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The Geology of the Windellama Area, New South Wales

Ruth Mawson

Abstract—Mapping of some 50 km^2 in the Windellama area has revealed a sequence of 1,700 m or more of Early Devonian carbonate and terrigenous sediments downfaulted into rocks at least in part of Late Silurian age. The Devonian succession consists of approximately 200 m of terrigenous sediments overlain by about 283 m of carbonates, the Windellama Limestone, overlain in turn by a further 1,200 m or more of sandstones and siltstones. The Windellama Limestone yielded rich macro and micro-faunas of Early Devonian (Lochkovian) age. The overlying terrigenous sediments have yielded a coral-trilobite-brachiopod fauna of Early Devonian (Praguian) age.

Introduction

Windellama is located on the southern tablelands of New South Wales, 40 km S.E. of Goulburn and 224 km S.W. of Sydney. It is an area of primarily rolling terrain, the landforms to the east becoming more rugged where the underlying sediments have proved more resistant to weathering and erosion. The landform pattern tends to be meridional, reflecting regional strike of the rocks.

Previous Investigations

The earliest comment on the geology of the Windellama area appeared in 1834 on the original survey plan drawn up by Robert Hoddle; limestone hills were marked and the occurrence of "fine black marble" noted. Rev. W. B. Clarke (1860), in reporting on the limestone outcrops between Jacqua and Windellama, assumed a relationship between these and the Bungonia limestone.

The commercial potential of the limestone was realized as early as 1874 when John Young opened a small marble quarry on Limestone Creek, Windellama, to provide material for tiling the Great Hall at Sydney University. The curator of the New South Wales Technological Museum, R. T. Baker (1909), regarded the "marble" from Windellama as "the best black marble yet found in New South Wales".

W. G. Woolnough (1909) was the first to refer to the fossiliferous limestones at Windellama as being Devonian in age and to note the lithologic contrast with Silurian limestones of the Bungonia district. In a detailed study of the limestone, J. E. Carne and L. J. Jones (1919) recognized two belts corresponding to those shown in Figures 3 and 4 of this paper. They considered the limestone to be of Silurian age. M. D. Garretty (1937) accepted this age assignment refining it to Late Silurian on the basis of fossils identified by W. S. Dun; no identifications were listed. He noted that between Bungonia and Windellama the sediments differed considerably from the surrounding Ordovician and Silurian sequences and, on the basis of further fossil identifications by W. S. Dun, dated these as Late Devonian.

G. F. K. Naylor (1949), in summarizing his previous work in the Goulburn district (1935*a*, 1935*b*, 1937, 1939), assigned all the limestone of the area a Silurian age and identified the terrigenous sediments as belonging to either Ordovician or Silurian belts.

It was not until 1970 that J. W. Pickett, in an unpublished report (1970), dated the Windellama limestone as Early Devonian (Siegenian-Emsian) age on the basis of: *Heliolites daintreei* Nicholson and Etheridge, *Favosites* cf. *ovatiporus* Hill and Jones, *Aulopora* sp., *Tryplasma* sp., *Microplasma* sp., and *Trupetostroma* sp.

Pickett and M. B. Huleatt (1971) refined the date to late Siegenian, based on a more complete faunal list. Pickett identified, *inter alia*, *Favosites* cf. *ovatiporus* Hill and Jones, *Heliolites daintreei* Nicholson and Etheridge, *Pseudamplexus princeps* (Etheridge), *Tryplasma* cf. *columnare* Etheridge, *Spathognathodus steinhornensis buchanensis* Philip, *S. inclinatus* (Rhodes), *Hindeodella priscilla* Stauffer, *Ozarkodina denckmanni* Ziegler, *Trichonodella inconstans* Walliser, *T. symmetrica pinnula* Philip, *Plectospathodus alternatus* Walliser.

In a report for the mining exploration firm of Asarco (Australia) Pty. Ltd., R. G. Dingwall and M. Kriewaldt (1972) suggested the sediments underlying the Windellama limestone to be Silurian and those overlying the limestone of

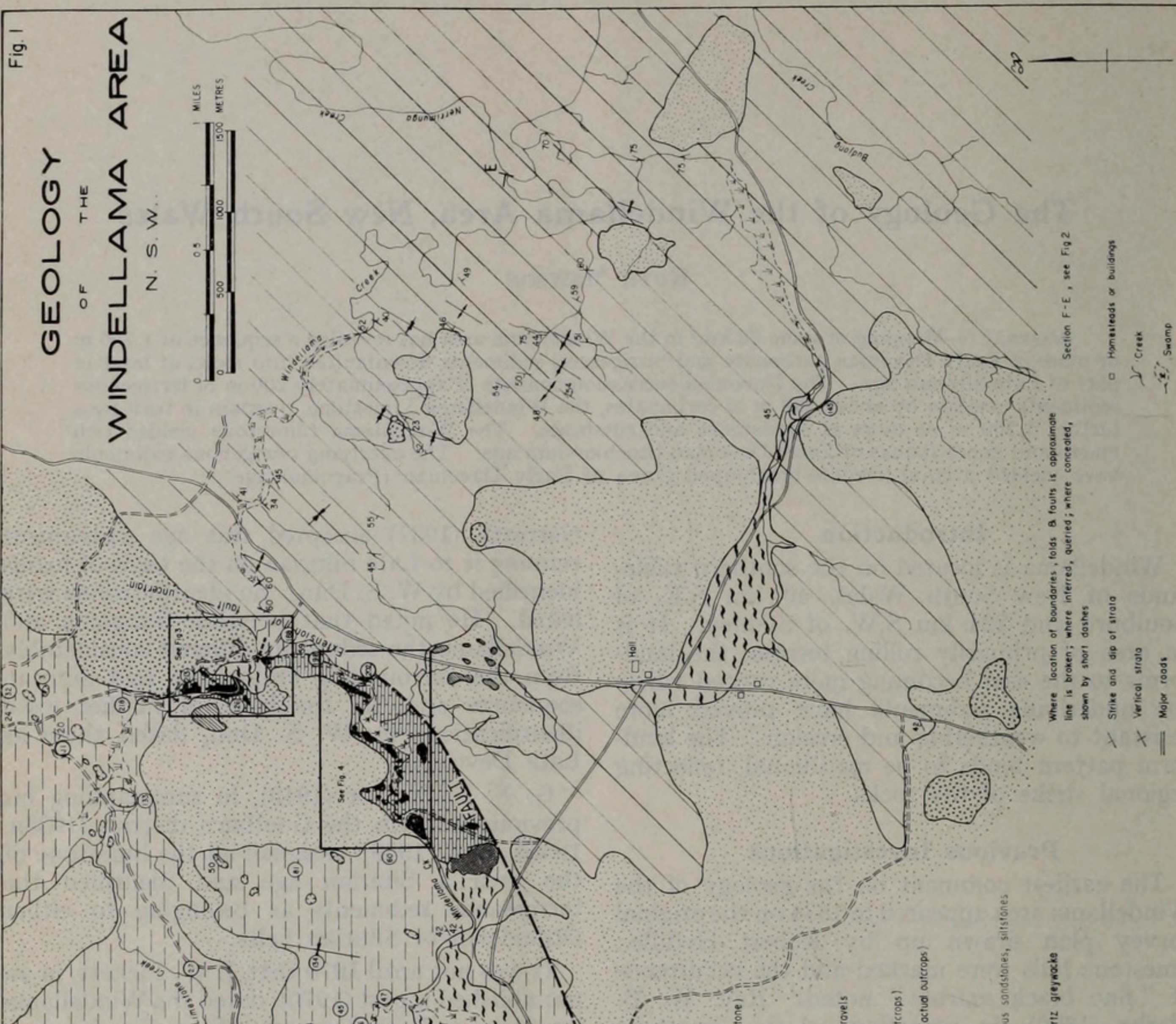
Fig. 1
GEOLOGY OF THE WINDELLAMA AREA
N. S. W.
0 0.5 1 MILES
0 500 1000 1500 METRES
LEGEND
CAINOZOIC
Alluvium, sand, clay, gravel, silt
Calcrete (apparently overlying Devonian limestone)
Bauxite, laterite, ironstone
Basalt
Manganiferous grits
Silcrete, conglomerate, sandstone, sands, gravels
Rhyolite (age uncertain)
DEVONIAN
Conglomerate, fossiliferous grit (actual outcrops)
Coarse fossiliferous, tuffaceous sandstones (actual outcrops)
Fossiliferous limestone (actual outcrops)
Inferred limestone (soil covered)
Sandstone, tuffaceous(?) sandstones, tuffaceous sandstones, siltstones
SILURIAN
Fossiliferous limestone
SILURIAN ?
Silty sandstone, siltstone, quartzite, shale, quartz greywacke
Geological boundary
Fault
Anticline
Syncline
Where location of boundaries, folds & faults is approximate line is broken; where inferred, queried; where concealed, shown by short dashes
Section F-E, see Fig. 2
Strike and dip of strata
Vertical strata
Major roads
Track
Homesteads or buildings
Creek
Swamp
Fossil locality
QUEENSLAND
NEW SOUTH WALES
VICTORIA
Sydney
Canberra
Melbourne
JACQUA FAULT
YARRALAW FAULT
Windellama Creek
Limestone Creek
Nerrimunga Creek
Bulgong
Pophams Creek
School
Hall
See Fig. 3
See Fig. 4

possible Permian age. The fossils found in the latter, collected northwest of the main body of limestone by Dingwall, were submitted to Dr. J. W. Pickett (1972 unpub. report) who identified: *Fenestella* sp., *Alveolites* sp., *Thamnopora* sp., generically indeterminate ectoprocts and coelenterates, and a small ribbed brachiopod. He suggested possible correlation with early Late Devonian marine sandstones at Goulburn and Nerriga.

Stratigraphy

Sedimentary rocks of Silurian and Devonian age occur within the area (Figures 1 and 2). The Devonian sediments are bounded on the west by a fault (the Yarralaw Fault) trending approximately north-south; a second inferred fault (the Jacqua Fault) marks their eastern and southern boundary. Overlying the Silurian-Devonian sequences is an extensive cover of Cainozoic sediments with, in one area, a minor veneer of loose ?Permian sediments, the latter being too limited in extent to be shown as a separate outcrop on Figures 1 and 3.

Silurian

The limestone that crops out in the south-western corner of the area mapped has been assigned a Late Silurian age on the basis of the presence of *Conchidium* or *Kirkidium* sp. The limestone is massive and jointed, but tends to dip steeply in a westerly direction. It is a compact limestone, somewhat dolomitized, dark grey to grey in colour, with scattered veins of calcite varying in thickness from 5 to 20 mm. Fossils from the limestone include: *Conchidium* or *Kirkidium* sp., and poorly preserved *Favosites* sp., *Heliolites* sp., large rugose corals, nautiloids, and abundant stromatoporoids.

The outcrop of limestone in the northwestern region is of a similar age, as indicated by the presence of *Conchidium* or *Kirkidium* sp., *Favosites* sp., gastropods and stromatoporoids. Despite some alteration owing to its proximity to the Yarralaw Fault, this limestone is of similar lithology to the limestone outcropping in the southeastern corner of the area mapped.

Sediments of Possible Silurian Age

The sediments cropping out in the south and east of the area consist of siltstones, argillaceous siltstones, shales, sandstones, quartzites, and cherts; in places, micaceous siltstone and shale grade into phyllite. The beds are generally from 1 to 30 cm thick and in areas of pronounced folding are strongly cleaved. They form a series of folds, the fold axes being approximately

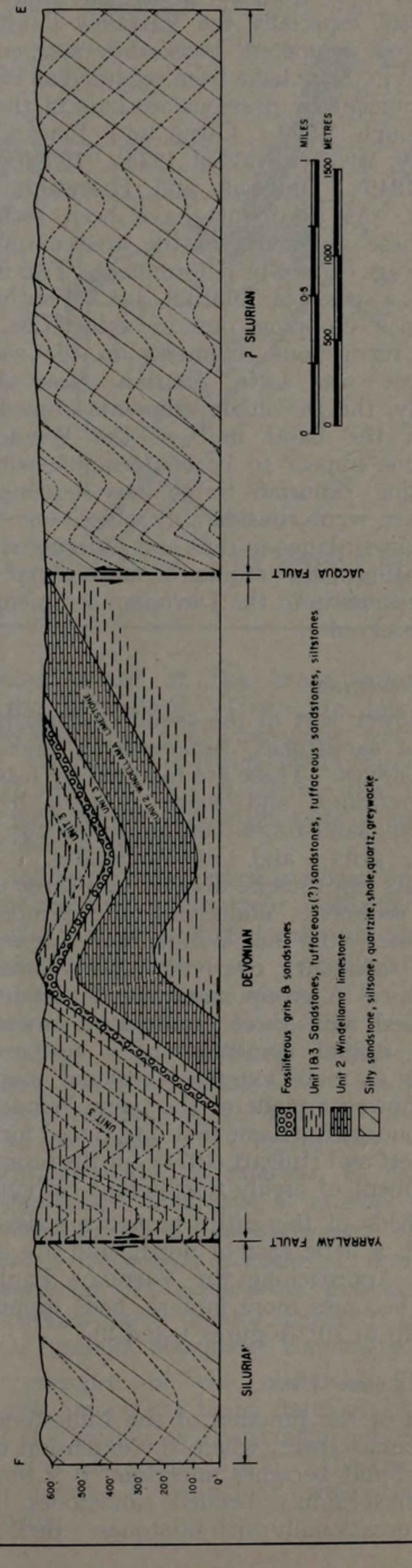

Fig 2 Bedrock Structure from Junction of Windellama and Nerrimunga Creeks 285° to Popham's Creek (F to E - see Fig.1)

meridional, running slightly east of north. Dips generally range from 40° to 52°, but adjacent to the faults, especially the Yarralaw Fault, and in the less competent beds, they steepen considerably. They have been regarded as Silurian or Ordovician by previous workers in the area (Woolnough, 1909 ; Carne and Jones, 1919 ; Garretty, 1937 ; Naylor 1935*a*, 1935*b*, 1937, 1939, 1949 ; Dingwall and Kriewaldt, 1972 unpub.). As no fossils have been recovered from these sediments in the area mapped, a positive age cannot be determined. Two factors suggest a possible Silurian age. Firstly, the limestones cropping out in association with similar terrigenous sediments in the west of the area are Late Silurian (see above). Secondly, the Devonian sediments immediately beneath the basal unit of the Windellama Limestone appear to be conformable with the underlying ?Silurian terrigenous sequence. If the latter were considerably older, one might expect discordance in dips and differing style of deformation. No sequence transitional from these sediments to the Devonian sediments has been observed.

Early Devonian

The lower part of the sequence consists of a series of sandstones, tuffaceous(?) sandstones, and siltstones. These are followed by fossiliferous limestones, and these in turn by fine tuffaceous sandstones, coarser tuffaceous sandstones, grits and conglomerates. These sediments can thus be divided into three units : 1. the sediments underlying the Windellama Limestone ; 2. the Windellama Limestone ; 3. the sediments overlying the Windellama Limestone. A group name could therefore be introduced with three constituent formations, but no formal nomenclature is proposed in advance of more extended regional mapping. Use is however made of the name Windellama Limestone, as the name first introduced formally by Pickett and Huleatt (1971), for the prominent development of highly fossiliferous carbonates.

The beds of the entire sequence strike in a direction a little east of north, and are gently folded. Approaching the Yarralaw Fault the folding becomes more intense, beds dipping at angles up to 70° (Figures 1 and 2).

(i) *The Lower Unit*

South of the junction of the Limestone and Windellama creeks, where the extension of the Jacqua Fault becomes uncertain, is a series of fine-grained thinly bedded sandstones, interbedded occasionally with siltstones. Beds range in thickness from 4 to 24 cm. The sandstones grade into fine tuffaceous(?) sandstones. Fossils found at localities 188, 198, and 202 (loose) consist of *Howellella* sp., other but indeterminate brachiopods, corals, and crinoid stems. The relationship of this lower unit to the ?Silurian sediments to the east is obscure. Because of poor outcrops and abundant soil cover the Jacqua Fault cannot be traced through the area, but the sediments of the lower unit are decidedly more sandy and not so shaly as the underlying ?Silurian sequence. It could be that there was no decided break in sedimentation between the two.

(ii) *The Windellama Limestone*

The Windellama Limestone crops out from the junction of Windellama and Limestone Creeks along the Windellama Creek to Burburba home-

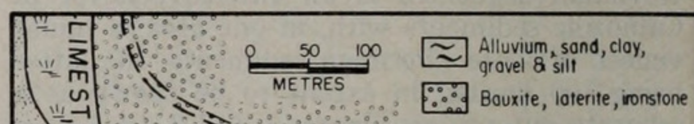

Fig 3. Detail of limestone outcrops along Limestone Creek

stead (Figure 4). The major outcrop occurs on Limestone Creek in the vicinity of a disused quarry approximately 200 m north of the junction of Windellama and Limestone creeks (Figure 3).

As far as one can tell from the limited outcrops, the limestone is conformable with the underlying sediments, but no actual outcrops demonstrate transition to or contact with the lower unit. Such a transition or contact is obscured by a cover of alluvium for a distance of only

Fig 4. Detail of limestone outcrops along Windellama Creek

from 3·5 to 4 m at the base of the limestone on the north side of Limestone Creek a little to the east of its junction with Windellama Creek.

The total thickness of limestone is at least 283 m. The lowermost limestone is dolomitized and richly fossiliferous. Veins of varying thickness and splashes of calcite are common. Algae and stromatoporoids are the predominant fossils of the limestone at this level, but there is a notable change in fauna up the sequence. Algal material gives way to corals, both tabulate and rugose ; brachiopods are also present.

Up the section the limestone becomes less dolomitic, more compact, well-bedded and silicified. This limestone is again richly fossiliferous, but the fauna consists almost entirely of corals, principally tabulates. Some stromatoporoids are to be found, but there is a complete dearth of brachiopods.

Exposures are good in the vicinity of the quarry on Limestone Creek ; here well-bedded, highly fossiliferous black micrites in beds from 2 to 20 cm in thickness have three developments of silicification : the lowermost (11·4 m in thickness) occurs 125 m above the base of the limestone, the second (1·4 m in thickness) occurs 171 m above the base of the limestone, and the topmost (4·2 m in thickness) occurs 180 m above the base of the limestone.

The highest beds of the Windellama Limestone appear to be the massive dark grey to black limestones found at the creek crossing at Burburba homestead. These are less richly fossiliferous, and are extensively veined by calcite. North of the Windellama Church, there is a flat with outcrops of calcrete that may be connected with yet higher horizons of limestone not known in outcrop.

The following conodonts have been extracted from the topmost development of silicified beds : *Ambalodus* aff. *galerus*, *Belodella* sp. *devonica*, *Hindeodella equidentata*, *H. priscilla*, *Icriodus woschmidti*, *Ligonodina diversa*, *L. elegans*, *L. salopia*, *L. silurica*, *Lonchodina cristagalli*, *L. greilingi*, *L. walliseri*, *Neoprioniodus bicurvatus*, *N. excavatus*, *N. multiformis*, *Ozarkodina denckmanni*, *O. media*, *O. australis*, *Paltodus acostatus*, *P. unicostatus*, *Plectospathodus alternatus*, *P. extensus*, *P. flexuosus*, *Spathognathodus canadensis*, *S. exiguus philipi*, *S. remscheidensis*, *S. steinhornensis optimus*, *S. wurmi*, *Trichonodella excavatus*, *T. inconstans*, *T. symmetrica*, *T. symmetrica pinnula*. The identifications were kindly checked by Dr. G. C. O. Bischoff, Macquarie University.

The presence of the conodont *Icriodus woschmidti* among the fauna dates at least this part of the section as Lochkovian (cf. Savage, 1973 ; Link and Druce, 1972). The remainder of the fauna is consistent with this age assignment.

(iii) *The Upper Unit*

No direct contact between the Windellama Limestone and the overlying Devonian terrigenous sediments has been observed because of Cainozoic cover. Approximately 800 m north and slightly to the west of the junction of the Windellama and Limestone creeks (locality 218) there are fine grained fossiliferous siltstones, sandstones and tuffaceous sandstones. Similar lithologies and fossils occur at localities 32, 42, 45, 47, 60, 81, 91, 93, 102, 110, 112, 126, 133, and 167. The fauna of these sediments consists of *Howellella* sp., *Aulacella* sp., and other but indeterminate brachiopods, *Pleurodictyum megastoma*, *Cladopora* cf. *corrigia*, *Syringaxon* sp., *Fenestella* sp. nov. cf. *F. dargoensis*, indeterminate trepostome bryozoan, crinoid stems, *Koneprusites* sp., *Acanthopyge australis*, *Leonaspis* sp., *Cheirurus* (*Crotalocephalides*) *gaertneri* (*Alberti*), *Phacops* sp. and scutelluid trilobites. The presence of *C.* (*C.*) *gaertneri* (Alberti) dates these sediments as Early Devonian (Praguian).

The fine tuffaceous sandstones give way to a series of coarser fossiliferous tuffaceous sandstones that are best exposed in the northeast part of the area. In places, expecially at locality J1, the tuffaceous sediments show spheroidal weathering. Fossils found in this material at localities 3 and 27 include: *Howellella* sp., other orthid, spiriferid and rhynchonellid brachiopods, bryozoans, crinoid stems, rugose and tabulate corals.

Above the coarse tuffaceous sediments a series of poorly cemented, coarse-grained sandstones, grits and conglomerates containing pebbles of quartzite and clasts of clay is found.

Fossils collected earlier by R. G. Dingwall of Asarco (Australia) Pty. Ltd. from coarse weathered sandstones about 1·5 km N.W. of Burburba homestead were thought to be possibly Late Devonian in age (Pickett, 1972) but the presence of the fossils listed above, particularly the trilobites, including *Cheirurus* (*Crotalocephalides*) *gaertneri* (Alberti), from locality 218 where these deposits are *in situ*, confirms an Early Devonian age. Faunas similar to those from locality 218 and those collected by Dingwall have been found at localities 46 and 134.

?Permian

Immediately overlying the outcropping limestones on the left bank of Limestone Creek (locality 213) and also to a lesser extent on the right bank (locality 126), are blocky siltstones containing generally fragmentary Devonian trilobites, corals and brachiopods; these blocks are lithologically identical to the fossiliferous Devonian sediments cropping out about locality 218 to the north. This sequence is overlain upslope by laterites here regarded as probably Tertiary in age. The fossiliferous Devonian rocks are however, problematic. Blocks almost a cubic metre in size are present and conceivably still larger blocks may be buried; none of the material whatever shows evidence of rounding —all blocks are angular but much of this angularity is presumably due to breakup along joint planes during weathering. It seems probable that this material has been transported, possibly from the north from the area where outcrops of similar material are known, and spread out as a veneer across the truncated edges of the Devonian limestones, possibly during Permian times.

Cainozoic

Much of the area is capped by Cainozoic rocks: conglomerates, sandstones, grits, laterite and bauxite, silcrete, manganiferous grits and basalt, deep weathered remnants of a formerly vast sheet of sand, gravels and minor basalts.

The Tertiary sandstones are flat-lying, quartz arenite beds consisting predominantly of quartz grains with a few quartzite and shale fragments scattered throughout. Grain size ranges from fine to very coarse sand; sorting is usually poor; sub-rounded grains predominate. Because of poor consolidation, the sandstone readily weathers to sands and gravels. The manganiferous grits consist of sands and gravels cemented by a ferruginous and manganese-rich cement. The grains are predominantly sub-angular to sub-rounded, and are very poorly sorted. Some investigation of these has been made as regards their commercial value. The conglomerate that crops out in two isolated localities, 145 and 157, has angular to rounded clasts of up to 25 cm in diameter set in a fine matrix.

A small outcrop of Tertiary basalt occurs adjacent to a large outcrop of silcrete north-west of the junction of the Windellama and Limestone creeks. In this section it can be recognized as an alkaline olivine basalt containing clusters of olivine phenocrysts. Pinkish mauve titaniferous pyroxene is present, and the plagioclase is arranged subspherulitically. Needles and anhedra of opaque minerals and interstitial zoned plagioclase are also present.

Silcrete, laterite and bauxite deposits, derived from the weathering of older rocks and of Tertiary basalt, crop out frequently in the area.

Red to brown pisolitic ironstone weathers to produce a very distinctive pavement of spherical nodules about 5 mm in diameter. Vermiform laterites are common.

Between the Windellama Church and Burburba homestead there is a large deposit of calcrete, presumably derived from Devonian rocks, possibly the topmost horizons of the Windellama Limestone. Calcrete has also developed on some of the limestone outcropping along Windellama Creek to the northeast.

Structural Features

The fold pattern of the Silurian and Devonian bedrock is shown on Figures 1 and 2. The fold axes strike slightly east of north. Dips average about 46°, but to the west the dip of the thinly-bedded, strongly cleaved shales and fine sandstones increases sharply and in places near vertical bedding can be observed.

The patchiness and paucity of outcrop make the establishment of faults in the area difficult; two major faults are however, inferred: a NNE trending fault in the west of the area along which the Devonian sequence has been downthrown against a demonstrably Silurian section shown to contain two lenses of fossiliferous limestone of Late Silurian (probably Ludlovian) age. This fault appears to be the southward extension of a fault shown on the Goulburn 1 : 250,000 sheet (Brunker and Offenberg, 1970) as separating Late Devonian sandstones on the east from an Ordovician flysch section to the west; Brunker and Offenberg (1970) show this fault extending almost to Yarralaw Creek. The presently mapped fault, obviously an extension of Brunker and Offenberg's fault, has been here named the Yarralaw Fault. The Devonian sequence is noticeably more arenaceous than the typically shaly Silurian sequences to the west.

The intrusion of a prophyritic devitrified rhyolite that crops out in the NW corner of the mapped area may have been related to the fault. The rhyolite contains large feldspar fragments, quartz, and very altered spherulitic amphiboles. A very fine-grained red " quartzite ", consisting of at least 90 per cent quartz, lies adjacent to the rhyolite. It is apparently the altered product of the country rock. Large outcrops of quartz near the postulated junction of the two faults give further indication of a fault.

Owing to poor outcrops a second fault, the Jacqua Fault, cannot be picked up with precision on the ground but is inferred from the mapping. Mapping of the Windellama Limestone (Figure 1) shows that southwards along strike the limestones are consistently replaced by unfossiliferous shaly and sandy sediments thought to be of Silurian age, a relationship consistent with NE trending fault in this area. Towards the NW, where it would lie within generally poorly outcropping shales and sandstones (towards the eastern boundary of Figure 1) the position of the fault is uncertain. Similarly, the extension of the fault westward becomes speculative because of the widespread cover of Cainozoic sediments and the virtual absence of outcrop away from Windellama Creek. Almost due east of Burburba homestead, along the line of the fault, a typical fault breccia exhibiting slickenside crops out and can be traced for about 50 to 70 m along the fault line. Loose reef quartz abounds along the line of the fault S and SE of Burburba homestead.

The area about and south of the junction of Limestone and Windellama creeks presents some problems in interpretation. A small, more or less E-W tear fault is evident, deduced from the lateral displacement of the basal beds of the limestones. On the north side of Limestone Creek these are displaced eastwards about 125 m relative to the basal limestone on the south side of the fault; the limestones on the north side therefore give the appearance of being replaced southward along strike by sandstone. The fault may be a small right lateral wrench fault.

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School of Earth Sciences,
Macquarie University,
North Ryde, N.S.W., 2113.

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