths are substantially disaggregated.

The bulk of the plagioclase occurs as small prismatic crystals (0.1 - 0.2 mm) which exhibit strong zoning. More equant crystals (0.4 - 1.2 mm) are very strongly zoned (An_{84} -An_{45}), with large cores (partly sericitized) surrounded by a thin rim. Tiny anhedral grains of clinopyroxene (0.1 mm) are largely replaced by pale green actinolitic (?) hornblende and/or biotite. Biotite ($\underline{Mg}$ = 39.40) is the dominant ferromagnesian phase and appears to be present solely as a replacement mineral of the pyroxene and hornblende. Glomeroporphyritic clusters (1 mm) of blocky plagioclase are uncommon. Fine-grained magnetite is the major accessory phase.

The second type of microgranodiorite xenolith occurs in very finely devitrified rocks near the contact with the Tent Hill Volcanics. These xenoliths contain microphenocrysts of unaltered augite, magnesio-hornblende and Mg biotite of composition identical to that of the Dundee Rhyodacite host. Biotite and hornblende replace clinopyroxene. Crystals (0.2 mm) of pyrite, and magnetite containing blebs of ilmenite or ilmenite lamellae, are usually abundant. Plagioclase forms euhedral to subhedral microphenocrysts that are moderately zoned (An_{62}-An_{39}) and, with augite, frequently produces an ophitic to subophitic texture. The groundmass is slightly more coarsely devitrified than that of the host.

Small mafic xenoliths of similar composition are sparsely scattered throughout the Dundee mass. These microporphyries contain phenocrysts of primary biotite (0.2 - 0.3 mm) and tiny grains of clinopyroxene which are mostly replaced by pale green amphibole. Plagioclase occurs as strongly zoned, tiny prismatic crystals (0.1 - 0.2 mm). As with the other types of microgranodiorite xenoliths, the groundmass texture closely resembles that of the host.

Other, less important, mafic xenoliths found in the Dundee Rhyodacite include hornblende-magnetite, clinopyroxene-magnetite and coarse-grained hornblende-clinopyroxene-plagioclase-magnetite types. They range in size from 2 - 20 mm and are commonly altered.

(d) Accidental Xenoliths:

Foreign xenoliths in the Dundee Rhyodacite closely resemble the country rocks around the individual masses. The northern masses (excluding the Wyberba and Sunnyside masses) carry inclusions of quartz-orthoclase porphyry and occasional recrystallized argillaceous sediments (Wilkinson et al., 1964). The Wyberba and Dundee masses contain xenoliths which are of dominantly volcanic origin. Most are found near the margins of the masses where fragments of the (Emmaville Volcanics) country rock were most likely to be incorporated in the Rhyodacite flow. The Dundee mass offers the widest variety of xenoliths. They range in size from 1 mm to 4 cm, but most measure 8 mm.

The most common xenolith types include fine-grained rhyodacite breccias (dominant), two-feldspar quartz rhyolites, biotite rhyolites, crystal-rich rhyodacites and fragments of siliceous vitrophyre. Although phenocrysts are frequently altered, the groundmasses of most xenoliths have remained glassy or, at worst, have been only incipiently recrystallized. This suggests that most volcanic fragments were incorporated only a short time before the Dundee Rhyodacite magma solidified.

The fine-grained rhyodacite breccias contain angular or poorly-rounded crystal fragments of quartz, zoned plagioclase, calcic augite (sometimes replaced by pale green hornblende) and small flakes of biotite. The felsic matrix is glassy or finely devitified and may contain microcrystalline biotite and titanomagnetite. Flattened lenticles of very similar composition occur in the Tent Hill Volcanics near the contact with the Dundee mass.

Crystal-rich rhyodacite xenoliths are of two types. The most common variety contains abundant microphenocrysts of fragmented plagioclase, quartz, clinopyroxene, hornblende and shredded biotite. The other type features larger euhedra (2 - 4 mm) of the same minerals, but a paucity of crystal fragmenta and therefore resembles the (cognate) autoliths described previously.

THE TENT HILL VOLCANICS

The Tent Hill Volcanics (new name) form a prominent ridge along the western and northern margins of the Dundee (Rhyodacite) mass. Formerly termed the Tent Hill Porphyrite (Lawrence, 1969), the rocks have been considered by all previous workers to be intrusive adamellites (e.g. Shaw, 1964, who grouped them with rocks he called "The Older Porphyries"). They have a black, glassy groundmass and are typically closely jointed in outcrop.

The field relations and outcrop pattern suggest that the Tent Hill Volcanics are related to the formation of the Dundee Caldera and may be the quenched products of a magma which erupted from an arcuate ring fracture near, or at, the caldera rim. The volcanics range from siliceous rhyodacite to crystal-rich andesite and the average composition of those analysed falls within the range of the Dundee Rhyodacite. When mineral data are assessed, it will be argued that the Tent Hill Volcanics and Dundee Rhyodacite are probably comagmatic.

The Tent Hill Volcanics are the result of a number of eruptions which produced relatively thin ignimbrite flow sheets. The lateral and vertical mineral zonation in these flow units is considered sufficient to account for the observed range in chemical composition. Border-facies Dundee Rhyodacite closely resemble Tent Hill Volcanics at the contact zone. Although both are younger than the Emmaville Volcanics it was not possible to positively determine the relative ages of these two units. However, xenoliths of unequivocal Tent Hill Volcanics material have not been found in the Dundee Rhyodacite, suggesting the Rhyodacite is probably the older unit.

Although the modal abundances of phenocrysts and lithic fragments are highly variable, the optical characteristics, average composition and habit of phenocryst phases in the Tent Hill Volcanics is the same as in the Dundee Rhyodacite. Plagioclase ranges from An_{66} to An_{35}, and An_{57} to An_{16} in a particularly leucocratic sample, but the average range is An_{49} to An_{36}. Clinopyroxene compositions (av. Ca_{44} Mg_{36} Fe_{20}) are very similar to the Dundee Rhyodacite average, but some salites were analysed (Ca_{47} Mg_{37} Fe_{16}).

The textures of the Tent Hill Volcanics are distinctive. Unmetamorphosed rocks are either glassy or the groundmass is very finely devitrified and eutaxitic textures are often beautifully preserved. As in the Dundee Rhyodacite, fragments of all the major phenocryst phases are distributed throughout the groundmass and examples of arrested microbrecciation of crystals are common. Pumiceous and foreign lithic fragments are ubiquitous.

The Tent Hill Volcanics can be divided into a number of textural types, each type grading both laterally and vertically into volcanics with a subtly different texture. However, some locations appear to be dominated by a specific textural type.

Near Moorlands Homestead, 7 km southeast of Emmaville, the Volcanics range from crystal-rich eutaxites similar to Dundee Rhyodacite of the contact facies, to black, glassy ignimbrites containing fewer and smaller phenocrysts and reduced abundances of clinopyroxene and hornblende. Coarsely porphyritic autoliths are common in Volcanics near the Dundee Rhyodacite contact, but are absent in the more crystal-poor ignimbrites. Southeast of the homestead a single outcrop of thin-laminated ash-fall tuff marks part of the top of one ignimbrite unit. The tuff lacks lateral continuity which would indicate that it is unlikely to be a base-surge or lag-fall deposit.

At the southern extremity of the Tent Hill Volcanics, 12 km southeast of Emmaville, crystal-rich, altered ignimbrites predominate. These rocks are characterized by their high modal abundance of phenocrysts, often coarsely banded appearance, and a plethora of pumice fragments and foreign xenoliths. Although the rocks are firmly welded, few pumice fragments are flattened and eutaxitic textures in the groundmass of the host are only incipiently developed. Equivalent rocks with well developed eutaxitic textures occur north of Tent Hill. They are associated with ignimbrites containing large phenocrysts of zoned plagioclase (An_{57}-An_{16}) which commonly form large clusters (8 - 10 mm). Such rocks probably represent the most acid variants of the Tent Hill Volcanics.

Because the Tent Hill Volcanics are closely jointed they are prone to weathering. In some cases alteration may be attributed to the passage of hydrothermal fluids, especially near the contact with the Dundee Rhyodacite (cf. Vernon, 1959). Furthermore, the Volcanics north of Tent Hill have survived biotite-, and locally, hornblende-grade contact metamorphism induced by the intrusion of the Mole Granite. These various processes have in some cases resulted in the development of a number of alteration minerals and considerable retexturing of the groundmass and some phenocryst phases. Epidote, sericite, kaolinite, biotite, chlorite and, locally, hornblende, are the major replacement minerals. Rutile and leucoxene are the oxidation products of granular ilmenite, and epidotized hornblende may also contain calcite.

Xenoliths: Monomineralic aggregates of plagioclase, clinopyroxene and hornblende, and composite clusters of these minerals, which were described in the Dundee Rhyodacite section of this chapter, also occur in the Tent Hill Volcanics near the Rhyodacite contact. Autoliths very similar to those in the Dundee Rhyodacite are also present in these volcanics. The autoliths are flattened, lenticular masses exhibiting all the characteristics of distorted pumice fragments. A second type of cognate xenolith, containing coarsely crystalline plagioclase euhedra (< 6 mm) and reduced amounts of ferromagnesian minerals, frequently coexists with the flattened autoliths. These felsic cognate xenoliths more closely resemble autoliths in the Dundee Rhyodacite because they assume a smooth lenticular or rounded form.

As well as the xenoliths described above, these rocks contain pumice lenticles of rhyodacitic composition which are common to most of the Tent Hill Volcanics east of Emmaville. These are the fine-grained rhyodacite breccias which occur as foreign xenoliths in the Dundee Rhyodacite. Specimens from the Volcanics appear to be remarkably uniform in composition, showing only minor variations in the modal content of clinopyroxene and hornblende. However they are generally poorer in clinopyroxene than equivalent xenoliths in the Dundee Rhyodacite, although this may reflect a sampling bias.

The great majority of foreign lithic fragments in the Tent Hill Volcanics appears to be derived from the adjacent Emmaville Volcanics. Clasts range in composition from rhyolitic to andesitic with quartz-feldspar rhyolites and biotite rhyodacites dominant. Most have well preserved eutaxitic textures. The xenoliths average 2 - 3 mm in diameter but range to a maximum of 20 mm.

PLATE 1. VOLCANIC TEXTURES AND STRUCTURES IN THE TENT HILL VOLCANICS AND DUNDEE RHYODACITE

A. Tent Hill Volcanic - Moorlands Homestead, 7 km southeast of Emmaville. Well-developed eutaxitic texture, abundant kinked and partly shredded biotite, broken euhedral hornblende phenocryst with magnetite inclusion (lower right). Felsic minerals are fragmented phenocrysts of quartz and zoned plagioclase.

Plane polarized light; x 19

B. Border-facies Dundee Rhyodacite - Glenoak Homestead, 12 km southeast of Emmaville. Autolith (upper half of photograph) with faintly visible eutaxitic texture or vestigial flow structures in the felsic groundmass. The groundmass of the host is comparatively structureless, and contains abundant phenocryst fragmenta and microcrystalline opaque oxides. Eutaxitic textures typical of border facies Dundee Rhyodacite are poorly developed in this specimen although the rock is strongly welded.

Plane polarized light; x 19

C. Same field of view as B, crossed polarized light. The coarse "mozaic" devitrification of the autolith contrasts with the much finer devitrification textures of the host.

D. Eutaxitic texture in Dundee Rhyodacite from the Wyberba mass. Fragments of quartz and plagioclase phenocrysts are abundant. Resorbed quartz - upper right, blocky crystal of clinopyroxene with magnetite inclusion - lower left.

Plane polarized light; x 19

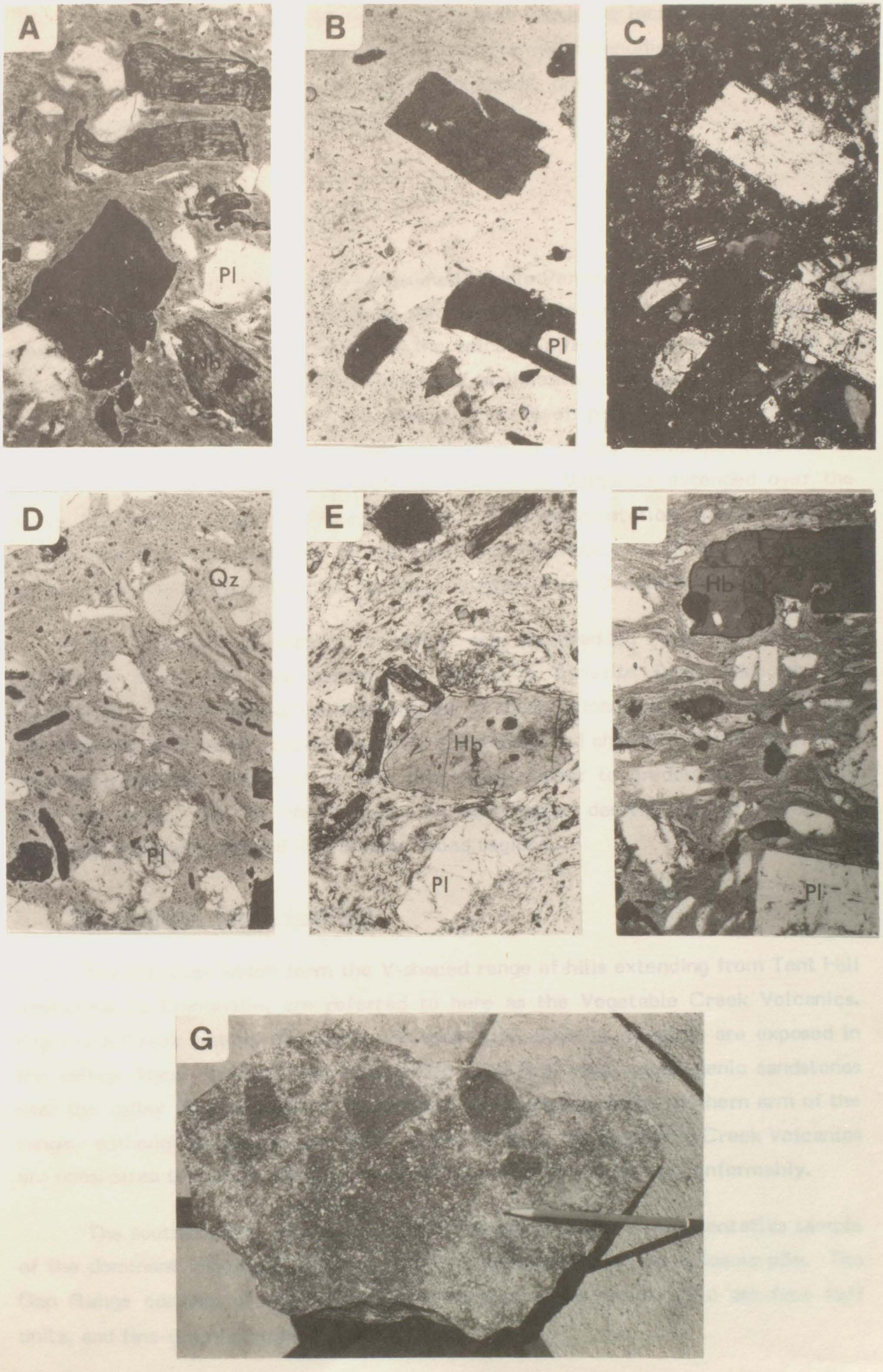
E. Sample No. 178A.

F. Sample No. 155.

E and F are strongly welded Emmaville Volcanics with whole-rock and mineral chemistries similar to the Dundee Rhyodacite. They are outflow-facies rhyodacites from the Dundee Caldera. Samples from near the Dundee Rhyodacite contact, south of Rangers Valley.

Plane polarized light; x 19

G. Volcanoclastic rhyodacite breccia - Dundee Rhyodacite contact, 6 km west of Deepwater. The prominant, dark clasts are glassy or very finely devitrified, welded rhyodacites. For detailed description see text.


A
Pl
Hb
B
Pl
C
D
Qz
Pl
E
Hb
Pl
F
Hb
Pl
G

Xenoliths rarely observed in the Tent Hill Volcanics include aggregates of recrystallized quartz (up to 8 mm) and porphyritic microgranodiorites. The microgranodiorites, found only in rocks near the contact, are the same as those in the Dundee Rhyodacite described previously.

THE EMMAVILLE VOLCANICS

The Emmaville Volcanics, of presumed Middle Permian age, mainly consist of an indeterminate number of individual ash flows and lavas of dominantly rhyolitic composition. The original thickness of the volcanic pile probably exceeded 300 m, but south of Emmaville scattered windows of sedimentary basement rocks are now exposed and erosion has unroofed several high-level plutons. The Emmaville Volcanics are texturally and compositionally similar to the Wallangarra Volcanics north of Tenterfield, suggesting that the Emmaville Volcanics extended over the entire Tenterfield region in Permian times. This interpretation implies that the plutons now well exposed in the central portion of the area cyrstallized under a thin cover of ignimbritic rhyolites and, possibly, outflow-facies Dundee Rhyodacite.

The dominant ignimbitic rhyolites are interbedded with a variety of rhyodacite lavas and, less commonly, dacite to andesite lavas and ash-flow rhyodacites. The stratigraphic relationships of these volcanic units are not known, and attempts to correlate rocks of similar mineralogy and chemical composition have been unsuccessful. However certain lithologies appear to predominate in widely separated areas, and for the purpose of petrographic description the Emmaville Volcanics have been divided into several broad regions.

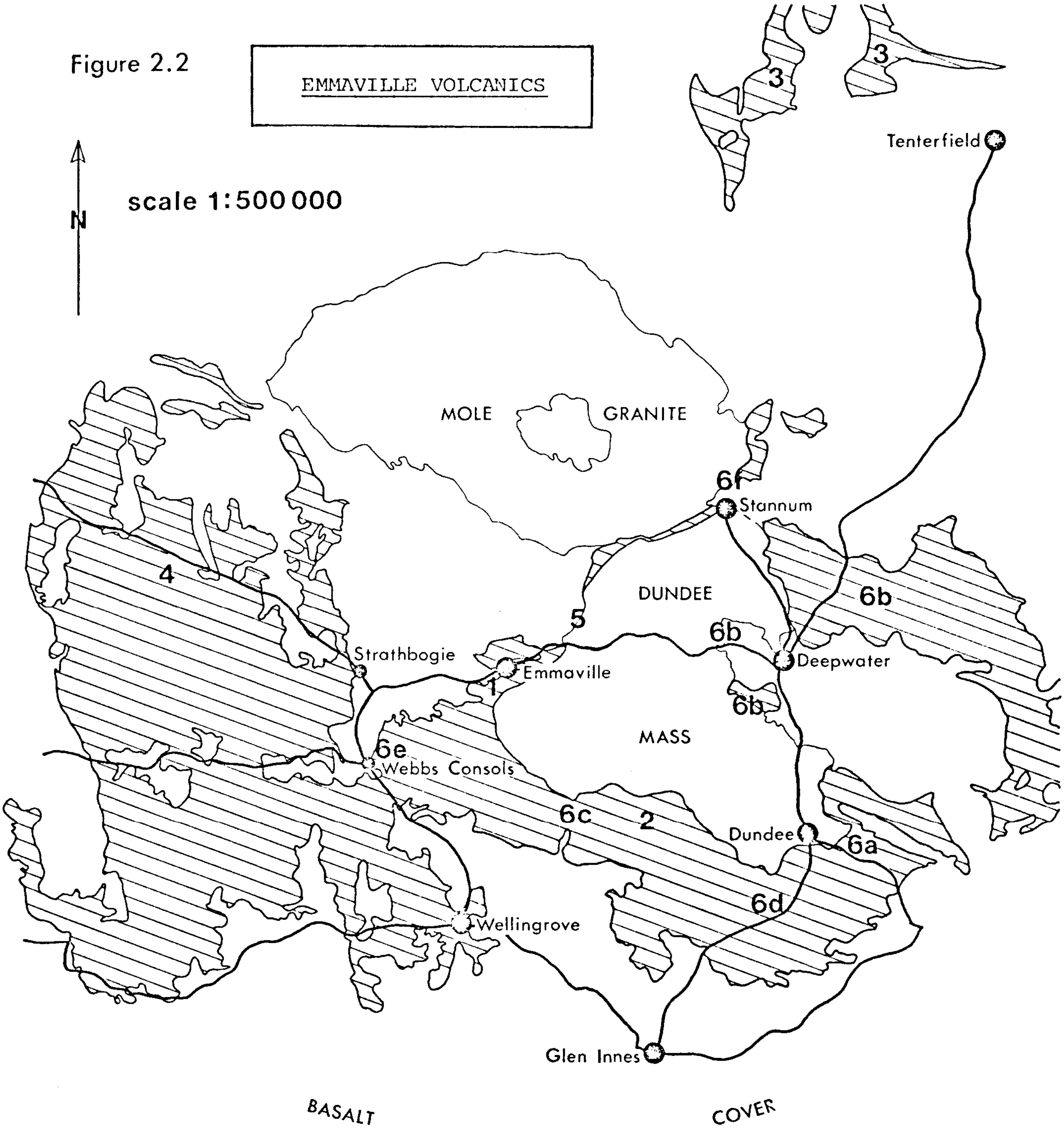
1. The Vegetable Creek Volcanics

The rhyolites which form the V-shaped range of hills extending from Tent Hill westwards to Emmaville, are referred to here as the Vegetable Creek Volcanics. Vegetable Creek bisects the range and cassiterite-bearing rhyolites are exposed in the valley. These rhyolites are interbedded with flat-lying volcanogenic sandstones near the valley floor and similar rocks occur on the slopes of the northern arm of the range. Although outcrop is very poor at this locality, the Vegetable Creek Volcanics are considered to overlie the Early Permian basement sediments unconformably.

The southern arm, known as the Gap Range, provides a representative sample of the dominant lithologies through a >60 m thick section of the volcanic pile. The Gap Range consists of an undetermined number of subaerial lithic ash-flow tuff units, and fine-grained breccias.

Figure 2.2

EMMAVILLE VOLCANICS



REGIONS DESCRIBED IN TEXT

1. Vegetable Creek Volcanics
2. Twin Mount Volcanics
3. Wallangarra Volcanics
4. Emmaville Volcanics - Strathbogie to Ashford
5. Ottery Rhyolite
6. Emmaville Volcanics
    - (a) east of Dundee
    - (b) northeast of Deepwater
    - (c) south of Emmaville
    - (d) Dundee to Glen Innes
    - (e) Webbs Consols Mine area
    - (f) Mole Granite area

Regardless of the abundance of angular lithic fragments and pumice lenticles, the rocks are all two-feldspar quartz rhyolites. This is because the great majority of clastic material has a composition similar to that of the host. Individual ash-flow units (>1 m to< 10 cm) can be traced using the size and abundance of lithic fragments as diagnostic criteria but this is not always successful owing to the sorting of clasts both vertically and laterally within the flows.

Modal variation in the major phenocryst phases quartz, plagioclase and K-feldspar is extensive, and rhyolites range from crystal-rich to crystal-poor types. The crystal-poor varieties generally contain more abundant plagioclase euhedra and reduced amounts of phenocryst fragmenta. Rhyolites from near the base of the volcanic pile are locally sheared. Excluding these rocks, the Vegetable Creek Volcanics display well preserved eutaxitic textures. Limited flowage in the groundmass prior to welding is indicated in those rocks with uniformly oriented biotite phenocrysts. Biotite (< 2%) is the only primary mafic mineral and although widespread, is virtually absent from the most siliceous rhyolites.

The abundance of lithic fragments in the Vegetable Creek Volcanics varies from 2% to 90%. As well as rhyolite clasts, fragments of finely laminated siltstone or massive fine-grained sandstone, and clasts of andesite composition are reasonably common. They range in size from < 1 mm to > 12 mm depending on rock type. The fragments are usually well sorted.

The rhyolite clasts display an interesting variety of textures. The dominant types are probably sub-rounded fragments containing quartz, sodic plagioclase and blocky K-feldspar phenocrysts in a welded felsic groundmass. Tiny fragments of rhyolitic glass (< 0.5 mm) accompany the phenocrysts in these rhyolite clasts, and are distinguished by very fine devitrification textures which differ from those of the host. Some rhyolite lithic fragments are devoid of phenocrysts and fine to extremely coarse spherulitic devitrification textures are sometimes spectacularly developed. Others are essentially unaffected by this form of alteration and contain unflattened V- and Y-shaped shards whose outlines are accentuated by fine axiolitic devitrification of the original glass.

2. The Twin Mount Volcanics

The Twin Mount Volcanics (new name) were originally mapped as Dundee Adamellite Porphyrite by geologists of the New South Wales Geological Survey (Brunker and Chesnut, 1976). Twin Mount (4 km south of Rangers Valley Homestead) and its sister peak are composed of flow-banded rhyolite and rhyodacite lavas. These volcanics have gradational contacts with clinopyroxene-bearing ignimbritic rhyodacites in the north, and in the south grade into siliceous rhyolites with coarse devitrification textures and less pronounced fluidal structures. Most of the volcanics at Twin Mount are conspicuously banded with alternating pale and darker layers measuring up to 5 cm in thickness. The mineralogy of the respective layers is the same, but the darker bands have the more finely devitrified groundmass.

The principal phenocryst phases are quartz, K-feldspar, zoned plagioclase (< 6 mm) and brown biotite. The rhyodacites contain increased amounts of biotite, minor hornblende and variable amounts of clinopyroxene. The ferromagnesians originally formed mafic clusters, now totally replaced by epidote, chlorite, relict titanomagnetite and exsolved ilmenite. Plagioclase infrequently forms glomeroporphyritic aggregates exhibiting synneusis structures.

Lithic fragments in the lavas are small, and constitute < 1% of the rocks. Crystal-poor rhyodacites with spherulitic devitrification textures and clasts of finely devitrified high-silica rhyolite occur in equal abundance.

3. The Wallangarra Volcanics

The Wallangarra Volcanics (Butler, 1974) outcrop over an area of ~120 km^2 between the Tenterfield Fault and the township of Ballandean 15 km northwest of Wallangarra. The margins of the volcanic pile are defined by the Tenterfield Fault in the south, and the contact with the Stanthorpe Adamellite in the north and west. Near Wallangarra the volcanics are intruded by a small pluton of Bungulla Porphyritic Adamellite but this contact is obscured by small masses of leucoadamellite porphyry. Andrews (1907) and Saint Smith (1914) referred to the rocks as acid grey feldspar porphyry, but Simmonds (1958) and Olgers and Flood (1970) recognized rhyolites and hornblende-bearing rhyodacitic volcanics. Butler (1974, p.76) described the Wallangarra Volcanics as "a near horizontal sequence" of altered ignimbrites and weathered fluidal rhyolite and suggested that the sequence may be more than 300 m thick. This estimate may be a reasonable approximation of the original thickness of the volcanic sequence.

Small inliers of recently unroofed Stanthorpe Adamellite outcrop near Wyberba and porphyritic acid intrusive rocks are widely distributed (not shown on map). The Wallangarra volcanics are overlain by the Wyberba and Sunnyside masses of the Dundee Rhyodacite. Although Olgers and Flood (1970) and Butler (1974) correlated them with the Late Permain to Triassic Drake Volcanics north of Tenterfield, the Wallangarra Volcanics are here equated with the Emmaville volcanics south of the Bolivia Range. The Emmaville and Wallangarra Volcanics are lithologically similar and both are older than the Dundee Rhyodacite.

The Wallangarra volcanics consist of a large number of rhyolitic ash-flows interbedded with hornblende-bearing rhyodacite lavas displaying fluidal groundmass structures and a well developed foliation. Rhyolitic lavas are uncommon and are restricted to locations north of Wallangarra and west of the Sunnyside mass near the Tenterfield Fault. The entire volcanic sequence has been thermally metamorphosed by the Stanthorpe Adamellite and smaller plutons of leucoadamellite porphyry.

Phenocrysts of quartz, oligoclase, K-feldspar and biotite are common to both rhyolites and rhyodacites. The total phenocryst content ranges from 10% to 30% and this variation may reflect sorting within individual ash-flows (e.g. Sparks et al., 1978). The rhyodacites are characterized by increased abundances of zoned plagioclase (andesine-oligoclase) and biotite, and by the appearance of hornblende. All the prismatic phenocryst minerals contribute to the strong foliation in those rhyodacites which have pronounced fluidal groundmass structures. The principal accessory minerals are ilmenite, iron sulfides, and apatite which occurs solely as an inclusion in hornblende.

The ignimbritic rhyolites may contain numerous small (< 2 mm) flattened pumice fragments more coarsely devitrified than the groundmass of the host. Elongate lenticles of finely granular quartz oriented parallel to the foliation are common. Similar structures are also present in siliceous ignimbrites of the Emmaville Volcanics south of Emmaville.

Chloritization and recrystallization of ferromagnesian phenocrysts, and the growth of microcrystalline biotite in the groundmass of rhyodacitic volcanics are the most common effects of the contact metamorphism. Original microscopic eutaxitic textures are generally preserved.

4. Emmaville Volcanics - Strathbogie to Ashford

Emmaville Volcanics extending from Strathbogie Homestead 25 km westwards towards Ashford, have not been described or mapped in detail by previous workers. The purpose of sampling these volcanics was to briefly document the rock types present and to draw comparisions with the Emmaville Volcanics nearer Emmaville.

The Emmaville Volcanics west of Strathbogie are compositionally similar to those near Emmaville. They are intruded by high-level granites, granite porphyries and adamellites and are in part overlain by Tertiary basaltic rocks. The volcanics are dominantly siliceous rhyolites with very pronounced eutaxitic textures. Embayed quartz and altered K-feldspar (2 mm) are the dominant phenocryst phases, accompanied by sericitized sodic plagioclase and chloritized biotite with associated titanomagnetite and pyrite. Relatively large (2 - 8 mm) compressed pumice lenticles with the same mineralogy as the host display coarse spherulitic or axiolitic devitrification textures. Biotite-rich and poorly compacted lenticles are highly susceptible to pervasive chloritization. The rhyolites usually contain abundant rhyolitic lithic fragments (av. 3 mm) and lesser amounts of metasedimentary clastic material. The rhyolitic clasts and the host may contain traces of allanite.

Although only a minor component of the volcanic sequence, ignimbritic rhyodacites rich in volcanoclastic debris, are widely distributed. Near Strathbogie, a coarsely porphyritic hornblende-bearing rhyodacite lava is poorly exposed. This lava resembles the rhyodacites outcropping near the Mole Granite contact west of Stannum.

5. The Ottery Rhyolite

The Ottery Rhyolite (new name) is a distinctive pale-coloured unit which forms a sinuous north-trending belt between the Tent Hill Volcanics and the sedimentary basement rocks in the vicinity of the Ottery Mine. The rhyolite was termed a silicified acid tuff by Kenny (1939). It is intruded by the Ottery host adamellite, and the contact zone has been subject to extensive kaolinization, silica veining and shearing parallel to the contact. North of the mine the rhyolite outcrop thins dramatically (3 m) and ultimately disappears near Glen Creek 2 km further north. Most outcrops display a joint pattern identical to that of the adjacent sediments, with a prominent cleavage oriented $325^{0}/085^{0}$ NE.

The Ottery Rhyolite is most appropriately correlated with the Emmaville volcanics outcropping further to the south. The Rhyolite is a useful marker defining the eastern boundary of the Tent Hill Volcanics which are seen to overlie the Rhyolite in the vicinity of the Ottery Mine.

The Ottery Rhyolite is a strongly welded ignimbrite containing up to 15% volcanic and metasedimentary microxenoliths. The glassy groundmass is choked with randomly oriented shards showing fine axiolitic or granular devitrification textures. This groundmass supports anhedral phenocrysts (0.5 - 1.5 mm) of embayed quartz, kaolinzed K-feldspar and subordinate sericitized, weakly zoned sodic andesine. The volcanic fragmental material includes vitrophyric rhyolite clasts with spherulitic devitrification textures (dominant), quartz two-feldspar rhyolites (with or without biotite) and vitrophyric rhyodacites. These fragments range from 1 mm to 2 cm, the largest showing evidence of plastic deformation after incorporation into the host. The metasedimentary xenoliths are massive siltstones or very fine-grained massive sandstones. They are generally smaller (<2 mm) and less abundant than the volcanic clasts.

6. Emmaville Volcanics South of Emmaville and the Bolivia Range

The large area of Emmaville Volcanics which broadly surrounds the Dundee Rhyodacite mass has been divided into six regions (ref. Figure 2.2). The variations in rock types from region to region suggest that certain forms of volcanic activity were restricted to specific centres or locations along a single, large vent. However, the variations may partly reflect differing levels of erosion of the sub-horizontally stratified volcanic pile.

(a) East of Dundee:

Glassy and finely devitrified ignimbritic rhyodacites displaying well developed microscopic eutaxitic textures occur near the Dundee Rhyodacite contact east of Dundee. These rocks contain phenocrysts of Mg biotite, magnesio-hornblende, calcic augite and zoned andesine. Mineral and whole-rock analyses of a typical specimen (Table 4, No. 18) indicate a possible cogenetic relationship with the Dundee Rhyodacite. Although the modal abundance and degree of fracturing of phenocrysts is variable, in thin section many samples resemble Dundee Rhyodacite of the border facies. Further east, the glassy rhyodacites give way to altered acid rhyodacites (Table 4, No. 210), andesite (No. 206) and finally acid rhyodacites (No. 306A) and altered rhyolitic lithic tuffs more typical of the Emmaville Volcanics in other regions.

The andesite outcrops over a very small area 200 m east of the Dundee Rhyodacite contact. It contains zoned plagioclase (<3 mm) and calcic augite (>2 mm) which occur as discrete phenocrysts and form monomineralic and bimineralic clusters (5 mm). Biotite, a minor phenocryst phase, is variably chloritized and epidotized and contains inclusions of exsolved ilmenite. The glassy groundmass contains abundant laths of poorly zoned andesine which impart a weakly developed pilotaxitic texture. Accessory minerals are pyrite, ilmenite and magnetite, the latter commonly occurring as an inclusion in clinopyroxene. Chloritization of clinopyroxene is confined to the mafic clusters.

The andesite lava is associated with altered ignimbritic rhyodacites, some of which contain relict clinopyroxene. The pale green (actinolitic?) hornblende which replaces the clinopyroxene is itself chloritized and epidotized. Like the andesite these rocks have suffered low-grade thermal metamorphic reconstitution shown by the development of microcrystalline biotite in the devitrified groundmass and epidotization of plagioclase phenocrysts.

Rhyolitic crystal tuffs and lithic tuffs predominate further east. Phenocrysts of K-feldspar (frequently perthitic orthoclase), zoned plagioclase, quartz and biotite are ubiquitous but there exists considerable modal variation. Spherulitically devitrified vitrophyric rhyolite and porphyritic rhyolite clasts predominate, with rhyodacitic and occasionally andesitic clasts present in some specimens. Sedimentary xenoliths are rare and only one, which featured numerous "microporphyroblasts" of cordierite, was found.

The Nioka Porphyritic Dacite (Table 4, No. 13) is associated with lithic ash-flow rhyolites 13 km south-southwest of Dundee. The lava has a rhyodacitic composition and contains 5 mm phenocrysts of strongly zoned plagioclase (oscillatory zoned in part), perthitic orthoclase (up to 15 mm), hornblenditized prisms of augite (3 mm), resorbed quartz and 2 mm crystals of biotite. Small crystals of metamorphic biotite are abundant in the recrystallized quartzo-feldspathic groundmass. The dominant opaque phase is chalocpyrite which forms dispersed masses containing pyrite, and very minor bornite as an alteration product.

(b) Deepwater Area:

The Emmaville Volcanics between Deepwater and the Bolivia Range are dominated by rhyodacites which vary from highly siliceous types to rocks approaching dacitic composition. Strongly zoned plagioclase (andesine) and dark brown biotite are essential minerals and may be accompanied by hornblende, clinopyroxene, quartz and very minor K-feldspar in the more siliceous rhyodacites.

Biotite-grade contact metamorphism has affected the entire region, increasing to hornblende-grade near the contact with the Bolivia Range Leucoadamellite and at several localities well distant from exposed plutons. Tiny crystals of biotite (or actinolite) pervade the groundmass of some specimens, and biotite phenocrysts contain exsolved ilmenite or skeletal titanomagnetite octahedra. Biotite may also be rimmed by, and contain inclusions of, granular sphene. Clinopyroxene (1 mm) is frequently rimmed by green amphibole or totally replaced by amphibole or chlorite. The plagioclase and biotite are epidotized and sericitized, and plagioclase may also be replaced by calcite. Chlorite replaces all the primary ferromagnesian minerals in strongly altered specimens.

Although vestigial eutaxitic textures are common, the absence of phenocryst fragmenta in some recrystallized rhyodacites suggests that both lavas and ignimbrites are represented. Monomineralic plagioclase clusters (3 - 4 mm) occur in all rock types but 2-3 mm hornblende-clinopyroxene-magnetite-plagioclase aggregates (frequently chloritized) are restricted to the less silicic rhyodacites.

In the northeast of the region near the Bolivia Range - Mt Jonblee Leucoadamellite contact, small volumes of rhyolite are interbedded with the metarhyodacites. The rhyolites have a recrystallized or coarsely devitrified groundmass and some contain small (2 mm) clasts of ignimbritic biotite rhyolite. Further south, the rhyodacites lose prominence and give way to metarhyolites with partly recrystallized eutaxitic textures. Many of these ignimbrites contain up to 3% volcanoclastic material. The clasts range in composition from vitrophyric rhyolite to coarsely devitrified biotite rhyolite and rhyolitic lithic tuffs. A number of small, allanite-bearing leucoadamellite porphyry stocks have intruded the acid volcanic sequence.

The Emmaville Volcanics near the Dundee rhyodacite contact 6 km west and southwest of Deepwater are unusually heterogeneous, grading from rhyolitic lithic tuffs to rhyodacitic lithic and crystal tuffs approaching the contact. The rhyodacites southwest of Deepwater are crystal rich (50 - 60%) and show an increase in modal clinopyroxene near the Dundee Rhyodacite. Eutaxitic textures are pronounced in the clinopyroxene-bearing ignimbrites, but there is a concommitant decrease in the abundances of volcanoclastic (rhyodacitic) material and coarsely devitrified felsic cognate xenoliths. The cognate xenoliths are identical to those described from the Dundee Rhyodacite and Tent Hill Volcanics, and vestigial flow structures or attenuated shards are sometimes visible. Epidotization of plagioclase and chloritization of the primary ferromagnesian minerals is common, but relict phenocrysts are optically identical to those in the adjacent Dundee Rhyodacite. The hydrothermal alteration is similar to the metasomatism that has locally affected the Tent Hill Volcanics and border-facies Dundee Rhyodacite near Tent Hill and Moorlands Homestead (Vernon, 1959; this thesis).

A narrow band of ignimbritic rhyodacites separates the Dundee Rhyodacite from the sedimentary basement rocks 6 km west of Deepwater. Border-facies Dundee Rhyodacite grades into very coarse clastic tuffs or breccias which further east pass into more leucocratic ash-flow tuffs with macroscopic eutaxitic textures.

The coarse volcanic breccias have the same mineralogy and many of the textural characteristics of border-facies Dundee Rhyodacite, with abundant phenocryst fragmenta; glomeroporphyritic aggregates (<4 mm) of clinopyroxene, biotite, minor hornblende, plagioclase and magnetite, and abundant coarsely devitrified cognate xenoliths (see Plate 1). Clasts ranging from 5 mm to 10 cm may comprise 40% of the rock and include the following types:

(i) Finely devitrified flow-foliated rhyolites with phenocrysts of altered K-feldspar and minor biotite, and numerous clots of decussate biotite (< 0.2 mm), in an altered quartzo-feldspathic groundmass.

(ii) Plastically deformed ("wispy") microxenoliths of acid rhyodacite tuff, containing phenocrysts of zoned plagioclase and flow-aligned flakes of biotite in a uniform, finely devitrified felsic groundmass peppered with opaque iron oxide.

(iii) Angular and stretched fragments which resemble the Dundee Rhyodacite.

(iv) Acid rhyolites with 1 - 2 mm phenocrysts of quartz, kaolinized K-feldspar and zoned oligoclase, and very minor biotite (now altered to iron oxides and chlorite), set in a flow-banded, glassy groundmass which features lenses of granular quartz.

(v) Ignimbritic rhyodacites with 1 - 3 mm phenocrysts of clinopyroxene, biotite, zoned andesine, quartz and chloritized hornblende set in a glassy groundmass. Eutaxitic wextures are well preserved.

(vi) Altered ignimbritic rhyodacites with Dundee Rhyodacite mineralogies and containing angular fragments of plagioclase-rich andesite (1.5 mm), flow-banded rhyolite and coarsely devitrified vitrophyric rhyolite (1.5 mm).

(vii) Microporphyritic rhyolite containing tiny fragmental phenocrysts of quartz, plagioclase and very minor biotite, set in a finely devitrified acid groundmass.

(viii) Rare metasedimentary microxenoliths (5 mm) composed of almandine garnet, granoblastic quartz and fine-grained biotite.

Phenocrysts in the host (especially the ferromagnesian minerals) and much of the clastic material of the rhyodacite breccias, exhibit the effects of metasomatic alteration.

The ignimbrites which outcrop east of the rhyodacite breccias are also hydrothermally altered. These rhyodacites have phenocrysts of zoned plagioclase, biotite, Approximately 3 km south of the Dundee Rhyodacite contact, thin-banded (1 - 5 cm) ash-fall tuffs are interbedded with ignimbritic crystal and lithic tuffs of rhyolitic and rhyodacitic composition. These rocks are highly altered. The devitrified groundmass is frequently choked with microcrystalline actinolite or biotite, and chlorite, calcite and epidote replace biotite and feldspar phenocrysts. Relict phenocrysts of clinopyroxene (chloritized or epidotized) may occcur in K-feldspar-bearing rhyolites of quite siliceous composition. The ash-fall tuffs consist of pale-coloured layers of devitrified rhyolite which alternate with darker layers of more crystal-rich rhyodacite tuffs. Angular fragments of vitrophyric and altered porphyritic rhyolite (1 - 4 mm) are very abundant in some layers. Although not common, iron sulfide-bearing quartz-chlorite-sericite veinlets were noted in all rock types.

Further south the volcanic sequence is dominated by phenocryst-rich, highly siliceous ash-flow rhyolites. The rhyolites contain fractured phenocrysts of epidotized K-feldspar and poorly zoned plagioclase (up to 3 mm), resorbed quartz and a few flakes of biotite which are normally chloritized or epidotized and contain large grains of pyrrhotite or iron oxide. Small grains of iron sulfide are scattered throughout the welded groundmass or are confined to fracture veinlets. The lithic component of the rhyolites varies from 1 to 20%.

(e) Webbs Consols Mine Area:

The Webbs Consols Mine region is dominated by lavas and ash-flows of rhyolitic composition. The thin wedge of layered volcanics separating the orebody host adamellite from granophyric "granite" to the west, is particularly heterogeneous. Strongly welded pumiceous ash flows are interbedded with flow-laminated rhyolite lavas and a 3 m-thick bed of siliceous rhyolite featuring lithophysae 2 cm in diameter. Intruding the volcanic pile are numerous pipes of "intrusive rhyolite" containing phenocrysts of metamict allanite. Other rock types include welded crystal tuffs, lithic tuffs, and the reconstituted analogues of these rocks in which original eutaxitic textures have been destroyed by spherulitic devitrification. All rocks have a similar mineralogy with phenocrysts of zoned sodic andesine-oligoclase, orthoclase, quartz and variable amounts of biotite. Magnetite, ilmenite and iron sulfides occur in the groundmass and as inclusions in biotite.

East of the Mine, ash-flow rhyolites with eutaxitic textures predominate, whereas west and northwest of the Mine ignimbritic rhyolites and minor hornblende-bearing rhyodacites display spherulitic devitrification textures. Further south the base of the volcanic pile is exposed and thinly bedded, fine-grained volcanogenic sediments overlie siliceous siltstones of the Early Permian basement sequence.

All the rocks in the Webbs Consols area have experienced low-grade contact metamorphism and they are also pervasively altered due to deep weathering. The development of microcrystalline biotite in the groundmass and decussate recrystallization of biotite phenocrysts is common, but the felsic components of the groundmass are largely unaffected and delicate textures (e.g. spherulites) may be preserved.

The Emmaville Volcanics 20 km southeast of Webbs Consols near Wellingrove consist of a diverse range of lithologies. McKay (1975) has described coarse volcanoclastic breccias, tephra deposits and strongly welded ignimbrites with well developed eutaxitic textures. (Laminated ash-fall tuffs are absent - cf. south of Dundee (section 6(d)).) Broken and fractured phenocrysts of quartz, zoned oligoclase (av.) and orthoclase are common to all rocks, and minor hornblende may accompany biotite in the ignimbrites. The clastic component of the volcanic breccias and lithic ash-flow tuffs consists of laminated rhyolite lava, welded tuffs, disaggregated pumice and felsic cognate pumiceous material devoid of phenocryst fragmenta.

There is considerable variation in the abundance of phenocrysts and clastic material in both the ash-fall and ash-flow volcanics. However the rhyolitic lavas are virtually devoid of lithic fragmenta.

(f) Mole Granite Area:

The reconstitution of volcanic rocks up to 5 km southeast of Stannum may be attributed to the combined influence of the emplacement of the Mole Granite and Bolivia Range Leucoadamellite. Contact metamorphism increases from biotite-grade to hornblende-hornfels facies 0.5 - 1 km from the Mole Granite contact, and up to 0.5 km from the Bolivia Range Leucoadamellite. The rocks southeast of Stannum are lithic tuffs and crystal tuffs of rhyodacitic composition, accompanied by very minor andesites. Weakly metamorphosed ignimbritic rhyodacites near Deepwater have phenocrysts of epidotized plagioclase, and chloritized biotite and hornblende (0.5 - 1.5 mm), the latter hosting grains of magnetite and exsolved ilmenite. The groundmass contains numerous microlites of biotite and (minor) hornblende, small aggregates of epidote and patches of calcite.

Further towards the Mole Granite rhyodacites with abundant K-feldspar grade into phenocryst-rich and lithic rhyodacites. Banded lithic tuffs, 0.5 km from the Bolivia Range Leucoadamellite contact 5 km southeast of Stannum, are coarsely recrystallized and contain abundant metamorphic hornblende and biotite. Biotite and actinolitic (?) hornblende replace the primary ferromagnesian phenocrysts in both the

TABLE 4: MINERALOGY OF ANALYSED EMMAVILLE VOLCANICS

Code No. Rock Type Analysis No.	Mg No. Biotite	Mg No. Amphibole	Mg No. Clinopyroxene	Plagioclase Composition	Opaque Mineralogy M^{i} - Magnetite with Ilmenite Exsolution Lamellae
169 Rhyodacite 28	Av. 47.5	54-43 Edenitic hornblende & Ferro-hornblende	59.7-53.3 Salite	An_{46}-An_{41} Av.$An_{41.7}$ $Or_{5.2}$ $Ab_{53.1}$	M^{i} $M_{78.7}$ $U_{21.3}$
291c Rhyodacite 23	Av. 40.8	39-45.5 Ferro-hornblende		An_{59}-An_{36}	ilmenite, pyrite, sphalerite
156# Rhyodacite	Av. 58 Mg biotite		80.6-67.3 Av. 70 Calcic Augite	An_{64}-An_{42}	ilmenite, pyrite, M^{i} $M_{44.2}$ $U_{55.8}$, $M_{62.7}$ $U_{37.3}$
156A# Rhyodacite	Av. 52.5 Mg biotite	Av. 54 Actinolitic hornblende	62.9-66.8 Calcic Augite	An_{66}-An_{52}	ilmenite, pyrite, M^{i}
155* Rhyodacite 25	Av. 52.2 Mg biotite	Av. 57 Magnesio-hornblende	69.8-65 Av. 65.5 Calcic Augite	An_{52}-An_{33}	pyrite, ilmenite, M^{i} $M_{73.8}$ $U_{26.6}$, $M_{89.4}$ $U_{10.6}$
138 Rhyodacite 34	Av. 43 Fe biotite		Av. 62 Calcic Augite & Salite	An_{57}-An_{28}	chalcopyrite, pyrite, very minor bornite
306A Acid Rhyodacite-Rhyolite 20	25.3			An_{55}-An_{30}	pyrite, ilmenite $I_{99.1}$ $H_{0.9}$ marcasite
253 Meta Rhyodacite 22	Av. 40			Av. An_{30} some Albite	M^{i} $M_{59.9}$ $U_{40.5}$ ilmenite $I_{99.7}$ $H_{0.3}$
285 Dacite-Andesite 29	Av. 46.2 Fe biotite			An_{58}-An_{43}	pyrite, chalcopyrite, M^{i} ilmenite. $M_{91.3}$ $U_{8.7}$, $M_{84.9}$ $U_{15.1}$, $I_{98.3}$ $H_{1.7}$, $I_{99.8}$ $H_{0.2}$
176* Rhyodacite 21	Av. 52 Mg biotite	59.3-55.6 Av. 58 Magnesio-hornblende	66-63.4 Av. 65.6 Calcic Augite-Salite	An_{52}-An_{36}	ilmenite, pyrite, M^{i}. $M_{91.3}$ $U_{8.7}$, $M_{84.9}$ $U_{15.1}$
178* Rhyodacite	Av. 53 Mg biotite	Av. 57.8 Magnesio-hornblende & Tschermakitic hornblende	Av. 64.4 Calcic Augite	An_{42}-An_{36}	pyrite, ilmenite, M^{i}.
210 Acid Rhyodacite 27	43.5-34.6 Av. 38 Fe biotite	40.5-37.4 Av. 38 Actinolitic hornblende		An_{62}-An_{29}	ilmenite, M^{i}
264 Andesite 33	Av. 47 Mg biotite	66.7-56.3 Actinolitic hornblende & Magnesio-hornblende	80.6-62.1 Av. 67-62 Salite	An_{63}-An_{48}	ilmenite I_{100} $H_{0.0}$, Magnetite
18* Rhyodacite 31	52.7-50.7 Av. 51.5 Mg biotite	58.9-57 Magnesio-hornblende	Av. 64.4 Calcic Augite	An_{49}-An_{34}	pyrite, ilmenite $I_{99.6}$ $H_{0.4}$ M^{i} $M_{72.3}$ $U_{23.7}$, $M_{74.0}$ $U_{26.0}$
206 Andesite 30			80.2-67.9 Av. 76 Calcic Augite	Phenocryst An_{58}-$An_{38.5}$ Groundmass (cores) An_{55}	M^{i} $M_{69.1}$ $U_{31.1}$, ilmenite, pyrite

Rocks with Dundee Rhyodacite whole-rock chemistry but more primitive mineralogies.

* Strongly welded, glassy equivalents of the Dundee Rhyodacite.

TABLE 5 : Modal Data for Volcanic Rocks

Code No.	Analysis No.	Rock type	Groundmass	Plagioclase	Quartz	K-feldspar	Biotite	Hornblende	Clinopyroxene	Clastic Component	Opaques	Accessory Minerals	Comments
average of	24	Dundee Rhyodacite	48.4	32.1	4.2	-	9.3	3.9	1.3	-	0.8	tr.	tr. orthopyroxene
-		"	54.3	28.3	2.7	-	7.4	3.4	3.3	-	0.6	tr.	Wyberba mass
-		"	45.2	35.2	2.3	-	10.1	6.5	tr.	-	0.7	tr.	"
397	17	"	43.8	33.1	6.5	-	11.3	1.5	3.6	-	0.2	tr.	Dundee mass
X105A	-	"	20.7	46.3	-	-	17.1	8.8	4.9	-	2.2	tr.	mafic xenolith
13b#	34	Nioka "Dacite"	53.8	23.7	5.7	11.3	2.4	2.0	0.6	-	0.5	tr.	Hb. replaces cpx
18#,	31	Rhyodacite	59.2	21.8	2.6	10.5	2.3	3.1	-	-	0.5	tr.	"
218A#	39	Acid Rhyodacite	59.0	4.3	1.8	18.4	1.2	-	-	14.6	0.7	tr.	
264#	33	Meta-Andesite	79.5	8.1	-	-	0.7	10.7	1.0	-		<0.1	opaques in g'mass
291c#	23	Meta-Rhyodacite	20.6	21.9	0.6	-	4.7	2.2	-	-	<0.1	tr.	bi after Hb, cpx
41*	11	Rhyodacite	64.9	20.5	2.9	-	4.5	3.1	0.4	3.1	0.6	tr.	
259A*	10	Acid Rhyodacite	81.6	10.8	1.2	-	2.6	2.3	1.0	0.2	0.3	<<0.1	Chlorite after bi
256B*	8	Andesite	47.9	28.9	-	-	2.2	7.6	5.2	6.7	1.5	<<0.1	Chlorite after Hb, cpx
39*	4	Rhyodacite	74.5	14.6	1.4	-	4.0	1.9	1.3	1.1	1.0	tr.	Chlorite after bi
66F*	7	Andesite	34.9	43.2	5.1		4.4	8.0	tr.	3.1	1.3	tr.	Hb, bi after cpx

Emmaville Volcanics   * Tent Hill Volcanics

Data Sources - Shaw (1964), this study.

host and the acid volcanic lithic fragments. The darker layers in these banded tuffs contain more plagioclase and hornblende phenocrysts than the paler layers, are more crystal rich and the groundmass is peppered with microcrystalline hornblende. Andesite lavas (Table 4, No. 264) in the same area contain discrete phenocrysts and clusters of zoned plagioclase (0.5 - 2.5 mm); microphenocrysts of hornblende, and clinopyroxene aggregates rimmed by green hornblende with opaque inclusions. The groundmass consists of recrystallized glass, iron oxides and tiny crystals of plagioclase and hornblende.

Foliated and massive porphyritic rhyodacites and welded tuffs separate the Mole Granite and Tent Hill Volcanics west of Stannum. The massive rhyodacites are coarsely porphyritic, with phenocrysts and clusters of zoned plagioclase in synneusis relationship (2 - 6 mm), large (3 mm) crystals of hornblende (X = pale brown, Y = rich olive green, Z = grass green) minor K-feldspar and decussate biotite pseudomorphs. Actinolitic (?) hornblende partly replaces primary hornblende phenocrysts and is itself partly replaced by decussate biotite. The coarsely devitrified groundmass also supports phenocrysts of deeply embayed bipyamidal quartz and microphenocrysts of ilmenite and titanomagnetite.

By comparison, the foliated porphyries are more siliceous and modal K-feldspar increases, largely at the expense of hornblende. Hornblende phenocrysts have inclusions of sphene. The growth of secondary (metamorphic) hornblende has produced a distinct foliation in the recrystallized groundmass. The welded tuffs are also foliated but are readily distinguished from the porphyries by the presence of hornblenditized clinopyroxene (< 1%) and the abundance of fragmented phenocrysts.

Metarhyodacites separating the Mole Granite and Pyes Creek Leucoadamellite north of Stannum, exhibit vestigial eutaxitic textures. They have a mineralogy similar to the porphyries west of Stannum and may contain angular fragments of recrystallized rhyolite (up to 14 mm). Both crystal-rich and phenocryst-poor varieties are represented. Only the imprint of the contact metamorphism distinguishes these rocks from Emmaville Volcanics in several other regions.

Emmaville Volcanics - Summary of Lithologies

Dundee Rhyodacite Contact - Ignimbritic rhyodacites (frequently hydrothermally altered) with the same mineralogy as the Dundee Rhyodacite.

East of Dundee - Rhyolitic crystal tuffs and lithic tuffs; minor ignimbritic rhyodacite; rhyodacite and andesite lavas.

North and northeast of Deepwater - Rhyodacite ash flows and lavas, ignimbritic rhyolites.

South of Emmaville - Rhyolitic ash flows, minor rhyodacitic crystal tuffs, rhyolitic ash-fall and pumiceous ash-flow tuffs.

South of Dundee - Ignimbritic siliceous rhyolites, rhyolitic and siliceous rhyodacitic crystal and lithic tuffs, rhyolitic and rhyodacitic ash-fall tuffs.

Webbs Consols Mine Area - Rhyolite ash flows, minor rhyolitic lavas and ignimbritic rhyodacites.

Wellingrove - Rhyolitic volcanoclastic breccias, rhyodacitic lithic ash-flow tuffs and minor rhyolite lavas.

Stannum - Rhyodacite lithic tuffs and crystal tuffs, very minor andesite, porphyritic rhyodacite lavas and ignimbrites near the Mole Granite contact

West of Strathbogie - Welded rhyolitic ash-flow tuffs, very minor ignimbritic dacite and porphyritic rhyodacite lava.

Vegetable Creek Volcanics - Rhyolitic lithic ash-flow tuffs and breccias.

Twin Mount Volcanics - Flow-banded rhyolite and rhyodacite lavas.

Wallangarra Volcanics - Rhyolitic ash flows, minor rhyodacite and rhyolite lavas

Ottery Rhyolite - Rhyolitic lithic ash-flow tuff.