AUSTRALIA

1:100 000 GEOLOGICAL MAP COMMENTARY

ARALUEN

NEW SOUTH WALES

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

DEPARTMENT OF RESOURCES & ENERGY

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INTRODUCTION

The ARALUEN (8826) Sheet area lies between latitudes 35°30′ and 36°00′S, and longitudes 149°30′ and 150°00′E, and covers an area of about 2500 km^2. It was mapped by the Bureau of Mineral Resources (BMR) between October 1977 and May 1979; the fieldwork was done by the authors, who spent a total of 16 man-months in the field.

Majors Creek in the north and Monga and Araluen in the northeast are the only settlements of any size in the Sheet area (Fig. 1) and all have populations of less

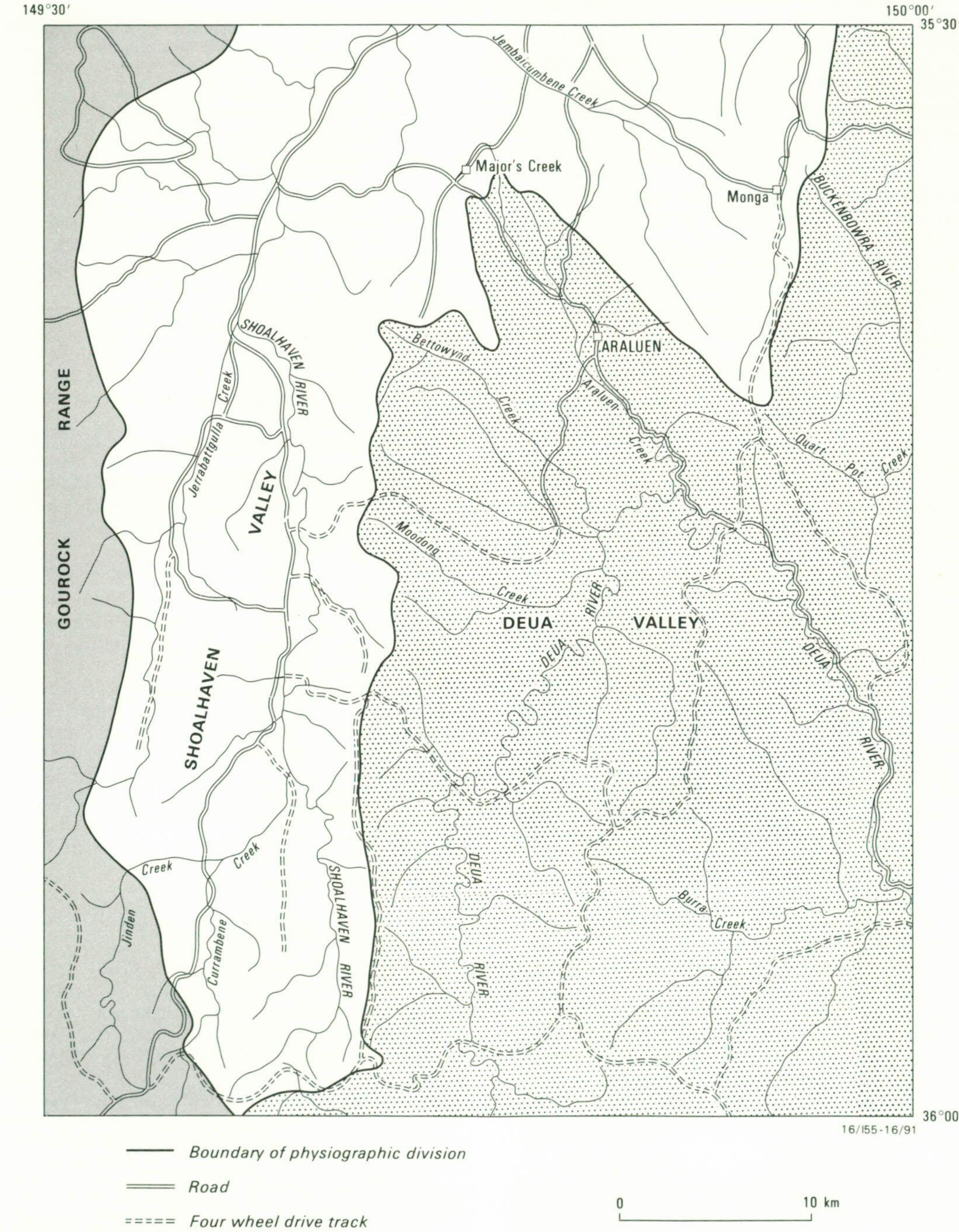

Fig. 1. Major drainage systems, physiographic divisions, roads.

than 100. There are many pastoral properties in the Shoalhaven River catchment in the west and the Jembaicumbene Creek valley in the north, and some in the valleys of Araluen Creek and the Deua River below Araluen Creek. The western edge of the area, along the Gourock Range, is uninhabited, as are the headwaters of the Deua River and the eastern edge of the Sheet area in the catchments of the Buckenbowra River and Quartz Pot Creek.

Vehicular access is good in the inhabited areas, with a network of farm tracks and formed dirt and sealed roads (Fig. 1). However, around much of the eastern and western borders of the Sheet area and in the Deua River headwaters there are only a few rough and often very steep fire trails. The main roads through the area are the Braidwood–Cooma road (sealed) which follows the Shoalhaven River for much of its way, and the Braidwood–Moruya road through Araluen and along the lower Deua River valley. Good gravel roads link Majors Creek with these main roads, and Captains Flat, to the west of the Sheet area, with the Braidwood–Cooma road. The Kings Highway, between Braidwood and Batemans Bay, crosses the northeast corner of the Sheet area at Clyde Mountain; it is part of the major route linking Canberra with the coast.

The Sheet area is covered by 1:25 000 scale colour aerial photography flown in early 1977 by the New South Wales Central Mapping Authority.

Physiography

Elevations range from 100 m to 1469 m above sea level.

There are three main physiographic subdivisions (Fig. 1).

One is the rugged Gourock Range in the west, with relief of up to 600 m and a maximum elevation of 1439 m at Bald Mountain (GR 264188). The Gourock Range forms the divide between the Shoalhaven River to the east and the Molonglo River to the west (in MICHELAGO)*, and thus is part of the Great Dividing Range.

Another subdivision is the catchment of the Shoalhaven, an area of relatively subdued relief but moderate to high elevation. In the north a gently undulating landscape at about 700 m above sea level has relief of less than 100 m. The relief increases southwards towards the headwaters of the Shoalhaven river, and several ranges and hills, such as the Bombalawa Range, Jinden Hill, and Middle Mountain, rise up to 250 m above the surrounding country, which here is about 850 m above sea level.

The third area covers half of ARALUEN, on the eastern side of the Sheet area, and is a region of rugged relief with deeply incised valleys and steep rocky ridges. Maximum relief is over 800 m, on the east side of the Minuma Range.

Most of the area is in the catchment of the Deua River, which follows a devious path, flowing initially north, then northeast, southeast, south, and eventually east to the sea. Much of the Deua's course is marked by deeply entrenched meanders, and obviously it has undergone major rejuvenation. The Deua has a much lower base level than the Shoalhaven, and, in the geological time frame, can be described as being in the process of capturing the Shoalhaven's headwaters.

The most prominent physical feature of the Sheet area is the major steep east-facing escarpment that forms the watershed between the north and west flowing Shoalhaven River System and the east and southeast flowing Deua River and other streams that, like the Deua, flow comparatively directly to the eastern coast. The highway from Canberra to Batemans Bay descends this 700 m escarpment at Clyde Mountain.

Climate and vegetation

Rainfall in the area varies from about 700 mm in the northwest to at least 1750 mm in the northeast, reflecting the combination of orographic and coastal influences along the coastal ranges in the east (McAlpine & Yapp, 1969). Mean annual figures given by McAlpine & Yapp are: Araluen 904 mm, Krawarree 804 mm, Majors Creek 963 mm, and Monga 1736 mm. Most of it falls in the summer. Snow falls occasionally on the high peaks in winter.

No temperature data are available for ARALUEN, but an indication of probable values is given by records in McAlpine & Yapp (1969) for stations in surrounding areas. The average January maximum is about 25°C over a wide range of elevations, and minimum about 11°C in the higher country and 14°C in the lower parts. In July, the coldest month, temperatures in the higher country average 11°C (max.) and −1°C (min.) and in the lower areas about 17°C (max.) and 3°C (min.). Winter frosts are common and at times severe in the higher country but relatively rare in the lower-lying areas around Araluen.

Most of the Sheet area is covered by the vegetation study of the Queanbeyan–Shoalhaven by Story (1969). The Sheet area contains wet, intermediate, and dry sclerophyll forest, temperate rain forest, savannah woodland, and heathland.

Previous investigations

Virtually no geological work of use for 1:100 000-scale mapping had been done in the area before the present geological mapping, owing to the relatively difficult access. Only the thesis work by Johnson (1964) on the Minuma Range and Krawarree area and by Goleby (1977) on the Majors Creek area provided useful information for the present work. Geological accounts that briefly mention aspects of the geology of the area include those of Anderson (1892), Brown (1930), Craft (1932), Veevers (1953), and Gilligan (1975). The geology of the adjoining MICHELAGO (Richardson, 1979) and BRAIDWOOD (Felton & Huleatt, 1977) Sheet areas has been mapped in recent years.

STRATIGRAPHY

ORDOVICIAN (Ouf, Ous)

Ordovician flyschoid sedimentary rocks crop out over a large proportion of ARALUEN, as they do elsewhere in the Lachlan Fold Belt. Most of the Ordovician in this region of New South Wales varies little in lithology, being dominantly quartz-rich turbidite beds. A profusion of local names has been applied by previous workers. We consider it inadvisable either to apply any of these names or to introduce a new name, until a satisfactory study can be made of the Ordovician flyschoid rocks over a large area.

The three meridional outcrop belts in ARALUEN were originally part of a single depositional basin receiving

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* Capitalised names refer to 1:100 000 Sheet areas.

similar quartz-rich flyschoid sediments (Cas & others, 1980). The eastern belt has been the most severely deformed, and the central belt the least. In the eastern belt original sedimentary features are only rarely preserved.

The sequence comprises interbedded sandstone, siltstone, and shale, all of which show evidence of deposition from turbidity currents.

The sandstone is typically fine to medium grained, poorly sorted, grey to brown, and composed dominantly of quartz and matrix, with minor feldspar, mica, lithic grains, and heavy minerals. Between 25% and 50% consists of a matrix of unidentified phyllosilicate material. The combined proportion of feldspar, muscovite, lithic fragments, and heavy minerals rarely exceeds 5%. Quartz generally occurs as subangular grains up to 0.5 mm (rarely up to 1 mm), and often shows undulose extinction. Feldspar is present as subangular to angular grains generally less than 0.4 mm. Both potassium feldspar and plagioclase are present, plagioclase being much more abundant and less altered. Muscovite forms elongate plates, often bent around quartz grains, up to 0.25 mm. Lithic grains are subangular, up to 0.4 mm across and are usually composed of fine siltstone and mudstone; rare chert and fine quartzite grains also occur, but volcanically derived grains appear absent. Heavy minerals include zircon, tourmaline, and apatite, often euhedral, though more commonly subhedral.

Sandstone grades into siltstone and shale by an increase in the proportion of phyllosilicate matrix accompanied by a decrease in grainsize of the coarser component.

Black shale beds are relatively rare compared to areas of Ordovician strata west of ARALUEN. Thin beds up to 5 m were found in the headwaters of Jinden Creek, and along the Minuma Range at GR 424147, 435335, and 438353; the Minuma Range localities contain graptolites. Unfossiliferous black shale is present in the central belt at GR 471264.

Chert is very rare, and was seen only in the southern part of the Gourock Range, near Pikes Saddle at GR 313138. It is dark grey and well bedded (beds up to 10 cm thick).

The original lithology is modified in many areas by metamorphism and deformation. In the central belt this is limited to contact metamorphism adjacent to plutons, resulting in hornfels within about 1 km of contacts. In the western belt hornfels is affected by a later slaty cleavage, resulting in flattening of porphyroblasts. In addition there is widespread metamorphism of sandstone to quartzite and of the finer-grained rocks to slate. In the eastern area phyllite and schist have formed as a result of a very strong deformation adjacent to the Comerong Rift Zone (see Middle to Late Devonian palaeogeographic sketch, western margin of map sheet). This has resulted in a pervasive segregation cleavage which, in ARALUEN, has almost totally destroyed the original texture of the rock, to produce laminations alternately quartz-rich and chlorite-muscovite-rich, 1 to 5 mm thick (or sericite-rich where deformation is less intense). This is mapped as a separate unit (Ous).

A measured section in Moodong Creek (from GR 547400 to GR 500383), in a monotonous proximal-flysch sequence, contained 3600 m. A total thickness in excess of 4000 m is therefore likely.

Turbidity current structures include graded bedding, plane lamination, current ripple lamination, convolute bedding, load casts, and flute casts. These are particularly well developed in the central area; in the west deformation has largely destroyed bedding-plane structures such as flute casts, and in the east only the major graded beds are recognisable. The structures are indicative of turbidite beds deposited mostly in the proximal part of turbidity currents; beds A and B of a Bouma sequence (Bouma, 1962; Walker, 1967) are well-developed and widespread. Current-direction measurements made on bottom structures of individual beds all indicate a southerly source, supporting the suggestion made by Owen & Wyborn (1979) and Cas & others (1980) that much of the Ordovician flysch of southeastern Australia was deposited in a very large fan system whose sediment source was to the south.

Of the three graptolite localities found in the course of the mapping only that at GR 435335 provided well preserved material, and none of the faunas has been examined in detail. All are thought to be late Eastonian to early Bolindian in age. A fourth locality, at GR 655674, found by members of the Australian National University Geology Department, has yielded a graptolite fauna of Darriwilian age.

The sequence in ARALUEN is considered to have an age range from Darriwilian or older to early Bolindian.

The base of the Ordovician is not seen either in ARALUEN or in adjoining areas, so its relationship to older rocks is unknown. The sequence is overlain unconformably by all other units: the angular unconformity with the Late Silurian sediments is only slight, but there is a marked angular discordance with the Late Devonian sediments and volcanics.

Analyses of some specimens of the Ordovician strata are listed in the Appendix.

SILURIAN SEDIMENTARY AND VOLCANIC ROCKS

Three Silurian units are recognised: the De Drack Formation, the Long Flat Volcanics and the Palerang beds.

These units have previously been described from BRAIDWOOD (Felton & Huleatt, 1977). Garretty (1936) named the Silurian rocks of the Mount Fairy area (in BRAIDWOOD) the 'Mount Fairy Series'. The name was subsequently used by Joplin & others (1953) for an extensive area of sandstone, shale, greywacke, and limestone in the west of BRAIDWOOD, and was later modified to 'Mount Fairy Beds' by Best & others (1964). Felton & Huleatt (1977) demonstrated that strata placed by earlier workers in the 'Mount Fairy Beds' ranged in age from Ordovician to Devonian. They formalised the name to Group status, and restricted it to units of Silurian age. As defined by Felton & Huleatt (1977), the Mount Fairy Group contains three facies: the shallow-marine, sedimentary, De Drack Formation at the base, followed by the submarine to subaerial massive felsic and mafic volcanics of the Woodlawn and Long Flat Volcanics and the Currawong Basalt, and the flyschoid Covan Creek and Palerang Formations at the top. It seems inappropriate to us to include these three very different facies in the same group, and therefore we have not used the name Mount Fairy Group.

DE DRACK FORMATION (Sud)

The name De Drack Formation was first published by Huleatt (1971) and subsequently amended and formally described by Felton & Huleatt (1977). Felton & Huleatt used the name in BRAIDWOOD for a transgressive, shallow-marine, clastic and carbonate sequence that unconformably overlies Ordovician strata and is overlain conformably by Late Silurian volcanics—the Woodlawn Volcanics in the west and Long Flat Volcanics in the east. Huleatt (1971) had misinterpreted the stratigraphic relationships between sedimentary strata and volcanics, and considered the volcanics to be older.

Best & others (1964) mapped and named four isolated limestone lenses of Silurian age in ARALUEN—at Bendethera, Wyanbene, Marble Arch, and Cleatmore. Our work shows that these limestone lenses, together with a fifth, occur in a continuous belt of terrigenous strata that rest unconformably on Ordovician strata and are overlain conformably by the Long Flat Volcanics, that is, in a similar stratigraphic context to the De Drack Formation.

We therefore use the name De Drack Formation for these sedimentary rocks, and consider the limestone lenses to be members of the De Drack Formation. The name is taken from De Drack Hill, GR 365996, BRAIDWOOD.

The type section was designated by Felton & Huleatt (1977) as being in Fairy Meadow Creek, between GR 373027 (base) and GR 369029 (top), BRAIDWOOD.

In ARALUEN the De Drack Formation crops out in a narrow belt from Bendethera in the south to Wyanbene in the north, mainly on the steep eastern side of the Minuma Range. In addition, two areas mainly composed of limestone occur further north at Marble Arch and Cleatmore, and several inliers of terrigenous strata are found beneath the Devonian Minuma Range Group on the western side of the Minuma Range.

The dominant lithology of the De Drack Formation is interbedded quartz arenite, siltstone, and shale, with local developments of limestone, chert, black mudstone, and volcaniclastic arenite.

Quartz arenite generally forms beds from 5 cm to 1 m thick. Bedding contacts are sharp. Large load casts are often found at the base of thicker arenite beds. Neither graded bedding nor cross-stratification was seen.

The arenite is moderately to well sorted, medium to fine grained, and light grey to brown. It is composed of moderately well-rounded quartz grains, often showing a bimodal size distribution, the larger size being the better rounded and in the range 0.5 mm to 1 mm, and the smaller, more angular, grains being less than 0.25 mm across. Other, rarer, grains are of composite quartz, fine siltstone, and accessory tourmaline and zircon, whereas feldspar is absent. The Silurian arenite appears similar in the field to the Ordovician arenite but is seen to differ in thin section by containing little matrix and no feldspar, and by the tourmaline and zircon being much better rounded. Perhaps these differences are the result of reworking of the Ordovician sediment.

Both siltstone and shale are invariably deeply weathered and very few were examined in thin section. The siltstone appears similar in grain composition to the arenite but has a more abundant clay matrix and its grains have a unimodal size distribution.

Black mudstone is locally developed at the base of the formation along the Minuma Range. It ranges from apparently unbedded to moderately bedded (beds 20 cm thick), and may be examined best on the Mongamula Firetrail at GR 423332. It is also extensively developed near Bendethera at GR 445205. The mudstone was not thin-sectioned, but in hand specimen it is unlaminated and often contains small scattered cubes of pyrite up to 0.3 mm across.

A grey to buff massive cherty rock also occurs locally near the base of the formation on the east side of the Minuma Range, between GR 425270 and GR 426346. In thin section, the rock is usually found to be a fine siliceous siltstone or mudstone occasionally with vague circular (radiolarian?) tests visible; at one locality (GR 424286) there is a true chert, with well preserved radiolaria.

Volcaniclastic arenite forms beds from 0.25 m to over 10 m thick towards the top of the formation, and is always deeply weathered in outcrop. The grainsize of the larger grains varies from 0.5 mm up to about 10 mm, and the rock appears poorly sorted, with a large clay component. Recognisable clasts in the rock include bipyramidal quartz, feldspar, and fine-grained volcanic tuff. The volcaniclastic arenite is generally interbedded in the typical quartz arenite/siltstone/shale of the formation, but at GR 429271 volcaniclastic arenite was found interbedded with nodular limestone in beds 0.25 to 0.50 m thick at the top of the small limestone lens (Sul) at that locality.

The limestone lens at GR 426267, 1 km west of Flash Jacks Peak (not named on map; GR 438270), was found during the present work but is considered too small to name. It crops out over an area of about 100 m × 100 m and is formed of massive, grey, coarsely recrystallised limestone, with occasional patches of crinoid ossicles and rare corals. Bedding is only visible in a creek on the southern side of the lens where volcaniclastic rocks are interbedded and where nodular limestone beds also occur. A cave extends through the lens from an entrance in a gully on the north side towards a spring on the eastern edge, at its lowest topographic point. Thin veins of galena were found in float from the limestone on its northern side.

The four limestone lenses named by Best & others (1964) are defined and described below.

Bendethera Limestone Member (Sub)

The Bendethera Limestone Member was presumably named after Bendethera Homestead (GR 474179). The limestone caves near Bendethera have been known since the late 19th century (Anderson, 1892) and the limestone has been briefly referred to by Carne & Jones (1919) and Brown (1930; 1933).

The Bendethera Limestone Member forms four separate bodies near Bendethera. The section on the hillside around Bendethera Cave (GR 438208) is here nominated as the type locality for the member, none having previously been proposed. Outcrops of limestone are abundant, though much is covered by extremely thick *Acacia* scrub, which is restricted to the limestone areas.

The limestone is in general massive, white to grey, coarsely recrystallised sparite, with macrofossils uncommon. Bedding is usually absent, though nodular beds up to 40 cm thick were seen in a creek at GR 436195. A tuff bed about 5 m thick was also seen at GR 438196 in the same creek, near the base of the limestone. The limestone lens on the Deua River at GR 471206 is less altered than the main mass of limestone. It appears to rest with only slight angular discordance on Ordovician flyschoid rocks, and is overlain unconformably by the Devonian Comerong Volcanics. The base of the lens is formed by about 3 m of nodular limestone with some large colonies of *Favosites* in growth position, and this is overlain by about 90 m of thick-(though well) bedded, grey biomicrite with fairly common tabulate corals, algal layers, and crinoids, and rare rugose corals and brachiopods.

Wyanbene Limestone Member (Suw)

The Wyanbene Limestone Member is presumed to have been named after the Wyanbene Cave, formed in the limestone. It has previously been described by Anderson (1892). A type section is here designated as being on the ridge-top between the headwaters of Curmulee Creek and Wyanbene Creek, from GR 428348 to GR 425346. About 100 m of limestone is exposed, resting on Silurian quartz arenite at the base and overlain by Silurian chert at the top of the ridge. The limestone has a total area of 0.2 km^2, and generally forms good outcrop except where mantled by landslide debris from the overlying Minuma Range group.

The unit is formed of massive recrystallised sparite to biosparite with small areas of micrite. Bedding is not obvious. Although the rock appears grey and featureless on natural surfaces, etching with acid reveals that much of it is quite richly fossiliferous, mainly with crinoid ossicles, though rare corals and brachiopods are also found. A grey lichen appears responsible for obscuring these lithological details on the weathered surface.

Marble Arch Limestone Member (Sum)

The Marble Arch Limestone Member was first named as such by Best & others (1964), the presence of limestone at this locality having previously been noted by Carne & Jones (1919). Marble Arch is a limestone arch across Reedy Creek. The type locality is here nominated as the gorge on Reedy Creek which extends some 200 m downstream from Marble Arch Cave (GR 432428) to the junction of Reedy Creek with Moodong Creek.

The limestone forms good exposures over a distance of about 800 m and a width of 150 m, exclusively in the Reedy Creek valley. It appears to form a lens in terrigenous strata of the De Drack Formation. The limestone is within the contact metamorphic aureole of the Braidwood Granodiorite, which crops out within 50 m of it. As a result it has been strongly recrystallised, such that no original texture remains, and it is now a coarse sparite, tending to marble. Some areas have a saccharoidal texture, whereas a cleavage is developed in other areas. No fossils have been found.

Cheitmore Limestone Member (Suc)

The Cheitmore Limestone Member was apparently named after Cheitmore Caves, which are within the main limestone mass, and the spelling followed that used by Carne & Jones (1919), Anderson (1892), and Trickett (1900). However, by the mid 1960s local usage had changed the spelling to 'Cleatmore' (see Bendoura 1:50 000 Topographic Sheet 8826-IV, Edition 1, 1965: Cleatmore homestead, GR 653903, 1000 yard transverse Mercator grid). According to the International Stratigraphic Guide (Hedberg, 1976, pp. 41-2) a stratigraphic name should not be altered just because the spelling of the original feature has changed.

The Cheitmore Limestone Member crops out in two nearby areas at GR 432462, which together cover less than 0.1 km^2. The type section is here designated as on the eastern edge of the more northerly of these two areas. Exposure is good in both areas, and consists of grey, strongly recrystallised limestone, within which fossils, apart from patches of crinoid ossicle, are very rare. Bedding has been almost destroyed by the recrystallisation, though one dip of 50° to the west was measured. The limestone is surrounded by dacite of the Long Flat Volcanics, which it underlies. Alteration of the limestone was caused by the nearby Braidwood Granodiorite, which crops out within 50 m of the limestone.

Depositional environment

The very few sedimentary structures seen in the De Drack Formation were rare load casts at the base of the thicker arenite beds. However, the geographically widespread (though volumetrically small) fossiliferous limestone suggests that much, if not all, of the unit was deposited in a shallow-marine environment. Within this broad environment there were several facies. The limestone lenses appear to have formed as bioherms, within which crinoids probably were the major contributor of material; the bioherms were surrounded by clastic sediment. Black mudstone is most common low in the sequence; it may have formed in small restricted basins during the initial transgressive phase of the formation. Chert appears later in the sequence, and may well be related to the commencement of volcanism in the area (Long Flat Volcanics), which would have helped increase the dissolved silica level of the sea water so that radiolaria could proliferate. The lack of sedimentological information on the clastic rocks which form the bulk of the formation precludes any detailed discussion of its depositional environment.

Fossils

Fossils were found only in the limestone lenses, the clastic rocks appearing completely unfossiliferous. The extensive recrystallisation could have destroyed many macrofossils. However, parts of the Bendethera and Wyanbene Limestone Members and the unnamed lens at GR 427267 contain a coral fauna, in which tabulate corals dominate, and occasional brachiopods. Little work has been done on these faunas, however, and they indicate no more than a possible Late Silurian age.

Conodonts have been recovered from all the limestone lenses except Marble Arch. Although little detailed study has been made of these faunas, R.S. Nicoll (BMR) has provided the following preliminary note:

> 'The limited conodont fauna obtained from limestone lenses in ARALUEN is not well preserved nor very diversified. The identified fauna is dominated by two taxa, *Ozarkodina confluens* and *O. excavata*, which are found throughout the section and at all localities. Elements of the genus *Belodella* were recovered from Wyanbene.
>
> 'Both species of *Ozarkodina* are long-ranging, *O. confluens* from Wenlock to Early Devonian and *O. excavata* from Llandovery to Early Devonian. The genus *Belodella* is, however, more restricted, being

limited to the Ludlovian to earliest Devonian in Bohemia (Walmsley & others, 1974*). Because earliest Devonian forms such as *Icriodus* are absent from these limestones, although common elsewhere in southeast Australia in earliest Devonian rocks, a Ludlovian or Pridolian age is suggested for the ARALUEN limestone bodies'.

Relationships

The De Drack Formation rests unconformably on Ordovician sediments both in ARALUEN and in BRAIDWOOD (Felton & Huleatt, 1977). The break in ARALUEN appears to represent mainly a period of non-deposition, with only slight difference in attitude between the Late Ordovician and Late Silurian rocks.

For the most part in ARALUEN the relationship with the Long Flat Volcanics is either concealed by the overstepping Minuma Range Group and Comerong Volcanics or destroyed by the Braidwood Granodiorite, but, for the short distance over which the contact between the De Drack Formation and the Long Flat Volcanics is exposed, the De Drack Formation passes up conformably into the Toggannoggra Rhyolite Member.

LONG FLAT VOLCANICS

The first mention of volcanics in the upper Shoalhaven valley was by Anderson (1893) who named the sequence the Long Flat Porphyries and noted that they were intruded by the granite around Braidwood. Joplin & others (1953) thought the porphyries were Late Devonian and used the term 'Manar Porphyry'. The name Long Flat Volcanics was first formally used by Best & others (1964). Mapping in the volcanics has been carried out as student projects by Kennedy (1961), Johnson (1964), Brush (1973), and Goleby (1977). Several units were distinguished by these students and there is a consensus that dacitic units are overlain by a more felsic rhyolitic unit. Another student, White (1961), mapped dacitic volcanics in the Bombay Creek area (BRAIDWOOD) and called them the 'Bombay Volcanics'. These dacites extend south into ARALUEN west of the Shoalhaven Fault. We consider that they may be equivalent to the dacitic parts of the Long Flat Volcanics, and the name Bombay Volcanics, formalised by Best & others (1964), could be discarded. However, further mapping in BRAIDWOOD would be required to prove this relationship.

In ARALUEN the volcanics can be divided into three members, two of which have small lenses of interbedded sediments ('Sus' on the map). The three sub-units are here named the Kadoona Dacite Member, the Wongabel Rhyodacite Member, and the Toggannoggra Rhyolite Member. Also the Long Flat Volcanics are intruded by a high-level porphyry which is extensive and intimately associated with the Toggannoggra Rhyolite Member. The intrusion is distinctive, has been accurately delineated, and is here formally named the Kain Porphyry. It is probably best regarded as part of the Long Flat Volcanics.

The Long Flat Volcanics have undergone low-grade metamorphism (mainly albitisation of plagioclase phenocrysts and alteration of mafic phenocrysts), like the Silurian volcanics of the Canberra region (Wyborn & others, 1981).

Analyses of some specimens from the Long Flat Volcanics are listed in the Appendix.

Kadoona Dacite Member (Suk)

The Kadoona Dacite Member is the basal unit of the Long Flat Volcanics. The name is derived from Kadoona homestead (GR 383361), the nearest available name to the type locality (GR 392373). The dacite overlies the De Drack Formation, presumably conformably, as tuffaceous and volcaniclastic sediments are present near the top of the De Drack Formation at GR 427387 and GR 433428. In the Wyanbene Caves area the dacite is missing and the De Drack Formation passes directly up into the overlying Toggannoggra Rhyolite Member. Tuffaceous sediments at the top of the De Drack Formation at GR 422336 may be contemporaneous with the dacite. The dacite is overlain with a sharp contact by the Toggannoggra Rhyolite Member; this contact is exposed in a gully at GR 355430, where it dips at 66° to the north. A specimen containing both rock types was collected, and a thin section across the contact shows no signs of weathering—porphyritic dacite ignimbrite with poorly developed eutaxitic layering and common altered mafic phenocrysts is overlain by poorly welded rhyolite ignimbrite with well preserved eutaxitic layering and rare mafic phenocrysts (altered biotite). Alkali-feldspar phenocrysts are absent in the dacite, but common in the rhyolite. Fragments of the dacite 10 mm across are contained in the rhyolite near the contact.

Assuming moderate dips to the west in the area west of Cleatmore Caves (GR 433462) about 1000 m of dacite could be present. The primary mineralogy can be most closely observed by sampling from the dacite type locality (GR 392373), where the effect of the metamorphism is less than elsewhere. The rock is grey-green, and phenocrysts, in a fine-grained groundmass—possibly devitrified glass—comprise about 60%. The groundmass is mostly structureless, but rare, weak foliation around some phenocrysts could be eutaxitic layering indicative of ignimbritic eruption rather than eruption as a lava flow. Plagioclase is the dominant phenocryst, followed in decreasing order of abundance by quartz, orthopyroxene, biotite, clinopyroxene, magnetite, and hornblende, with accessory ilmenite, allanite, apatite, and zircon.

The plagioclase is up to 3 mm across and possesses well developed oscillatory zoning around An_{50} to An_{60}. Rims more sodic than An_{50} are either absent or very narrow. Blebs of clinopyroxene are commonly included in the plagioclase. Many of the plagioclase phenocrysts are less than 0.5 mm across and are fragments of originally larger crystals. Quartz occurs as rounded, partly embayed, crystals up to 5 mm across, while orthopyroxene and clinopyroxene occur as euhedral phenocrysts up to 3 × 2 mm. The orthopyroxene is partly altered to bastite, but the clinopyroxene is unaltered. Red-brown biotite (1 × 0.5 mm) and green-brown hornblende (2 × 1 mm) have narrow reaction rims of opaques and possibly very-fine-grained pyroxenes, perhaps indicating dehydration associated with extrusion. The hornblende has the

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* WALMSLEY, V.G., ALDRIDGE, R.J., & AUSTIN, R.L., 1974—Brachiopod and conodont faunas from the Silurian and Lower Devonian of Bohemia. *Geologica et Palaeontologica*, 8, 39-47.

pleochroic scheme X = pale yellow-brown, Y = brown, Z = greenish-brown, which is distinct from the green hornblende in the adjacent Ballallaba Adamellite and Braidwood Granodiorite. Magnetite (1%) is commonly associated with other mafic phenocrysts and is up to 0.5 mm across. Microxenoliths up to 5 mm across contain two pyroxenes, plagioclase, and opaques.

Other rocks from the Kadoona Dacite Member, 46 of which have been examined petrographically, are similar to, but more altered than, that from the type locality. With progressive alteration orthopyroxene is replaced by bastite, biotite by chlorite plus opaques, clinopyroxene by actinolite, and then plagioclase by albite. The albitisation of plagioclase releases calcium, much of which becomes fixed in mafic minerals as epidote and/or carbonate or rarely prehnite. Thus at this stage pyroxenes may be pseudomorphed by epidote and/or carbonate. Hornblende is also replaced by epidote at this stage but the opaque-rich altered margins are not affected. Almost all samples from the Kadoona Dacite Member can be described in terms of varying degrees of alteration from an original rock that must have been quite similar to the rock from the type locality. Some rocks lack biotite and/or hornblende (e.g. GR 385425 and GR 432458); others are crystal-enriched (up to 75% crystals) and have well developed eutaxitic textures, indicating ignimbritic deposition (e.g. GR 374415 and GR 414370). Hornblende is particularly common (5%) in rocks from GR 386413, GR 358438, and GR 433482.

The presence of abundant phenocrysts of calcic plagioclase with no sodic rims and anhydrous mafic silicates (two pyroxenes) is analogous to that described by Wyborn & others (1981) for S-type* volcanics where such phenocyrsts can be regarded as primary restite. Here the volcanics are I-type* (metaluminous) and clinopyroxene is a primary restite phase instead of cordierite. The hornblende and biotite in the dacite may also be restite; if so, enough water must have been available at the source for partial melting to produce tappable magmas before all hornblende and biotite were consumed in incongruent melting reactions to pyroxene. It can be shown chemically that the Kadoona Dacite Member of the Long Flat Volcanics is the extrusive equivalent of the Ballallaba Adamellite and other plutons of the western Bega Batholith, which are grouped as the Glenbog Suite (Beams, 1980).

Togganoggra Rhyolite Member (Sut)

The Togganoggra Rhyolite Member conformably overlies the Kadoona Dacite Member, and where the dacite is absent near Wyanbene Caves it directly overlies the De Drack Formation. The name is derived from Togganoggra homestead at GR 360524 and the type locality is nearby in the bed of the Shoalhaven River at GR 361526. Here good exposures of a creamy-buff porphyritic rhyolite with about 30% phenocrysts are present on the right bank of the river; the rhyolite is typical of most of the unit, though the groundmass colour varies with the degree of weathering and metamorphism (albitisation), from pale-cream through buff to pale-grey and dark-grey. At the type locality the rock is albitised, plagioclase phenocrysts are altered to pale-olive albite and alkal feldspar is dark-pink. At localities where the rhyolite is not albitised (e.g. GR 422390, GR 360439, GR 405365, and GR 417368) the groundmass is grey, plagioclase is white, and alkal feldspar is white to pale-pink.

Thirty-five samples of rhyolite were examined petrographically. Most contain 30-35% phenocrysts in a groundmass which in many samples shows eutaxitic layering indicative of ignimbritic deposition. Plagioclase and quartz in roughly equal abundance are the most common phenocrysts, both occurring as crystals up to 3 mm across.

When unalbitised the plagioclase is zoned around An_{30}-An_{25} but some crystals have small cores as calcic as An_{60} with broad An_{25-30} rims. These cores probably represent relict restite, while the rims are liquid precipitates. When albitised the plagioclase commonly contains alteration patches of epidote, sericite, or calcite, while epidote and calcite are common alteration products in the rest of the rock. Even in albitised plagioclase the original presence of small calcic cores can be recognised by the presence of distinct strongly altered cores (mainly sericitised) surrounded by less altered rims.

Alkali feldspar is present in most samples; occasionally it is more abundant than plagioclase (e.g. at GR 370441), while elsewhere it may be uncommon or absent, such as around Wyanbene Hill (GR 412370). The alkali feldspar is commonly around 1 to 2 mm across, rarely up to 5 mm (e.g. GR 348427). In unalbitised rocks it is homogeneous with 2Vx = 30-40° indicating a sanidine composition, but in albitised rocks the mineral is unmixed with a composition of about Or_{60-70}. Chloritised biotite (2%, 1 × 0.5 mm) is the only recognisable essential mafic phenocryst, though rare crystals altered to epidote and chlorite could have been pyroxene. Epidote, opaques, and calcite are other alteration products of the biotite. Only in one sample, from GR 360439, is a little fresh biotite still preserved. This sample also carries fresh plagioclase and sanidine. Accessory minerals include allanite (rarely up to 0.5 mm), opaques, apatite, and zircon.

The thickness of the Togganoggra Rhyolite Member is difficult to estimate. Interbedded sediments at GR 356464, and GR 355432 dip steeply to the west, whereas sediments at GR 357496 dip steeply to the southeast. This suggests that a large syncline trending north-northeast is present in the area between Warragandra (GR 347483) and Fernleigh (GR 358467). If this assumption is correct, the rhyolite could be 1000 m thick in this area. At GR 449598, west of Majors Creek, columnar jointing in the rhyolite indicates more gentle dips. The broad expanse of rhyolite northwest of Majors Creek could be quite flat-lying and perhaps less than 1000 m thick.

Wongabel Rhyodacite Member (Sur)

The term Wongabel Rhyodacite Member has been introduced for a belt of rocks within the Togganoggra Rhyolite Member in the Majors Creek area. The rhyodacite in the area around GR 460540 to the south is interpreted as the same rhyodacite repeated by folding along a northeasterly axis. Thus an anticline is inferred to run through the centre of the belt of rhyodacite west of Majors Creek and a syncline through the Togganoggra Rhyolite Member immediately to the south of this belt. Both these northeast trending folds are truncated by the Braidwood

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* For discussion of these terms see Chappell & White (1974), White & Chappell (1977), and Chappell (1984).

Granodiorite. An alternative interpretation is that there are two rhyodacite units and the whole volcanic sequence dips continuously to the northwest; however, this is less likely as the total thickness of the volcanics would then be very great—perhaps 3000 m above the Kadoona Dacite Member. If the first interpretation is correct then the Wongabel Rhyodacite Member is a unit perhaps 300 m thick within the Toggannoggra Rhyolite Member. It is possible that the rhyodacite represents a single ignimbritic eruption so that its status as a member could be reduced to a bed within the Toggannoggra Rhyolite Member.

The name is derived from Wongabel homestead (GR 443568) and the type locality is here given as bouldery outcrops beside the road at GR 466588. The rock here is a dark blue-green crystal-rich ignimbrite with about 50% phenocrysts up to 3 mm across. The colour is typical of the rhyodacite and effectively distinguishes it from the Toggannoggra Rhyolite Member. Thirteen samples of the unit were examined petrographically. Mineralogically they fit between the Kadoona Dacite Member and the Toggannoggra Rhyolite Member. The samples contain about 40-50% phenocrysts, mostly plagioclase and quartz, in a groundmass with well-preserved eutaxitic layering. Glass shards are visible in a sample from GR 469615. Plagioclase, where unalbitised, as at the type locality, is strongly zoned from An_{60} to An_{30} with broad cores of An_{60-50}. In this respect this unit is intermediate between the dacite and the rhyolite. The rhyodacite contains alkali feldspar phenocrysts, like the rhyolite, but also has pseudomorphed pyroxene phenocrysts like the dacite. Both pyroxenes were originally present in a sample from GR 460595, clinopyroxene being replaced by epidote and orthopyroxene by chlorite. Epidote pseudomorphs with dark rims are probably after hornblende in this rock. At the type locality pyroxene is replaced by actinolite, chlorite, and epidote. Altered biotite is a common phenocryst occurring as crystals up to 1.5 × 1 mm. Pyroxenes are rarely over 1 mm. Allanite and opaques (0.5 mm) are also present.

Although the rhyodacite is mineralogically intermediate between the dacite and rhyolite, it can be shown using mainly the Sr content of the rocks that the rhyodacite and rhyolite are part of a different chemical suite from the dacite and are related to the Jinden and Braidwood plutons, whereas the Kadoona Dacite Member is more closely related to the Ballallaba Adamellite.

Kain Porphyry (Spk)

The name Kain Porphyry is here introduced for a high-level intrusive mainly within the Toggannoggra Rhyolite Member but also in intrusive contact with the Kadoona Dacite Member; the porphyry is in turn intruded by the Jinden Adamellite. The name is derived from Kain homestead (GR 325423) and the type locality is here given as the tors west of a forestry track at GR 348413. Here the porphyry is unalbitised and composed of about 60% phenocrysts of grey quartz and pale-green plagioclase, both about 5 mm across. Although this outcrop is separate from the main mass of the porphyry it is almost certainly linked with it at depth. Potential type localities closer to Kain have been rejected as the rocks there are more altered and plagioclase albitised. In fact nearly all of the Kain Porphyry is albitised except in the southeast. In hand specimen the texture is not obviously that of an intrusive, but the irregular distribution within the Toggannoggra Rhyolite Member suggests it is an intrusion. The contact with the rhyolite is exposed in poor outcrop at GR 361478.

Twenty-four specimens of the porphyry were studied petrographically. They contain between 50 and 60% phenocrysts (up to 10 mm of quartz, plagioclase (An_{50-60} when unalbitised), and widely scattered pink alkali feldspar. Alkali feldspar phenocrysts are absent at some localities, including the type locality. Mafic phenocrysts (5-10%) are predominantly chloritised biotite and altered pyroxene up to 2 × 1 mm and a little brown or greenish-brown hornblende. Hornblende is common at GR 335442 and GR 358439. The micrograniitic groundmass of the porphyry ranges in grainsize from 0.05 mm rarely up to 0.3 mm (GR 392338). Xenoliths are common in places. The thin section from GR 392338 contains a cognate xenolith 10 mm across composed of plagioclase (An_{60}), fresh clinopyroxene, quartz, and opaques. Grainsize is 0.5 mm. Accidental xenoliths up to 15 cm across from GR 341347 consist of cordierite, plagioclase, biotite, and quartz. A sample from close to the Jinden Adamellite (GR 366401) has been contact-metamorphosed by it. The groundmass and biotite phenocrysts are recrystallised, and pyroxene is altered to chlorite and actinolite.

Tuffisite near Mount Elrington

About 2 km west of Mount Elrington homestead (GR 394647) a tuffaceous rock crops out over a strike length of 2 km within the Ballallaba Adamellite. The body is about 10 m wide where it is best exposed in a creek bed at GR 376644, and trends north-northwest parallel to the eastern margin of the adamellite. As the body is fragmental and wholly contained within a granitoid pluton it must be an intrusive tuff ('tuffisite'). It has been mapped as a dyke. The rock consists mainly of crystals up to 0.5 to 1 mm across (70%) in a fine-grained granular matrix. Plagioclase is the main mineral present, commonly consisting of weakly oscillatorily zoned (An_{55-60}) grains and fragments of larger grains—narrow andesine rims are present on some crystals. Present in decreasing order of abundance, but the same grainsize as the plagioclase, are clinopyroxene, opaques, quartz, altered orthopyroxene, greenish-brown hornblende, epidote, sanidine, and apatite. Zircons up to 0.1 by 0.3 mm, and in some thin sections rare red-brown biotite up to 0.3 mm across, are also present. Rock fragments are common on a microscopic scale and include chert, fine tuff, porphyritic dacite, banded ignimbrite, and mudstone. Rock fragments up to 10 cm across include chert, mudstone, and leucogranite. Banding or bedding is present in some places and is best observed in boulders in the creek bed at GR 376644. The banding is caused by differences in grainsize of the crystals. Elongate crystals such as plagioclase laths and pyroxene prisms are aligned parallel to the banding. The attitude of the banding has not been established as the boulders carrying the banding are not in place. Presumably, in situ, the banding parallels the walls of the body. Although the tuffisite could not be traced any further north than GR 376650, a similar rock was found about 2 km into the BRAIDWOOD 1:100 000 Sheet area at GR 381702, about 5 km north along the strike of the tuffisite.

Another possible example of a tuffisite occurs at GR 360498. Here steeply dipping bedded tuff can be traced along strike for about 300 m. This body has been mapped as volcaniclastic sandstone (Sus), but it appears to cut through a contact between the Kain Porphyry and Toggannoggra Rhyolite Member and could therefore be intrusive. The body mineralogically and texturally is very similar to that near Mount Elrington, except that burial metamorphism has albitised the plagioclase and epidotised and chloritised the mafic minerals.

Mineralogically the tuffisite near Mount Elrington is quite like the Kadoona Dacite Member. Most tuffisites are believed to be emplaced by gaseous explosions of magma along contemporaneous fractures and are common in high-level plutonic complexes (e.g. Cobbing & others, 1981; Pitcher & Berger, 1972).

Metamorphism

Low-grade burial metamorphism of the Long Flat Volcanics has resulted in widespread albitisation of plagioclase, alteration of mafic phenocrysts, and unmixing of alkali feldspar. The effects are the same in the intrusive Kain Porphyry as in the extrusive rocks. A metamorphic zone boundary can be drawn between rocks with albitised and unalbitised plagioclase phenocrysts. Unalbitised rocks are present between Khan Yunis (GR 381279) and Cleatmore (GR 386439) adjacent to the Gundillion Fault, in the area around Wyanbene Hill (GR 411370) and Cleatmore Caves (GR 432451), near Hereford Hall (GR 309339), and near Moodong (GR 391564). Albitisation is widespread around Bendoura (GR 450670) and Fernleigh (GR 359469). It is erratic in the region west of Majors Creek. Contact metamorphism near the adjacent granitic bodies does not albitise the plagioclase phenocrysts even though temperatures must have been much higher there. The albitisation process must be greatly dependent on the availability of a suitable fluid.

The Long Flat Volcanics conformably overlie the Late Silurian De Drack Formation and yet were folded before the intrusion of adjacent Early Devonian granitic bodies. They are thus Late Silurian and may extend up into the Early Devonian.

PALERANG BEDS (Sup)

The name 'Palerang Formation' was introduced by Huleatt (1971) and Felton & Huleatt (1977) for a poorly known sedimentary unit exposed in the southwest corner of BRAIDWOOD and apparently conformable on the 'Bombay Volcanics' of these authors (Long Flat Volcanics herein). The name is derived from Palerang Trig. Station (GR 358761, BRAIDWOOD).

Felton & Huleatt (1977) commented that the unit is poorly exposed and details of its stratigraphy uncertain. For this reason they declined to nominate a type section, preferring to designate exposures on a fire trail at GR 359776 (BRAIDWOOD), albeit meagre, as a representative section. Our more recent reconnaissance of this area has shown that the geology is complex, and not properly understood, confirming that no type section should yet be designated. In addition, outcrop at the locality nominated as a representative section by Felton & Huleatt is very poor, and the locality is not suitable for a type section. In view of the present uncertainties regarding the stratigraphy of the 'Palerang Formation' in its type area, we consider it should be regarded as an informal unit, the Palerang beds, pending clarification of the geology in the type area.

Fine sandstone, siltstone, and shale which crop out in ARALUEN over about 4 km^2 east of the Big Hole, are tentatively correlated with the Palerang beds in BRAIDWOOD. The rocks occupy a similar stratigraphic position, possibly conformable on top of the Long Flat Volcanics and are of similar lithology.

The Palerang beds in ARALUEN consist of poorly exposed quartz arenite, siltstone, and shale which are fairly thinly bedded (1 to 10 cm) and locally contain graded bedding and small-scale crossbedding. Typical exposures can be seen on the ridge at GR 428449 and in a stream bed at GR 413429. The unit is overlain unconformably by, and faulted against, the Minuma Range Group.

The depositional environment is uncertain from the meagre evidence available, but the presence of graded beds is taken to indicate deposition by turbidity currents, probably in a marine environment.

No fossils have been found in the Palerang beds, either in their type area or in ARALUEN, but a Late Silurian age, possibly Pridolian, is suggested by the beds' relationship with the Long Flat Volcanics and because they are intruded by Early Devonian granite in BRAIDWOOD.

EARLY DEVONIAN GRANITOIDS

JINDEN ADAMELLITE (Dgj)

Previous maps at 1:250 000 scale (Joplin & others 1953; Best & others, 1964) included the Jinden Adamellite as part of a belt of granitic rocks of the Bega Batholith in the western part of ARALUEN and BRAIDWOOD known as the Boro Granite. Our mapping has separated the Boro Granite into a number of different plutons. Of these, the Jinden Adamellite is the main granitoid east of the Shoalhaven Fault. It has closer chemical affinities with the Braidwood Granodiorite than with the granitoids west of the Shoalhaven Fault.

Jinden Creek crosses the centre of the adamellite and flows into the Shoalhaven River at GR 383299.

The type locality is here designated as the exposures in the bed of Jinden Creek at GR 364268. These are accessible along a track that follows the creek upstream from Yarra Glen (GR 380298). The type locality, for about 150 m along the creek, has excellent exposures of medium-grained hornblende-biotite adamellite containing about 8% mafic minerals. The adamellite is cut by abundant aplitic dykes and irregular bodies and contains some pegmatitic patches.

A more accessible reference locality is at GR 372321 on the main Braidwood–Cooma road where freshly broken boulders several metres across lie on the western side of the road. The rock here lacks aplite.

The Jinden Adamellite crops out over 185 km^2 between the Shoalhaven and Gundillion Faults. It extends into COBARGO for probably only a short distance. At its northern end it intrudes the Long Flat Volcanics and in the south it intrudes Ordovician sediments and the Euranbene Adamellite. Tors are reasonably common and several excellent pavements are exposed in Jinden and Currambene Creeks such as at the type locality and GR 350259. Leucogranite and aplitic bodies within the adamellite form more rubbly exposures and are generally more resistant and better exposed than the surrounding adamellite. Leucogranite hills occur at GR 368327, 351336, 346336, 369355, 345264, and 330232.

There is a considerable variety of rock types in the Jinden Adamellite, which can be explained in terms of crystal fractionation and local magma segregation in a single magma body.

The main rock type is a hornblende-biotite adamellite with between 5 and 10% mafic minerals. Colour index is greatest at the margins and lowest in the centre. Grainsize ranges from 1-2 mm in places to 3-4 mm. Near the margins the rock is a medium-grained hornblende-biotite adamellite, with about 10% mafic minerals including distinctive euhedral hornblende phenocrysts similar to, but somewhat smaller than, those in the western phase of the Braidwood Granodiorite. Dark cognate xenoliths are relatively common in this marginal phase, which is up to 3 km wide at the northern end and grades inwards into a lighter even-grained white adamellite with average grainsize of 2-3 mm. At the centre of the body around Krawarree Creek the adamellite has about 5-6% mafic minerals.

Aplitic dykes and leucogranite bodies are common throughout. The largest leucogranite, southwest of Trafalga Hill (GR 371353), occupies almost 3 km^2. The leucogranites are fine-grained (less than 1 mm), and contain only about 2-3% mafics. A porphyritic rock-type intermediate between the medium-grained adamellite and the fine-grained leucogranite is present in places. Most outcrops on the slopes of Mount Italy (GR 320279) and east of Hereford Hall (GR 309339) are of this rock type. The rock contains phenocrysts of plagioclase, quartz, biotite, and rarely hornblende of similar size to those in the adamellite in a fine-grained aplitic groundmass. Colour index is generally about 3 to 5. There is a complete range in proportions of phenocrysts to groundmass, with aplite at one extreme and adamellite at the other. The Jinden Adamellite would be an ideal subject for a study on the mechanisms of aplitic segregation in a magma body.

Fresh specimens of the Jinden Adamellite are generally difficult to obtain—saussuritisation of plagioclase and chloritisation of biotite are the main alteration effects. In more extreme cases hornblende is altered to chlorite and epidote. Plagioclase occurs as subhedral zoned grains with broad cores of An_{40-50} and narrow, more sodic, rims; it is commonly saussuritised or sericitised and associated with patches of secondary epidote. Rounded inclusions of either epidote or actinolite are common in some plagioclase cores; the inclusions are probably pseudomorphing clinopyroxene similar to the clinopyroxene inclusions in plagioclase cores from the Braidwood Granodiorite. One relatively fresh rock from GR 369231 contains unaltered clinopyroxene inclusions in some of the plagioclase cores. Quartz and perthitic alkali feldspar occur as interstitial anhedral grains and large 2-4 mm plates. Rarely quartz and orthoclase form plates from 5 to 10 mm with inclusions of mafics and plagioclase. In some samples the alkali feldspar is orthoclase, in others microcline.

Biotite is the most abundant mafic mineral, forming subhedral flakes averaging 1 mm. It is pleochroic from pale-yellow-brown to dark-red-brown, commonly surrounds equant magnetite grains, and in many samples occurs in mafic clusters with hornblende and magnetite. In the most mafic marginal samples hornblende occurs as euhedral phenocrysts about 5 × 2 mm, pleochroic with X = pale-yellow-brown, Y = greenish-brown, Z = green or brownish-green. Smaller green hornblendes contain actinolitic cores after clinopyroxene but only rarely is clinopyroxene still preserved (e.g. at GR 369231). In the most felsic adamellites with about 5-6% mafic minerals, hornblende is rare or absent and when present occurs as euhedral to subhedral pale-green prisms. Magnetite, euhedral allanite up to 0.5 mm across, anhedral to subhedral sphene, and apatite occur as accessory minerals. Allanite is more abundant than sphene in most samples.

The porphyritic rocks near Mount Italy and east of Hereford Hall are more felsic than the most felsic equigranular adamellites, containing less than 5% mafics. Plagioclase and quartz 2-4 mm across are the main phenocrysts, the quartz commonly bipyramidal. Smaller biotite and magnetite grains also are phenocryst phases and occasionally hornblende and allanite are present as well. These phenocrysts are similar in size and habit to the same minerals in the even-grained adamellite. The groundmass in the porphyries consists of about equal proportions of quartz, sodic plagioclase, and potash feldspar with a micrographic texture. Rarely quartz and potash feldspar are in graphic intergrowths. Groundmass grainsize ranges from 0.1 to 1.0 mm.

The aplites are similar in composition to the porphyry groundmass. Widely scattered phenocrysts like those in the porphyries are present even in the most felsic aplites.

The Jinden Adamellite intrudes the Ordovician strata and the Late Silurian Toggannoggra Rhyolite Member. It is faulted against the Kadoona Dacite Member, and is overlain by possible Late Devonian conglomerate at GR 307263. Chemically the Jinden Adamellite can be grouped with the Braidwood Granodiorite as a suite so it is likely to be of similar age, i.e. Early Devonian.

A specimen from GR 356379 has been dated* by K-Ar on biotite and a biotite-whole-rock Rb-Sr isochron. The K-Ar age is 406 ± 6 Ma and the Rb-Sr age 402 ± 6 Ma with initial $^{87}Sr/^{86}Sr$ ratio 0.7071, thus confirming an Early Devonian age.

BALLALLABA ADAMELLITE (Dab)

The Ballallaba Adamellite was included in the elongate mass of granitic rocks collectively known as the Boro Granite by previous workers (Joplin & others, 1953; Best & others 1964). As the granitoid near Boro (GR 425075, BRAIDWOOD) is a separate body, we have named the pluton that crops out over much of the area west of the Shoalhaven Fault in ARALUEN the Ballallaba Adamellite.

The name is derived from Ballallaba homestead at GR 372583. The type locality is here designated as a tor 3 m high about 20 m west of the Captains Flat-Braidwood Road at GR 321568. The adamellite here is medium-to-coarse-grained with prominent rounded phenocrysts of pale-grey quartz about 10 mm across and white plagioclase up to 10 mm. The rock contains about 10% mafic minerals—mainly biotite, but hornblende and allanite (with yellowish alteration haloes) are also visible in hand specimen. This rock is typical of most of the Ballallaba Adamellite and is very similar to much of the Boro Granite in BRAIDWOOD. The locality was sampled for K/Ar dating by Evernden & Richards (1962).

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* Isotopic dating was carried out under contract by the Australian Mineral Development Laboratories (AMDEL), Adelaide, unless otherwise indicated.

The Ballallaba Adamellite forms most of the granitoid west of the Shoalhaven Fault in ARALUEN. Our mapping indicates that there are two plutons, the larger (Dab_1) cropping out north of their common boundary southeast of Round Mount (GR 299478). The northern pluton occupies an area of about 175 km^2 in ARALUEN and extends a few kilometres north into BRAIDWOOD. The southern pluton (Dab_2) occupies about 40 km^2 and is intruded by a 6 km^2 leucogranite in the vicinity of Bald Peak (GR 279371). The southern pluton has a rather irregular shape and may be composite.

Both plutons crop out as large tors and are better exposed than the Jinden Adamellite. The two show similar compositional variation; the margins contain 15-16% mafics, but for the most part both plutons contain about 10% mafics. The mafic margins of both plutons are well exposed near GR 327458, southeast of Round Mount, where a narrow screen of metasediments separates them. The rock types north and south of the screen are very similar, both being granodiorites with about 15% mafics. With increasing distance from the screen, both plutons become more felsic. The most distinctive characteristic of hand specimens is the presence of rounded phenocrysts of quartz about 10 mm across, even in the most mafic marginal rocks. Rarely quartz crystals can be seen rimmed by biotite suggesting they were a very early crystallising phase or perhaps restite. Xenoliths, though present at most outcrops, are relatively small (less than 10 cm) and inconspicuous compared with those in the Braidwood Granodiorite. Leucogranites associated with the Ballallaba Adamellite tend to be concentrated into relatively large bodies near the margins, whereas those associated with the Jinden Adamellite form small bodies throughout. These differences can perhaps be attributed to the level within the pluton at which leucogranite separation occurred: not far below the present surface in the Jinden Adamellite, but at greater depths in the Ballallaba Adamellite.

There is very litle petrological variation. Nearly all specimens are medium-to-coarse-grained and rather inequigranular; plagioclase in every case is more abundant than perthitic orthoclase. Mafic minerals make up 8-12%, becoming more abundant than this towards the margins, especially near the mutual contact of the two intrusive phases.

Quartz and plagioclase are present as phenocryst phases, quartz commonly about 10 mm across and plagioclase rarely up to 10 mm. The large ovoid quartz grains are often composite. Plagioclase is subhedral to euhedral with broad, mainly sericitised, cores (around An_{45} when fresh) and narrow rims of oligoclase. Biotite is the most common mafic mineral, occurring as subhedral books up to 3 mm thick, pleochroic from pale-yellow-brown to reddish-brown. Hornblende is present as euhedral brownish-green prisms up to 4 × 2 mm, commonly showing more greenish margins. In the marginal granodiorites the hornblende is not primary: it is anhedral and green rather than brownish-green and has cores of actinolite after clinopyroxene. Some crystals still contain clinopyroxene cores. The green hornblende is probably a late magmatic alteration of pyroxene, whereas the actinolite cores were probably formed by subsolidus alteration.

Allanite (euhedral, about 1 mm) is a common accessory phase. Other accessories include apatite, zircon, and opaques. Unlike the Jinden and Braidwood plutons, sphene is absent.

Evernden & Richards (1962) obtained a biotite K-Ar date of 390 Ma (i.e. 398 ± 13 Ma using the new decay constants) from GR 321568. A sample of marginal granodiorite collected during the present survey from GR 328458 was dated by K-Ar on biotite and a Rb-Sr biotite-whole-rock isochron. The K-Ar age obtained was 394 ± 6 Ma and the Rb-Sr age was 389 ± 8 Ma with initial $^{87}Sr/^{86}Sr$ ratio 0.7085. This suggests an Early Devonian age, like the Jinden and Braidwood plutons, but the rather high initial ratio for an I-type granitoid could mean that the isotopic systems were reset in the Early Devonian and thus a Late Silurian age is possible.

Chemical analyses of the Ballallaba Adamellite are given in the Appendix. Along its western edge the Ballalaba Adamellite intrudes the Ordovician strata and in the northeast it intrudes the Kadoona Dacite Member. Most of its eastern contact is faulted: along the high-angle-reverse Shoalhaven Fault it is thrown against the Toggannoggra Rhyolite Member, the Kain Porphyry, the Jinden Adamellite, and the Big Hole Formation. The pluton is not internally deformed, which indicates that it post-dates the cleavage in the Ordovician sequence. Thus the cleavage, at least west of the Shoalhaven Fault, is almost certainly pre-Devonian.

BRAIDWOOD GRANODIORITE (Dgb)

The first published account naming the granitic rocks of the Braidwood district was by Baker (1915) who used the term 'Braidwood red granite'. Joplin & others (1953) showed the approximate extent of the Braidwood Granodiorite (their 'Braidwood granite') on the 1st Edition Canberra 4 miles-to-1-inch Geological Sheet. They thought the body was Late Devonian or Carboniferous. Joplin (1963) presented an analysis of the Braidwood granite and Best & others (1964) refined its distribution. Vallance (1969) first recognised that the body consists mainly of granodiorite. Felton & Huleatt (1977) also stated that the main rock type is a hornblende-biotite granodiorite, but still used the term 'Braidwood Granite'. We here name the body the Braidwood Granodiorite but do not propose a type locality in this work as one should be selected near Braidwood in the BRAIDWOOD 1:100 000 Sheet area.

The Braidwood Granodiorite is a multiple intrusion occupying about 350 km^2 in ARALUEN and BRAIDWOOD. Two separate injections of magma of approximately the same composition can be distinguished. At several places along the boundary between the two phases there are narrow screens of Ordovician metasediments: at Frogs Hole Mountain (GR 475515) a screen about 200 m wide and 1200 m long is cut by aplitic dykes. At GR 506626 a metasedimentary screen 700 m long contains metadacite dykes which were probably feeders to the Long Flat Volcanics. They are hornfelsed to the assemblage: quartz-plagioclase (An_{35})-microcline-ferrosalite (pale-green)-sphene. Another small screen is present at GR 504645 and there is a sharp re-entrant at the southern end of the contact between the two phases. The boundary between the two phases has not been mapped in detail in BRAIDWOOD but our reconnaissance would put it through Braidwood township where a small screen of metavolcanics occurs, north to Brushy Hill (GR 563792) and then east to the eastern margin of the granodiorite near Mountain Ash Hill (GR 622800). Assuming this boundary, the eastern phase occupies about

365 km^2, of which 270 km^2 is in ARALUEN, and the western phase 225 km^2, of which 80 km^2 is in ARALUEN.

Both phases form abundant boulders and tors on the plateau in the north but in the dissected valleys to the southeast pavements and slabs are also common. On the floor of the Araluen valley outcrops are sparse and the granodiorite is commonly deeply weathered. The eastern and western phases are generally similar in appearance, both being medium-grained equigranular pale-grey rocks with about 15-20% mafic minerals. Plagioclase is commonly very pale-green and the potash feldspar, although mostly pale pink, is not abundant enough to give an overall pinkish tinge to the rock. In hand spoecimen the western phase can be distinguished from the eastern phase by the presence of acicular hornblende up to about 10 mm long. In the eastern phase the hornblende is always more equant and no more than 2 mm long.

Cognate xenoliths are common throughout, as rounded or discoid bodies up to 40 cm across. At GR 498383, in the bed of Appletree Creek, there are excellent exposures of granodiorite in which xenoliths comprise up to 50% (Fig. 2). The xenoliths are fine-grained and rich in mafics.

Apart from the normal hornblende-biotite granodiorite a number of other rock types are present. Near the centre of the eastern phase, around Fox Hill (GR 539580) the rock is more felsic (12% mafic minerals), coarser, relatively free of xenoliths, and an adamellite. Thin sections of specimens from GR 440437 and 429387 in the western phase show that these specimens are also adamellites, with about 15% mafic minerals.

Marginal tonalites from GR 513391, 601612, and 605616 contain about 25% mafic minerals, but most specimens from near the contact are mafic granodiorites with about 20% mafic minerals.

At GR 593615 a dyke-like body about 700 m long and up to 30 m across is exposed (Dmd). It ranges from pyroxene hornblendite to mafic quartz diorite and pegmatitic hornblende diorite. The body is surrounded by normal hornblende-biotite granodiorite.

Aplite dykes and leucogranite stocks have been mapped but are not nearly as abundant as in the Jinden Adamellite. Near Majors Creek, gold and sulphide mineralisation is present in east-trending pyritic aplite dykes and pyritised granodiorite. It is also associated with a leucogranite stock on the edge of the pluton. Aplite, leucogranite, and mineralisation are associated more with the western phase, probably because it crystallised from a more hydrous magma.

Of the 70 thin sections studied, most were from the *eastern phase*. The phase is zoned, with a relatively mafic margin and a relatively felsic core, total mafics ranging from 20% near the margin (25% in the rare marginal tonalites) to 12% in the core. Only the most felsic examples are adamellites. Average grainsize is 2-4 mm, though quartz and potash feldspar can be up to 6 mm in the adamellite. In the granodiorite plagioclase forms euhedral to subhedral, normally zoned prisms with broad cores rarely as calcic as An_{65}. The cores are surrounded by an oscillatorily zoned shell followed in most by a narrow rim of about An_{20}. Some plagioclase grains contain blebs of clinopyroxene up to 0.2 mm across included in cores that have mottled extinction. Rarely cores with clinopyroxene inclusions are less calcic than the immediately surrounding clinopyroxene-free plagioclase. A specimen from GR 530614 contains a plagioclase crystal with inclusions of orthopyroxene 0.1 mm across, the orthopyroxene surrounded by narrow reaction rims of clinopyroxene. This is the only occurrence of orthopyroxene we have observed in the Braidwood Granodiorite. Quartz and weakly

Fig. 2. Cognate xenoliths in the Braidwood Grnaodiorite, GR 498383. BMR neg. M2566/2A.

perthitic orthoclase are interstitial to plagioclase and mafic minerals, and commonly form irregular plates up to 4 m across.

Clinopyroxene was the earliest-formed mafic mineral. At a late magmatic stage it was partly altered to, and overgrown by, green hornblende and in most specimens only a few relicts still exist. The orthopyroxene-bearing rock from GR 530614 (see above) has had relatively little late-magmatic hydration and much of the original clinopyroxene is still preserved. In most examples, clinopyroxene that has survived the late-magmatic stage is commonly altered at a sub-solidus stage to intergrown pale-green actinolite and opaques. Thus actinolite cores surrounded by green hornblende rims are not uncommon. A specimen from GR 506644 contains scattered elongate prisms of clinopyroxene up to 10 mm long almost completely altered to intergrown actinolite and biotite. The presence of these prisms makes the rock appear like the western phase of the Braidwood Granodiorite in hand specimen. Biotite is the second-most common mafic mineral after green hornblende in the eastern phase, occupying between 5 and 8% of the rock. It is pleochroic from pale-yellow-brown to brown or red-brown and commonly forms overgrowths on magnetite grains. Magnetite is an early-crystallising, essential mineral, occupying about 3% of the rock; it is present as equant grains 0.5 mm across, commonly in mafic clots with biotite, hornblende, and clinopyroxene. Apatite prisms are invariably present as inclusions in the magnetite or clustered around magnetite grains if the grains are embedded in quartz or orthoclase. In most samples the magnetites are surrounded by a narrow rim of sphene, indicating they have equilibrated to low-temperature conditions through the expulsion of titanium from an original high-temperature titanomagnetite.

Interstitial sphene and allanite are late accessory minerals in the eastern phase. Sphene is the more common and occurs as subhedral grains up to 1 × 0.5 mm.

The eastern-phase adamellite from the centre of the intrusion differs from the granodiorite in that the hornblende is euhedral and primary, rather than after clinopyroxene. The hornblende has a characteristic brownish-green pleochroism in the Y direction that is absent from the green hornblende in the granodiorite. A few patches of intergrown green hornblende, calcite, biotite, and opaques may be after relict clinopyroxenes derived from the granodiorite. Sphene and less abundant allanite form euhedral early crystals in the adamellite rather than interstitial crystals.

Nine thin sections of xenoliths from the eastern phase were examined, most coming from the xenolith-rich outcrops at GR 498383. All the xenoliths are somewhat similar: they consist of either (1) subhedral crystals, 0.5 mm or less across, of plagioclase, clinopyroxene, biotite, opaqes, and apatite crowded in quartz and orthoclase plates or (2) subhedral crystals of plagioclase and opaques surrounded by interstitial green hornblende and sphene. Both textural types occur in different areas of the same thin section. Hornblende only rarely occurs embedded in quartz or orthoclase. Some thin sections are composed mainly of the first textural type, and clinopyroxene is common; others are composed mainly of the second textural type, and clinopyroxene is rare. Most xenoliths have scattered phenocrysts up to 4 mm across of slightly zoned plagioclase (An_{50-60}) with clinopyroxene inclusions.

The rare marginal tonalites from the eastern phase contain 25% mafics, mostly primary brownish-green hornblende and 5% red-brown biotite. Clinopyroxene and magnetite are accessory. Plagioclase occurs as euhedral stumpy prisms and quartz is interstitial. Allanite is a rare interstitial accessory. The presence in these marginal rocks of primary hornblende rather than clinopyroxene may be an indication of local contamination by external water.

Pyroxene hornblendite in the mafic dyke-like body (Dmd) at GR 593615 contains clinopyroxene up to 2 mm across, and sericitised plagioclase crystals embedded in poikilitic brown hornblendes up to 5 mm across with narrow brownish-green rims. Apatite prisms up to 1 mm long and opaques are accessory and calcite is a common alteration product associated with the sericitisation of plagioclase. More felsic rocks from the body are hornblende-quartz diorites with 35% mafics and are not unlike the marginal tonalites.

The *western phase* does not show the same zoning from mafic rim to felsic core as does the eastern phase, but more felsic (14% mafics) adamellites do occur at GR 429387 and GR 440437. The main difference between the eastern and western phase is their hornblende content. The western phase contains euhedral primary hornblende crystals up to 10 × 5 mm, pleochroic with X = pale-greenish-brown, Y = greenish-brown, Z = brownish-green. Most smaller hornblende grains have a similar pleochroic scheme but some specimens also contain small green hornblendes with clinopyroxene cores similar to those in the eastern phase. The large brownish hornblende crystals never contain clinopyroxene cores, but magnetite and apatite occur as inclusions in some of them. Sphene is relatively rare in the western phase and is everywhere anhedral-interstitial. Felsic minerals and biotite are similar in size and habit to those described in the eastern phase. The presence of primary hornblende in the western phase probably means that it was richer in water than the eastern phase. This may be significant in the distribution of aplite dykes and gold mineralisation in the Braidwood Granodiorite—both are more abundant in the western phase.

The Braidwood Granodiorite intrudes Ordovician and Late Silurian sedimentary rocks and the Late Silurian Long Flat Volcanics. It is overlain by the Late Devonian Gundillion Conglomerate at GR 433372. Chemical evidence (see Appendix) indicates that the Long Flat Volcanics are in part the extrusive equivalents of the Braidwood Granodiorite but were folded prior to the final emplacement of the Braidwood Granodiorite. The granodiorite is thus more likely to be Early Devonian than Late Silurian.

Two specimens of the Braidwood Granodiorite from GR 579627 and GR 463372, were dated isotopically. Biotite K-Ar ages from the two localities were 415 ± 4 Ma and 412 ± 4 Ma and the hornblende K-Ar ages 403 ± 4 and 401 ± 6 Ma respectively. Biotite-whole-rock Rb-Sr pairs gave ages of 399 ± 6 Ma with initial $^{87}Sr/^{86}Sr$ ratios of 0.7058 and 0.7059 respectively. Except for the biotite K-Ar results, the ages obtained are similar to others from the Bega Batholith, i.e. Early Devonian. The biotite K-Ar ages are anomalous and, on the basis of the 410 Ma age for the Silurian-Devonian boundary proposed by Wyborn & others (1982), are pre-Devonian.

No evidence has been found for the relative ages of the eastern and western phases. Theoretical arguments can be made depending on the origin of the extra water in the western phase. If the water was primary-magmatic the eastern phase would probably be the older. If it was meteoric or connate, then the western phase would probably be the older. An oxygen and hydrogen isotope study could possibly solve the problem.

NELLIGEN GRANODIORITE (Dgn)

The Nelligen Granodiorite is part of the Moruya Batholith, which extends from Nelligen south for 60 km to Bodalla. Griffin & others (1978) described it as compositionally straddling the granodiorite-adamellite boundary and containing about 5-6% biotite. Most of the pluton crops out in BATEMANS BAY, but about 5 km^2 occurs in ARALUEN, where it is overlain by Late Devonian sediments of the Merrimbula Group. Specimens of the pluton from ARALUEN are mostly adamellites, with 5% biotite and accessory magnetite, allanite, and apatite. The reader is referred to Griffin & others (1978) for a more detailed account of its geochemistry, and relationships with the other plutons of the Moruya Batholith.

MERRICUMBENE GRANODIORITE (Dgm)

Joplin & others (1953) first mapped granitic rocks in the Merricumbene area, but they used no name. Best & others (1964) used the name Merricumbene Granite for a body described as a leucocratic hornblende granodiorite.

The Merricumbene Granodiorite underlies most of the flat grassy area centred on Merricumbene beside the Deua River and is about 8.5 km^2 in area. The *type locality* is here given as tors up to 1.5 m high in the bed of the Deua River at GR 629410. The rock is white, medium-grained, and contains about 15% mafic minerals. Hornblende forms widely scattered euhedral prisms up to 10 mm long, oriented meridionally to give a primary foliation. The hornblende is pleochroic with X = pale-greenish-brown, Y = brownish-green, Z = green, absorption $X<Z<Y$. Reddish-brown biotite up to 1 mm across is slightly more abundant than hornblende and commonly contains rounded magnetite inclusions. Euhedral zircons and late interstitial sphene are accessory. Plagioclase forms euhedral stumpy prisms up to 4 mm displaying strongly oscillatorily zoned cores around An_{40-45} and narrow rims of An_{16-18}. Slightly undulose quartz and lesser perthitic orthoclase occur as anhedral interstitial plates up to 3 mm.

Elsewhere, the Merricumbene Granodiorite is very poorly exposed as rare, scattered, weathered boulders less than 1 m across, or as pavements in the bed of the Deua River. The outcrop is too poor to assess internal variation. At GR 624405 the granodiorite is cut by a northwest-striking dacite (hornblende-plagioclase) porphyry dyke. The hornblende has the same pleochroic scheme and is the same size as that in the granodiorite, and the plagioclase the same oscillatorily zoned An_{40-45} composition, but the narrow An_{16-18} rims are absent.

The Merricumbene Granodiorite from the type locality was dated by K-Ar on biotite and hornblende, and by Rb-Sr using a biotite-whole-rock pair. Biotite K-Ar gave 400 ± 6 Ma, hornblende K-Ar gave 369 ± 8 Ma and the Rb-Sr age was 394 ± 6 Ma with $^{87}Sr/^{86}Sr$ initial ratio of 0.7047. The ages (Early Devonian) are in accord with dates on the Moruya and Bega Batholiths, though the hornblende appears to have leaked argon. The initial ratio is close to those given by Compston & Chappell (1979) for Moruya Batholith plutons.

TALLAGANDA GRANODIORITE (Dgt), ROSSI GRANODIORITE (Dgr)

The Tallaganda and Rossi Granodiorites (new names) are part of a poorly known group of granitoids immediately west of the Mulwaree Fault extending from BRAIDWOOD through the southeast corner of CANBERRA and the northwest corner of ARALUEN, into MICHELAGO. The granitoids, along with the Ellenden Granite to the north (BRAIDWOOD) and the Gourock Granodiorite to the south, are strongly foliated, and Joplin & others (1953), applying an age connotation to the foliation, considered them to be Late Silurian. Felton & Huleatt (1977) and Richardson (1979) mapped but did not name them; they considered them to be related to the Boro Granite, and thus Early Devonian.

In ARALUEN the two plutons we have distinguished are in part separated by screens of Ordovician sediments. Both are strongly foliated biotite granodiorites that extend outside ARALUEN. In BRAIDWOOD and CANBERRA they are poorly delineated, but they are fairly well mapped in MICHELAGO.

The Tallaganda Granodiorite mostly lies in ARALUEN and MICHELAGO and probably extends for only about 1 km northwards into BRAIDWOOD. We define it here. The name is derived from Tallaganda State Forest which is partly underlain by the granodiorite. The pluton is elongated north-northeast, about 2 km wide, and over 14 km long. It occupies about 10 km^2 in MICHELAGO, 8.5 km^2 in ARALUEN, and probably less than 2 km^2 in BRAIDWOOD. The type locality is here designated as the bluffs about 3 m high on the southwest side of the Hilltop-Rossi Road at GR 293680. Here the granodiorite is strongly foliated (strike 030°, dip vertical) and contains dark discoid xenoliths flattened in the foliation plane.

The Rossi Granodiorite is named from the township of Rossi in BRAIDWOOD at GR 274730. It extends northward along the eastern edge of CANBERRA for 13 km where it intrudes gabbros of the 'Lockhart igneous complex' (Abell, 1981; 1982). Most of the pluton crops out in BRAIDWOOD, where its boundaries have not been delineated. We feel it is inappropriate to define the pluton until it is mapped in BRAIDWOOD and therefore give no type locality. In ARALUEN it is best exposed as tors up to 2 m high at GR 270684, on the very edge of the Sheet area. Immediately south of this exposure the granodiorite is cut by an east-trending dolerite dyke which is strongly foliated along with the granodiorite in a meridional direction. Thus the foliation was imposed after the emplacement of the east-trending dolerite dyke swarms in the area, which reach a maximum in the adjacent Ballallaba Adamellite.

The Tallaganda Granodiorite is a foliated quartz-rich rock with about 10% mafic minerals, mostly biotite. The biotite is reddish-brown and recrystallised into fine-grained schistose veins and patches and is commonly intergrown with epidote and lesser secondary sphene and opaques. Hornblende has not been identified in any specimens, but it may have been present in small amounts before deformation, the deformation altering it to epidote, opaques, and biotite. Quartz is composite, with a great range of internal grainsizes. Larger grains (5 mm) have undulose extinction and smaller grains have recrystallised into polygonal aggregates. Plagioclase is subhedral, up to 4 mm, and strongly sericitised and saussuritised. K-feldspar is present as uncommon microcline grains up to 1 mm with coarse patch, vein, and braided perthite lamellae. Euhedral allanite grains up to 1 mm are common accessories; they appear unaffected by the deformation, though they are commonly overgrown by epidote.

The Rossi Granodiorite in ARALUEN is slightly more mafic than the Tallaganda Granodiorite and has been more strongly recrystallised during deformation. Quartz is almost completely recrystallised into polygonal-grain aggregates about 0.2 mm across, though some undulose patches up to 1 mm are relicts from original igneous grains. Biotite has recrystallised into schistose veins and patches associated with epidote, sphene, and opaques, but in contrast to the Tallaganda Granodiorite the biotite is greenish (titanium-poor), epidote is coarser-grained and occurs as well-formed crystals, and sphene is more abundant. Plagioclase is clear rather than altered, but contains inclusions of well-formed epidote crystals suggesting a metamorphic recrystallisation. Primary opaques are rimmed by secondary sphene. Original igneous allanite is unaltered. Several specimens from around GR 268670 contain a few crystals of dark-blue-green hornblende up to 2 × 1 mm. The hornblende is either included in plagioclase or surrounded and penetrated by small flakes of recrystallised biotite. Perthitic microcline has undulose extinction and recrystallised margins; in contact with plagioclase it participates in the development of bulbous myrmekite.

The two plutons are probably the same age. The fact that they are deformed does not necessarily mean they are older than the adjacent undeformed Ballallaba Adamellite as they are separated from it by the major Mulwaree Fault, a fault likely to mark a strain discontinuity. All three plutons are intruded by east-trending dolerite dykes that are geochemically related to mid-to-Late Devonian mafic magmatism in the Comerong Rift Zone. These dolerite dykes are foliated in the foliated plutons and unfoliated in the unfoliated Ballallaba Adamellite. They provide evidence that the foliated plutons were deformed after the Late Devonian and therefore probably in the Carboniferous Kanimblan fold episode. The Rossi and Tallaganda Granodiorites are quartz-rich, like the Ballallaba Adamellite and related plutons of the Glen Bog Suite of I-type granitoids along the western margin of the Bega Batholith (Beams, 1980). They are therefore likely to be of similar age, i.e. Early Devonian.

Chemical analyses are given in the Appendix.

GOUROCK GRANODIORITE (Dgg)

The Gourock Granodiorite (new name) consists of strongly foliated and partly fault-bounded granitoid masses that crop out on the western edge of ARALUEN in the Gourock Range. The type locality is here given as the cluster of elongate tors up to 2 m high on the southern side of the firetrail at the head of Jerrabattgulla Creek, GR 272335. Here the rock is a medium-grained strongly foliated hornblende granodiorite. The pluton is elongated meridionally, being about 22 km long and less than 2 km wide. Total area of outcrop is about 14.5 km^2 (about 0.5 km^2 cropping out in MICHELAGO) divided between two separate bodies, a northern body of about 7 km^2 and a similar-sized southern body. Both consist of mafic granodiorite at their northern ends but towards the south in the northern body, around GR 265390, and south of GR 280305 in the southern body, foliated leucogranite is present. At the southern end of the northern body the leucogranite forms a number of meridional dykes; at the southern end of the southern body the rugged and inaccessible country precludes accurate mapping of the leucogranite contact.

The mafic parts of the Gourock Granodiorite are medium-grained foliated rocks similar to the Rossi and Tallaganda Granodiorites except that they are more mafic (colour index about 20) and contain more abundant hornblende. The hornblende is partly altered to biotite and epidote and is commonly fragmented into smaller grains embedded in a mass of biotite flakes. Hornblende entirely surrounded by quartz is much less altered and fragmented. The hornblende is commonly zoned, the cores pleochroic with X = pale-brown, Y = brownish-green, Z = green and rims of X = pale-brown, Y = green, Z = bluish-green. Smaller grains and fragmented grains have the latter pleochroic scheme, suggesting they have changed composition during deformation. Some small grains are distinctly bluish in the Z direction, indicating addition of alkalies during deformation. Biotite is only partly recrystallised by the deformation, unlike that in the Rossi and Tallaganda Granodiorites, which is totally recrystallised. The primary biotites are brown with greenish-brown rims and are bent and deformed, with gross undulose extinction. The green rims are surrounded by mosaics of smaller recrystallised brownish-green grains; recrystallisation is almost complete where hornblende is associated. Allanite forms widely scattered unaltered euhedral crystals up to 1 mm by 0.5 mm. It is not as common as in the Rossi and Tallaganda Granodiorites. Quartz forms large undulose grains with recrystallised margins and is cut by zones of recrystallisation that parallel the secondary foliation defined by schistose banding of mafic minerals. Some plagioclase grains still retain normal igneous oscillatorily-zoned cores (An_{40-45}) and narrow oligoclase rims, but others, with common epidote inclusions, and mottled, less calcic, cores are probably recrystallised grains. Perthitic K-feldspar is very rare in some rocks which would be called tonalites on their present mineralogy. However, this is probably a secondary effect caused by recrystallisation and the reaction

$$\text{K-feldspar} + \text{hornblende} + H_2O \rightleftharpoons \text{biotite} + \text{plagioclase}.$$

The original rock was probably a granodiorite.

The leucogranites of the Gourock Granodiorite are medium-grained (2–4 mm, with recrystallised quartz patches up to 8 mm) and contain less than 5% recrystallised greenish-brown biotite. Perthitic microcline is abundant and hornblende is absent, whereas plagioclase is much less common than in the granodiorite. Allanite is a rare accessory and epidote a common alteration product.

The leucogranites are just as deformed as the granodiorites, based on the degree of recrystallisation of quartz, but because of the lack of abundant biotite the rock does not possess the well developed schistose foliation of the granodiorite.

The Gourock Granodiorite, like the foliated plutons to the north, is cut by foliated dolerite dykes, so similar arguments about its age can be used. Thus it is likely to be Early Devonian in age and to have been deformed in the Carboniferous. Although the degree of deformation in the Gourock Granodiorite, based on quartz recrystallisation, is as great as in the Rossi Granodiorite and Tallaganda Granodiorite to the north, other minerals are less recrystallised. Biotite is generally only bent and is still brown rather than brownish-green; some plagioclase grains retain igneous zoning, and epidote crystals are less well formed. These criteria suggest that the temperature was lower to the south during deformation. Indeed further south still, in the Anembo Granodiorite, the degree of deformation is much less as well, though a secondary foliation is still easily recognisable.

Isotopic dating was carried out on a sample of Gourock Granodiorite from GR 261410. The sample yielded a K-Ar biotite age of 373 ± 6 Ma and a biotite-whole-rock Rb-Sr isochron age of 380 ± 6 Ma. Both these dates are probably somewhat younger than the true age, since deformation has partly reset the isotopic systems. The $^{87}Sr/^{86}Sr$ initial ratio of 0.7103 is high for an I-type granitoid, again suggesting resetting. The ages recorded by the isotopes are presumably somewhere between the intrusive age in the Early Devonian and the deformation age in the Carboniferous, and as such do not necessarily indicate a particular geological event.

Chemical analyses are given in the Appendix.

ANEMBO GRANODIORITE (Dcj)

The Anembo Granodiorite crops out over about 220 km^2 in the southeast of MICHELAGO, and occupies only about 7.5 km^2 in the southwest of ARALUEN. It was named by Richardson (1979) after the village of Anembo in MICHELAGO and she nominated as type locality a road-cut just south of Anembo at GR 191335.

In ARALUEN the Anembo Granodiorite crops out as abundant large grey tors up to 15 m high, in a rugged and heavily forested area at the southern end of the Gourock Range. The rock is typically a slightly foliated, medium-to-coarse biotite-hornblende granodiorite, which becomes more strongly foliated close to its contact with Ordovician country rock.

Hornblende forms about 10% of the rock and is often fragmented to smaller grains and partly or completely altered to biotite and epidote. When unaltered it is pleochroic and comonly slightly zoned (X = pale-brown, Y = brownish-green, and Z = green). Biotite forms 10-15% of the rock, and is relatively unaffected by deformation, unlike biotite in granitoids further north along the Gourock Range. Some crystals, however, are surrounded by a mosaic of very small biotite crystals. Allanite is also present as scattered unaltered euhedral crystals up to 0.5 mm across, with a frequency of one or two crystals in each thin section.

About 25-30% quartz is present as large grains with recrystallised margins and undulose extinction. Plagioclase also forms 25-30% of the rock; it forms large (to 5 mm) euhedral crystals commonly oscillatorily zoned with cores of An_{40-45} and narrow rims of about An_{15}. Microcline forms about 10-15% and shows typical cross-hatched twinning. Both plagioclase and microcline crystals can show minor effects of deformation by way of a mosaic of very small crystals around their rims.

The Anembo Granodiorite is thought to be the same age as the granitoids further north in the Gourock Range, that is, Early Devonian, even though the effects of deformation are much less. Chemical analyses are given in the Appendix.

EURANBENE ADAMELLITE (Dae)

The Euranbene Adamellite (new name) is a coarse-grained felsic intrusive occupying forested country east of Pykes Saddle (GR 310145) and extending for an unknown distance into COBARGO. The type locality is here given as the rubbly boulders beside the firetrail at GR 342141. The adamellite is poorly exposed and mostly highly weathered. At the type locality it contains about 5% dark minerals (biotite, chloritised biotite, and epidote), partly sericitised plagioclase, microcline, and composite quartz. Secondary muscovite is associated with the partly altered biotite. Grainsize of the felsic minerals is 5-8 mm. The quartz grains are distinctive in hand specimen and resemble those in the Ballallaba Adamellite. We thus relate it to this body rather than the adjacent Jinden Adamellite. No definite age relationships with the Jinden Adamellite were found, but the shape of the Eurambene Adamellite suggests that it was intruded by the Jinden Adamellite.

UNNAMED GRANITOIDS AND APLITIC GRANITES (gm)

Several small unnamed granitoids crop out in ARALUEN, and are briefly described below.

Adamellite porphyry at GR 322181. This elongate body of 0.3 km^2 consists of rock with 30% phenocrysts of quartz, plagioclase, and recrystallised mafics 2 mm across in a microgranitic groundmass with average grainsize of 0.3 mm. The plagioclase phenocyrsts are strongly zoned, with An_{55} cores and An_{25} rims. Both biotite and hornblende are present and the colour index is 6. The rock is similar to porphyritic types in the adjacent Jinden Adamellite and is probably related.

Adamellite porphyry at GR 299140. This body is similar to that described above but is coarser. Phenocrysts (50%) of quartz (6 mm), plagioclase (4 mm), slightly recrystallised biotite (3 mm), and brownish-green hornblende (1 mm) are embedded in a microgranitic groundmass with average grainsize of 0.5 to 1 mm. Colour index is 8. The rock is probably related to the Jinden Adamellite.

Adamellite porphyry at GR 451143. This elongate body 1 km long is remote from any large granitoids. It contains phenocrysts (50%) of quartz (4 mm), plagioclase (4 mm) with strong oscillatory zoning (An_{50-15}), orthoclase (4 mm), and red-brown biotite (2 mm) in a microgranitic groundmass with 0.5 mm grainsize. Amphibole is absent except for rare pale actinolitic inclusions in the cores of plagioclase phenocrysts. Colour index is 5.

Adamellite porphyry at GR 431273. This body, which is 500 m across, is very similar to the body at GR 451143. It has phenocrysts (60%, up to 5 mm across) of quartz, strongly zoned plagioclase, and orthoclase in a microgranitic groundmass (0.3 mm). Colour index is 3, the main mafics being biotite, magnetite, and allanite.

Microgranite at GR 542126. This oval body, 200 m long, has an average grainsize of about 0.5 to 1 mm and colour index of 12. Hornblende is absent. The rock may have been hydrothermally altered, as much of the orthoclase is altered to muscovite rosettes and the biotite is highly chloritised.

Aplitic granite bodies are associated with the three main I-type granitoids in ARALUEN — the Ballallaba and Jinden Adamellites and the Braidwood Granodiorite. They are most abundant in the Jinden Adamellite and these have been described. Leucogranites associated with the Ballallaba Adamellite are larger than those in the Jinden Adamellite and occur near its margins.

Aplitic granite bodies associated with the Braidwood Granodiorite occur east of Gundillion, near Majors Creek (GR 478608) and at GR 588606 and GR 503638. The body east of Gundillion occupies 3 km^2 and is nonconformably overlain by Late Devonian sediments. The body at GR 478608 is associated with east-trending gold-bearing aplite dykes within the Braidwood Granodiorite.

All the aplitic granites are quite similar as they are all allotriomorphic-equigranular, with only 1 or 2% biotite. Some also have graphic quartz and orthoclase intergrowths. Grainsize ranges from 2 mm in some to 0.1 mm in smaller bodies, though most are about 0.5 to 1 mm. Magnetite, epidote, and, in a few bodies, muscovite, are accessory minerals.

Leucogranites north of Monga are similar to the leucocratic parts of the Monga Granite and are therefore probably Late Devonian.

THE EDEN-COMERONG-YALWAL RIFT ZONE

COMERONG VOLCANICS

The name Comerong Volcanics was first used by Best & others (1964) for a meridional belt of felsic and basic volcanics mapped by McElroy & Rose (1962) in the Monga area and further north. These rocks were shown by Best & others to extend southwards, through the eastern part of ARALUEN. The volcanics are part of a belt of mid-to-Late Devonian volcanics—overlain by the Late Devonian sedimentary Merrimbula Group — that have long been correlated with similar volcanics in the Eden area (Brown, 1933). More recently, McIlveen (1975) made a stratigraphic, tectonic, and mineral-assessment study of all the associated rocks and introduced the structural term 'Eden-Comerong-Yalwal Rift Zone' and the palaeogeographic term 'Budawang Volcanic Rift'. As we show (page 20) that the zone is not purely volcanic, but that granitic and gabbroic intrusives are also involved, and as the term 'Budawang Synclinorium' (Rose, 1969) has already been used as a structural term, we do not favour the use of the term 'Budawang Volcanic Rift'. Instead we suggest that the term 'Eden-Comerong-Yalwal Rift Zone' should be retained, but as a palaeogeographic term. For simplicity, as the area we mapped is part of the Comerong zone, i.e. the central part of the Eden-Comerong-Yalwal Rift Zone, we use the term 'Comerong Rift Zone'. Evidence that the Merrimbula Group should not be included in this zone, but is part of a later palaeogeographic domain, is given on page 28.

In ARALUEN the Comerong Volcanics can be subdivided into two phases—an extensive rhyolitic phase and a more restricted basaltic phase that overlies the rhyolite and in places is interbedded with fine-grained sedimentary strata. Although the basalt everywhere overlies the rhyolite in ARALUEN, this is not the situation everywhere in the rift zone. McElroy & Rose (1962) report basalt at the base of the rhyolite near the junction of Belowra and Yadboro Creeks in ULLADULLA and Fergusson & others (1979) describe basalt and rhyolite intimately associated near Eden. We have also mapped a unit of basalt during the reconnaissance mapping in BATEMANS BAY that is at the base of the sequence in some places and is both underlain and overlain by rhyolite in others. Thus the basalt and rhyolite do not form separate stratigraphic units, but were intimately associated as a bimodal suite.

Rhyolite (Dmr)

Rhyolite is the most widespread rock type associated with the Comerong Rift Zone. Meridional belts have been preserved along either side of the Merrimbula Group that has been downfolded into the rift zone during the Carboniferous Kanimblan fold episode. The thickness belt is preserved east of the Donovan Fault, where rhyolite lava and lesser ignimbrite, probably over 1000 m in total thickness, are excellently exposed in rocky hills, cliffs, and gorges. Extensive areas north of Bendethera are also formed of rhyolite which is identified as Comerong Volcanics, mainly on petrographic and geochemical evidence. Marginal to this area of rhyolite north of Bendethera are belts of coarse volcanic breccia (Dma). At GR 426265 the breccia appears to be interbedded with Silurian sediments, but the apparent interbedding could be interpreted as sediments cut by an intrusive tuff-breccia or tuffisite. The presence in the area northwest of Bendethera of extensive, coarse volcanic breccia up to 100 m thick with fragments up to 30 cm across indicates that this area was a major eruptive centre even though it is about 20 km west of the main axis of the Comerong Rift Zone. In most areas the rhyolite is no more than openly folded or tilted even along the bounding faults of the rift zone. However, along the Deua River north of Bendethera homestead steep dips in the rhyolite are revealed by eutaxitic layering, and the presence of several tight folds is indicated by the outcrop trace of the base of the rhyolite.

Sixty-three thin sections of rhyolites were examined petrographically. By far the most common rock type is a lava with devitrified glassy groundmass and less than 5% phenocrysts. Most specimens have only 2-3% phenocrysts. Beta quartz (0.5-1 mm) and albite (1 mm by 0.5 mm) make up most of the phenocrysts. The quartz is commonly corroded and rounded, and the albite contains alteration patches of sericite or calcite. Where calcite is absent fluorite patches up to 0.2 mm are common in the albite. One specimen from GR 523199 contains fluorite patches rimmed and partly replaced by calcite within albite phenocrysts and also a little fluorite rimmed by calcite in the groundmass. Fluorite is also common in the groundmas of most specimens that do not contain calcite alteration. The widespread development of calcite alteration, particularly within albite, suggests that albite is not the primary plagioclase composition but that a more calcic plagioclase has been altered to albite-plus-calcite, perhaps during metamorphism associated with Carboniferous deformation. Burial metamorphic minerals are abundant in the basalts of the Comerong Volcanics (see below). Where plagioclase is sericitised rather than altered to albite-plus-calcite it is commonly completely replaced by sericite, such as at GR 633464, 653632, and

438270. At only one locality (GR 582343) are primary plagioclase phenocrysts preserved; these grains were slightly zoned around An_{40} to An_{30}.

Apart from quartz and plagioclase, other phenocrysts present in the rhyolites are altered pyroxene, opaques, zircon, apatite, alkali feldspar, and biotite. Altered pyroxene is a rare phenocryst phase in about 50% of the samples studied. Octagonal outlines testify to the original character of the crystals. Grains are up to 1 mm across and altered to green biotite or chlorite plus opaques and, where calcite alteration is present in the rest of the rock, a dark, high-relief carbonate—possibly siderite or ankerite. Opaques (0.3 mm) and euhedral zircons (0.05 to 0.1 mm) are present in all specimens, commonly in association. Both are commonly moulded onto the edges of plagioclase phenocrysts. Apatite prisms (0.1 × 0.03 mm) are also associated with some opaques and zircons. Although most zircons are equant, some are needle-like and up to 0.3 mm long. The comparatively high zircon content of these rhyolites and the common presence of fluorite distinguish them from the Silurian Togganoggra Rhyolite Member. Rarely the rhyolites contain phenocyrsts of unmixed alkali feldspar (about Or_{60}-Ab_{40}) up to 5 mm across. These are particularly abundant in a quartz-feldspar porphyry (Dmq) (30% phenocrysts) beside the Merricumbene Fire Trail at GR 591290. Float of this distinctive rock is common in the large tributary that joins Oulla Creek at GR 619315, so the rock body is probably more extensive than shown on the map. Quartz (4 mm), albite (2 mm), and chloritised biotite (1 × 0.5 mm) are also present in this porphyry, which is also present around GR 440215 in Con Creek. Here the rock has about 30% phenocrysts of quartz (4 mm), albite (2 mm), and chloritised biotite (1 × 0.5 mm), but alkali feldspar phenocrysts are absent.

The groundmass of the lavas consists of glass devitrified in patches up to 0.5 mm across. Some pinkish rocks have micrograntic or granophyric groundmasses. Banded lavas are present at GR 439246 and 523199, different bands several millimetres thick showing different degrees of devitrification. Ignimbrite and volcanic breccia account for about 20% of the thin-sections studied. Welded and devitrified glass shards, pumice fragments, lava fragments, broken crystals (quartz and albite), and lithic fragments are present in these rocks. Crystals commonly form about 5% of the ignimbrites, probably slightly more than in the lavas, indicating some crystal enrichment during ignimbritic eruption (Walker, 1972). The ratio of thin sections (80% lavas, 20% fragmentals) from the Comerong Volcanics is probably not a true indication of the actual proportions since the lavas tend to be fresher and form better outcrops. We would estimate that about 50% of the rhyolite is lava.

The rhyolite of the Comerong Volcanics is almost certainly the extrusive equivalent of the Late Devonian A-type granites associated with the Comerong Rift Zone (see pages 19–22). Although the rhyolite is only in contact with these granites along the Donovan Fault, the intrusive contact of the Mongamula Adamellite is within 250 m of outcrops of the rhyolite and separated from it by a belt of Ordovician sediments. The presence of fluorite in both the granite and the rhyolite and very similar chemical features (high Zr, high Na + K, low Sr) argue for coeval volcanism and plutonism.

Chemical analyses are given in the Appendix.

Basalt (Dmb)

There are three separate areas of basalt:

(1) The main exposures near Monga, north and west of Clyde Mountain, form a north-northeast-trending belt over 1 km wide extending into BRAIDWOOD at leat as far as GR 695730 (6 km NNE of the sheet boundary). To the south the basalt is faulted out by the Mongarlowe Fault, the western fault bounding the Comerong Rift Zone. Dips in the overlying Merrimbula Group are about 30–50° to the east, so a maximum total thickness of the basalt at Monga is about 750 m. Minor warping within the basalt could considerably reduce this estimate. Interbedded sediments have only been seen in the top 10 m, in a roadcut at GR 659620 where basalt overlies a bed of red siltstone and is in turn overlain by more red siltstone below the basal conglomerate of the Merrimbula Group. The siltstones could be fossil soil horizons. No bedding or cooling structures have been observed in the basalt, but vesicles and amygdales up to 10 mm across are abundant in places.

(2) At GR 680517 fine-grained aphyric basalt overlies rhyolite in a band about 30 m thick and is in turn overlain by a thin conglomerate at the base of the Merrimbula Group. Weathered siltstone is interbedded.

(3) In the Quart Pot Creek area a belt of interbedded basalt and fine clastics (Dms) extends over a strike length of about 3.5 km. It is overlain, possibly unconformably near GR 665435, by basal Merrimbula Group conglomerate and fossil soil, and passes down into rhyolite through rhyolitic tuff and reworked tuff. Maximum thickness is about 200 m in Quart Pot Creek. The clastics are mainly fine-grained grey to black cherty siltstone and mudstone with rare thin sandy beds. At GR 667450 pillow lava (pillows 20–30 cm across) is exposed in the bed of Quart Pot Creek.

Basalt in the Monga area contains altered olivine commonly 0.3–0.5 mm across and rarely up to 1 mm across. The alteration products are mainly chlorite and serpentine with opaque rims, but in some rocks the olivine is iddingsitised while in others sphene and quartz locally accompany chlorite and opaques. Plagioclase occurs as felted microlites up to 1 mm long. In samples from around GR 656627 the plagioclase is albitised and there is a complementary development of Ca-bearing low-grade metamorphic products including prehnite, pumpellyite, calcite, epidote, and sphene. These minerals and quartz commonly fill amygdales up to 10 mm across. Where the plagioclase has not been albitised, such as at GR 654625, 653615, 662626, and 656633, it is zoned from An_{70} to An_{50}. Overall, rocks with fresh plagioclase appear to dominate over those with albitised plagioclase in the Monga area, but there is no clear-cut metamorphic zone boundary that can be traced through the area. Rarely some rocks show signs of partial albitisation such as a rock from GR 662626 which is diffusely veined by pumpellyite alteration. In the altered zones plagioclase is pseudomorphed by albite-plus-pumpellyite, whereas between the veins it is still primary.

Clinopyroxene, opaques, and chloritised glass make up the rest of the basalt in the Monga area. The clinopyroxene ranges from interstitial grains 0.5 mm across to strongly ophitic grains 2 mm across. In some rocks, which are most commonly richer in olivine, the clinopyroxene is only weakly pleochroic, but in other olivine-poor rocks the clinopyroxene is pleochroic in shades of pink. Zoning is strong with pale-pink cores and dark-pink rims. These pink clinopyroxenes are titanium-rich and the trend from Ti-poor olivine-rich rocks to Ti-rich olivine-poor rocks is typical of low pressure fractionation of titanium enrichment accompanying iron enrichment in titanium-rich olivine tholeiites. Bladed ilmenite up to 1 mm long is present in all samples. Up to about 30% of most rocks consists of a groundmass of fine chlorite, interpreted as a replacement product of an original glassy groundmass. Granular epidote and sphene, prehnite, and pumpellyite accompany the chlorite in the albitised rocks. One albitised rock from GR 655628 contains a little quartz, in the groundmass and partly replacing olivine; the quartz is an alteration product and does not necessarily mean the basalt was oversaturated.

Basalt from the same belt as that at Monga was sampled in BRAIDWOOD around GR 692699, where there are excellent exposures in a gorge formed by Currowan Creek. The basalt is similar to that at Monga, being a titaniferous olivine tholeiite (not albitised). Several specimens from the area are coarsely porphyritic, containing plagioclase phenocrysts up to 10 × 1 mm, zoned from An_{70} to An_{40}.

The basalt cropping out at GR 680517 consists of plagioclase laths (not albitised) up to 1 mm long set in subophitic clinopyroxene (0.5 mm) and chlorite after glass. Olivine is absent and there is a little interstitial quartz present up to 0.1 mm across.

In the Quartz Pot Creek area the basalt is mostly albitised. The same Ca-bearing minerals have developed at Monga, but are not as conspicuous. Ophitic clinopyroxene, commonly titaniferous, envelops the albite, and chloritised glass with a little sphene, epidote, prehnite, and pumpellyite makes up the groundmass. One specimen from GR 669449 contains abundant granular hydrogrossularite in the groundmass. Olivine pseudomorphs are absent in basalt in the Quart Pot Creek area and groundmass quartz is quite common. Although the quartz may be an alteration product associated with albitisation, the basalt of this area may be oversaturated, in contrast to that near Monga. Only one specimen was not albitised—from the core of a pillow lava: it consists of plagioclase laths (An_{60-70}) in a great range of sizes up to 3 mm long, in a groundmass of chlorite, opaques, sphene, epidote, and quartz. Olivine and clinopyroxene are absent.

Basalt of the Comerong Volcanics can be grouped with gabbroic and granophyric intrusive rocks associated with the Comerong Rift Zone (Donovan Basic Complex and associates), and with the dolerite dyke swarms which are widespread west of the Comerong Rift Zone (especially within the Ballallaba and Jinden Adamellites) to form a well defined association characterised by low-pressure fractional crystallisation (analyses given in the Appendix). Tholeiitic iron enrichment is well developed, but the association is also enriched in incompatible elements such as K, Rb, P, Ti, Zr, Nb, and rare earths, indicating that it is transitional into alkali basalt (Coombs, 1963). Although McIlveen (1975) compared the magmatism of the Comerong Rift Zone with that associated with extensional tectonism in the Basin and Range Province of the western United States (Christiansen & Lipman, 1972), basalts are mainly alkaline in that province (e.g. Christiansen & McKee, 1978; Duffield & others, 1980). Perhaps a better magmatic analogy is the Afar Rift of Ethiopia, where basaltic volcanism is of the transitional type (Barberi & others 1975; Bizouard & others, 1980).

Chemical analyses are listed in the Appendix.

MIDDLE TO LATE DEVONIAN INTRUSIVES ASSOCIATED WITH THE COMERONG RIFT ZONE

Two groups of basic intrusives form part of the magmatism associated with the Comerong Rift Zone. These are (1) the irregular and stock-like intrusives (Dg) including the Donovan Basic Complex, and (2) the dolerite dykes.

Donovan Basic Complex

This complex, exposed over an area of 2.3 km^2, intrudes and is surrounded by rhyolite of the Comerong Volcanics. Recrystallisation of the rhyolite is evident in thin-sections from samples within 100 m of the contact. The complex is centred on Mount Donovan (GR 608281). It is compositionally zoned from bottom to top. At the lowest part on the northern side (GR 601285) the rock is a fine-grained two-pyroxene gabbro with about 5% opaques and 50% zoned plagioclase (An_{60-30}). Orthopyroxene (up to 1 × 0.5 mm) is the main pyroxene at this level. It is mostly altered to bastite, but fresh colourless cores are preserved in some grains. Clinopyroxene forms subophitic grains up to 2 mm, some cored by orthopyroxene. Interstitial apatite and zircon up to 1 mm long, a little interstitial graphically intergrown quartz and orthoclase, and minor red-brown biotite make up 5%. Chlorite, calcite, and rutile are common alteration products. At higher elevations, around the saddle at GR 603282 the grainsize is the same (around 1 mm), orthopyroxene is less abundant and entirely altered, clinopyroxene, euhedral apatite (4%), opaques (10%), and zircon are more abundant, and the clinopyroxene is more euhedral and slightly pink (titaniferous). The rock is here a two-pyroxene magnetite gabbro. Above the saddle on the slopes of Mount Donovan, opaques and apatite are less abundant, orthopyroxene is absent, plagioclase becomes less common at the expense of graphically intergrown quartz and orthoclase, zircon continues to increase in abundance, and clinopyroxene forms elongate prisms rimmed by blue-green amphibole. The rock here is a quartz gabbro or quartz monzogabbro. At the summit the rock is a pyroxene granophyre of granodioritic composition. Clinopyroxene forms acicular crystals up to 20 × 0.2 mm (i.e. an axial ratio of 100). Finely intergrown quartz and orthoclase make up about 40% of the rock, while a few homogeneous crystals of quartz and orthoclase are surrounded by graphic intergrowths of the two minerals. Plagioclase prisms (2 × 1 mm) are strongly zoned, but their composition is optically indeterminate as albite twinning is rarely present. Zircon with perhaps baddeleyite is most abundant in this part of the intrusion, forming 0.4% of the rock (based on Zr analyses—Appendix). It occurs as needles up to 2.5 mm long and as skeletal prisms averaging 0.3 mm across. Apatite is less abundant here than lower in the intrusion, but still forms prisms up to 1 mm. Secondary rutile is common. At GR 606281, about 100 m northwest of the summit trig, the pyroxene granophyre is intruded by a fine-grained (0.5 mm) leucocratic granophyre dyke 2 m thick consisting of quartz and orthoclase (70%), zoned plagioclase, chloritised pyroxene, and zircon needles (0.2%). Calcite is a common alteration product of plagioclase and is present lining miarolitic cavities. One cavity contains fluorite surrounded by calcite.

Although these compositional changes can be interpreted as being due to either concentric (vertical) zoning or horizontal layering, a horizontal layering is suggested by the presence of fractionated granophyric rocks near the western margin at GR 598281. Here the contact reaches its greatest elevation.

The large compositional variation in the Donovan Basic Complex makes it ideal for dating by the Rb-Sr whole-rock isochron method. Seven samples were analysed by AMDEL for Rb-Sr, yielding a model-3 isochron with mean square of weighted deviates of 4.0, indicating residual variance beyond that due to experimental error. The isochron gives an age of 355 ± 13 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7066 ± 0.0008. The date is in accord with the complex being part of the Comerong Rift Zone magmatism. The slightly high initial ratio for a mantle-derived magma combined with the high MSWD could indicate that the age of intrusion is a little older than 355 ± 13 Ma.

Chemical analyses are listed in the Appendix.

Other basic stocks and a sill (Dg)

Six minor intrusions similar in composition to parts of the Donovan Basic Complex have been mapped, and are presumed to be the same age. One is an olivine gabbro sill intruding the De Drack Formation and Comerong Volcanics east of Deua Trig (GR 424257). The sill is almost 4 km long and 200 m thick. It is medium-grained and contains fresh plagioclase (An_{65-40}), ophitic clinopyroxene up to 5 mm, up to 10% olivine (fresh at GR 438245 and 437239) and blades of ilmenite up to 1 mm. Some altered grains could be after both olivine and orthopyroxene. The other five intrusions differ widely in size but all are transgressive; they are at GR 623310, 595280, 561335, 550325, and 619388. All are similar to the fractionated granophyric parts of the Donovan Basic Complex, being composed of plagioclase, graphic intergrowths of quartz and orthoclase, chloritised pyroxene, magnetite, zircon, and apatite. Chlorite, calcite, epidote, and rutile are common alteration products. Presumably more basic parts of these stocks occur at depth.

Dolerite dykes

Dolerite dykes are abundant in many areas and are particularly noticeable in the granitic plutons, though they have been found in all rock units older then the Minuma Range and Merrimbula Groups. Their apparent abundance in the granitic plutons is probably partly due to a favourable joint system but they are also easier to recognise in granitic areas because of the contrast in outcrop pattern. Dykes are most abundant in the Ballallaba Adamellite and the south central part of the Jinden Adamellite. Almost all the dykes in these two granitoids, and in the other granitoids in the western part of ARALUEN strike east or slightly south of east, whereas dykes near the margins of the Comerong Rift Zone are mostly meridional. If all these dykes are the same age a change in orientation of the principal stress direction is implied. Similar east-striking dykes are present in MICHELAGO (Richardson, 1979; Hayden 1980) and extend as far west as Googong Dam near Queanbeyan. Many of the larger dykes are over 30 m thick and appear to be steeply dipping. The longest dyke has been traced continuously within the Ballallaba Adamellite for over 10 km, and at least half a dozen dykes nearby are over 5 km long. Probably many small dykes are concealed by soil. Good exposures in a creek section perpendicular to the dyke orientation at Sheepstation Creek (GR 385670) give some idea of their possible extent within the Ballallaba Adamellite. Here thirteen dykes are exposed with a combined thickness of 145 m (average 11 m, range 2–30 m) along a 1.5 km section. Thus the dykes occupy 10% of the area, implying 10% meridional extension during dyke intrusion.

Fifty-seven thin sections of dolerite dyke rocks have been examined. Most are even-grained with average grainsize ranging from 0.3 to 1 mm. The dykes are composed mainly of euhedral zoned plagioclase (An_{70-40}) and anhedral clinopyroxene. In most specimens the clinopyroxene is subophitic and about 0.5 to 1 mm across, but in some (e.g. GR 313654, 371687, 346226) the clinopyroxene is ophitic and up to 4 mm. Most clinopyroxene is very pale-pink and weakly pleochroic, indicating moderate titanium content, but some samples have dark-pink pleochroic titaniferous clinopyroxene. Samples carrying titaniferous clinopyroxene are particularly common close to the Comerong Rift Zone (e.g. GR 590191, 595271, 549227), but equally titaniferous clinopyroxene is present further west (e.g. GR 357243, 269230, 380141). Titaniferous clinopyroxene does not appear to be present in dykes in the Ballallaba Adamellite. Almost all dykes contain an altered mafic mineral that crystallised earlier than clinopyroxene—either olivine or orthopyroxene or both. These grains are altered mainly to chlorite and serpentinite, but also to quartz, actinolite, calcite, epidote, and sphene. Rarely, altered grains in some samples have acute double terminations indicative of olivine (e.g. GR 369153, 346226), but mostly the alteration masks the original crystal shape. As orthopyroxene is present in the Donovan Basic Complex which is thought to be of a similar age to the dykes, both orthopyroxene and olivine could have been present in many dolerite samples. A little late brown or greenish-brown hornblende rims clinopyroxene in some specimens (e.g. GR 354582, 382667, and particularly 499650), a little late biotite is present in others (e.g. GR 371684, 313654, 339655), and a little interstitial quartz is common in most, particularly dykes intruding the Ballallaba Adamellite. Dykes containing titaniferous clinopyroxene rarely contain interstitial quartz. Thus, as in the basalts in the Comerong Volcanics, both oversaturated and slightly undersaturated liquids were probably present. Opaques are abundant (5–10%) in most specimens, magnetite, bladed ilmenite, and pyrite being identified; pyrite is prominent in hand specimens.

Although most dykes are even-grained, a few are porphyritic in plagioclase. Dykes at GR 336678 and 386656 contain 25% plagioclase phenocrysts up to 5 × 10 mm. A fine-grained dyke at GR 528461 contains 5% plagioclase (An_{80}) phenocrysts up to 5 mm, and another at GR 369153 has about 10% plagioclase phenocrysts (2 × 1 mm) and 2% altered olivine phenocrysts (1 mm).

Dykes from the foliated granitoids west of the Mulwaree Fault (Rossi, Tallaganda, and Gourock Granodiorites) have a similar orientation to those immediately east of the Fault (though those in the Gourock Granodiorite trend northwest rather than meridionally), and are thus likely to be the same age. These dykes are foliated along with the granitoids and thus indicate that the deformation that gave rise to the foliation was later than the dykes. The dykes contain plagioclase, actinolite, and opaques. Plagioclase is zoned (An_{70-30}), as in dykes east of the fault, but clinopyroxene has been entirely altered to a fine-grained intergrowth of actinolite. The plagioclase crystals are not strained or broken; flattening has been achieved entirely within the actinolite intergrowths and by realignment of plagioclase crystals.

The dykes are younger than the Early Devonian I-type granitic intrusions. They also intrude the probably Middle to late Devonian A-type Coondella Creek and Mongamula Adamellites, but have not been observed to intrude rhyolite of the Comerong Volcanics, the A-type Monga Granite, or the Merrimbula or Minuma Range Groups. Although several ages of dykes are possible, the overall similarity in composition, despite a range from slightly oversaturated mainly in the northwest to slightly undersaturated near the Comerong Rift Zone, indicates generation at much the same time. Chemical analyses (Appendix 1) show close similarities to the basalt of the Comerong Volcanics and to the least fractionated rocks of the Donovan Basic Complex. A mid-to-Late Devonian age is therefore probable, and this fits the stratigraphic constraints. A relatively fresh specimen from GR 346226 was dated by the whole-rock K-Ar method at 338 ± 5 Ma. This Early Carboniferous date suggests leakage of argon, perhaps during the Kanimblan fold episode.

Chemical analyses of some of the dolerites are contained in the Appendix.

Monga Granite (Dmg)

The Monga Granite was first recognised and named by Best & others (1964), who described it as a hornblende-biotite granite. The name is valid and is retained here. Monga is a small timber-milling village at the northeastern corner of the pluton.

The type locality is here designated as the bouldery outcrops of dark-pink medium-grained alkali granite beside the fire trail at GR 616561. The granite here is typical of most of the Monga Granite, though the dominant mineral, alkali feldspar, is unusually dark pink. Chloritised mafics occupy 7% of the rock and 15% greenish plagioclase is present.

The Monga Granite occupies an area of 23.5 km^2 southwest of Clyde Mountain where it underlies much of the Monga State Forest west of the Mongarlowe River. The pluton is truncated along its eastern side by the Mongarlowe Fault and cut internally by the Jembaicumbene Fault and a branch fault along McCarthys Creek. In most of the granite, outcrop is good, consisting of rubbly slopes and boulders less than 1 m across. Outcrop is poor along the Mongarlowe Fault, especially near Monga village where the granite is more mafic than normal and weathers to a rich yellow-brown soil. Here the few outcrops present are tors several metres across, e.g. at the age-determination locality, GR 644597.

The dominant rock type is a pale-pink even-grained alkali granite (grainsize 1-2 mm) dominated by pink alkali feldspar (at some localities the alkali feldspar is white). Quartz is subordinate, and pale-green plagioclase is a relatively minor (10-15%) constituent. Chloritised mafic minerals amount to 5%. Most granite south of the fault along McCarthys Creek is this leucocratic type but to the north the granite is darker—10-12% mafics are present around GR 630565. Exposures in the small area north of the Jembaicumbene Fault are granodiorite, containing up to 25% mafics including about 15% fresh biotite.

In the most leucocratic phase miarolitic cavities up to several centimetres across are common, indicating that the magma reached vapour saturation point in the late stages of crystallisation.

Most specimens of Monga Granite are true granites: alkali feldspar is more abundant than quartz, and plagioclase makes up only about 15%. The alkali feldspar is patch perthite grading into mesoperthite and in the more leucocratic types is graphically intergrown with quartz. Some of the quartz grains have a square beta habit and their margins are intergrown with alkali feldspar. The plagioclase is zoned albite-oligoclase, but in some samples has been completely albitised. It is commonly slightly porphyritic, up to 4 mm.

Biotite is the most common mafic, but in most specimens is completely chloritised. When fresh the biotite is pleochroic from pale-yellow-brown to dark-red-brown. Secondary opaques, white mica, and in most samples fluorite are associated with the chloritised biotite. Fluorite is also common in sericitised plagioclase adjacent to chloritised biotite. The secondary fluorite indicates that the original biotite was probably fluorine-rich. Colourless primary fluorite is also a common accessory mineral in the most leucocratic specimens, occupying interstitial positions. Darker specimens with up to 12% mafics contain in addition to biotite a mafic silicate pseudomorphed by dark-green ferroactinolite and chlorite. The pseudomorphs are euhedral and up to 1 mm across. They were probably mostly iron-rich pyroxene (hedenbergite), but some outlines resemble that of fayalite as they have acute double terminations. Primary ilmenite is common in the more mafic specimens, as are euhedral zircons, allanite, and apatite; these specimens contain more plagioclase (zoned up to An_{40}) and are adamellites. Adamellite at GR 622589 contains dark-green ferrohastingsite rather than altered hedenbergite as the second mafic phase and epidote as a common alteration product.

The most mafic specimen from the pluton, from GR 644597, is a granodiorite, with 35% zoned (An_{50-15}) plagioclase and only 15% perthite. Dark-red-brown biotite (15%) forms irregular poikilitic flakes up to 4 mm, interstitial to plagioclase and quartz, indicating very late crystallisation. The rest of the mafics (10%) are made up of altered hedenbergite (and possibly fayalite) and ilmenite, with accessory allanite, zircon, and apatite.

One specimen from GR 626558 is a sodic leucogranite, probably of metasomatic origin. It contains albite as the only feldspar.

As perthitic alkali feldspar is the dominant mineral, this granite resembles the Gabo Island Granite to the south (Collins, 1977) which intrudes the Boyd Volcanic Complex of early Frasnian age (Fergusson & others, 1979; Hall, 1960) and has been dated (K-Ar) (Thompson, 1975) at 363 ± 8 Ma (new constants). Further, Collins (1977) and Beams (1980) regard the granitic suite of Gabo Island as comagmatic with the rhyolite of the Comerong Volcanics. Thus the Monga Granite is probably Frasnian too. The most mafic specimen from the pluton, from GR 644597, was dated by K-Ar on biotite, yielding an age of 376 ± 6 Ma, and by Rb-Sr on a biotite-whole-rock pair, yielding an age of 371 ± 6 Ma and initial ratio 0.7095.

Petrographic features of the Monga Granite closely resemble those described by Loiselle & Wones (1979) as anorogenic or 'A-type' granites. The high alkali feldspar content, the presence of iron-rich mafics, the fluorine-rich system, the low water content as indicated by the late crystallisation of biotite (Maaloe & Wyllie, 1975), and the low oxygen fugacity as indicated by the assemblage hedenbergite-plus-ilmenite instead of sphene-plus-magnetite, are all characteristics of A-type granites. Further, the association of bimodal volcanics (Comerong Volcanics) in a rift zone setting (McIlveen, 1975, and page 17), after an earlier crystal melting event (to produce the Bega and Moruya Batholiths), is precisely the tectonic environment called for by Loiselle & Wones (1979).

It is not yet clear how A-type granites originate, but two hypotheses are favoured at present. Barker & others (1975) favour fractional crystallisation of an alkali basalt magma plus reaction melting with granulite-facies crust. Alternatively, White (1979) and Collins & others (1982) advocate direct re-melting of a previously melted crust. If the first hypothesis were applicable to the Monga Granite the basic magma which produced the Donovan Basic Complex and the basalts of the Comerong Volcanics would have had to undergo the fractional crystallisation and reaction melting. The fractional crystallisation observed in the Donovan Basic Complex does lead to granitic compositions similar to the adamellite in the Monga Granite so the first hypothesis would appear plausible in this case. However, vast amounts of basaltic magma would be required to produce a small amount of granitic material by fractional crystallisation. There should also be at least some rocks of intermediate composition preserved, especially in the Comerong Volcanics. The lack of such rocks argues in favour of the hypothesis of White and Collins & others.

Unnamed small alkali granites (Dag)

Several small leucocratic alkali granites intrude the Ordovician sediments to the north of the Monga Granite. These bodies resemble the leucocratic part of the Monga Granite and are probably related to it. Miarolitic cavities are present in the largest body. Another small body is at GR 590285, 25 km south of the Monga Granite.

Mongamula Adamellite (Dam), *Coondella Creek Adamellite* (Dac)

The existence of granitic rocks in the Coondella Creek area has long been known and the name 'Coondella Creek Granite' was used by Joplin & others (1953). However, because of inaccessibility, the distribution of the granite was unknown. We have mapped out the boundaries of two separate plutons in the area and propose calling them the Mongamula Adamellite and Coondella Creek Adamellite. The plutons are very similar, but their internal variation cannot be detailed adequately at present as we have only done a few traverses along major streams. We therefore do not propose type localities here.

The Mongamula Adamellite is an elongate meridional body with a fault-bounded eastern margin. Its boundaries are quite accurately delineated because of its characteristic airphoto pattern.

The Coondella Creek Adamellite is similarly shaped and faulted on its eastern side. Its boundaries also are quite accurately delineated by airphoto pattern (mainly a vegetation effect).

Both plutons crop out as sparse tors up to about 2 m across, but weathering is commonly deep, and fresh specimens are not obtainable. More continuous pavements occur in creek beds, but even here fresh rock is rare near the surface. Colour, grainsize, and mafic content are similar for both plutons. They are both medium-grained (average 2-4 mm), equigranular, white to pale-pink adamellite-to-granite with up to 10% biotite, mostly chloritised. The Coondella Creek Adamellite is most mafic at its margin at GR 577193. Elsewhere specimens with as little as 3% chloritised biotite are present in both plutons but the pattern of internal variation in mafic content is not clear at present. No internal contacts were seen, except with aplitic dykes.

No difference between the two plutons could be seen in thin section. Except for the most mafic rocks with 10% biotite all specimens contain more perthitic potash feldspar than plagioclase. The most leucocratic are granites with alkali feldspar making up more than 65% of total feldspar. Coarse vein and patch pethite are well developed in all specimens. Plagioclase is mostly sericitised, but where fresh is zoned andesine-albite. Biotite where not chloritised forms subhedral to anhedral pale-brown to red-brown flakes up to 2 mm across. In some specimens biotite is interstitial, indicating low water fugacities (Maaloe & Wyllie, 1975). Euhedral zircon up to 0.3 by 0.1 mm and apatite rarely up to 1 mm by 0.3 mm are common accessories. Opaques are rare. Secondary muscovite is present in most specimens and secondary fluorite in all of them. The fluorite has three distinct modes of occurrence: it is most common as alteration patches up to 0.3 mm across in the cores of sericitised plagioclase crystals; less commonly it is intergrown with chloritised biotite and rarely it forms late veins and interstitial patches less than 0.5 mm across. Tourmaline is a common accessory in some specimens, as radiating prisms up to 5 mm across.

The Mongamula and Coondella Creek Adamellites are very similar and are likely to be the same age. The abundant highly perthitic alkali feldspar, interstitial biotite, and common zircon and fluorite are similar to features in the Monga and Gabo Island Granites, suggesting a Late Devonian age. The Mongamula and Coondella Creek Adamellites are thus probably part of the Comerong Rift Zone magmatic group, but confirmation of this must await a geochemical and/or geochronological study.

LATE DEVONIAN SEDIMENTARY ROCKS

MINUMA RANGE GROUP (Duu)

The presence of Devonian fluviatile strata in the Minuma Range was first mentioned by Anderson (1892) and subsequently by Craft (1932). However, Joplin & others (1953) showed the area as undifferentiated Silurian sedimentary strata and volcanics. It was not until the unpublished work of Johnson (1964) that the stratigraphy of the Devonian sedimentary rocks was described, their distribution mapped, and their age established as Late Devonian.

Johnson (1964) introduced the name Minuma Range Group to include five Late Devonian formations, in ascending order, the Gundillion Conglomerate, Long Swamp Creek Formation, Grieg Creek Conglomerate, Deua Formation, and Khan Yunis Formation. Our mapping has confirmed the validity of Johnson's work and his formation names are published here for the first time, except for his 'Grieg Creek Conglomerate' which we rename Curmulee Conglomerate, since 'Grieg Creek' is pre-empted.

Our work has linked the area in the south of ARALUEN mapped by Johnson with areas near Ballallaba Bridge and Majors Creek in the north where Kennedy (1961) and Goleby (1977) mapped Late Devonian sedimentary rocks. These rocks, though included in the Minuma Range Group, are of a different facies to those in the south, so a new name, 'Big Hole Formation', is introduced here for them.

Gundillion Conglomerate (Duu_1)

Johnson nominated as type section natural exposures about 500 m north of the homestead, just north of a stream that cuts through the ridge formed by the Gundillion Conglomerate, from GR 390402 to 386401. Equally good exposures are found along the track to Wyanbene Caves about 250 m south of the type section, and just south of the same stream. The type section exposes about 150 m of massive, strongly jointed, coarse (clasts to 35 cm) conglomerate at the base, becoming finer upwards and passing into a sequence of coarse litho-feldspathic quartz arenite and pebbly arenite interbedded with finer conglomerate containing clasts up to 5 cm across.

The Gundillion Conglomerate crops out mostly on the steep eastern side of the Minuma Range. It ranges from less than 2 m to 150 m thick in the type section. North of Hanging Rock it thins rapidly and is found only rarely towards Wallaces Gap, the overlying Big Hole Formation resting directly on the Long Flat Volcanics at most places along the Bendoura Range. A small outcrop of conglomerate resting on the Jinden Adamellite at GR 307263 is also tentatively included in the Gundillion Conglomerate.

The formation is typically a reddish-purple, poorly sorted, coarse polymict conglomerate. Clast size reflects the thickness of the unit; where it is thickest, such as at Hanging Rock, Gundillion, and in the south at GR 430157 and GR 395129, the base can be extremely coarse, with boulders up to 1 m across, though normally no more than 30 cm. In intervening areas clasts rarely exceed 10 cm. There is an overall fining upwards as a result of a decrease in megaclast size and an increase in the proportion of sandy matrix; interbeds of coarse lithic-feldspathic quartz arenite, locally pebbly, appear towards the top. Most clasts in the unit are moderately to well rounded, though angular clasts are occasionally found, particularly near the base. Clast composition is dominated by fine-grained quartzite and siltstone similar to those in the Ordovician; other clasts include chert, vein quartz, and felsic volcanics where the unit rests on the Long Flat Volcanics.

Where the formation is thin, a breccia occurs at the base. At GR 424148, on the track from the Minuma Range to Bendethera, a very poorly sorted fine breccia about 3 m thick rests unconformably on red-stained Ordovician quartzite and is overlain by another 3 m of red shale beneath the conglomerate. The breccia, derived from the underlying Ordovician, probably represents a basal soil horizon. A similar though thinner fossil soil is developed further south at GR 402128, and very locally in areas to the north along the Minuma Range.

A very coarse unsorted breccia, with clasts up to 30 cm dominantly of chert, rests on the Wyanbene Limestone Member at GR 425344. The surface of the limestone appears to have developed karst features prior to deposition of the breccia, with solution-widened fissures infilled by breccia. The basal part of the breccia is an unbedded chaotic deposit, but it becomes finer upwards and passes into initially poorly bedded then after about 10 m into well-bedded poorly sorted arkosic arenite which is locally pebbly. Clasts (chert and dacite) match nearby Silurian rocks and the breccia was probably scree. Although the breccia has been included in the Gundillion Conglomerate it may well be younger than the main part of the unit, if, as seems likely, the Wyanbene Limestone Member and associated rocks had appreciable topographic expression at the start of deposition of the Minuma Range Group. The field evidence is inconclusive.

It is thought that the Gundillion Conglomerate was deposited as a series of coalescing alluvial fans. Meagre current-direction evidence from rare cross-beds, channelling, and pebble imbrication suggests a dominant derivation from the east.

Two main areas of fan development are apparent, in the north around Gundillion and Hanging Rock, and at the southern end of the Minuma Range from GR 425160 to GR 395127. In both areas the Gundillion Conglomerate is up to 150 m thick, and in each of the two areas there is a central zone of thinning between the thickest developments.

The formation is generally absent north of Hanging Rock, but it thickens rapidly to about 50 m at Hanging Rock. Farther to the south it thins to about 20 m near The Big Hole, then thickens to about 150 m at the type section near Gundillion. South of Gundillion it is invariably less than 20 m thick and often less than 10 m. However, at the southern end of the Minuma Range (GR 428158) the thickness is about 80 m, although it then thins in little over one kilometre to about 10 m on the Bendethera Fire Trail at GR 426143, and to less than 5 m at GR 402128, about 3 km to the southwest. One kilometre west from GR 402128 it is over 100 m thick.

The Gundillion Conglomerate rests with marked unconformity on the Late Silurian sedimentary and volcanic sequences, on the Ordovician strata, on the Braidwood Granodiorite (GR 433372), and on a related but unnamed leucogranite between The Big Hole and Wyanbene Caves Creek.

It is overlain gradationally by shale and arenite of the Long Swamp Creek Formation, the highest conglomerate or pebbly arenite bed being taken as the top.

The formation is unfossiliferous. It is considered to be Late Devonian in age since it rests unconformably on the Early Devonian Braidwood Granodiorite and is conformable beneath units of the Minuma Range Group that contain Late Devonian faunas.

Long Swamp Creek Formation (Duu_2)

Long Swamp Creek (not named on the map) rises on the western slope of the Minuma Range and joins the Shoalhaven River at GR 397283.

We nominate as type section exposures on the east bank of the Shoalhaven River at GR 404265, where about 100 m of interbedded shale and lithic arenite are seen to overlie pebbly arenite at the top of the Gundillion Conglomerate. The upper contact with the Curmulee Conglomerate is not exposed here. The type section differs from that suggested by Johnson (1964), which was some 2 km to the south. Both sections have similar exposures, but the one preferred here is more accessible.

The Long Swamp Creek Formation extends from the southern edge of the Sheet area north to Wyanbene Caves Creek where it appears to pass laterally into the Big Hole Formation. In the area between Khan Yunis homestead and Deua Trig (GR 424258) the outcrop pattern is complicated by the effect of the relief of the Minuma Range on the formation's gentle dip (cross-section F–G–H–I).

The formation typically consists of grey-brown mudstone and shale interbedded with lithic quartz arenite, locally feldspathic. Rare siltstone occurs more particularly in the south.

The arenite is greyish to light brown, with light coloured feldspar and dark lithic grains often visible. It is dominantly fine-to-medium-grained, though coarse arenite is by no means rare, and pebbly arenite is very occasionally found. The fine-grained arenite is generally moderately sorted, the sorting becoming poorer as grainsize increases. Quartz generally shows slight undulose extinction and often has overgrowths. It generally forms 30–50% of the arenite. Feldspar invariably forms less than 10%, potash feldspar predominating over plagioclase; both feldspars are invariably highly altered. Lithic grains generally form 20–50% of the arenite; felsic volcanic fragments dominate—sedimentary fragments are always minor. Volcanic grains, where fresh enough to be identified, can be recognised as deriving from the felsic Silurian Long Flat Volcanics. Sedimentary grains include quartzite, siltstone, and shale; most can be readily correlated with Silurian and Ordovician sedimentary rocks in the region.

The decrease in grainsize to siltstone and shale is accompanied by a decline in the proportion of feldspar and lithic grains, and an increase in the proportion of clay matrix.

Sedimentary structures are rare, most beds being planar and in sharp contact with adjoining beds. Cross-bedding, which may occur in sets from 10 to 40 cm thick, is rare. Measurements of a limited number of current directions both by us and by C. Powell (Macquarie University, pers. comm.) indicate derivation of the sediment generally from the west, but there is a large scatter and the sample is too small to be reliable. It is possible that transport was both longshore and offshore. The only other features are the local presence of small load casts of arenite into underlying shale, very poorly preserved brachiopods near the base (see below), and an upward increase in the sandstone:shale ratio from around 0.2 near the base to 4 or 5 near the top.

The Long Swamp Creek Formation is considered to have been deposited in a shallow-marine environment because of the marine fossils and the absence of redbeds. The upward increase in sand and the average thickness of around 100 m are typical of a deltaic sedimentation cycle (Miall, 1979), though against this interpretation is the relative lack of cross-beds. However, provided the rate of sediment supply was not too high, it would be possible for the internal structures of beds to be destroyed by bioturbation, so we postulate a marine deltaic origin for the Long Swamp Creek Formation.

The unit was estimated to be about 100 m thick at its type section, but east of Deua Trig (GR 424258), about 2.5 km east of the type section, it appears to thicken fairly rapidly to about 150 m. North from the type area it appears to remain about 100 m thick, while southwards it thins gradually to about 50 m at the Bendethera track (GR 424152; not named on map) and about 20 m at the edge of the Sheet area.

The Long Swamp Creek Formation rests conformably and gradationally on the Gundillion Conglomerate. It is overlain conformably by the Curmulee Conglomerate, the boundary being an abrupt change from lithic quartz arenite and minor shale to coarse conglomerate.

It passes laterally northwards into the Big Hole Formation (well-bedded, fairly well-sorted lithic quartz arenite with very minor shale). This facies change is shown diagrammatically on the map north of Wyanbene Caves Creek, but in detail there is a complex but poorly exposed interfingering, and examples of both lithologies occur 1 to 2 km north and south of this line.

The badly preserved brachiopods were found by C. Powell, Macquarie University (pers. comm.) at GR 421286. The specimens are preserved as moulds in a deeply weathered mudstone and cannot be identified. Johnson (1964) reported rare unrecognisable shell fragments from two other, unstated, localities. Determination of age, therefore relies, as with the Gundillion Conglomerate, on faunas from the overlying Deua and Khan Yunis Formations, and the age is considered to be Late Devonian.

Curmulee Conglomerate (Duu$_3$)

Johnson (1964) used the name 'Grieg Creek Conglomerate' in his unpublished work for a prominent conglomerate bed above the Long Swamp Creek Formation in the Minuma Range, but the name is pre-empted and thus unavailable. We here introduce the name Curmulee Conglomerate. Curmulee Creek drains the eastern slope of the Minuma Range near Wyanbene.

The Curmulee Conglomerate crops out mainly on the western slope of the Minuma Range.

The type section is designated as the small, steep gully at GR 420321 on the eastern side of the crest of the Minuma Range 2.5 km south of Wyanbene Caves Mountain. The section exposes all of the unit, here about 20 m thick, and includes its upper and lower contacts.

Typical of the formation is a reddish-brown massive medium-grained polymictic conglomerate with maximum clast size usually about 5 cm. Minor pebbly arenite, coarse arenite, and siltstone lenses occur locally. The clasts are of shale, siltstone, quartz arenite, quartzite, and rare volcanic and granitic rocks, set in an arenitic matrix of quartz, feldspar, and lithic fragments. Most are well-rounded to very well-rounded.

Locally, e.g. near the base of the type section, there are voids between the larger clasts. A gradation to pebbly arenite occurs towards the top of the unit, through a reduction in the proportion of pebbles to matrix, and in the overall size of pebbles to 2–3 cm. Interbeds of quartzo-feldspathic lithic arenite also appear towards the top of the unit in beds up to 30 cm thick.

There are few sedimentary structures, most of the conglomerate being massive to thick-bedded. In the lower part, bedding, where present, is marked by an indistinct variation in pebble size and pebble-to-matrix ratio. Bedding becomes better defined up-section, though the unit is nowhere well-bedded. Lenses of arenite and siltstone, when present, are rarely continuous over more than 10 m. Cross-bedding is very rare. The Curmulee Conglomerate is considered to have been deposited in a beach or very shallow-marine environment, mainly on the evidence of the well-rounded pebbles and the lack of matrix at some horizons, both of which suggest the influence of wave action.

The conglomerate reaches a maximum thickness of about 20 m along the crest of the Minuma Range between GR 417270 and the type locality. It thins rapidly to the south and gradually to the west and north. Where it crops out on the Shoalhaven River, both at its northernmost occurrence at GR 398377 and east of Khan Yunis, it is about 10 m thick. At its southern limit it is pebbly arenite. Johnson (1964) indicated that the unit thickened to the northwest (to 100 m). However, our own field observations suggest the opposite.

The Curmulee Conglomerate conformably overlies the Long Swamp Creek Formation and is in turn overlain conformably by the Deua Formation. The basal contact is an abrupt change from fine, well-bedded arenite with minor interbedded shale to massive conglomerate, while the upper contact is a transition over some 2–5 m through pebbly arenite interbedded with coarse arenite into arenite with shale interbeds typical of the Deua Formation. The top of the unit is taken as the top of the highest pebbly arenite bed.

No fossils have been found in the Curmulee Conglomerate, but since it conformably underlies the Deua Formation which contains a Late Devonian fauna, a similar age is indicated.

Deua Formation (Duu_4)

Johnson (1964) introduced the name Deua Formation for the predominantly reddish-purple to reddish-brown arenite that overlies the Curmulee Conglomerate in the Minuma Range. McIlveen (1975) published but did not define the formation. The unit was named after Deua Trig (GR 424257 not named on the map).

The type section nominated here by us extends from GR 403290 (base) to 393280 (approximate top). The lower part follows a tributary of the Shoalhaven River and the upper part is along the river itself. The base is well exposed but the top is not seen. The type section nominated here is essentially that proposed by Johnson (1964), but is extended along the Shoalhaven River to include beds placed by Johnson in the overlying Khan Yunis Formation.

The Duea Formation is the most widespread unit in the Minuma Range Group south of the Gundillion–Wyanbene area. It underlies much of the western slope and crest of the Minuma Range from Wyanbene south.

The formation consists of reddish-purple to reddish-brown lithic quartzofeldspathic arenite with minor shale horizons.

The arenite is generally well-bedded (beds 10 to 50 cm thick), medium-to-fine-grained, and often contains red or grey shale clasts up to 2 cm across. It is moderately to well sorted, has relatively little fine matrix, and is cemented by secondary quartz. Quartz typically forms about 50%, feldspar 15%, and lithic fragments about 10%; minor heavy minerals and mica may also be present; the rest is clay matrix and quartz cement. Quartz is generally moderately to well rounded with straight to slightly undulose extinction. Feldspar grains are mostly subangular to subrounded, and invariably strongly altered. Detrital muscovite is very minor but ubiquitous, as are tourmaline and zircon.

A feature of much of the arenite is the presence on many bedding planes of shale clasts up to 2 cm, though usually less than 1 cm, across. These vary from greenish-grey to red and are commonly flattened and deformed; thus they are probably rip-up clasts, unlithified when incorporated into the arenite.

Siltstone and shale are minor constituents. They are usually yellowish-brown but sometimes reddish-purple, and form beds less than 15 cm thick, mainly near the base.

Both cross-bedding and ripple marks are common in the Deua Formation. Cross-beds form tabular sets from 15 cm to 50 cm thick, and current-direction measurements at the type section by Johnson (1964), C. Powell (pers. comm.), and ourselves show directions mainly from the northwest quadrant but with a large scatter. Both asymmetrical and interference ripple marks are present, showing similar directions and scatter to the crossbeds, although far fewer were measured. The only other indicators of environment are the shale rip-up clasts in many arenite beds, the local marine fossils, and the red to purple colour.

Conybeare & Crook (1968, p. 19) suggest that shale clasts may occur in alluvial, beach, or turbidite deposits. Since marine fossils are present and graded beds absent, the shale clasts suggest a shallow-marine origin, having probably originated as sun-dried flakes on a tidal mud flat washed to sea during storms or very high tides, to be incorporated eventually in offshore deposits. We therefore suggest that the Deua Formation represents an offshore sand body deposited rapidly enough to retain the reddish colour imparted during weathering of a landmass possibly to the west of the area.

The formation rests conformably on the Curmulee Conglomerate, the contact being gradational over several metres and well exposed in the type sections of the two units. In the south, where the Conglomerate is missing, the Deua Formation rests conformably on the Long Swamp Creek Foramtion, again with a gradational contact over several metres. The upper contact with the Khan Yunis Formation is nowhere clearly exposed, but is thought to be gradational.

The Deua Formation does not crop out north of Gundillion, being faulted out of the sequence, so its relationship to the Big Hole Formation is uncertain. However, we consider that it may be entirely younger than the Big Hole Formation, and so is not preserved to the north because of the present erosion level.

The thickness in the type section is estimated as 360 m. Over most of its range in ARALUEN the formation appears to be between 300 and 350 m thick, although it does appear to thin to the south and may be only 200 m thick near the southern edge of the Sheet area.

Johnson reported poorly preserved brachiopods and bivalves from three localities, and our mapping discovered a fourth. At all sites specimens were very rare, and preserved as moulds. Johnson (1964) identified the brachiopods as *Cyrtospirifer* sp., *Camarotoechia* sp. cf. *pleurodons*, and *Atrypa* sp., and the bivalves as

?*Phthonia* sp. and ?*Aviculopecten* sp. These indicate a broadly Late Devonian age.

Khan Yunis Formation (Duu$_5$)

Johnson (1964) introduced the name Khan Yunis Formation for the redbed fluviatile uppermost unit of the Minuma Range Group in the area he mapped. The name was published, without description, by McIlveen (1975). Since Johnson's work has remained unpublished the unit is here formally described for the first time.

The name is derived from Khan Yunis property (homestead at GR 382279) within whose limits the unit crops out extensively. Exposure of the formation is nowhere better than mediocre.

The type section is nominated as extending from the lowermost exposed bed at GR 400245 to the faulted top at 382245. About 550 m is present. Exposure along the type section is biased towards the coarser arenite beds, claystone horizons being poorly exposed.

The formation consists of interbedded yellowish-brown to reddish-brown arenite, reddish-brown siltstone, and red claystone. Conglomeratic and pebbly arenite horizons also occur.

Three informal subdivisions can be recognised in the vicinity of Khan Yunis, but not in the south and therefore are not mapped. The basal 150 m consists of coarse to very coarse (in places pebbly) cross-bedded quartzofeldspathic lithic arenite with minor reddish or more rarely yellowish claystone and siltstone. This is followed by about 300 m of interbedded medium to coarse quartzofeldspathic arenite, and red claystone-plus-siltstone, in about equal amounts. Finally, overlying this is at least 100 m (eroded top) of coarser arenite with minor claystone and siltstone similar to that at the base.

The subdivisions differ mainly in grainsize, rather than grain composition. The arenite is commonly rather poorly sorted, and has the typical composition: 50–60% quartz, 5–10% feldspar, and 5–15% lithic fragments. Matrix and quartz overgrowths form the remainder. Quartz is moderately to well rounded, generally simple, and only a few grains have undulose extinction. Inclusions are rare and mostly consist of liquid-filled vacuoles. Secondary quartz overgrowths are fairly common, particularly in the coarser rocks, and the original outline of each grain iscommonly marked by a line of micaceous flakes or fine opaque oxides. Feldspar is commonly subangular and usually completely altered to ?sericite or ?kaolin; both microcline and plagioclase have been recognised in the less altered grains. Lithic fragments vary from well-rounded to subangular, and are of a wide variety of rock types. Sedimentary clasts predominate over felsic-volcanic and granitic types. Most igneous fragments are strongly altered, though some volcanic ones are similar to the Long Flat Volcanics. The sedimentary clasts mostly resemble the Ordovician flysch. Detrital mica (mainly muscovite), tourmaline, zircon, apatite, and an opaque (?iron oxide) mineral are rare accessories.

Reduction in grainsize to siltstone is accompanied by a corresponding decrease in the proportion of feldspar and lithic grains and a resultant increase in quartz. The siltstone and claystone are generally a strong red but rarely may be yellowish-brown. The claystone commonly develops a distinct cleavage which is approximately parallel to the Gundillion Fault and is most intense close to it.

Pebbly arenite, grading into conglomerate, is locally present, e.g. at GR 391287 in the Shoalhaven River, and appears to be best developed from about 150 m to 250 m above the base of the formation in the Khan Yunis area. The phenoclasts may be up to 8 cm across (i.e. small cobbles) in the conglomerate but are around 2 cm in the pebbly arenite. They are composed dominantly of sedimentary rock; many are of vein quartz. The matrix is similar in appearance and composition to a typical arenite in the formation except that the lithic sand-sized component is more abundant.

Several features suggest that the Khan Yunis Formation is fluviatile, the middle part deposited by a meandering river system and the lower and upper parts by braided river systems. Measured cross-bed directions indicate flow predominantly towards the southeast.

The arenite horizons are 5–20 m thick and are made up of sets of cross-beds 1–20 m thick. Individual sets of cross-beds are laterally continuous over some 20–30 m. Individual arenite horizons are normally laterally continuous over only about 1 km; in the middle part of the formation each arenite horizon is followed by red siltstone and claystone 1–20 m thick, in places containing possible root traces. This part of the formation is therefore made up of a large number of fining-upwards cycles of cross-bedded arenite followed by siltstone and claystone, and is compatible with various models which have been proposed for meandering stream environments (e.g. Allen, 1970; Walker & Cant, 1979), the arenite representing river-channel deposits and the siltstone and claystone being overbank floodplain sediment. The upper and lower parts of the formation presumably represent periods of rapid sediment supply, and resemble the model for a sandy braided fluvial system proposed by Walker & Cant.

The top of the formation is everywhere cut out by the Gundillion Fault, so the original total thickness is unknown. The 550 m exposed in the type section is considered the maximum preserved and exposed thickness. The exposed thickness diminishes both to the south and north of the type section because of the Gundillion Fault.

Although the contact was not seen in the field, regionally the Khan Yunis Formation appears to rest conformably on the Deua Formation. The evidence indicates that there is structural conformity, with the marine Deua Formation passing up gradationally into the non-marine Khan Yunis Formation. The top of the Khan Yunis Formation is everywhere a faulted contact against the Jinden Adamellite and the Long Flat Volcanics.

Johnson (1964) reported the discovery of a rich fish fauna from a coarse pebbly arenite near the base of the Khan Yunis Formation and briefly described part of it. We found no new localities. Johnson indicated the presence of the genera *Bothriolepis, Remigolepis* and ?*Phyllolepis*. The fauna is in need of revision before any definite age can be suggested with confidence, but G. Young (BMR pers. comm. 1981) considers that a Fammenian age is likely.

The Khan Yunis Formation is therefore taken to be of Late Devonian age, possibly entirely Fammenian.

Big Hole Formation (Duu$_6$)

The Late Devonian sediments in the Minuma Range were mapped by Johnson (1964) only as far north as Gundillion, but Kennedy (1961) had noted Late Devonian rocks further north around the Ballallaba–Majors Creek road, and Goleby (1977) subsequently mapped that area. Goleby tried to apply Johnson's stratigraphic nomenclature to this area, recognising the Gundillion Conglomerate, Long Swamp Creek Formation, 'Greig Creek Conglomerate' (our Curmulee Conglomerate), and Deua Formation. Our mapping covered both Johnson's and Goleby's areas and the intervening country as well, and we consider that, apart from the basal Gundillion Conglomerate, it is not possible to apply Johnson's formation names north of Gundillion. We therefore introduce the name Big Hole Formation for the Late Devonian sedimentary strata overlying the Gundillion Conglomerate north of Gundillion, and consider the formation to be a northern lateral equivalent of the Long Swamp Creek Formation.

The Big Hole is a large collapse doline at GR 405428, 2 km east of Gundillion cemetery.

We nominate as type section the western side of the Big Hole. The Big Hole (Jennings, 1966; 1967) has vertical sides, is 40-60 m in diameter, and 114 m deep on its western side. It is considered to be a subjacent karst doline, although it exposes no carbonate rocks and is developed entirely in Late Devonian quartzose clastics. Jennings suggested it was created by collapse into an underlying cavity in presumed Silurian limestone. About 15 m of Gundillion Conglomerate is exposed at the bottom. The Big Hole contains the best exposures of the Late Devonian sequence in the area. The type section is accessible for close examination only to experienced and well-equipepd speleologists (the rock is too friable to climb), but arenite typical of the formation is well exposed, mainly as float, on the hillside east of the Big Hole. Exposures typical of the formation in the northern part of its distribution can be found along the Majors Creek–Ballallaba road, around Wallaces Gap.

In its type area the Big Hole Formation consists of well-bedded medium to coarse arenite with only minor interbedded siltstone and shale. Shale becomes more important further north, and forms about a third of the unit near Wallaces Gap.

Arenite forms beds from 10 cm to several metres (rarely over 1 m) thick. Cross-bedding is common and there is also some channelling. The arenite is mostly moderately sorted, medium to coarse, and composed of quartz (50%), lithic fragments (25%), and matrix (25%). Feldspar forms less than 5% in the south and is virtually absent in the north. Quartz forms subangular to moderately rounded grains, and generally has simple extinction. Rare embayed grains betray their volcanic origin. The lithic fragments vary widely in composition, but most are volcanic and can be matched with rock types in the Long Flat Volcanics; others include quartzite and siltstone similar to those in the Ordovician, and rare granite. Accessory minerals include zircon, tourmaline, muscovite, and iron oxides. Feldspar when present is strongly altered; however, the indications are that both plagioclase and potash feldspar are present.

Shale crops out poorly and is invariably strongly weathered (brown). It forms interbeds generally less than 50 cm, but rarely up to 2 m, thick.

The marine fossils, channelling and common cross-bedding and the low proportion of shale suggest the Big Hole Formation was deposited in a shallow-marine environment subjected to moderate currents.

The Big Hole Formation rests conformably on the Gundillion Conglomerate, or where this is absent, unconformably on the Long Flat Volcanics. The stratigraphic top of the unit is not preserved, being everywhere truncated by the present erosion level. The Big Hole Formation is considered to be a lateral equivalent of the Long Swamp Creek Formation, the two interfingering in the area of Gundillion. The Big Hole Formation differs from the Long Swamp Creek Formation in having a much higher proportion of arenite to shale, and in the arenite being coarser.

The Big Hole Formation has a preserved thickness of about 140 m in its type area, and a similar thickness is preserved along the Bendoura Range. Little more than 100 m is present near Wallaces Gap.

Several fossil localities are known from northern outcrops of the formation. Goleby (1977) described several forms from the generally poorly preserved faunas collected by him. He identified the brachiopods *Cyrtospirifer* aff. *ningbingensis* and a rhynchonellid (genus indet.), and the pelecypods *Edmondia* sp. and *Spathella* aff. *typica*. The fauna is too limited and poorly preserved to be dated more precisely than Late Devonian.

MERRIMBULA GROUP (Dum)

The existence of a Devonian shallow-marine and terrestrial sequence cropping out discontinuously from Merrimbula in the south to the Shoalhaven valley in the north was first recognised by Clarke (1860). Since then, various workers have examined parts of the belt, the major contributions being by Brown (1931), Hall (1960), Steiner (1975), and McIlveen (1975). Much of this work was concentrated on the coastal exposures around Eden, 100 km to the south, whereas the outcrop of these Devonian rocks in ARALUEN received very little attention.

Hall (1960) was the first to formally name the sequence, introducing the name Merrimbula Formation, with a basal conglomerate distinguished as the Wolumla Conglomerate Member. Subsequently the more detailed study of Steiner (1975) resulted in the elevation of the name Merrimbula to group status, and the naming of three constituent formations, the Twofold Bay, Bellbird Creek, and Worangle Point Formations. The Wolumla Conglomerate was considered a basal member of the Twofold Bay Formation.

Steiner (1975) considered the Twofold Bay and Worangle Point Formations to be terrestrial and the Bellbird Creek Formation to be shallow-marine. A broadly similar sequence of facies can be recognised in ARALUEN, but since the sequence between there and Eden has yet to be mapped at 1:100 000 scale we consider it premature to extend Steiner's formation names and prefer for the present to use simply 'Merrimbula Group'.

The Group crops out in the Budawang Synclinorium (Rose, 1969), which extends along the entire eastern side of ARALUEN, varying from 3.5 to 9 km wide. North of ARALUEN the unit crops out for some 80 km and then disappears under the Permian Sydney Basin sediments, while southwards the outcrop continues about 35 km before the keel of the synclinorium is brought to the surface as a result of the gentle northerly plunge.

We have mapped three informal sub-units in ARALUEN. A basal conglomerate/red shale/purplish arenite unit (Dum$_1$), absent from most of the southern half of the synclinorium in ARALUEN, passes up into light-brown to grey interbedded fine arenite and shale (Dum$_2$), which in turn passes up into a thick redbed sequence (Dum$_3$).

The basal sub-unit, generally 10 m (up to 30 m) thick, crops out continuously along both edges of the synclinorium in the north. It consists of a locally developed basal conglomerate (with well rounded pebbles of quartzite, vein quartz, and fairly rare volcanic material up to 6 cm across) which passes up into a thin sequence of poorly sorted, purplish, medium-grained quartzo-feldspathic, lithic arenite (commonly pebbly) with interbeds of reddish shale or siltstone in fining-upwards cycles. A reddish, poorly sorted sandy siltstone with angular grains and scattered small angular clasts of basement rock up to 1 cm across is locally developed at the base, e.g. in Oulla Creek at GR 630307, and may be a fossil soil.

The middle sub-unit consists of interbedded medium to fine quartz arenite and shale or siltstone. The arenite is pale cream to brownish or grey, and the shale or siltstone grey. The arenite is moderately well sorted. Feldspar is minor and lithic grains are rare. Small-scale cross-beds are common. Towards the top, the arenite becomes purplish, marking a transition to the uppermost subunit. Brachiopods, poorly preserved, occur at several localities in the north but become increasingly uncommon southwards. The thickness also decreases southwards, from over 1000 m (estimated) near Clyde Mountain (where the top is eroded) to less than 200 m in the southeast.

The uppermost sub-unit consists of interbedded reddish to purple or brown arenite and red shale in fining-upwards cycles. It is most completely preserved in the south and thins, because of erosion, progressively northwards as the very gentle southerly plunge of the synclinorium (concomitantly with a thickening of the underlying unit) causes successively lower beds to be exposed within the core. The arenite forms beds up to 15 m thick, and is typically strongly cross-bedded, moderately sorted, and dominantly composed of quartz, though lithic grains become increasingly significant upwards; feldspar is fairly rare (less than 5%). Red shale forms beds up to 30 m thick, and is often strongly cleaved, particularly near the centre of the synclinorium. Shale becomes more abundant upwards, mainly through increase in thickness of the shale beds. The arenite/shale ratio decreases from about 2.0 near the base to about 0.5 at the top.

The lowermost and uppermost sub-units, containing fining-upwards cycles from arenite to red shale and prominent cross-bedding, are probably fluvial. The middle sub-unit containing shale and cross-bedded arenite in discrete beds rather than fining-upwards cycles, grey rather than red shale, and poorly preserved brachiopods, was probably deposited on a shallow marine shelf.

The Merrimbula Group rests with apparent conformity or disconformity on both basalt and rhyolite of the Comerong Volcanics, and nonconformably overlies the Nelligen Granodiorite. It rests unconformably on the Ordovician in the south where the Comerong Volcanics are absent.

The correlation between the Merrimbula and Minuma Range Groups appears simple, though it cannot yet be confirmed by fossil evidence. We suggest that sub-unit Dum$_1$ of the Merrimbula Group can be correlated with the Gundillion Conglomerate, Dum$_2$ with the Long Swamp Creek, Deua, and Big Hole Formations, and Dum$_3$ with the Khan Yunis Formation.

The two groups probably originally formed a continuous blanket of sediment across the Sheet area.

The brachiopods in the middle sub-unit in ARALUEN are too poorly preserved to be dated. Work on the Merrimbula Group elsewhere (McIlveen, 1975) suggests a late Frasnian to Famennian age.

Tertiary basalt (Tb)

In the upper Jerrabattgulla Creek valley Tertiary basalt flows crop out along the Shoalhaven Fault. Most of the basalt forms lobes extending east from the fault line but there is some west of the fault, and the different height of the base on either side of the fault indicates 30 m of vertical movement along this part of the fault since the basalts erupted. At least three flows are present in the largest lobe, at GR 300320, in a total thickness of 90 m.

The main rock-type is alkali basalt with olivine phenocrysts up to 2 × 1 mm. The groundmass consists of microlites of plagioclase, titanaugite, and opaques, with minor interstitial orthoclase. Analcite commonly fills amygdules and lines vugs, and in a specimen from GR 299314 appears primary-interstitial as it contains inclusions of titanaugite and opaques. An alkali basalt at GR 304332 contains (in addition to olivine phenocrysts) opaques and titanaugite microlites embedded in poikilitic plagioclase crystals up to 2 mm.

Basalt at GR 303341 was dated by the whole-rock K-Ar method at 19.1 ± 0.4 Ma (Early Miocene). This age is similar to that of the Snowy Mountains Province basalts (Wellman & McDougall, 1974). The dated sample differs from others collected in that it contains interstitial nepheline and possibly also pseudoleucite. The bulk of the rock consists of olivine phenocrysts (1 mm) in a groundmass of plagioclase microlites and opaques, embedded in poikilitic titanaugite up to 1 mm.

Quaternary alluvium (Qa)

Most of the alluvium in ARALUEN occurs as simple flood-plain overbank deposits along the main rivers. The main areas are around Mount Elrington Plain and Krawarree on the Shoalhaven River, on the Buckenbowra River around GR 710500, and in the Araluen valley.

At Mount Elrington Plain the alluvials are ponded against the Shoalhaven Fault scarp. At Krawarree several terraces are present up to 10 m above the present flood plain, and these older deposits could correlate in age with deposits near the headwaters of the Shoalhaven such as at Snowball, Wambagugga Swamp, and east of Middle Mountain which seem too extensive to relate to the small catchments above them. Perhaps these deposits are remnants of a planated area to the south which has since been removed through rapid headward erosion by Woila Creek in COBARGO.

The alluvial deposits in the Araluen valley were extensively worked for gold between 1851 and 1920. The alluvials are up to 10 m thick and consist mostly of arkosic grits and clay seams. The basal 1 metre contains nearly all the gold and consists of many granodiorite boulders in an open framework of coarse grit. Similar deposits in a narrow strip along Jembaicumbene Creek (also up to 10 m thick) were also dredged for gold. These are not shown on the map.

STRUCTURE

There is little evidence in ARALUEN of any significant deformation before the end of the Silurian. The contact between the Late Ordovician quartz-rich flysch sequence and the Late Silurian quartz sandstones of the De Drack Formation can be traced for many kilometres along the eastern escarpment of the Minuma Range, and, though it represents a time break of some 20-30 Ma, is probably only locally unconformable. South of Con Creek, around GR 450197, the contact is marked by a sedimentary breccia 1 m thick, but the sandstone above the breccia is parallel with the flysch sequence below. Some uplift and tilting evidently took place during the time break since a deep-water environment in the Ordovician was replaced by a shallow-marine environment in the Silurian. Evidence for the absence of mid-Silurian deformation in ARALUEN is consistent with our earlier conclusions in TANTANGARA and BRINDABELLA (Owen & Wyborn, 1979), namely that the first major deformation happened progressively later to the east across the Lachlan Fold Belt.

At the end of the Silurian, or perhaps in the earliest Devonian, just before the large Early Devonian I-type plutons were emplaced, the whole region was strongly deformed. Tight, upright, meridional to NE-trending folds with wavelengths commonly around 300-500 m formed in the Ordovician flysch (Ouf). Axial-plane cleavage is usually weakly developed. In Moodong Creek (centre of Sheet area) and the Deua River area to the south, folding is asymmetrical and the sequence mainly youngs to the west, but elsewhere, e.g. in the Curmulee Creek Valley (around GR 460300) and the area north of Bendethera Mountain, limbs are of about equal length. The rather massive felsic Long Flat Volcanics apparently form open broad northeast-trending folds with wavelengths of several kilometres.

After the intrusion of the large Early Devonian plutons into the central and western parts of ARALUEN the region became relatively stable, so that when the next major compression occurred, probably in the Carboniferous, the area reacted mainly by faulting along the margins of some of the large granite bodies. Strata of the Late Devonian Minuma Range Group were tilted during this compression, and locally folded, e.g. as seen in road cuts at GR 390597, near Nithsdale. Here tight folds plunging at 20-30° to the southwest are associated with a NW-trending left-lateral wrench fault along which there has been 1400 m of apparent displacement.

In the Carboniferous, in contrast to the relatively rigid response of the crust in the central part of ARALUEN, the eastern part of the Comerong Rift Zone and the belt west of the Mulwaree Fault were quite strongly deformed. West of the Mulwaree Fault Early Devonian granitic intrusives were compressed from east to west and a steep meridional foliation has formed. Dolerite dykes of probable Middle to Late Devonian age in the granites were cleaved during this compression. The response of the Ordovician strata in this belt is difficult to establish: outcrop is relatively poor and bedding-cleavage relationships have not revealed any downwards-facing structures but it is likely that the combined effects of folding at the end of the Silurian and in the Carboniferous have produced downward-facing structures, or at least a tightening of the end-Silurian folds in the Carboniferous.

In the Comerong Rift Zone the structure is more complex. The initial rifting along the major faults of the rift zone—the Mongarlowe, Donovan, and Buckenbowra Faults—probably accompanied extrusion of the Middle-Late Devonian Volcanics. These faults probably originally had dip-slip movements, but their sense of motion was reversed in the Carboniferous compression.

Meridional axial-plane cleavage formed in the fine-grained strata of the Merrimbula Group during the folding (Fig. 3). The faults do not mark the limits of the Carboniferous deformation, as effects can be seen in Ordovician rocks to the east and west of the rift zone. In the west, downward-facing structures are present south and west of Merricumbene, but the main effect is to the east since movement on the Buckenbowra Fault was not as great as on the faults bounding the western side of the rift. Within about 1.5 km of the Buckenbowra Fault the Ordovician rocks have been overturned, so that earlier, end-Silurian, folds are now downward-facing, with the sense of tectonic transport to the west. The downward-facing zone is well exposed in Quart Pot Creek and also on the Kings Highway east of Clyde Mountain, just within BATEMANS BAY. Mesoscopic effects include the formation of a second cleavage, commonly at high angles to the earlier end-Silurian cleavage, so that spectacular kink folds have been formed (Fig. 4). In this zone the first cleavage is better developed than elsewhere in ARALUEN and the strata have a phyllitic sheen. The downward-facing belt has been traced as far as Bimberamala River (ULLADULLA: 30 km north-northeast of Quart Pot Creek) where the Buckenbowra Fault is absent, and it can be established that Devonian strata have been deposited directly on recumbent Ordovician strata (personal observation by D.W.). This zone of downward-facing Ordovician strata differs from others in the Lachlan Fold Belt (Stauffer & Rickard, 1966; Rickard & others, 1983) that appear to be related to an early recumbent folding of the Ordovician flysch with tectonic transport to the east; it has been suggested that such downward-facing zones are related to soft-sediment slumping within the flysch pile, away from the continental margin (Rickard & others, 1983). The most plausible explanation for the downward-facing zone east of the Comerong Rift combines the effects of three events:

(1) Upright tight-to-isoclinal folding at the end of the Silurian.

(2) Downwarping of the folds along monoclinal flexures during the mid-Devonian rifting and volcanism, to produce recumbent folds with sense of tectonic transport to the west.

(3) Complete overturning of the end-Silurian folds during upright folding of the Devonian strata in the Carboniferous.

The boundary of the downward-facing zone is marked in ARALUEN by an F_2 anticlinal axis near Quart Pot Creek. West of this axis end-Silurian folds are downward-facing. As this line is traced northwards it appears to merge into a west-dipping thrust fault where the massive Nelligen Granodiorite interferes with the folding of the sedimentary rocks.

Movements on faults post-dating the Carboniferous compression can be proved in two areas: (1) south of Merricumbene the Mongarlowe Fault cuts obliquely across the cleavage direction produced during Carboniferous folding of the Merrimbula Group; and (2) a 30 m vertical displacement of Miocene basalt on the Shoalhaven Fault, together with a young fault scarp nearby, indicates recent fault movements.

Fig. 3. Axial plane cleavage formed in fine-grained strata of the Merrimbula Group during Carboniferous folding, GR 643386. BMR neg. M2611/33A.

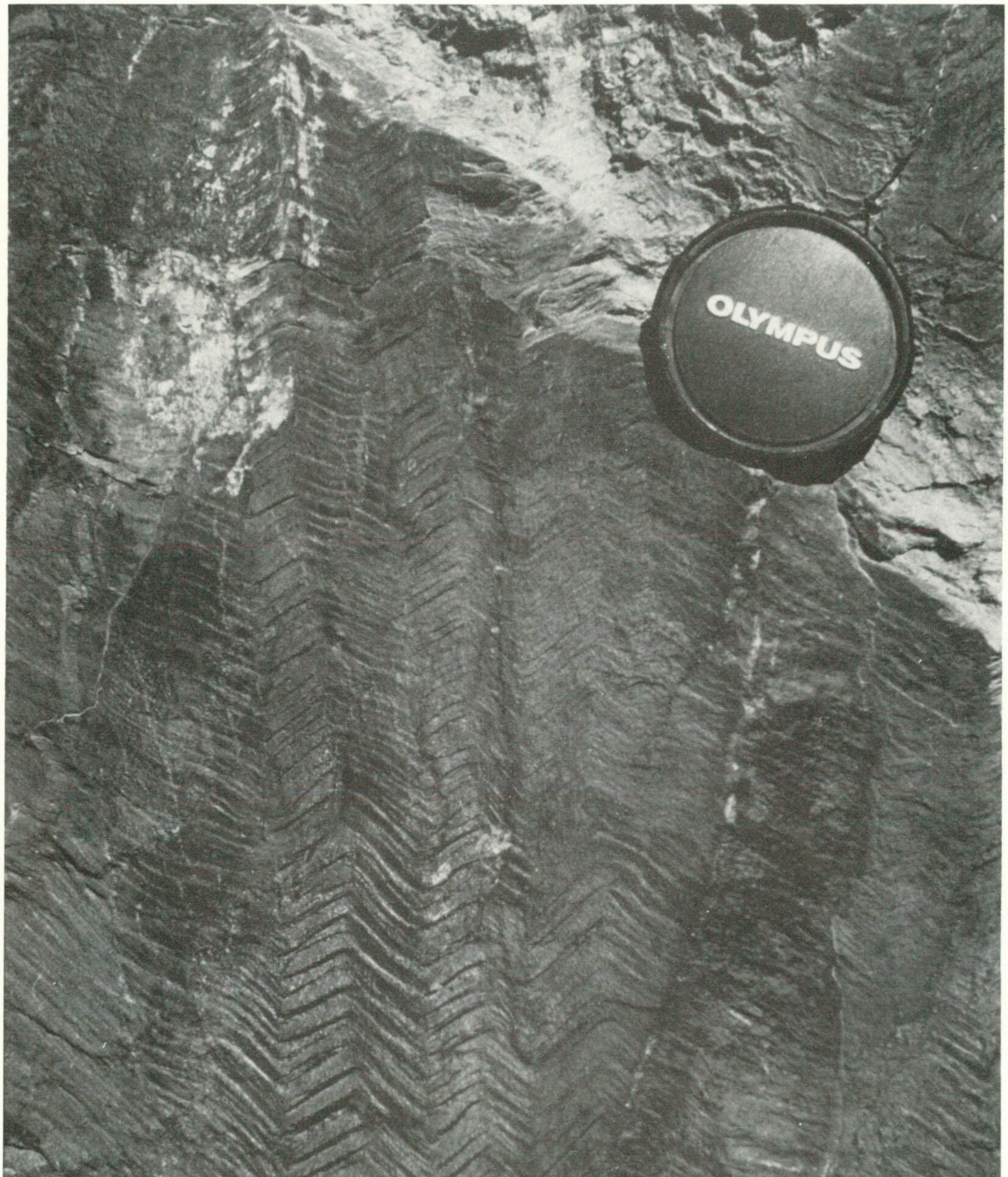

Fig. 4. End-Silurian cleavage in Ordovician greywacke, kink-folded to form a second, probably Carboniferous, cleavage. Quart Pot Creek, GR 680441. BMR neg. M2566/5A.

ECONOMIC GEOLOGY

The mines and mineral prospects in ARALUEN are listed and described by Gilligan (1975).

Gold is the only commodity to have been mined extensively. The known mineralisation can be related to three rock associations: gold, silver, copper, molybdenum, lead, and barium are associated with granitoid intrusives; lead, zinc, copper, and possibly antimony are associated with volcanics; and iron, silver, lead, zinc, and copper are associated with Silurian limestone at Wyanbene and Bendethera.

Granitoid-related mineralisation

Mining in the Araluen–Majors Creek goldfield began in 1851, peaked in the mid 1860s, and then gradually declined until mechanical dredging began in 1900. Dredging ceased in 1920, and there has been little commercial activity since. In the period from 1858 (when mining records started) to 1920, some 1 200 000 ounces (37.2 tonnes) of gold was won (Middleton, 1970).

Most deposits worked were in hydrothermal veins, with quartz and/or calcite gangue and frequent sulphide mineralisation (Kennedy, 1961; Gilligan, 1975; Goleby, 1977). Deposits in the Braidwood–Majors Creek area appear to be derived from the Braidwood Granodiorite (Kennedy, 1961; Gilligan, 1975). Most of the veins are associated with the western phase of the Braidwood Granodiorite and, in the Majors Creek area, also with probable aplitic differentiates. Some mineralisation is present also in the central more felsic part of the eastern phase in the Bells Creek area (GR 534595). The presence of euhedral hornblende phenocrysts in the western phase, as distinct from early clinopyroxene in the eastern phase, indicates that the western-phase magma contained water and thus had greater potential for providing hydrothermal solutions during crystallisation and differentiation.

Erosion of the Braidwood Granodiorite formed large placer deposits in Jembaicumbene Creek, the Shoalhaven River, Araluen Creek, and the Deua River, where mechanical dredging was carried out from 1900 to 1920 (Clift, 1971). These deposits were more productive than the vein deposits of the Majors Creek area.

At GR 517568 low-grade molybdenite mineralisation is disseminated in a 50-m-diameter aplite pipe within the eastern phase of the Braidwood Granodiorite. Analyses of the aplite averaged 0.11% Mo (Middleton, 1970). Molybdenite occurs as fine flakes with associated pyrite and a little chalcopyrite. Another molybdenite prospect (GR 362312) is present in the Jinden Adamellite near Krawarree.

At GR 280611 a barite vein carrying minor galena is present at the contact of an east-trending dolerite dyke in the Ballallaba Adamellite.

Volcanic-related mineralisation

At the Krawarree lead-zinc-copper prospect (GR 375469) galena, sphalerite, chalcopyrite, and pyrite occur in chloritised phyllite and rhyolite of the Long Flat Volcanics. Gilligan (1975) states that the occurrence is partly stratabound and partly disseminated; however, the mineralisation appears to be related to an east-trending fault and so could have been remobilised.

At the Budawang copper prospect (GR 686666), in basalt of the Comerong Volcanics, native copper occurs sporadically in basalt vesicles, and minor chalcocite and copper carbonate occur in quartz-epidote veins (Lishmund, 1968).

Stibnite has been reported to occur at GR 647617 near a faulted contact between the basalts of the Comerong Volcanics and Ordovician flysch (Gilligan, 1975).

Sediment-hosted mineralisation

Silver-lead-zinc mineralisation (Anderson, 1892) is associated with the Bendethera and Wyanbene Limestone Members of the De Drack Formation, and there are no obvious related igneous rocks. Lishmund & Dawood (1972) record pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, and specular hematite in the Wyanbene deposit, and an extensive ironstone with an oxidised capping is present. During the mapping thin veins of galena were found in float from the unnamed limestone lens at GR 427267, on the lens's northern side. It is possible that the ore minerals in these deposits were derived from the limestone by low-temperature fluid circulation.

GEOLOGICAL HISTORY

The pre-Ordovician history of the area cannot be deduced directly, as no rocks older than Darriwilian (Middle Ordovician) are present at the surface. However, Sr isotopes (Compston & Chappell, 1979) and Nd isotopes (McCulloch & Chappell, 1982) of Early Devonian I-type granitoids of the Bega Batholith indicate that the source rocks of the granitoids had a crustal prehistory of up to 1000 Ma before the Early Devonian.

By the Middle Ordovician, quartz-rich turbidites were being deposited and palaeocurrent directions consistently indicate north-flowing turbidity currents. Geochemical analyses of the turbidites (Appendix 1) show them to be not significantly different geochemically from those further west (Wyborn & Chappell, 1982). The thickness of the turbidites is unknown but is believed to exceed 4000 m. In the Early Silurian, deformational events to the south and west (Owen & Wyborn, 1979) cut off the sediment supply, but the area remained submarine. Further tectonism, probably in the mid Silurian, uplifted the area, producing shallow-marine conditions, at least in the western half of the Sheet area. Evidence of the palaeoenvironment in the eastern half of the Sheet area at this time is lacking, although an early slump-like deformation may have been associated with this uplift (as suggested by outcrops at Surf Beach, BATEMANS BAY, GR 478388). In the Late Silurian, shallow-marine clastic sediments (De Drack Formation) were laid down in the western half of ARALUEN with only slight discordance on the Ordovician turbidites, and several limestone bodies were formed in the shallow seas.

At this time volcanics were being deposited well to the west, in the Canberra area, as a result of partial melting of the crust. The zone of melting soon extended eastwards beneath the ARALUEN area; the shallow seas rapidly retreated and subaerial volcanism (Long Flat Volcanics) prevailed, at first giving rise to dacite (Kadoona Dacite Member) and then rhyolite and rhyodacite (Toggannoggra Rhyolite Member and Wongabel Rhyodacite Member), mainly as ignimbrite sheets. After volcanism ceased, in the latest Silurian or earliest Devonian, there was widespread subsidence in the region, extending west to Captains Flat and northwards to Woodlawn. A turbidite-like unit, the Palerang beds, was deposited in the subsided area and this is correlated with the Carwoola Beds in the Captains Flat area and the Covan Creek Formation north of Woodlawn.

In the Early Devonian the entire area was compressed strongly, and tight meridional to northeast trending folds formed in the sedimentary strata and more open northeast-trending folds in the volcanics. Somewhat later in the Early Devonian, after compression had been released, major plutons comagmatic with the Long Flat Volcanics were emplaced. Presumably the region had by then become a landmass.

At least three suites of I-type granitoids were intruded. A western suite consisting of the Ballallaba Adamellite and Anembo Granodiorite, and possibly also the Tallaganda and Rossi Granodiorites, is characterised by a high quartz content, high Fe and Ca, and low Na and Sr. This suite is chemically equivalent to the Kadoona Dacite Member. A central suite comprising the Jinden Adamellite and Braidwood Granodiorite has high K, Rb, REE, Ba, and Sr, and is comagmatic with the Toggannoggra Rhyolite Member and Wongabel Rhyodacite Member. An eastern suite (Merricumbene Granodiorite) is high in Na and Sr and low in Fe, and has no known extrusive equivalents. However, it is quite similar chemically to the Moruya Batholith (Griffin & others, 1978). All these plutons give K-Ar and Rb-Sr mineral dates in the range 395 to 405 Ma. The three suites can be matched with suites identified in the Bega Batholith to the south by Beams (1980).

In the late Middle Devonian, extensional faulting and monoclinal flexing of the folded Ordovician strata now exposed at the eastern edge of the Sheet area formed the meridional Comerong Rift Zone. Partial melting of the mantle caused tholeiitic magma to migrate into the crust, and the elevated geothermal gradient in turn partially melted the residual granulitic material left after the period of Late Silurian–Early Devonian I-type magmatism. The resulting lower-crustal melts were relatively anhydrous and fluorine-rich, typical characteristics of A-type magmas (Loiselle & Wones, 1979; Collins & others 1982). The products of this biomodal (tholeiitic and A-type) magmatism were the Comerong Volcanics, the Monga Granite, Mongamulla Adamellite, Coondella Creek Adamellite, and Donovan Basic Complex. Sparsely porphyritic rhyolite lava and ignimbrite dominated the volcanic material, but volcanic breccia was abundant at a volcanic centre to the north of Bendethera, 15 km west of the rift zone, and in the Monga area 600 m of olivine tholeiite was extruded. Tholeiitic magma was also intruded into the upper crust as dolerite dykes, swarms of which have been mapped both immediately to the west of the rift zone and in the west of the Sheet area, mainly in the Ballalaba and Jinden Adamellites. Next to the rift zone the dykes are meridional but in the west of the Sheet area they are east-trending, thus illustrating a 90° shift in the direction of principal stress.

Subsidence continued along the Comerong Rift Zone after magmatism ceased and this allowed an extensive sheet of fluviatile, deltaic, and shallow-marine sediment to be laid down over the whole area in the Late Devonian (Minuma Range Group and Merrimbula Group).

In the Carboniferous, much of the area occupied by plutons was tilted and faulted, but the Comerong Rift Zone and a meridional belt coinciding with the western edge of the Sheet area were zones of weakness and these areas were strongly folded and cleaved. Plutons west of the Mulwaree Fault were foliated during the deformation (while those to the east of the fault remained unstressed), and adjacent to the Comerong Rift Zone tight folds of Early Devonian age in the Ordovician rocks were refolded into downward-facing structures.

There is no evidence in ARALUEN of geological events in the Mesozoic. Presumably the area was land, being planated. In the Early Miocene, movement was renewed locally along old fault lines and alkali basalt was extruded, as evidenced by the small area of basalt straddling the Shoalhaven Fault in the headwaters of Jerrabattgulla Creek. About 30 m of net vertical movement has taken place along the fault since the basalt was erupted.

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APPENDIX: WHOLE-ROCK ANALYSES

Long Flat Volcanics

Sample number	77840121	77840130	77840131	77840201	77840268	77840373	77840382	77840390	77840391	77480440
Rock type	dacite	rhyodacite	rhyolite	rhyolite	hornfelsed dacite	rhyodacite	dacite	rhyolite ignimbrite	dacite	rhyolite
Grid reference	395440	466587	449598	421652	302262	359412	373410	408367	414370	330446
SiO_2	67.32	71.15	76.21	76.60	63.16	74.18	70.00	75.24	65.08	74.19
TiO_2	0.54	0.40	0.12	0.13	0.60	0.14	0.45	0.18	0.63	0.15
Al_2O_3	13.89	14.07	12.26	12.19	15.22	13.37	14.52	12.62	14.63	13.42
Fe_2O_3	1.73	1.13	0.57	0.49	2.42	0.58	1.27	0.51	1.80	0.59
FeO	2.95	1.90	1.00	0.82	3.41	0.98	2.32	1.07	3.88	0.92
MnO	0.10	0.07	0.05	0.05	0.11	0.04	0.06	0.09	0.12	0.04
MgO	2.00	0.68	0.15	0.17	2.63	0.27	0.93	0.40	1.89	0.33
CaO	2.99	3.54	1.16	0.77	4.97	1.38	3.58	1.45	5.75	1.21
Na_2O	2.80	2.65	3.20	3.50	2.10	3.71	2.65	3.32	2.24	3.73
K_2O	2.87	2.53	3.93	4.01	2.39	3.92	2.86	3.94	1.76	4.02
P_2O_5	0.11	0.10	0.02	0.02	0.11	0.02	0.09	0.04	0.02	0.04
H_2O+	1.88	1.06	0.81	0.90	1.65	0.88	0.91	0.59	1.36	0.78
H_2O-	0.08	0.06	0.05	0.02	0.03	0.02	0.01	0.08	0.06	0.07
CO_2	0.50	0.10	0.35	0.25	0.03	0.05	0.01	0.16	0.06	0.03
Rest	0.15	0.17	0.21	0.18	0.30	0.17	0.16	0.20	0.19	0.19
Total	99.91	99.61	100.09	100.10	99.13	99.71	99.82	99.89	99.47	99.71
Ba	500	600	840	860	1100	820	520	780	360	780
Rb	120	100	160	160	100	160	120	160	65	180
Sr	180	260	190	170	200	150	180	210	200	200
Pb	95	44	280	40	490	24	22	70	290	75
Th	12	8	16	18	14	22	18	22	16	18
U	6	<4	6	4	<4	<4	4	6	4	8
Zr	160	270	120	120	170	110	220	140	160	140
Nb	<4	<4	<4	4	6	8	8	4	<4	4
Y	32	32	38	38	26	34	30	40	28	34
La	30	20	40	30	20	40	40	50	30	40
Ce	70	60	80	90	70	90	60	130	100	130
V					160	10	60	20	140	
Cr	10				24	6	21	<10	20	<10
Co	15	5	<2	<2	12	<1	2	<5	15	<5
Ni	8	5	5	5	2	<1	<1	<5	10	<5
Cu	12	8	8	2	13	11	10	4	18	6
Zn	50	38	25	22	115	23	45	61	71	27

Ordovician Sedimentary Rocks

Sample number	77840387	77840384	77841621	77841622	77841623	77841625	77841626	78840180	78840181
Rock type	mudstone	fine sst.	laminated siltstone	phyllitic slate	quartz arenite	siltstone	mudstone	sandy phyllite	silty phyllite
Grid reference	307144	255308	280269	273275	246270	303142	303142	696441	687432
SiO_2	68.37	73.81	59.23	56.73	74.19	70.55	64.03	70.39	62.88
TiO_2	0.71	0.68	0.83	0.81	0.68	0.80	0.84	0.70	0.68
Al_2O_3	16.42	12.68	20.04	21.33	12.33	14.93	18.17	13.87	17.11
Fe_2O_3	1.48	1.76	1.98	3.56	0.53	3.32	1.33	1.22	1.03
FeO	2.31	2.26	4.47	3.75	3.53	1.60	3.96	3.82	5.47
MnO	0.02	0.02	0.04	0.08	0.03	0.02	0.06	0.05	0.05
MgO	1.62	1.62	3.20	2.55	2.05	1.17	2.55	2.05	3.28
CaO	0.04	0.18	0.07	<0.01	0.48	<0.01	<0.01	0.16	0.05
Na_2O	0.24	1.05	0.36	0.21	1.43	0.11	0.16	1.08	0.06
K_2O	3.87	2.76	5.29	5.87	2.94	3.17	4.76	3.12	4.39
P_2O_5	0.11	0.14	0.11	0.11	0.15	0.03	0.03	0.13	0.08
H_2O+	4.27	2.65	4.15	4.54	1.74	3.91	3.92	2.76	4.04
H_2O-	0.08	0.24	0.17	0.14	0.10	0.14	0.04	0.27	0.31
CO_2	0.07	0.02	0.01	0.03	0.03	0.03	0.02	0.08	0.10
Rest	0.24	0.19	0.23	0.28	0.17	0.24	0.28	0.18	0.18
Total	99.85	100.06	100.18	99.99	100.38	100.02	100.15	99.88	99.71
Ba	560	500	720	940	420	640	920	400	580
Rb	210	140	250	320	140	145	250	190	240
Sr	46	34	28	34	95	8	19	85	18
Pb	11	10	9	34	17	16	50	60	8
Th	18	20	24	28	20	22	22	22	18
U	6	8	4	4	4	4	6	<4	8
Zr	160	240	120	70	250	220	120	220	90
Nb	10	20	24	24	24	20	26	14	14
Y	150	55	46	70	28	34	38	30	26
La	110	40	60	90	30	30	50	70	40
Ce	300	100	110	130	90	60	120	170	110
V	100	80	120	120	70	90	120	70	120
Cr	90	60	100	90	55	75	95	50	90
Co	10	35	20	25	30	135	15	15	10
Ni	30	95	170	230	30	100	55	20	30
Cu	23	30	25	40	20	35	30	10	15
Zn	120	75	80	110	60	320	360	75	90

Long Flat Volcanics (incl. Kain Porphyry)

Sample number	77841501	77841514	77841534	77841536	77840357	77840132	77840264	77840430	77840443
Formation	Long Flat Volcanics	Long Flat Volcanics	Long Flat Volcanics	?Long Flat Volcanics	Long Flat Volcanics	Kain Porphyry	Kain Porphyry	Kain Porphyry	Kain Porphyry
Rock type	dacite	dacite	dacite	metadacite dyke	dacite	rhyodacite porphyry	qtz. feld. porphyry	qtz. feld. porphyry	albitized porphyry
Grid reference	389574	458537	471652	506625	392373	408590	427449	341347	363461
SiO_2	65.09	65.79	67.40	72.74	65.89	69.00	67.29	68.21	67.44
TiO_2	0.63	0.53	0.55	0.22	0.62	0.42	0.65	0.30	0.42
Al_2O_3	14.87	15.27	15.82	13.03	14.59	14.82	15.34	15.47	14.91
Fe_2O_3	1.55	1.21	2.12	1.13	1.51	1.19	0.74	0.60	1.22
FeO	4.03	3.48	1.75	0.96	3.76	2.19	3.91	2.60	2.31
MnO	0.10	0.08	0.11	0.09	0.19	0.09	0.10	0.08	0.07
MgO	2.30	1.68	1.93	0.68	2.27	1.23	1.38	1.08	1.67
CaO	4.98	4.10	4.21	3.41	4.34	4.08	4.43	4.97	2.63
Na_2O	2.24	2.70	2.50	2.93	2.37	2.60	2.67	2.64	3.30
K_2O	2.28	3.07	1.25	3.33	2.68	3.01	2.38	1.51	3.66
P_2O_5	0.14	0.11	0.13	0.06	0.09	0.12	0.21	0.10	0.11
H_2O+	1.47	1.49	1.86	0.71	0.74	1.31	1.21	1.44	1.67
H_2O-	0.08	0.10	0.05	0.07	0.43	0.01	0.09	0.06	0.07
CO_2	0.03	0.18	0.07	0.04	0.03	0.10	0.02	0.06	0.04
Rest	0.18	0.17	0.19	0.16	0.18	0.20	0.25	0.21	0.21
Total	99.97	99.96	100.02	99.56	99.69	100.37	100.67	99.53	99.73
Ba	380	450	440	520	400	740	560	370	700
Rb	100	160	60	170	140	110	100	70	150
Sr	190	180	340	180	180	320	320	310	240
Pb	190	50	12	55	17	70	280	390	32
Th	16	16	10	18	10	12	18	12	20
U	<4	4	6	<4	<4	4	<4	<4	6
Zr	160	150	390	42	160	190	450	280	190
Nb	<4	<4	4	8	6	6	8	<4	<4
Y	28	30	32	34	30	24	30	22	26
La	20	30	20	40	60	30	40	30	40
Ce	100	100	90	110	150	60	60	100	120
V	130	120	50	30	130		80	50	70
Cr	30	20	10	20	50	15	12	20	30
Co	15	10	<5	<5	45	38	5	10	10
Ni	10	5	5	10	15	8	<1	10	10
Cu	16	15	8	9	15	15	7	7	25
Zn	77	62	79	94	70	38	60	75	61

Braidwood Granodiorite

Sample number	77840100	77840105	77840107	77840118	77840403	77840404	77840464	77841521	77841530	77841559
Rock type	granodr.	adamellite	granodr.	granodr.	diorite	hnblendite	granodr.	granodr.	granodr.	granodr.
Grid reference	499619	533565	528461	506395	591614	593615	597627	473519	506644	599612
SiO_2	65.54	67.51	65.24	64.17	53.18	44.44	66.31	64.36	65.08	58.55
TiO_2	0.59	0.45	0.58	0.65	1.07	1.66	0.57	0.59	0.60	0.89
Al_2O_3	14.72	14.10	14.34	14.97	17.28	14.27	15.18	14.96	14.89	16.89
Fe_2O_3	1.95	1.30	1.81	2.01	2.58	3.19	1.44	1.53	2.00	2.12
FeO	2.79	2.35	2.97	3.10	5.64	6.59	2.93	3.37	2.86	4.73
MnO	0.10	0.07	0.08	0.09	0.12	0.17	0.08	0.10	0.10	0.09
MgO	1.81	1.61	2.25	2.30	4.31	10.30	2.03	2.23	1.94	3.20
CaO	4.67	3.58	4.40	4.93	7.35	10.49	4.24	4.95	4.63	6.17
Na_2O	2.45	2.40	2.95	2.50	2.01	3.31	2.41	2.53	2.53	2.50
K_2O	3.01	3.77	3.37	3.18	3.06	0.83	3.70	2.94	3.02	2.19
P_2O_5	0.16	0.12	0.16	0.17	0.27	0.48	0.15	0.16	0.17	0.20
H_2O+	1.19	1.29	1.43	1.34	2.01	2.74	0.57	1.36	1.52	2.09
H_2O-	0.09	0.03	0.05	0.06	0.07	0.03	0.05	0.08	0.09	0.07
CO_2	<0.05	0.25	0.05	0.10	0.08	1.13	0.10	0.07	0.15	0.17
Rest	0.19	0.24	0.19	0.22	0.30	0.39	0.21	0.20	0.22	0.26
Total	99.26	99.07	99.87	99.79	99.33	100.02	99.97	99.43	99.80	100.12
Ba	700	620	680	820	840	360	620	560	580	680
Rb	120	150	130	120	140	20	150	130	130	85
Sr	350	320	360	400	470	1200	360	380	370	490
Pb	30	600	34	100	38	90	14	44	60	3
Th	14	14	14	14	12	6	18	16	18	8
U	6	4	4	4	4	<4	6	6	6	4
Zr	190	170	190	220	300	140	180	200	190	190
Nb	4	<4	<4	6	6	<4	<4	<4	<4	16
Y	28	24	26	26	40	24	24	26	26	26
La	<10	30	20	20	30	20	40	20	30	40
Ce	80	100	90	70	110	100	130	80	110	80
V					230	250	110	60	130	200
Cr	10	10	10	10	50	490	20	30	20	35
Co	8	10	8	5	20	45	15	10	15	35
Ni	5	5	8	10	20	185	5	10	10	80
Cu	12	5	15	15	5	55	10	21	17	15
Zn	45	30	40	48	83	91	49	74	68	75

Braidwood Granodiorite

Sample number	77841563	77841564	77841565	77841582	77841583	77841584	77841585	77841586	77841587	77841594
Rock type	granodr.	xenolith	xenolith	xenolith	granodr.	xenolith	xenolith	xenolith	xenolith	granodr.
Grid reference	498383	498383	498383	498382	498382	498382	498382	498383	498383	463372
SiO_2	63.43	49.75	52.34	50.70	60.47	49.62	51.30	52.89	50.18	64.73
TiO_2	0.73	1.05	0.98	1.06	0.88	1.41	1.21	1.27	0.97	0.66
Al_2O_3	15.42	17.68	17.03	16.97	16.18	16.73	16.97	16.72	17.75	14.71
Fe_2O_3	2.15	4.11	3.01	3.80	2.39	4.65	3.88	3.65	4.11	1.98
FeO	3.24	5.97	6.04	5.60	4.11	6.40	5.82	5.53	5.24	3.24
MnO	0.09	0.16	0.15	0.16	0.09	0.18	0.15	0.14	0.14	0.07
MgO	2.55	4.50	4.55	4.95	3.00	4.75	4.40	3.95	4.20	2.49
CaO	5.26	8.97	8.85	9.37	6.25	8.87	8.76	7.95	9.16	5.08
Na_2O	2.65	2.65	2.45	2.60	2.60	3.00	2.80	2.60	2.55	2.55
K_2O	2.98	2.57	2.35	2.47	2.30	2.26	2.25	2.52	2.53	3.10
P_2O_5	0.17	0.67	0.25	0.40	0.21	0.27	0.61	0.47	0.78	0.13
H_2O+	1.09	1.56	1.96	1.85	1.25	1.63	1.74	1.91	1.99	0.93
H_2O-	0.09	0.08	0.06	0.05	0.06	0.09	0.05	0.06	0.06	0.13
CO_2	0.10	0.28	0.05	0.01	0.06	0.08	0.05	0.29	0.02	0.01
Rest	0.25	0.32	0.27	0.29	0.26	0.27	0.30	0.28	0.33	0.22
Total	100.20	100.32	100.34	100.28	100.11	100.21	100.29	100.23	100.01	100.03
Ba	820	760	700	740	740	620	760	820	860	600
Rb	120	110	100	95	90	95	95	95	100	140
Sr	440	660	560	580	500	540	580	560	700	340
Pb	10	10	14	10	10	19	85	10	8	13
Th	16	14	12	6	14	10	14	10	10	12
U	4	<4	<4	6	<4	4	<4	<4	<4	12
Zr	190	210	18	120	230	90	150	140	180	160
Nb	16	14	14	16	12	18	14	20	14	14
Y	24	44	34	42	20	28	34	34	42	24
La	20	40	30	40	20	30	40	40	30	30
Ce	80	140	70	100	70	60	90	90	150	70
V	150	300	300	300	220	390	310	240	300	160
Cr	25	20	20	30	30	15	15	10	10	40
Co	30	30	40	40	40	45	35	35	35	35
Ni	20	20	95	10	10	10	15	5	30	10
Cu	15	85	55	65	15	60	55	50	70	35
Zn	55	95	80	85	65	100	85	80	85	50

Jinden Adamellite

Sample number	77840124	77840318	77840347	77840348	77840376	77840378	77840399
Rock type	granite	adamellite	aplite	adamellite	hnbl. grd.	hnbl. grd.	adamellite
Grid reference	372321	318286	364268	364268	350388	356379	377189
SiO_2	69.48	71.43	76.78	69.57	68.35	68.50	68.55
TiO_2	0.48	0.37	0.07	0.43	0.49	0.52	0.46
Al_2O_3	14.20	13.56	12.55	14.13	14.15	14.26	14.36
Fe_2O_3	1.09	1.71	0.37	1.61	1.64	1.30	1.47
FeO	2.35	1.39	0.47	1.81	2.41	3.07	2.26
MnO	0.07	0.05	0.02	0.06	0.08	0.08	0.08
MgO	1.38	0.79	0.12	1.27	1.36	1.33	0.69
CaO	3.25	2.55	0.74	3.02	3.47	3.60	3.59
Na_2O	2.40	2.61	2.73	2.54	2.64	2.53	2.61
K_2O	3.92	3.89	5.63	4.04	3.48	3.37	3.71
P_2O_5	0.11	0.08	0.01	0.09	0.12	0.14	0.12
H_2O+	1.27	0.97	0.46	0.69	1.17	1.04	1.02
H_2O-	0.05	0.12	0.07	0.03	0.07	0.06	0.06
CO_2	0.10	0.04	0.08	0.03	0.10	0.03	0.05
Rest	0.22	0.17	0.11	0.19	0.20	0.20	0.20
Total	100.37	99.73	100.21	99.51	99.73	100.03	99.23
Ba	640	680	180	680	620	640	640
Rb	160	180	190	160	150	140	180
Sr	230	200	95	240	280	250	250
Pb	430	22	250	16	110	75	34
Th	18	26	36	16	22	20	18
U	6	4	<4	<4	<4	<4	6
Zr	170	190	65	180	190	200	170
Nb	6	8	4	8	8	8	<4
Y	38	44	10	24	24	32	24
La	40	<20	20	30	50	60	40
Ce	110	<20	50	80	80	90	120
V		50	10	70	90	80	80
Cr	10	11	11	21	17	16	20
Co	8	3	1	1	2	3	5
Ni	5	<1	<1	5	3	1	5
Cu	5	7	7	6	8	8	8
Zn	35	34	12	35	40	50	41

Ballallaba Adamellite

Sample number	77840092	77840095	77840166	77840198	77840206	77840210	77840213	77840257
Rock type	granite	granite	aplite	hnbl. grd.	grd.	porph. adamellite	mafic hnbl granite	mafic grd.
Grid reference	346667	332613	373637	383663	321568	293469	328458	261410
SiO_2	71.99	71.78	77.06	68.36	70.70	72.02	66.34	69.34
TiO_2	0.34	0.39	0.08	0.45	0.41	0.33	0.55	0.67
Al_2O_3	13.00	13.24	12.36	14.25	13.83	14.05	14.59	13.79
Fe_2O_3	0.76	0.94	0.52	1.50	1.01	0.80	1.43	1.09
FeO	2.19	2.34	0.60	2.63	2.54	2.09	3.54	3.82
MnO	0.08	0.07	0.02	0.07	0.07	0.06	0.09	0.09
MgO	0.82	0.93	0.12	1.49	1.08	0.75	1.90	1.12
CaO	2.53	2.91	0.56	3.87	2.87	2.38	4.29	3.27
Na_2O	3.10	2.75	2.71	2.48	2.87	3.13	2.47	3.24
K_2O	3.29	3.29	5.72	3.11	3.29	3.42	2.85	2.35
P_2O_5	0.07	0.08	0.02	0.08	0.08	0.08	0.10	0.14
H_2O+	1.39	1.30	0.42	1.43	0.94	0.91	1.11	0.73
H_2O-	0.09	0.10	0.02	0.05	0.07	0.03	0.05	0.05
CO_2	0.05	0.05	0.05	0.10	0.03	0.04	0.04	0.02
Rest	0.15	0.15	0.11	0.19	0.15	0.14	0.18	0.16
Total	99.85	100.32	100.37	100.06	99.94	100.23	99.53	99.88
Ba	520	520	220	600	480	440	480	360
Rb	160	170	230	140	150	150	130	110
Sr	110	120	34	170	120	120	160	140
Pb	60	46	110	110	36	38	120	36
Th	16	16	38	38	22	22	18	16
U	<4	4	8	<4	<4	<4	<4	<4
Zr	150	160	75	150	150	150	160	300
Nb	4	<4	8	6	8	4	6	14
Y	38	60	42	30	40	30	30	55
La	30	20	60	50	30	40	40	20
Ce	90	80	70	60	90	70	70	60
V			<10	100	70	40	130	90
Cr			2	26	7	5	18	9
Co	8	5	<1	8	5	3	10	8
Ni	5		3	5	3	3	4	4
Cu	8	2	7	7	6	7	13	9
Zn	48	45	43	50	47	42	60	65

Western Foliated Granites

Sample number	77840230	77840413	77840303	77840385	77841599	77841600	77841601	77841602
Formation	Gourock Gdr.	Gourock Gdr.	Anembo Gdr.	Anembo Gdr.	Tallaganda Gdr.	Rossi Gdr.	Rossi Gdr.	Tallaganda Gdr.
Rock type	foliated leucogr.	foliated granodr.	biotite adamellite	hnbl. granodr.	foliated granodr.	foliated granodr.	foliated granodr.	foliated granodr.
Grid reference	285271	272335	265164	256238	270684	270684	268670	279667
SiO_2	76.09	66.69	70.77	65.50	71.78	71.92	71.81	72.51
TiO_2	0.15	0.63	0.38	0.62	0.40	0.44	0.45	0.41
Al_2O_3	12.68	14.55	14.78	14.61	13.61	13.81	13.81	13.11
Fe_2O_3	0.52	1.11	0.54	1.82	1.38	0.42	1.24	1.10
FeO	1.06	3.95	2.23	3.64	1.75	2.76	2.04	2.26
MnO	0.03	0.09	0.04	0.09	0.05	0.05	0.05	0.07
MgO	0.20	1.54	0.96	2.10	0.75	0.74	0.76	0.78
CaO	0.85	4.31	3.30	4.72	3.10	3.19	3.17	2.98
Na_2O	3.27	3.52	2.50	2.75	3.50	3.25	3.20	3.60
K_2O	4.41	2.18	3.45	2.76	2.33	2.68	2.63	1.96
P_2O_5	0.02	0.14	0.07	0.09	0.07	0.07	0.08	0.07
H_2O+	0.55	0.87	0.67	1.07	0.78	0.57	0.74	1.02
H_2O-	0.01	0.07	0.09	0.07	0.08	0.07	0.08	0.08
CO_2	0.03	0.04	0.05	0.08	0.01	0.02	0.01	0.02
Rest	0.12	0.16	0.15	0.17	0.15	0.15	0.15	0.20
Total	99.99	99.85	99.98	100.09	99.74	100.14	100.22	100.17
Ba	380	370	420	420	400	410	410	350
Rb	200	100	165	130	95	130	115	70
Sr	55	190	130	160	180	170	170	190
Pb	20	44	24	14	5	13	8	5
Th	26	14	24	20	14	22	20	20
U	4	4	10	<4	6	4	4	<4
Zr	120	220	110	130	150	160	170	160
Nb	8	<4	14	14	12	16	12	14
Y	48	32	105	36	28	34	28	30
La	40	30	20	30	10	50	50	20
Ce	50	100	80	80	70	80	70	70
V	20	110	55	160	50	55	50	50
Cr	2	10	15	20	10	10	10	10
Co	<1	10	30	40	30	35	35	35
Ni	<1	5	<5	10	140	10	35	510
Cu	4	10	5	10	15	25	5	70
Zn	20	62	40	55	30	50	45	40

Comerong Volcanics

Sample number	77840013	77840016	77841550	77841577	78840153	78840163	78840169	78840173
Rock type	rhyolite	rhyolite	rhyolite lava	rhyolitic ignimbrite	basalt	porph. basalt	rhyolite lava	granoph. rhyolite
Grid reference	633464	595335	523199	485191	653615	692699	298645	633485
SiO_2	76.73	77.14	76.18	75.47	47.35	46.61	75.58	76.61
TiO_2	0.18	0.17	0.21	0.22	2.19	2.56	0.18	0.19
Al_2O_3	11.77	11.66	12.06	11.96	16.40	16.20	13.43	12.07
Fe_2O_3	0.99	1.06	0.58	0.77	3.61	6.31	0.17	0.54
FeO	0.58	0.88	1.38	1.31	6.71	4.81	0.92	1.31
MnO	0.02	0.06	0.07	0.04	0.18	0.19	0.01	0.03
MgO	0.10	0.09	0.08	0.16	7.18	7.63	0.28	0.46
CaO	0.17	0.38	0.62	1.12	7.62	7.79	0.21	0.25
Na_2O	3.35	3.05	2.95	2.85	3.69	3.28	4.85	3.28
K_2O	4.61	4.65	4.80	4.45	0.38	0.15	2.98	3.97
P_2O_5	0.02	0.05	0.01	0.03	0.50	0.40	0.05	0.01
H_2O+	0.66	0.69	0.66	0.82	2.95	2.80	0.19	0.76
H_2O-	0.20	0.03	0.08	0.04	0.66	0.56	0.13	0.20
CO_2	0.05	0.10	0.27	0.71	0.01	0.22	0.13	0.02
Rest	0.23	0.21	0.18	0.24	0.22	0.20	0.17	0.24
Total	99.66	100.22	100.13	100.19	99.65	99.71	99.28	99.94
Ba	720	700		680	190	55	760	760
Rb	170	220	85	210	12	2	100	160
Sr	75	50	490	80	320	340	110	90
Pb	180	250	3	370	5	5	24	18
Th	22	20	8	24	4	<4	26	22
U	8	6	4	4	<4	<4	6	6
Zr	280	190	190	280	230	190	160	300
Nb	14	12	16	30	12	8	16	22
Y	36	65	26	70	34	38	50	85
La	70	20	40	50	20	20	50	90
Ce	150	110	80	130	150	120	150	200
V			200	5	260	280		<5
Cr	38	110	35	10	170	110		15
Co	<2	<2	35	30	40	45		35
Ni	5	<2	80	<5	65	50		<5
Cu	18	8	15	10	40	85		35
Zn	130	38	75	90	100	110		180

Comerong Volcanics

Sample number	78840178	78840185	78840186	78840192	78840193	78840211	78840214	78840225
Rock type	dark rhyodacite	basalt	basalt	rhyolite	rhyolite	rhyodacite breccia	rhyolite	rhyolite
Grid reference	688519	669449	669449	683385	690384	597359	624341	595339
SiO_2	69.38	46.45	48.08	77.56	77.37	71.28	76.18	77.60
TiO_2	0.84	2.82	2.37	0.17	0.17	0.80	0.19	0.17
Al_2O_3	13.66	14.75	15.29	11.79	11.95	12.34	11.98	11.81
Fe_2O_3	0.19	1.01	0.89	1.01	0.21	0.15	0.57	0.91
FeO	4.91	10.81	10.04	0.51	1.15	4.14	1.31	0.79
MnO	0.09	0.20	0.19	0.02	0.05	0.07	0.04	0.03
MgO	1.11	5.98	5.93	0.13	0.19	0.64	0.09	0.06
CaO	1.24	8.97	7.20	0.23	0.16	1.25	0.96	0.21
Na_2O	3.65	3.69	4.60	2.65	2.90	3.28	2.58	3.00
K_2O	2.78	0.05	0.04	4.75	4.74	3.73	4.77	4.55
P_2O_5	0.02	0.64	0.49	0.05	0.05	0.16	<0.01	0.03
H_2O+	1.63	3.78	3.72	0.50	0.46	1.12	0.48	0.45
H_2O-	0.27	0.48	0.50	0.20	0.24	0.16	0.21	0.15
CO_2	0.05	0.10	0.33	0.04	0.04	0.68	0.31	0.05
Rest	0.31	0.18	0.19	0.18	0.19	0.19	0.22	0.20
Total	100.13	99.91	99.86	99.79	99.87	99.99	99.89	100.01
Ba	1200	10	35	580	620	540	680	640
Rb	140	6	<2	240	210	160	230	220
Sr	240	85	150	46	90	70	60	60
Pb	22	4	36	20	34	9	28	19
Th	16	4	6	18	20	22	22	20
U	6	<4	<4	8	6	6	6	4
Zr	410	260	220	150	150	290	270	180
Nb	14	14	14	14	16	16	26	16
Y	60	46	38	65	65	50	85	75
La	60	40	40	50	50	60	70	80
Ce	170	110	130	160	150	150	210	200
V	60	290	240	<5	<5	60	<5	<5
Cr	25	160	190	25	55	10	10	10
Co	35	40	35	35	30	35	30	40
Ni	10	35	70	5	25	<5	<5	<5
Cu	25	50	40	20	20	10	10	35
Zn	75	110	110	100	80	75	95	90

Mafic Dykes & Sills

Sample number	77840094	77840097	77840117	77840199	77840205	77840307	77840337	77840397	77840465	77840477
Rock type	dolerite dyke	dolerite dyke	dolerite dyke	dolerite dyke	dolerite dyke	dolerite dyke	dolerite dyke	dolerite dyke	gabbro sill	gabbro sill
Grid reference	313654	354582	509394	382667	362598	369153	346226	352260	433263	435246
SiO_2	47.80	48.84	48.32	49.44	46.08	48.30	48.22	49.89	48.38	48.79
TiO_2	2.12	2.66	3.19	3.01	1.66	1.43	1.70	1.49	1.83	2.23
Al_2O_3	14.74	13.73	15.08	13.80	16.97	16.06	15.97	15.94	16.40	15.76
Fe_2O_3	2.86	2.76	5.01	3.88	2.68	2.17	1.67	0.80	1.62	0.98
FeO	9.05	9.42	8.30	9.88	8.13	7.68	9.38	3.06	8.09	9.80
MnO	0.21	0.23	0.35	0.25	0.18	0.18	0.19	0.16	0.15	0.18
MgO	6.25	5.50	4.10	4.64	7.57	7.55	6.75	7.48	6.32	5.50
CaO	9.85	9.91	8.58	8.80	9.51	10.52	10.30	9.74	7.62	7.84
Na_2O	3.25	3.00	3.50	3.22	2.69	2.70	2.81	2.51	4.58	3.73
K_2O	0.45	0.51	1.00	0.72	0.69	0.60	0.32	1.03	0.05	1.25
P_2O_5	0.36	0.50	1.57	0.60	0.24	0.20	0.22	0.02	0.37	0.47
H_2O+	2.29	2.54	1.78	1.73	3.45	2.19	2.43	2.08	4.21	2.96
H_2O-	0.09	0.06	0.18	0.01	0.04	0.07	0.05	0.12	0.09	0.04
CO_2	0.05	0.10	0.10	0.05	0.25	0.04	0.10	0.06	0.05	0.07
Rest	0.19	0.18	0.17	0.17	0.18	0.21	0.20	0.20	0.17	0.36
Total	99.56	99.94	100.01	100.29	100.32	99.90	100.31	99.84	99.93	99.96
Ba	120	160	320	230		260	110	160	20	880
Rb	24	17	22	20	38	46	12	80	<2	34
Sr	350	310	460	310	420	170	275	230	190	820
Pb	820	560	100	220	560	24	260	6	28	3
Th	<4	<4	<4	6	6	6	4	4	4	8
U	4	<4	<4	<4	<4	<4	<4	<4	<4	4
Zr	150	230	210	260	130	110	110	140	160	210
Nb	<4	<4	<4	10	<4	<4	<4	4	4	4
Y	30	44	55	50	24	30	26	30	48	40
La	<10	<10	<10	<20	20	20	50	<20	<20	<20
Ce	20	50	80	60	20	<20	110	70	80	80
V					30	280	250	220	210	270
Cr	10	18	10	60	80	310	120	270	210	210
Co	28	25	18	29	41	37	33	40	40	40
Ni	18	18	8	15	60	85	37	115	125	60
Cu	35	40	15	31	32	65	35	57	42	47
Zn	80	80	110	125	85	90	85	75	95	117

Donovan Basic Complex

Sample number	77840018	77840019	77840020	78840258	78840259	78840260	78840261
Rock type	felsic granophyre	diorite	gabbro	granophyre	granophyre	felsic granophyre	granophyre
Grid reference	606281	606281	603281	608280	607281	607282	606282
SiO_2	68.05	52.45	46.47	59.18	59.85	69.33	60.38
TiO_2	0.51	1.96	3.70	1.45	1.42	0.54	1.35
Al_2O_3	12.85	16.82	12.82	13.22	13.30	12.98	13.38
Fe_2O_3	1.01	3.11	3.69	1.24	2.18	0.65	2.60
FeO	4.25	7.12	11.00	8.59	7.97	4.45	7.41
MnO	0.10	0.19	0.25	0.19	0.19	0.08	0.17
MgO	0.53	2.40	4.55	1.46	1.53	0.64	1.27
CaO	1.61	7.40	8.23	5.09	4.21	1.22	4.54
Na_2O	2.55	3.55	2.40	2.85	3.00	1.95	2.97
K_2O	4.97	1.80	0.93	2.37	2.91	5.18	2.96
P_2O_5	0.11	0.97	2.11	0.47	0.48	0.10	0.45
H_2O+	1.70	1.75	2.68	1.74	1.31	1.41	1.42
H_2O-	0.12	0.09	0.08	0.37	0.43	0.30	0.39
CO_2	1.10	0.40	0.10	1.31	0.47	0.70	0.33
Rest	0.38	0.32	0.28	0.43	0.47	0.41	0.49
Total	99.84	100.33	99.29	99.96	99.72	99.94	100.11
Ba	1250	380	270	490	560	1200	580
Rb	220	80	38	80	130	270	110
Sr	80	380	270	210	250	70	260
Pb	200	620	350	18	24	22	22
Th	4	4	4	16	14	18	16
U	16	6	6	<4	4	6	4
Zr	1000	860	880	1950	2100	1200	2150
Nb	22	10	6	26	26	32	28
Y	80	50	60	75	80	80	80
La	40	20	30	80	70	80	90
Ce	130	70	120	200	210	230	210
V				15	15	<5	15
Cr	28	20	15	15	15	10	20
Co	5	15	28	25	25	30	50
Ni	5	5	20	<5	<5	<5	<5
Cu	10	25	38	45	20	15	35
Zn	95	75	120	150	140	90	140

Donovan Basic Complex

Sample number	78840262	78840263	78840264	78840265	78840266	78840267	78840268
Rock type	diorite	diorite	diorite	gabbro	gabbro	granophyre	granophyre
Grid reference	606283	605283	604283	604282	604282	599281	595282
SiO_2	52.89	51.51	51.77	47.36	47.96	63.45	61.85
TiO_2	2.02	2.09	2.62	4.48	4.70	1.10	1.09
Al_2O_3	16.79	16.19	15.15	14.59	14.71	13.27	13.21
Fe_2O_3	2.39	1.58	2.40	2.51	1.91	1.31	1.01
FeO	7.43	8.52	9.74	11.19	10.85	6.58	6.77
MnO	0.17	0.19	0.22	0.21	0.20	0.14	0.14
MgO	2.65	2.92	3.15	4.38	4.72	0.80	0.81
CaO	7.53	6.98	7.05	7.90	7.49	3.33	3.72
Na_2O	3.23	3.41	2.80	2.27	2.69	3.05	2.30
K_2O	1.55	1.80	1.45	0.86	0.92	2.71	3.40
P_2O_5	0.98	1.00	1.22	0.53	0.65	0.32	0.34
H_2O+	1.00	2.09	1.47	2.06	1.86	1.86	2.21
H_2O-	0.58	0.40	0.45	0.36	0.45	0.39	0.47
CO_2	0.16	0.32	0.19	0.66	0.26	1.40	2.37
Rest	0.30	0.29	0.32	0.24	0.23	0.41	0.44
Total	99.67	99.29	100.00	99.60	99.60	100.12	100.13
Ba	340	350	410	230		560	760
Rb	60	75	46	34	36	120	130
Sr	370	320	330	300	300	190	170
Pb	12	6	10	4	60	14	46
Th	8	4	12	8	4	24	14
U	4	<4	4	4	<4	4	6
Zr	900	800	940	760	780	1750	1750
Nb	18	18	16	16	14	30	30
Y	55	50	60	36	40	75	75
La	20	60	50	30	40	70	70
Ce	160	160	150	140	140	180	210
V	150	160	190	30	95	25	25
Cr	30	35	15	55	110	20	15
Co	30	25	45	35	35	15	10
Ni	5	30	5	35	45	<5	5
Cu	30	35	30	45	10	20	15
Zn	110	120	140	120	30	120	140

Monga Granite

Sample number	77840411	77840412	77840453	77840457	77840460	77840461	77841562
Rock type	leucogr.	granite	alkali leucogr.	granite	granite	granite	biotite adamellite
Grid reference	639629	618596	603583	616561	630564	632565	630563
SiO_2	76.01	70.81	76.46	74.83	69.94	70.51	71.29
TiO_2	0.19	0.53	0.17	0.26	0.52	0.51	0.54
Al_2O_3	12.17	13.32	12.12	12.24	13.76	13.43	13.13
Fe_2O_3	0.54	1.38	0.14	0.46	0.91	0.96	1.13
FeO	1.03	2.67	1.28	1.64	3.09	2.86	2.91
MnO	0.02	0.07	0.02	0.04	0.07	0.07	0.06
MgO	0.14	0.53	0.16	0.25	0.57	0.54	0.54
CaO	0.44	1.63	0.40	0.78	1.85	1.78	1.84
Na_2O	3.02	3.64	3.67	3.23	3.21	3.35	3.30
K_2O	4.99	3.78	4.21	4.75	4.08	4.18	4.05
P_2O_5	0.07	0.14	0.07	0.08	0.14	0.13	0.11
H_2O+	0.76	0.99	0.66	0.74	0.99	1.09	0.84
H_2O-	0.05	0.07	0.09	0.09	0.06	0.07	0.12
CO_2	0.04	0.17	0.04	0.16	0.09	0.06	0.05
Rest	0.16	0.26	0.14	0.17	0.21	0.22	0.22
Total	99.63	99.99	99.63	99.72	99.49	99.76	100.13
Ba	560	680	420	560	580	640	560
Rb	260	200	180	240	190	210	205
Sr	34	120	48	55	120	100	110
Pb	46	80	50	55	32	30	32
Th	24	32	24	26	24	28	30
U	8	8	10	6	8	6	6
Zr	170	490	160	240	410	400	380
Nb	4	12	4	6		12	22
Y	60	65	60	60	60	55	60
La	30	90	30	30	50	50	40
Ce	120	210	110	140	150	170	120
V	10	20			20	10	25
Cr	<10	10	<10	<10	10	10	10
Co	<5	<5	<5	<5	<5	5	30
Ni	<5	5	<5	<5	5	<5	85
Cu	9	11	33	9	12	12	15
Zn	40	93	28	44	81	70	70

Miscellaneous Rocks

Sample number	77840243	77840389	78840201	78840206
Formation			Merricumb. Granodr.	Merricumb. Granodr.
Rock type	Tertiary basalt	qtz. feld. porphyry	hnbl. granodr.	porph. gdr dyke
Grid reference	303341	309168	629410	624405
SiO_2	46.45	70.75	66.71	64.84
TiO_2	1.84	0.33	0.51	0.58
Al_2O_3	14.88	13.76	15.80	16.22
Fe_2O_3	1.71	1.10	1.28	1.78
FeO	9.16	1.90	2.35	2.54
MnO	0.16	0.07	0.07	0.05
MgO	8.40	0.78	1.79	1.90
CaO	9.06	1.91	4.33	4.52
Na_2O	2.63	3.04	3.90	4.06
K_2O	1.05	4.26	1.76	1.69
P_2O_5	0.38	0.09	0.12	0.15
H_2O+	3.58	1.19	0.77	1.04
H_2O-	0.52	0.07	0.23	0.25
CO_2	0.03	0.15	<0.04	0.04
Rest	0.23	0.15	0.19	0.21
Total	100.08	99.55	99.81	99.87
Ba	130	410	490	460
Rb	9	180	44	60
Sr	500	150	520	560
Pb	85	55	8	75
Th	4	24	<4	<4
U	<4	4	<4	<4
Zr	140	150	120	120
Nb	20	4	4	4
Y	16	38	14	14
La	20	40	30	20
Ce	50	90	110	90
V	220	45	75	85
Cr	230	10	20	15
Co	42	10	45	50
Ni	160	<5	5	45
Cu	55	19	35	110
Zn	90	62	50	50

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