CHAPTER 1

INTRODUCTION

In eastern Australia, the Cainozoic era was marked by the widespread eruption of volcanic rocks which extend from south-western Victoria through eastern New South Wales to northern Queensland. The eruptive activity included both lava field and central type volcanism. Notable among the latter type is the Tweed Shield Volcano* (Hill, 1951; Stephenson *et al.*, 1960; Wilkinson, 1968) which is located astride the state border separating north-eastern New South Wales and south-eastern Queensland (Fig. 1.1). This major shield structure has a diameter of about 100 km and consists of a volcanic pile of up to 1000 m of basaltic, andesitic and rhyolitic eruptives including rocks with both alkaline and tholeiitic affinities.

The focal point of the Tweed Shield Volcano is the Mount Warning complex (Solomon, 1964) located some 16 km south-west of Murwillumbah. The geology of this complex is still incompletely known. However it consists essentially of an intrusive sequence of gabbro, monzonite, syenite and trachyandesite (Ewart *et al.*, 1971) occupying an area of about 8 km x 5 km. Separating the Mount Warning complex from the lavas of the shield is an erosion caldera some 30 km in diameter. This forms the drainage basin of the Tweed River which has breached the eastern rim of the caldera to enter

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* Also known as the Mount Warning Volcanic Shield (McTaggart, 1961), the Mount Warning Shield Volcano (Solomon, 1964) and the Tweed Volcano (Wellman and McDougall, 1974a,b).

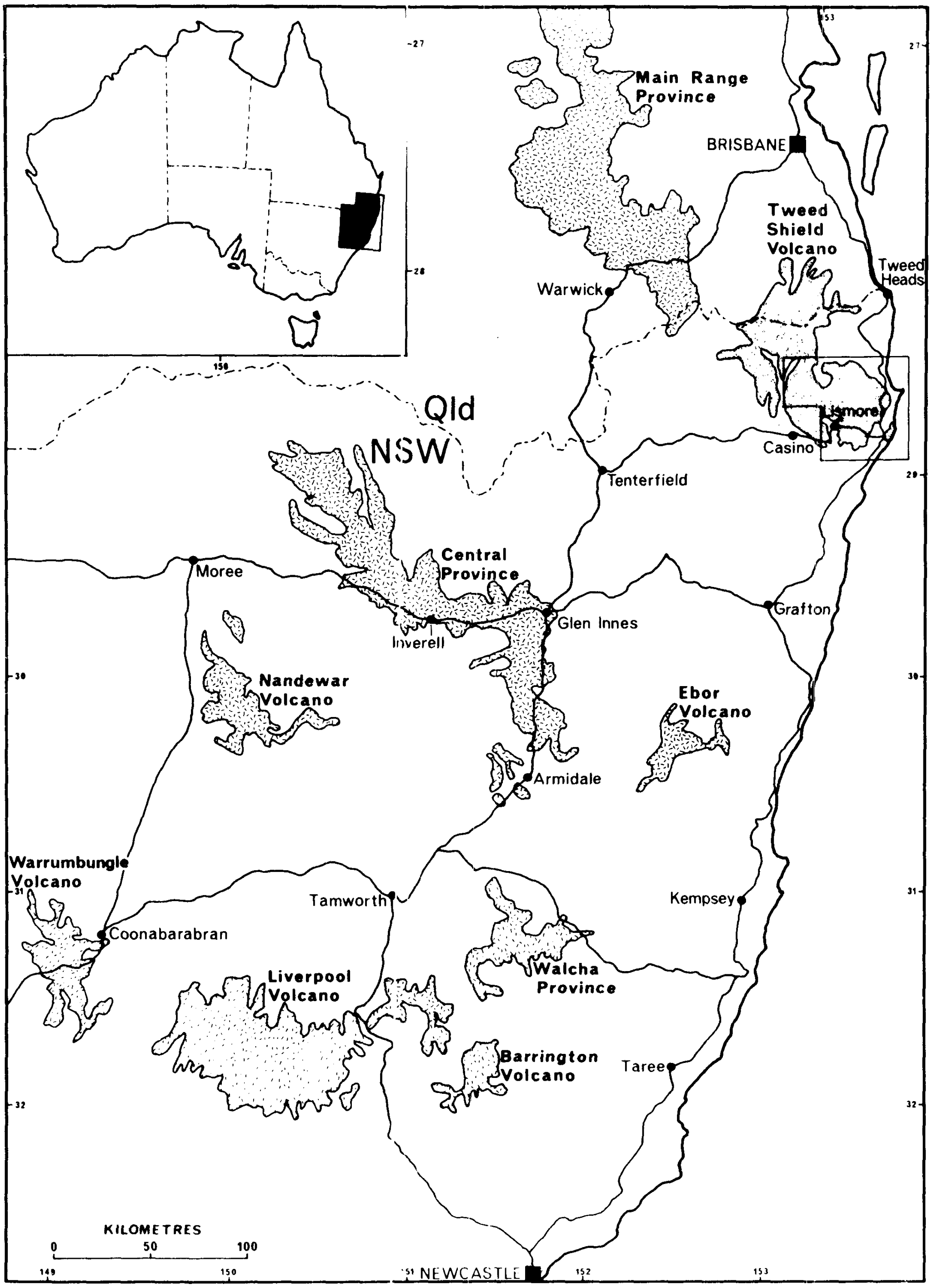

Fig. 1.1: Location of the Tweed Shield Volcano in relation to other major Cainozoic volcanic provinces in north-eastern New South Wales and south-eastern Queensland.

the Pacific Ocean at Tweed Heads. There is no evidence to suggest that formation of the caldera was directly controlled by subsidence. However Ewart *et al.* (1971) suggest that initial erosion of the caldera may have been facilitated by ring faulting around the Mount Warning complex.

The flanks of the volcano retain remnant constructional surfaces or planezes (Solomon, 1964) which reflect the original conical shield shape of the volcano (Fig. 1.2). A radial drainage pattern is well developed on the flanks of the Shield.

A thick cover of sub-tropical vegetation obscures outcrop over much of the steeper parts of the Shield. This severely hinders access for detailed field mapping and specimen collection, especially in the higher areas where rhyolitic rocks are more common. However in the lower areas where most of the land has been cleared for grazing and cultivation, access and outcrop are relatively good.

PREVIOUS WORK

Pioneering work by Richards (1916) led to the recognition of both mafic and felsic rocks in the volcanic sequence in southern Queensland now known collectively as the Lamington Volcanics (Stephenson *et al.*, 1960). Richards recognised a basalt-rhyolite-basalt sequence in the northern part of the Shield and provided petrographic and chemical data on many of the eruptives. The stratigraphy of the volcanics was further refined by Stephenson *et al.* (1960), McTaggart (1961) and, in the southern part, by McElroy (1962) and Mason (1969). Small areas near Minyon Falls and Nimbin were mapped by Crook and McGarity (1956) and Relph (1958) respectively. The

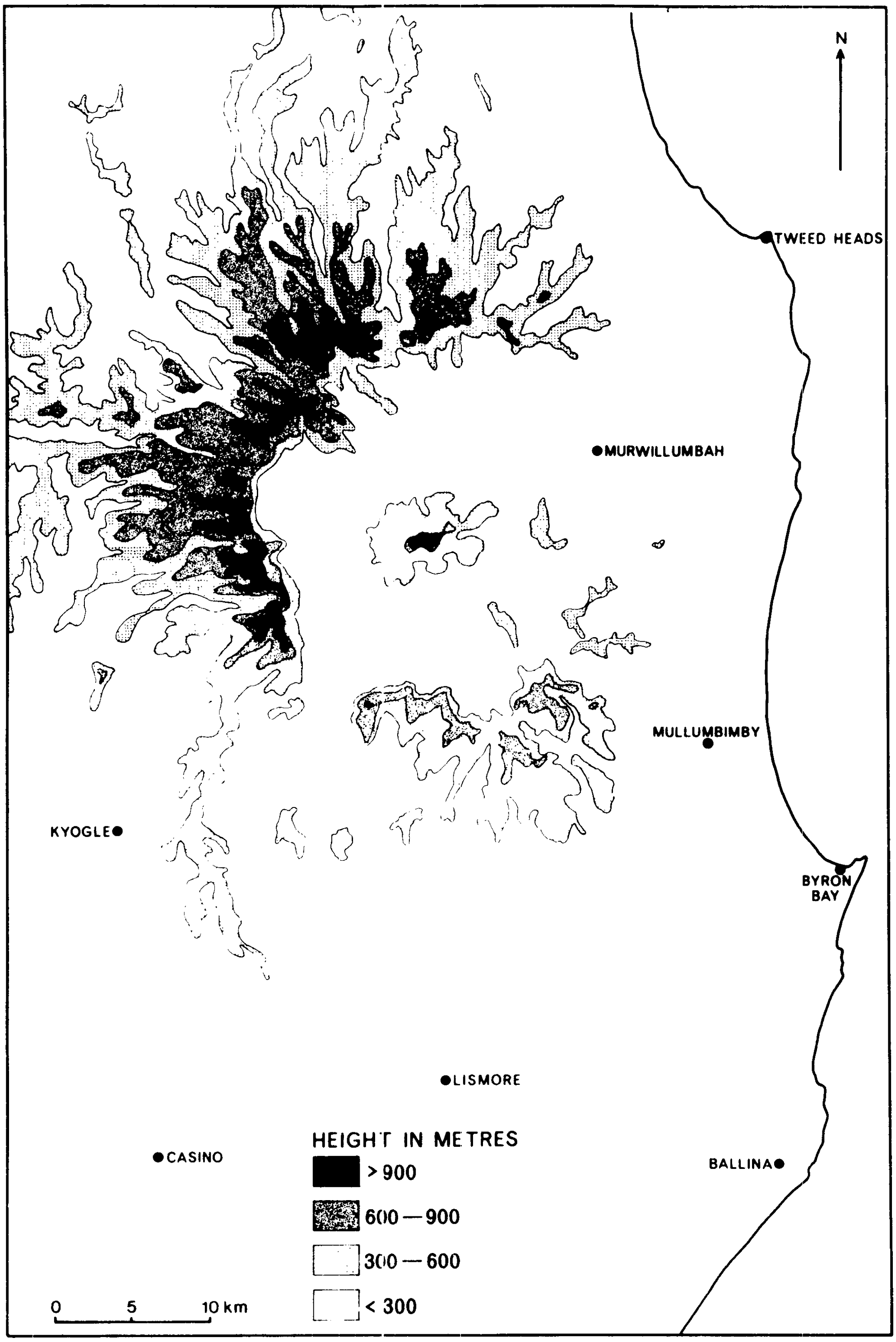

Fig. 1.2: Generalized topographic outline of the Tweed Shield Volcano illustrating the prominent erosion caldera, radial drainage pattern and remnant constructional surfaces (planezes).

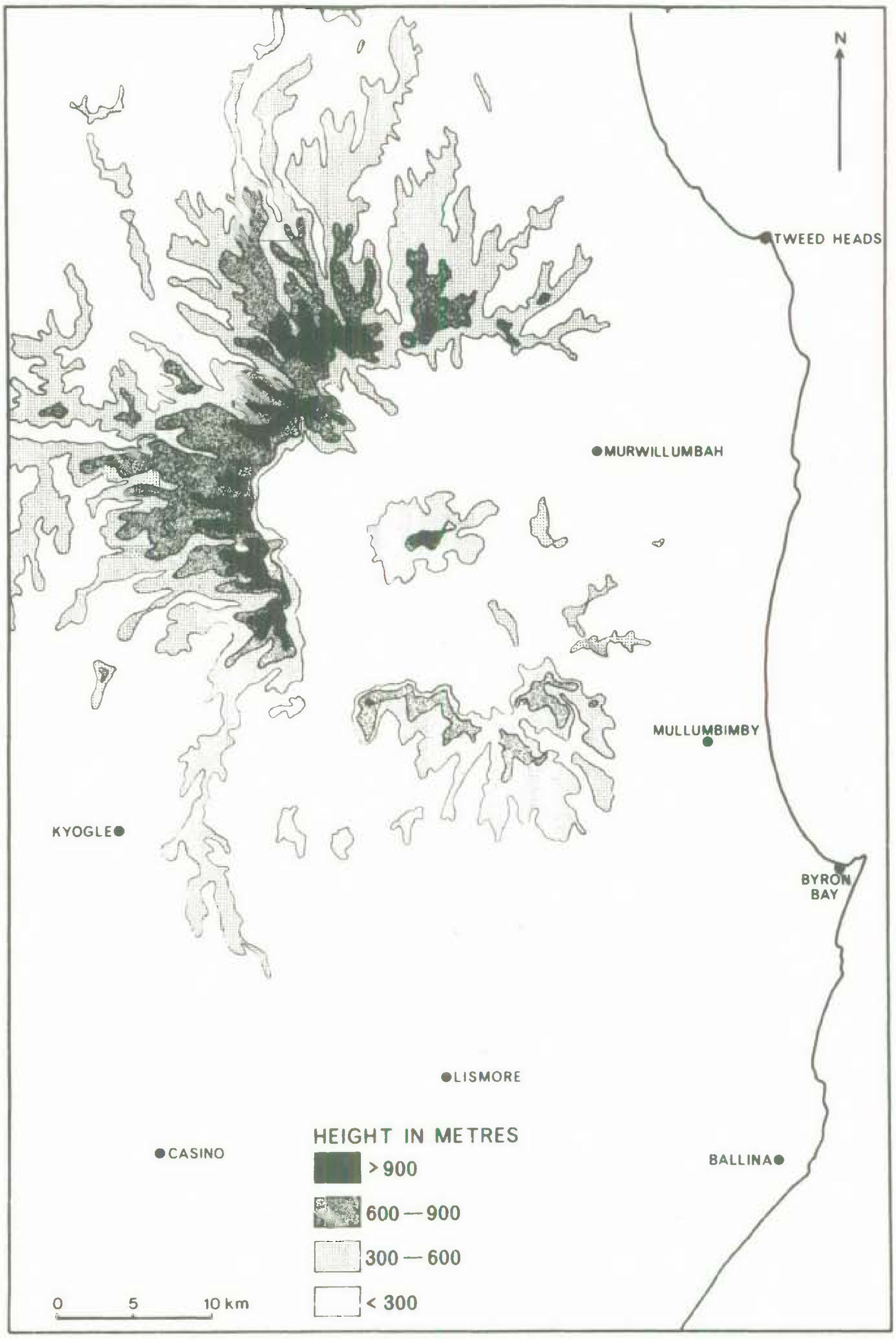

Fig. 1.2: Generalized topographic outline of the Tweed Shield Volcano illustrating the prominent erosion caldera, radial drainage pattern and remnant constructional surfaces (planezes).

development of the stratigraphic nomenclature by these authors is discussed in Chapter 3.

Browne (1933) discussed the petrographic and chemical data available at that time on the volcanics, noting the close chemical affinities of many of the analysed rocks with the "central magma type" of Mull (Bailey *et al.*, 1924). On the other hand McElroy (1962) gave petrographic details on some of the rocks more consistent with an alkaline succession, including the occurrence of groundmass nepheline. These apparent inconsistencies in mineralogical and chemical data led Wilkinson (1968) to discuss the magmatic affinities of the rocks. He noted that many of the rocks were typically tholeiitic in overall chemistry but that they often lacked petrographic criteria which commonly typify tholeiitic rocks. He suggested that the more basic tholeiitic rocks were transitional toward mildly alkaline types and noted the possibility of differing lineages in the shield, a conclusion that has been substantiated by subsequent work.

In the northern part of the Shield, D.C. Green (1970) recognised undersaturated alkaline basalts and transitional basalts and equated the latter with the transitional tholeiitic rocks of Wilkinson (1968). Subsequently, on the basis of petrographic and partial chemical data, Mason (1969) recognised both alkaline and tholeiitic types in the volcanic sequence east of Kyogle.

Wilkinson and Binns (1969) described a hawaiite of relatively high pressure derivation near Kyogle. A high pressure origin has also been assigned to a high-alumina tholeiitic andesite near Brunswick Heads, in the south-eastern part of the Shield (Duggan and Wilkinson, 1973).

K/Ar radiometric ages for rocks of the Shield have been reported by Webb *et al.* (1967), McDougall and Wilkinson (1967) and Wellman and McDougall (1974a). The data collectively indicate that the Shield is early Miocene (23-20 m.y.).

AIMS AND SCOPE OF THE PRESENT STUDY

Field and laboratory work on the rocks of the Tweed Shield Volcano commenced in February, 1969. The total area of the shield (~7000 km^2) is obviously too large to be covered in adequate detail in a single project and hence the investigation was confined to the southern portion of the Shield in the rectangle (Fig. 1.3) bounded by Kyogle in the west, Coraki in the south, the coastline to the east and in the north by the scarp defining the southern wall of the erosion caldera.

Following detailed stratigraphic mapping and laboratory studies, rocks with both alkaline and tholeiitic affinities were recognised. The former were not studied in detail but the latter were subsequently subjected to detailed mineralogical and geochemical studies which are reported in this thesis.

Specimen numbers refer to the collection number in the Department of Geology, University of New England and are listed, together with the rock name and grid reference, in Appendix IV. Grid references are based on the 1000 metre universal transverse mercator grid, Zone 56, Australian National Spheroid. They are taken from the 1:50,000 topographic sheets which were used as base maps for field mapping. Further details of field mapping and laboratory techniques are given in Appendix I.

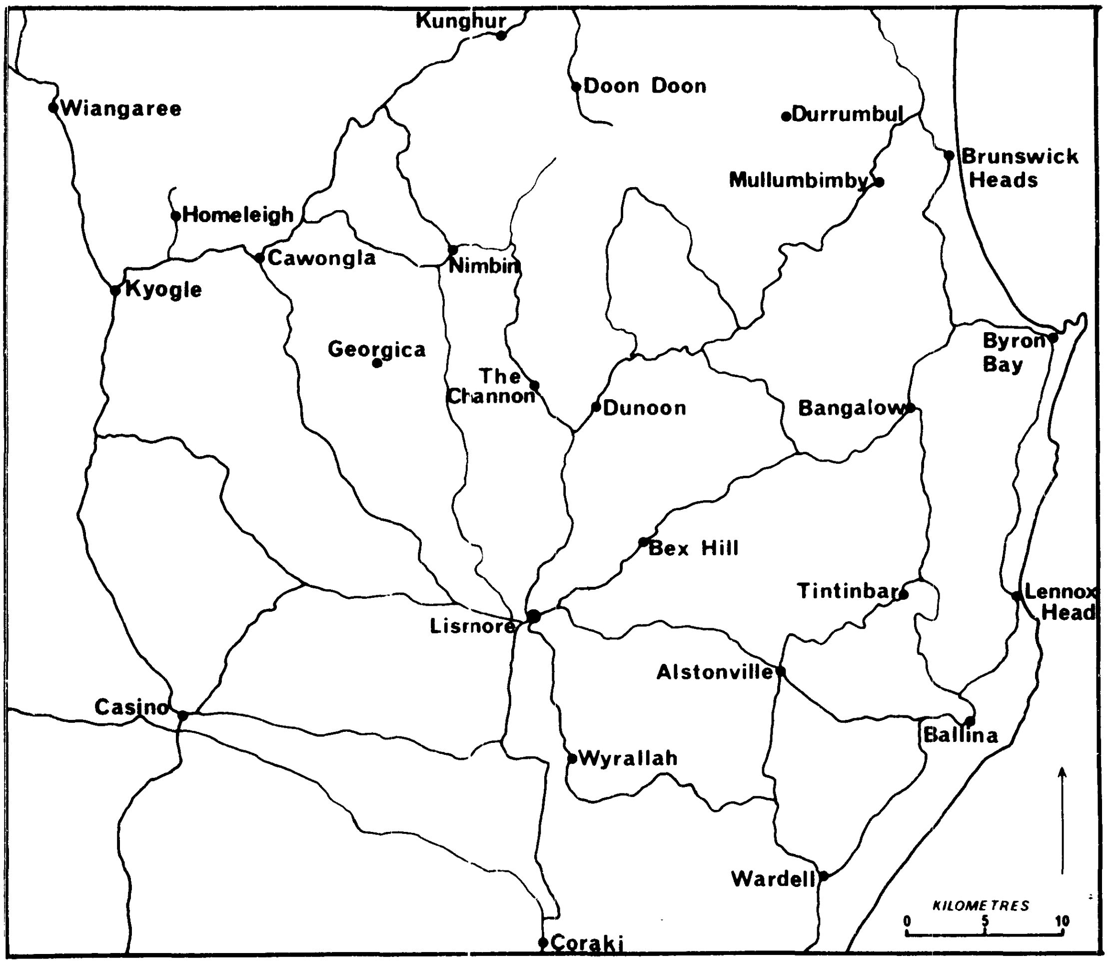

Fig. 1.3: Map of the area investigated showing the principal localities to which reference is made in the text.

CHAPTER 2

GENERAL GEOLOGY AND PRE-CAINOZOIC STRATIGRAPHY

The principal objective of this project has been a detailed study of the Cainozoic Lamington Volcanics in the Richmond-Tweed area and hence only a brief resume of published work on underlying Mesozoic and Palaeozoic rocks is warranted.

The principal structural element of the basement rocks underlying the Tweed Shield Volcano is the Clarence-Moreton Basin (McElroy, 1962,1969). This is a north-south elongated sedimentary basin containing Mesozoic shallow water terrestrial sediments. It extends from Woolgoolga in New South Wales northwards to Esk in southern Queensland (where it passes over the Esk Trough), and northwest towards Toowoomba where it joins the Great Artesian Basin.

Sediments of the Clarence-Moreton Basin rest unconformably on a sequence of Triassic rhyolite lavas and pyroclastics (the Chillingham Volcanics). The contact separating the Chillingham Volcanics from an undifferentiated sequence of older highly deformed Palaeozoic rocks (the Neranleigh-Fernvale Beds[*]; Fleming *et al.*, 1974) is at least partly fault controlled.

The brief summary of the stratigraphic sequence of pre-Cainozoic rocks is given below.

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[*] Previously known informally as the Neranleigh Fernvale "Group" (Bryan and Jones, 1950) but renamed the Neranleigh Fernvale Beds by Fleming *et al.* (1974) to accord with the Australian Code of Stratigraphic Nomenclature.

Neranleigh-Fernvale Beds

Rocks of the Neranleigh-Fernvale Beds crop out below Cainozoic volcanics along the coastal section from near Wardall northwards through Tintinbar and Byron Bay to Brunswick Heads and they also occupy that part of the Tweed Valley east of Mt. Warning. The main lithologies are greywackes, slates, phyllites, cherts and basic volcanics which have undergone extensive deformation and mild metamorphism.

The Neranleigh-Fernvale Beds have been traditionally assigned a Silurian age (Stevens, 1969) but recent radiometric data on boulders in a conglomerate (D.C. Green, 1973) and the discovery of some fragmentary invertebrate macrofossils (Fleming *et al.*, 1974) suggest that the Beds are Carboniferous.

Chillingham Volcanics

The Chillingham Volcanics (McElroy, 1962) occupy a belt up to 5 km wide trending north-north-west across the Tweed Valley from near Durrumbul to Numinbah. They consist of a sequence up to 1500 m thick of massive and fluidal rhyolites and rhyolitic tuffs. The rhyolites typically contain deeply embayed quartz and kaolinized feldspar phenocrysts up to 1 mm in diameter in a devitrified quartzofeldspathic groundmass. Tuffaceous varieties are sometimes ignimbritic although evidence of welding is often obscured by devitrification. They contain abundant relict glass shards and angular fragments of chert, micaceous schist and thermally altered greywacke and sandstone. Within the sequence are some shale horizons up to 15 m thick (McElroy, 1969).

Bundamba Group

The Bundamba Group, the basal unit of the Clarence-Moreton Basin, unconformably overlies the Chillingham Volcanics in the Tweed Valley whilst further south it rests directly on rocks of the Neranleigh-Fernvale Beds. The maximum thickness is approximately 1500 m but it is generally considerably less. The group includes rocks equivalent to the Marburg Formation (McTaggart, 1963) mapped along the western margin of the basin and in south-eastern Queensland. Quartzose and lithic sandstones dominate the sequence with minor shale, siltstone and pebble rich bands (McElroy, 1969). Microfloras in south-east Queensland indicate that the Bundamba Group is Late Triassic.

Walloon Coal Measures

The Walloon Coal Measures crop out in a broad belt from Koonorigan northward through Nimbin to Tyalgum and a small area about 2 km east of Wyrallah. Available data on the formation are summarized by Gould (1968, 1974). Principal lithologic types include grey and brown shales, siltstones, claystones, lithic sandstones and coal seams. Palaeontological data suggest a Middle Jurassic age (Gould, 1974).

Kangaroo Creek Sandstone

The Kangaroo Creek Sandstone, a massive unit of quartzose sandstone overlying the Walloon Coal Measure, occurs between Nimbin and Kyogle and also southward around Coraki. The maximum thickness is about 500 m

The principal rock type is a white or cream coloured quartzose sandstone. Thin conglomerate horizons contain abundant rounded chert and jasper pebbles. The formation is unfossiliferous but ages of underlying and overlying formations limit its age to Late Jurassic or Early Cretaceous.

Grafton Formation

The uppermost unit of the Mesozoic sequence is the Grafton Formation, restricted in outcrop to areas around Casino and southward toward Grafton. Outcrop is poor, friable claystones, siltstones and lithic-quartz sandstones (Late Jurassic or Early Cretaceous) being the principal lithologies.

CHAPTER 3

VOLCANIC STRATIGRAPHY

Preliminary mapping of the Lamington Volcanics in the southern portion of the Tweed Shield demonstrated that the basalt-rhyolite-basalt sequence proposed by McElroy (1962) was oversimplified because petrographic differences in the basic and intermediate volcanics are not apparent in hand specimens.

McTaggart (1961) noted that the Lamington Volcanics in south-east Queensland contain both alkaline and subalkaline representatives. He recognised thin but extensive acid pyroclastic and conglomerate horizons (the Hillview Rhyolite and Chinghee Conglomerate respectively) overlying a succession of alkaline volcanics (the Albert Basalt). These horizons in turn are overlain by a subalkaline basalt-rhyolite-basalt sequence, respectively designated the Beechmont Basalt, Binna Burra Rhyolite and Hobwee Basalt (see Fig. 3.1).

Although the validity of McTaggart's stratigraphic subdivision of the Shield in south-eastern Queensland recently has been questioned by some workers (Exon, 1972), his subdivision, with minor modification, nevertheless is adequate for the Richmond-Tweed area. However it is necessary to modify McElroy's nomenclature to include a second rhyolite unit at a lower stratigraphic level and to subdivide the Lismore Basalt into two formations on the basis of distinct petrographic differences. Mason (1969) mapped the Kyogle-Nimbin area and north to Wiangaree and recognised two petrographically distinct basaltic units. He also mapped a thin but widespread rhyolitic

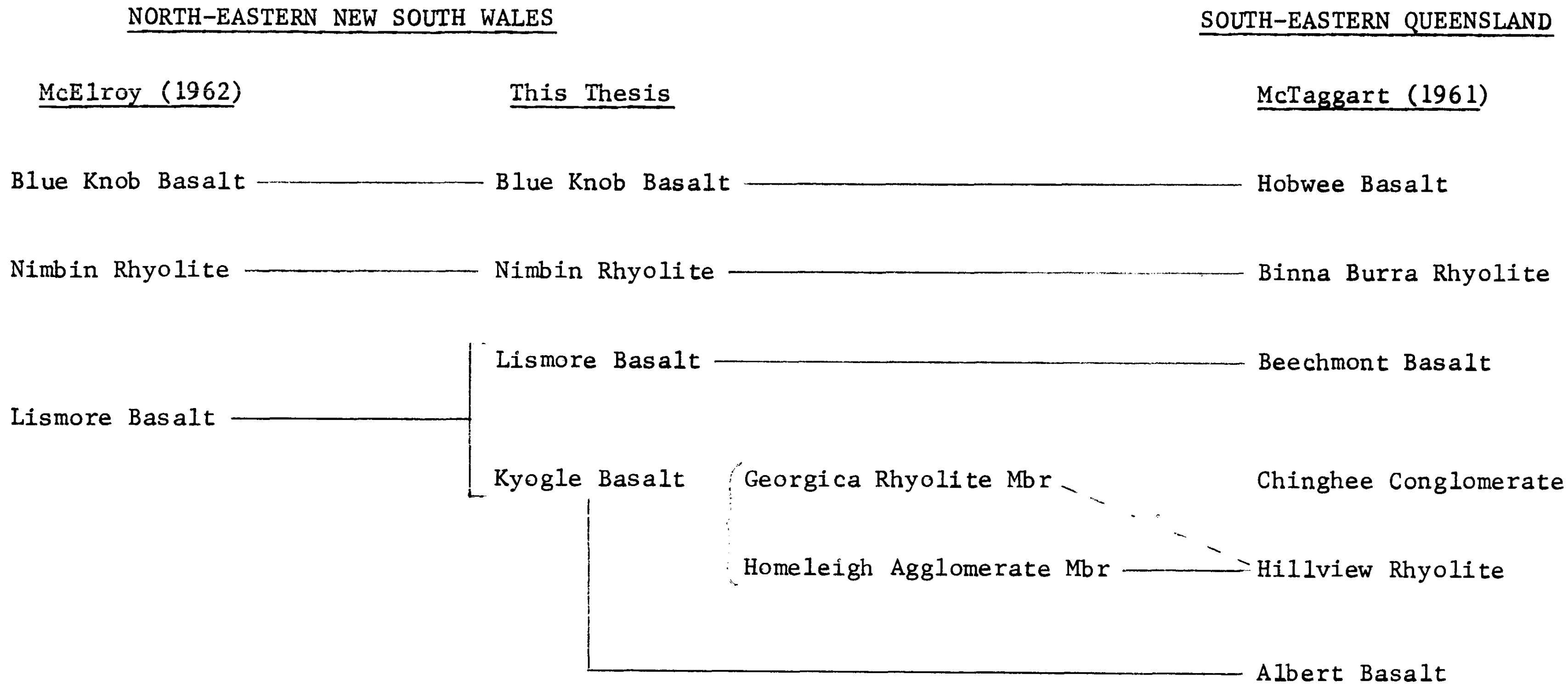

Fig. 3.1: Correlation Chart for the Lamington Volcanics.

pyroclastic unit which he correlated with the tuffaceous horizon below the rhyolite flow at Nimbin Rocks (Relph, 1958). Following McElroy (1962) Mason equated the rhyolite flow at Nimbin Rocks with the whole of the rhyolite sequence east of Nimbin. However, further mapping (accompanying map in this thesis) showed this to be in error and that it is necessary to distinguish between the two rhyolites (see below).

The following revisions of the existing stratigraphic nomenclature are proposed.

(1) A basaltic unit (the Kyogle Basalt) with alkaline affinities is the oldest stratigraphic unit of the Lamington Volcanics in this area. It rests unconformably on the Mesozoic sediments of the Clarence-Moreton Basin.

(2) A discontinuous pyroclastic unit within the Kyogle Basalt is named the Homeleigh Agglomerate Member of the Kyogle Basalt.

(3) The Georgica Rhyolite Member of the Kyogle Basalt overlies the Homeleigh Agglomerate Member. It is a rhyolite flow unit of limited areal extent occuring in the vicinity of Nimbin Rocks.

(4) The Lismore Basalt is restricted in definition to the widespread subalkaline basaltic unit overlying the Kyogle Basalt.

(5) The term Nimbin Rhyolite is now restricted to the thick sequence of rhyolitic flows and pyroclastics north-east and east of Nimbin. It includes several intrusive plugs which are likely eruptive centres of the rhyolites.

The relationship of these units to the succession proposed by

McElroy (1962) and a proposed correlation with the Tweed volcanic sequence in south-east Queensland is illustrated in Figure 3.1.

3.1 SYSTEMATIC DESCRIPTION OF STRATIGRAPHIC UNITS

3.1.1 Kyogle Basalt

The Kyogle Basalt attains its maximum thickness near Wiangaree and in the McKellar Range. Some 330 m of Kyogle Basalt are exposed at Hermits Peak, east of Wiangaree (005480) and 270 m near Boorabee Trig. station (049325). At these localities the Kyogle Basalt is overlain by a thin sequence of tholeiitic flows which represent the basal portion of the Lismore Basalt. However, the base is unexposed at both localities and the maximum thickness remains problematical.

The Kyogle Basalt thins eastward and south-eastward, lensing out in the vicinity of a line from Jerusalem Mountain (347355) through the Channon (270280) to Tuncester (215142). The pattern of distribution suggests that eruptive centres for the Kyogle Basalt were located in the Woodenbong area to the north-west of Kyogle where intrusions of alkali dolerite occur (McElroy, 1962). Eastward flow of the Kyogle Basalt was probably restricted by the topographic high produced by the Triassic Chillingham Volcanics (see accompanying map).

The petrography of alkaline eruptives within Kyogle Basalt has not been studied in any detail. However, brief petrographic data and several chemical analyses of representative specimens are given in Appendix III. Briefly, the Kyogle Basalt consists of predominant hawaiite and occasional alkali olivine basalt and basanite. Some hawaiites approach mugearite in composition. Sporadic flows of tholeiitic andesite occur throughout the Kyogle Basalt, especially east of Kyogle and Wiangaree. These represent the initial manifestations of tholeiitic activity in the Tweed Shield.

Homeleigh Agglomerate Member: The Homeleigh Agglomerate Members is a widespread subhorizontal vitroclastic unit within the Kyogle Basalt. It crops out over an area of some 120 km^2 from near Wiangaree in the north-west (000470) to near Nimbin in the south-east (230330) and the McKellar Range in the south-west (070285). At some localities, especially in the McKellar Range area, outcrop becomes discontinuous due to southward thinning of the unit and erosion and reworking prior to renewed basaltic volcanism.

The type locality for the Homeleigh Agglomerate is on the Homeleigh road 5 km north-east of Kyogle (048371; Mason, 1969) where approximately 30 m of volcanic agglomerate contain blocks up to 1 m in diameter, which include tholeiitic rhyolites and rhyolitic pitchstones and minor mugearite, benmoreite and trachyte.

The pyroclastic matrix consists of abundant rounded fragments of pumice together with fragments of alkaline and tholeiitic lavas and broken phenocrysts of quartz, sodic oligoclase and sanidine. Pumice fragments often show some evidence of plastic deformation prior to incorporation in the agglomerate unit. Cross bedding and some sorting observed 6.5 km west of Nimbin (150347) provide further evidence of reworking.

Near Wiangaree the Homeleigh Agglomerate is within 3 km of the southernmost part of the Hillview Rhyolite (McTaggart, 1961) and occurs at similar stratigraphic and topographic levels. Although the Hillview Rhyolite and Homeleigh Agglomerate are undoubtedly correlatives, the latter term is preferred in view of the present uncertain status of the Hillview rhyolite in south-east Queensland (Exon, 1972).

Georgica Rhyolite Member: The Georgica Rhyolite Member overlies the Homeleigh Agglomerate Member near Nimbin where it caps three adjoining hills as a single porphyritic rhyolite flow up to 100 m thick. The basal zone of (5-10 m thick) is vitreous. The entire flow and an associated feeder plug are petrographically identical. Part of the flow and the feeder plug form the prominent local landmark known as Nimbin Rocks (201344).

3.2.2 Lismore Basalt

The Lismore Basalt is by far the most widespread formation of the Lamington Volcanics in this part of the Tweed Shield. It occurs over virtually the entire area, from Kyogle eastward to the coast and from the northern extremities of the volcanic sequence southward to Coraki. The total outcrop area exceeds 3,000 km^2. In the northern part of the area it occupies lower areas in valleys where it crops out beneath the cliff-forming Nimbin Rhyolite. Southwards it covers the wide areas of low relief between Lismore, Ballina and Coraki. Around Kyogle the Lismore Basalt forms residual cappings overlying the Kyogle Basalt along the McKellar Range and east of Wiangaree.

Throughout much of the area, the upper portion of the Lismore Basalt has been removed by erosion. Where the Lismore Basalt has been protected by the overlying Nimbin Rhyolite, determination of its thickness is hindered by thick rhyolite scree concealing the upper contact. Estimates made on sections at several localities along the northern scarp indicate an average thickness of about 100 m sometimes attaining a maximum thickness of about 150 m. One measured section on the Nimbin-Mt. Nardi road (255380) has a thickness of 115 m. As the Lismore Basalt occurs over an area of more than 3,000 km^2 in this area it apparently represented a widespread and relatively thin veneer.

Rock types within the Lismore Basalt are predominantly tholeiitic andesite and icelandite. The petrography of these rocks is discussed in detail in Chapter 4. Occasional alkaline flows are also intercalated with the tholeiitic volcanics. An alkaline dyke cutting the Nimbin Rhyolite (396440) suggests that sporadic alkaline volcanism persisted throughout the eruption of the Lismore Basalt.

Individual flows within the Lismore Basalt are usually thin, rarely exceeding 10 m in thickness. The tholeiitic rocks characteristically weather to a deep red soil in strong contrast to the chocolate brown soils derived from the predominantly alkaline Kyogle Basalt. This difference in soil type provides an exceedingly useful criterion for mapping the two units. Interfaces between individual flows are highly irregular. The occasional preservation of a ropey upper surface suggests many of the flows were of pahoehoe type. On the other hand a flow below Rocky Creek dam (340355) contains blocks of vesicular lava, up to 1 m in diameter, in massive lava suggesting an "aa" type flow.

The disposition of the eruptive centres for the Lismore Basalt is unclear. Flows belonging to this Formation are preserved at Coraki, some 65 km south of Mount Warning. It seems most unlikely that lavas could have flowed this distance from a central vent and resulted in such a widespread veneer. It is more likely that subsidiary vents and fissures on the flanks of the Shield, as yet unlocated, were the principle eruptive centres for most of the lavas.

3.1.3 Nimbin Rhyolite

The Nimbin Rhyolite occupies most of the mountainous country from Sphinx Rock (215450) eastward to Jerusalem Mountain (347455) and also extends along many of the ridges radiating southwards from these high peaks (e.g. The Koonorigan, Gibbergunyah, Nightcap and Koonyum Ranges) and is the most resistant unit in the volcanic succession.

At its northern extremities, the base of the Nimbin Rhyolite occurs at a fairly constant altitude, about 300 m above sea level. Southward the altitude of the base falls so that at its southerly limits, e.g. Tuntable Creek (275410), Minyon Falls (380347) and near Rocky Creek Dam (340355), it is about 200 m a.s.l. or a little less. The base of an outlier 2.5 km east of Minyon (416337) is 170 m a.s.l. The Nimbin Rhyolite lenses out rapidly near Sphinx Rock, 1.5 km east of Blue Knob from a thickness of some 300 m to zero in a lateral distance of about 400 m. The original areal extent of the acid volcanics was probably about 300 km^2.

A maximum thickness of some 500 m is exposed on Mount Matheson (429294) where overlying Blue Knob Basalt is absent. However outliers of Blue Knob Basalt immediately west along the Koonorigan Range at an altitude some 150 m below the summit of Mount Matheson indicate the localised and irregular nature of these rhyolite flows.

Flows of porphyritic and aphyric rhyolite dominate the Nimbin

Rhyolite together with interstratified horizons of rhyolitic tuffs, rhyolitic agglomerates and pumice agglomerates up to 20 m thick. Individual rhyolite flows often have a considerable lateral extent with little change in vertical thickness. Flows vary from 50 to 150 m in thickness.

A zone of rhyolitic pitchstone more or less devoid of any devitrification and up to 10 m thick is commonly but not invariably preserved at the base of individual flows. Devitrified rhyolite may rest directly on underlying basalt, rhyolite or pyroclastics. The interface between glassy and devitrified rhyolite is characteristically highly irregular but nevertheless quite sharp.

Pyroclastic units are localised in areal extent and often show evidence of fluvial reworking including cross-stratification. Fragmentary material includes assorted blocks of rhyolite and highly altered tholeiitic volcanics and sedimentary material which rarely exceed 10 cm in diameter.

Rapid thickening of the Nimbin Rhyolite around Mount Matheson, Peach Mountain and Jerusalem Mountain suggest that centres of eruption are close by. Several small intrusives occur near these localities, comprising Doughboy Mountain (317458) and Mount Tarrawyra (315438) (both porphyritic rhyolite) and a small plug in Coopers Creek (369410) (aphyric rhyolite).

An outlier of rhyodacite capping a ridge 3 km east-south-east of Nimbin (245350) is included in the Nimbin Rhyolite on the basis of its position in the stratigraphic sequence overlying the Lismore Basalt. It has an areal extent of about 1 km^2 and a maximum thickness of about 50 m.

3.1.4 Blue Knob Basalt

The Blue Knob Basalt (McElroy, 1962) forms residual cappings in many higher areas, for example beneath Blue Knob (212446), Mount Neville (248441) and Mount Nardi (280421). Other small outliers cap Jerusalem Mountain (347455) and other high peaks in the Whian Whian State Forest and along the Koonyum Range.

Although the Blue Knob Basalt undoubtedly attains its maximum thickness beneath Blue Knob itself, the thickness at this locality is uncertain because the Nimbin Rhyolite is absent and the Blue Knob Basalt rests directly upon the petrographically similar Lismore Basalt. The probable thickness is estimated to be approximately 350 m.

The Blue Knob Basalt was erupted onto a highly irregular land surface shaped by the earlier Nimbin Rhyolite. The altitude of the base varies from about 450 m a.s.l. to 800 m a.s.l.

3.2 RADIOMETRIC AGES

Absolute age data on rocks from the Tweed Shield Volcano have been provided by Webb *et al.* (1967), McDougall and Wilkinson (1967) and Wellman and McDougall (1974a) and indicate an eruptive span of about 3 million years, from 23 to 20 million years b.p., for the Lamington Volcanics. The stratigraphic relations of one dated flow near Tabulum (23.6 m.y.; McDougall and Wilkinson, 1967), located some distance from the major shield structure, are uncertain and it is possible that this flow may have been associated with an earlier volcanic episode.

Unfortunately, all the radiometric data have been obtained on rocks from outside the present area of investigation. However, K-Ar ages on specimens from localities in south-eastern Queensland (Wellman and

McDougall, 1974a), provide internal consistency with the stratigraphic succession of McTaggart (1961). A similar time span probably applies to the southern portion of the Shield.

The petrological characteristics of dated rocks at Fingal Point and Burleigh Heads (McDougall and Wilkinson, 1967) suggest that they are best included in the Lismore and Beechmont Basalt despite somewhat older ages (22.6, 22.9 m.y. respectively). This suggests that minor tholeiitic volcanism commenced in the eastern portion of the shield prior to eruption of the Kyogle and Albert Basalts (22.5 m.y.; Wellman and McDougall, 1974b) and is consistent with the sporadic occurrence of tholeiitic eruptives throughout the Kyogle Basalt (Mason, 1969).

3.3 STRATIGRAPHIC DEVELOPMENT OF THE TWEED SHIELD

The stratigraphic and radiometric data permit reconstruction of the probable stratigraphic development of the southern portion of the Tweed Shield. The proposed sequence of events is summarised below.

(1) Eruption of alkaline lavas (Kyogle Basalt) from sources in the Woodenbong area commenced about 23.0 m.y. b.p.. Minor tholeiitic volcanism may have commenced at about the same time, particularly in the eastern portion of the area.

(2) Widespread eruption of a mixed suite of pyroclastics (Homeleigh Agglomerate) occurred probably simultaneously from several vents, followed by a rhyolite flow of limited area extent near Nimbin.

(3) Eruption of the Kyogle Basalt continued but only in the western portion around Kyogle.

(4) Voluminous eruption of tholeiitic lavas, probably from vents on the flanks of the Shield, formed the thin and widespread Lismore Basalt.

(5) Recommencement of rhyolitic volcanism from several vents east and north-east of Nimbin on the flanks of the shield formed the Nimbin Rhyolite.

(6) The Blue Knob Basalt, the youngest unit of the Tweed Shield sequence, represents the last major phase of tholeiitic activity.

Minor alkaline eruptive activity continued throughout stages 4 to 6 to produce small sills, dykes, plugs and flows of alkali olivine basalt and hawaiite.