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STRATIGRAPHY AND STRUCTURE CANBERRA 1:50 000 GEOLOGICAL MAP AREA

by

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SUMMARY

A revised interpretation of the geology of the Canberra area, based on recent mapping by the Engineering Sub-section of the Bureau of Mineral Resources and by others, is shown on the published 1:50 000 scale map. The Pittman Formation, previously confined to the Middle Ordovician, has been re-defined to also include the Upper Ordovician Acton Shale and the sequence that conformably overlies the Acton Shale; the Acton Shale has been reduced from formation status to that of a member within the Pittman Formation. The Black Mountain Sandstone has previously been regarded as probable Lower Ordovician, but part of the formation is now thought to conformably overlie the Lower Silurian State Circle Shale, and the Black Mountain Sandstone is now placed in the Lower Silurian. The Canberra Group is now considered to be Middle or Upper, rather than Lower Silurian, and has been re-defined; the base has been lowered to include the Camp Hill Sandstone, and at the top the St John's Church Beds are now included in the Group. The Deakin Volcanics, originally defined as a unit conformably underlying the Upper Silurian Yarralumla Formation, is now re-defined to also include the Upper Silurian volcanics that conformably overlie the Yarralumla Formation; the status of the Yarralumla Formation - whether formation, member or wedge - awaits a more detailed appraisal of the more recent mapping some of which lies outside the area shown. Additional folds and faults have been identified, mainly in the Woden and Belconnen areas; the recent mapping indicates that some re-interpretation of the orogenic history of the area is necessary.

INTRODUCTION

The Engineering Geology Sub-section of the Bureau of Mineral Resources has, since the early 1960's, been engaged in a program of detailed geological mapping of areas proposed for the extension of the Canberra urban area. Mapping has included the plotting of outcrops at a scale of 1 inch : 200 feet, (1:2400) and the recording of geological data from excavations during urban development. Some of this work is available as unpublished reports in the BMR Record series (see reference list). The geological sequence in the Canberra area was originally presented by Öpik (1954) and further detail in his bulletin (Öpik, 1958). Mapping has since been extended beyond the central Canberra City area, and new information from excavations requires some modification of Öpik's original interpretation. By 1970 the mapping had reached a stage where information was sufficient to enable a geological map of the enlarged Canberra urban area to be compiled.

The geology was compiled on a National Capital Development Commission map (TP 224/67), scale 1 inch : ½ mile (1:31 680). This map, extending from Mount Stromlo in the west to Queanbeyan in the east, and from Woden in the south to the northern extremity of the A.C.T., covered a considerably larger area than that previously mapped in detail by BMR; however, geological maps were available for most of the additional area. Two such maps accompanied geological reports (Phillips, 1956 and Moore, 1957), and a third was an undated field map of the northern part of the A.C.T. attributed to C.J. Sullivan (formerly of BMR). A geological map of Black Mountain, prepared by students of the Australian National University Geology Department, was made available by Dr K.A.W. Crook, and various maps and reports on adjoining areas (listed in the reference) were examined.

By early 1971, the geological information had been plotted and the stratigraphy interpreted. It was decided to publish the map at a scale of 1:50 000 and the map, accompanied by explanatory notes, was published in 1971 (Strusz & Henderson).

The present report was written originally to explain and discuss the revised stratigraphy as presented on the new map, and to provide a basis for the Explanatory Notes; it has since been revised and brought up to date for this Record and thus may be regarded as a supplement to the published Explanatory Notes. Some aspects of the stratigraphy are discussed in more detail or from a slightly different viewpoint to that expressed in the Explanatory Notes; stratigraphic columns have been compiled and some discussion on structure is included. Co-ordinates given in the text refer to the 1:50 000 scale geological map (Strusz & Henderson, 1971).

As the original compilation of the geology was made at a scale of 1 inch : ½ mile (1:31 680), some of the detail had to be omitted from the 1:50 000 scale published map. The original compilation is filed in the BMR drawing office.

STRATIGRAPHY

A summary of the geology of the stratigraphic units was published as Table 1 of the Explanatory Notes accompanying the 1:50 000 geological map of Canberra City, A.C.T. (Strusz & Henderson, 1971). A generalized stratigraphic column is shown in Figure 1 of the present report.

ORDOVICIAN

The oldest rocks in the area are Ordovician and comprise the Pittman Formation and its Acton Shale member. Öpik considered the Upper Ordovician Acton Shale to be the youngest Ordovician formation in the area. Recent mapping at Aranda (N6096000, E689000) in the Belconnen area has revealed that the Acton Shale is conformably overlain by rocks lithologically similar to the Pittman Formation as originally defined by Öpik. The Pittman Formation has therefore been re-defined to include Upper Ordovician beds younger than the Acton Shale, and the Acton Shale has been reduced from formation status to that of a member of the Pittman Formation. The oldest beds known in the Pittman Formation are lower Middle Ordovician (Öpik, 1958); the exact age of the youngest beds is not known as no fossils have been found in beds overlying the Acton Shale. Although the younger beds are lithologically similar to the lower part of the Pittman Formation, there is an apparent increase in the proportion of sandstone upward within the sequence and a corresponding decrease in the proportion of shale and chert. The stratigraphy of the Pittman Formation is set out in Figure 2, and was derived from the mapping of reticulation trenches in Aranda.

The thickness of the beds overlying the Acton Shale at Aranda appears to be at least 400 metres; a minimum thickness of about 300 metres is estimated near the Belconnen Naval Station (N6100000, E690000). Observations at Queanbeyan indicate that the succession is confused by strong folding and probable faulting, and it is not possible to make a reliable estimate of thickness; however, near the quarry on Mount Jerrabomberra (N6804000, E701500) sandstone and siltstone similar to that of the Pittman Formation conformably overlie the Acton Shale.

The thickness of that part of the Pittman Formation that lies below the Acton Shale appears to be at least 900 metres at Belconnen provided that beds are not repeated by faulting and isoclinal foliding. It could be thicker as the lower beds are faulted against Silurian rocks to the east. Öpik's estimate of about 230 metres appears to be conservative. In the Queanbeyan/ Sutton area on the eastern margin of the map Moore (1957) reports that chert is present in the higher part of the 'Muriarra Formation' which is equated to that part of the Pittman Formation underlying the Acton Shale. As chert is known throughout the sequence at Belconnen, the lower part of the Pittman Formation in the Queanbeyan/Sutton area may be older than the rocks exposed at Belconnen.

A maximum thickness of 130 metres for the Acton Shale was measured during recent mapping at Belconnen; Öpik gave a thickness of at least 65 metres. At Aranda there are two major beds of siliceous shale, and a number of minor lenses of similar shale were observed at other horizons. Both major beds of siliceous shale have been shown as Acton Shale on the map, but it is possible that they occupy two different horizons in the stratigraphic column, as shown by Figure 2. One of the beds is over 100 metres thick and is continuous with the Acton Shale that has been previously mapped to the north. Whilst no evidence was obtained to suggest that the two horizons of siliceous shale are the same bed repeated by faulting or folding, the lack of a second bed of siliceous shale elsewhere implies such a possibility.

LOWER SILURIAN

The Lower Silurian is represented by the State Circle Shale, whose age is established by graptolites, and by the Black Mountain Sandstone which appears to overlie it. On structural grounds Öpik (1958) considered that the Black Mountain Sandstone was older than the Pittman Formation; but new exposures within 1 km of Capital Hill (N6090500, E693000) and recent mapping on Black Mountain, particularly at its southern foot, seem to indicate that the sandstone is conformable with the State Circle Shale. A conformable gradation from State Circle Shale up into interbedded sandstone and shale and then into Black Mountain Sandstone has been observed at the southern foot of Black Mountain (N6093000, E691000). A similar section was mapped in a trench running northeast from the Black Mountain peninsula (N6093000, E691500); no evidence was seen in the trench of the South Black Mountain Fault which was supposed to form the boundary between the Shale and the Sandstone.

State Circle Shale (confirmed by graptolites) was exposed in excavations for Capital Circle on Capital Hill (inner ring road-not shown on 1:50 000 map), and the shale appears to be conformably bedded with sandstone considered to be of the Black Mountain Sandstone type, although there are several faults that tend to confuse the relationship. The sandstone at the top of Capital Hill, which Opik identified as belonging to the Black Mountain Sandstone, appears to conformably underlie State Circle Shale; the relationship is inferred from the bedding attitudes in the northwest quadrant of Capital Hill and it assumes that no major fault lies between the major outcrops; outcrop is not continuous. In excavations for the South African Chancery building (0.5 km northwest of Capital Hill), sandstone, probably Black Mountain Sandstone, appeared to conformably overlie State Circle Shale; however, the contact is faulted sub-parallel to bedding, and the relationship is not clear.

The exposures around Capital Hill appear to indicate that the Black Mountain Sandstone may, in fact, be two sandstones separated by the State Circle Shale. On Black Mountain most of the sandstone appears to be younger than the shale; however, Öpik observed an older sandstone lying adjacent to downfaulted State Circle Shale along the Black Mountain Fault at the northern end of the mountain (N6096000, E691500); this exposure has since been obscured.

The thickness of the State Circle Shale was formerly regarded as about 65 metres; however, on Capital Hill it may be as much as 200 metres thick. At the southern foot of Black Mountain the thickness is about 50 metres if it is assumed that the shale rests unconformably on mudstone which Öpik mapped as Pittman Formation; however, in a stratigraphic drill hole completed at that locality in March 1972 the shale grades down into mudstone similar to that on Black Mountain Peninsula which has been regarded as part of the Pittman Formation. The possibility exists that the mudstone, whose thickness is unknown, is not part of the Pittman Formation but is a Lower Silurian unit. A satisfactory explanation for the differing lithologies underlying the State Circle Shale has yet to be found. Recent mapping tends to confirm earlier estimates that the younger Black Mountain Sandstone on Black Mountain is at least 500 metres thick. The older sandstone on Capital Hill is probably at least 120 metres thick.

The expression of the Benambran Orogeny, as an angular unconformity between the Ordovician and Lower Silurian rocks, has not been observed directly in the Canberra area. The Capital Hill unconformity recognized by Öpik is now thought to be later, not earlier than, the State Circle Shale and therefore post Lower Silurian. Discordant structural relationships between Ordovician and Lower Silurian rocks in places such as Black Mountain could be interpreted as evidence of an earlier unconformity, but it is also possible that the supposed unconformable boundaries are faulted. Recognition of an unconformity is hindered by the similarity of sandstone in the Upper Ordovician sequence to that of the Black Mountain Sandstone; at Aranda, sandstone thought to belong to the upper part of the Pittman Formation may possibly be Black Mountain Sandstone and indeed it was mapped as such by Öpik. Phillips (1956) mapped the sandstone on Mount Jerrabomberra (N6083000, E701000), and regarded it as a fault-bounded inlier older than the surrounding Pittman Formation, thus conforming with Öpik's interpretation on Black Mountain. From its field relationship, however, the sandstone on Mount Jerrabomberra almost certainly overlies the Pittman Formation, although it is not clear whether the relationship is conformable or unconformable.

An unconformity would be present at the southern foot of Black Mountain if the mudstone on Black Mountain peninsula was part of the Pittman Formation, but it would not be present if the mudstone were Silurian. On the western side of Black Mountain the Black Mountain Sandstone is either unconformable with, or faulted against, the Pittman Formation. North of Aranda, near the Belconnen Naval Station, State Circle Shale appears to be conformable on the Pittman Formation; however, a relatively small thickness of sediments (about 300 metres) would have to represent sedimentation during a large part of the Upper Ordovician and part of the Lower Silurian time intervals; this does not seem likely, and the relationship if probably not as simple as it would appear. As an alternative, it is possible that either a fault or a local disconformity separates the Pittman Formation and State Circle Shale in this area. An unconformity may be present below the State Circle Shale along the Barton Highway east of Ginninderra Creek (N6102200, E690700); however, the presence of Ordovician rocks in this area has not been positively confirmed. Moore reports possible State Circle Shale near Fairbairn Avenue close to Sullivans Fault (N6089000, E701000); the shale is adjacent to rocks mapped as Pittman Formation, but the relationship is complicated by faulting.

The absence of recorded fossils between the lower Upper Ordovician (Acton Shale) and the upper Lower Silurian (State Circle Shale) can be taken as evidence of a stratigraphic discontinuity and hence an unconformity. A lack of fossils over a similar time range is common in southeastern Australia and is commonly regarded as indicating an unconformity (Packham et al, 1969). Some of the late Ordovician or early Silurian sequence certainly appears to be missing in the Canberra area, but whether this is due to an unconformity or entirely to faulting cannot be determined at this stage. The regional evidence favours an unconformable relationship and none of the Canberra evidence can be regarded as ruling out this possibility.

MIDDLE TO UPPER SILURIAN

Three stratigraphic units - the Fairbairn Group, Gladefield Volcanics and Colinton Volcanics - have been regarded as Middle Silurian by earlier workers. A fourth unit, the Canberra Group, was placed in the Lower Silurian, but recent investigations indicate that it probably ranges from Middle to Upper Silurian. The revised age of the Canberra Group raises the possibility that the units previously assigned to the Middle Silurian may be partly or wholly Upper Silurian.

Canberra Group

The Canberra Group, as defined by Öpik, comprises three conformable formations which are, in ascending order, the Turner Mudstone, the Riverside Formation and the City Hill Shale. On the accompanying map the base of the Canberra Group has been lowered to include the Camp Hill Sandstone, which is thought to conformably underlie the Turner Mudstone, and the upper limit of the Canberra Group has been raised to include the St John's Church Beds which are known to conformably overlie the City Hill Shale. Öpik recognized but did not name a unit of shale and mudstone that overlies the City Hill Shale; this unit has now been included in the St John's Church Beds. The stratigraphy of the proposed Canberra Group is shown in Figure 3. Only the thicknesses of the City Hill Shale and Camp Hill Sandstone are known accurately; elsewhere, exposures are scattered and lack continuity, and folding and faulting have introduced additional complexities.

The revised age of the Canberra Group is based on structural relationships and on recent palaeontological evidence. On Capital Hill and Camp Hill (N6091000, E693500), the Camp Hill Sandstone rests unconformably on rocks of Lower Silurian age; on Capital Hill it rests on Black Mountain Sandstone, and on Camp Hill it rests on a shale which is considered, on the basis of field occurrence and lithology, to be State Circle Shale. As the State Circle Shale is known to be upper Lower Silurian the Camp Hill Sandstone must be younger, possibly Middle Silurian*. Upper Silurian conodonts were recently identified from limestones at the site of the NRMA building, Northbourne Avenue, (N6094500, E693600) and near the corner of Lonsdale and Cooyong Streets (N6094200, E693800) (Link & Druce, 1972). These limestones were mapped as part of the Riverside Formation by Öpik; however, later mapping indicates that they are probably younger than the City Hill Shale and probably lie within the St John's Church Beds. The upper limit of the Canberra Group is therefore likely to be Upper Silurian.

Additional work is probably desirable at three localities where possible Canberra Group rocks are shown on the map. Phillips (1956) recognized west of Queanbeyan a narrow belt of Camp Hill Sandstone overlain conformably by a succession of sedimentary rocks (extending 5 km south from N6087000, E700200); an extension of this belt further north was mapped as Camp Hill Sandstone by Moore (1957) but it may not be as extensive as he has indicated. Downstream from Coppins Crossing, (within 0.5 km of N6094500, E683700) fossiliferous siltstone and limestone appear to be surrounded by volcanic rocks; the fossil assemblage differs from that of the Upper Silurian

* The brachopod Rhipidium, which Öpik (1958) has reported from the Camp Hill Sandstone, ranges up into the Middle Silurian (Williams, 1965).

Yarralumla Formation, and is not unlike assemblages in the Canberra Group; however, the age relationship is uncertain (D.L. Strusz, pers. comm.). Along Canberra Avenue near St Andrew's Church (N6090000, E693500), mapping by Gardner (1969) in a sewer tunnel, revealed rocks that may be part of the Canberra Group; however Öpik mapped that area as part of the Pittman Formation.

Fairbairn Group

The revised age of the Canberra Group makes it necessary to re-examine the relationship between the Canberra and Fairbairn Groups. The Fairbairn Group has been thought to be Middle Silurian and younger than the Canberra Group. Since the age of the Canberra Group is now thought to be Middle to Upper Silurian, an Upper Silurian age for the Fairbairn Group is indicated; however, fossil assemblages suggest that some of the formations in the two groups may be contemporaneous (D.L. Strusz, pers. comm.), and a Middle to Upper Silurian age is preferred. The relationship between the two groups has not been established in the field, and any such correlation would have to be based on detailed palaeontology. Öpik divided the Fairbairn Group into a number of formations (see Fig. 4).

Gladefield Volcanics

The Gladefield Volcanics are known to conformably overlie the Fairbairn Group (Moore, 1957); as far as is known the volcanics do not contain any fossils and their maximum age is that of the top of the Fairbairn Group.

Colinton Volcanics

The Colinton Volcanics are shown as Middle Silurian on the Canberra 1:250 000 map (2nd edition - Best et al. 1964) but an Upper Silurian age is indicated in the Explanatory Notes (Strusz, 1971).

UPPER SILURIAN

The Canberra Group, and the Fairbairn Group with the overlying Gladefield Volcanics, whose ages probably range into the Upper Silurian, have been discussed above and will not be included here. This section deals with the Deakin Volcanics and a conformable sedimentary sequence - the Yarralumla Formation which together comprise the Red Hill Group. Associated with the Deakin Volcanics are bodies of porphyritic igneous rocks whose origins (whether intrusive or extrusive) are in doubt; they include the Mount Painter Porphyry, the Mugga Mugga Porphyry and other un-named porphyries that mostly resemble the Mount Painter Porphyry.

Recent mapping in the Woden and Belconnen areas (area on map west of E695000 and south of N6105000) indicates that a considerable thickness of volcanics overlies the Yarralumla Formation with apparent conformity, and it is proposed that the Deakin Volcanics (Öpik, 1958) be re-defined to include these volcanics. The Yarralumla Formation would then be regarded as a sedimentary member or wedge within the volcanics; however, further mapping and evaluation of data are required before a complete review of the status of the Yarralumla Formation can be made. The Deakin Volcanics as now defined are at least 1000 metres thick, and the Yarralumla Formation is probably thicker than the original estimate of 165 metres; the local stratigraphic column (Fig. 5) derived from mapping in the east Woden area (within 3 km of N6088000, E690000) indicates that there is considerable variation in thickness of the sediments, and that interfingering of sediments and volcanics is not uncommon. A detailed correlation of the Woden sequence with the Upper Silurian sequence at Belconnen (typically exposed along co-ordinate N6100000 west between E682000 and E688000) is not possible; however, there is a general similarity in lithology and fossils.

The Deakin Volcanics are separated from the Canberra Group and other Middle to Upper Silurian units by the Deakin Fault, and their stratigraphic relationship has not been observed; however, the Yarralumla Formation is known from palaeontological studies to be younger than the Canberra Group. The volcanics in the northwestern part of the area (area on map north of N6110000 and west of E691500), shown as probable Deakin Volcanics, have not been investigated in sufficient detail to enable a definite correlation.

An attempt has been made to map some of the rock units within the Deakin Volcanics. Many of the massive volcanic rocks are similar petrographically; distinctions have been made mainly on colour, texture, and on slight variations in mineral composition.

The Mount Painter Porphyry has been regarded as an intrusive sill (Öpik, 1958) and this interpretation is essentially correct; however, recent petrological work on thin sections indicates that parts of the area shown as Mount Painter or other Silurian porphyries consist of extrusive lava flows and densely welded crystal tuffs. There are problems in mapping the boundaries between extrusive and intrusive rocks, and amendments to the mapping are to be expected. It is expected that some of the areas shown as Deakin Volcanics consist of intrusive rocks, and the Mugga Mugga Porphyry, formerly regarded as an intrusive stock (Öpik, 1958) is now thought to be a volcanic flow (Henderson, in prep.). A number of localities have been found in the Mount Painter Porphyry and in other porphyries, in addition to those described by Opik, where intrusive relationships with the adjacent rocks can be seen or reasonably inferred. They are around Mount Stromlo, (N6090000, E682800) near Hindmarsh drive south of Red Hill, (N6086300, E693500) and north of Belconnen town centre, at the Lake Ginnudam dam site (N6100000, E688200).

UNDIFFERENTIATED SILURIAN

An area north of the Barton Highway is mapped as undifferentiated Silurian. Some parts of it contain rocks similar to those of the Lower Silurian Black Mountain Sandstone and State Circle Shale. This area has not been mapped in detail, and it is also possible that the lower Silurian Murrumbateman Creek Formation and the Middle Silurian Westmead Park Formation (Smith, 1964) extend south into it. It is not known in many places whether the elongated porphyry bodies within the area are intrusives, or volcanic rocks interbedded with the sediments; some of them are definitely intrusive. Outcrops of chert one of which occurs beside the Gundaroo Road about one kilometre north of its junction with the Barton Highway, have previously been regarded as Ordovician, but recent mapping indicates that they are siliceous ash tone, interbedded with mudstone which is probably of similar age to the Canberra Group.

SILURIAN TO DEVONIAN GRANITIC INTRUSIVES

Several small bodies of granitic rock intrude the sedimentary and volcanic rocks in the area. They include the Greenwood Granite, the Barrack Creek Adamellite which is partly porphyritic, and the porphyritic Glebe Farm Adamellite. An unnamed pink dacite porphyry in the southwest of the area is possibly intrusive, (Rossiter, 1971). The age of the granitic bodies is probably similar to that of the Murrumbidgee Batholith, which has been dated isotopically as late Silurian or early Devonian. From the age of the rocks they intrude, the Greenwood Granite is post-Ordovician, the Barrack Creek Adamellite is post-Middle Silurian and the Glebe Farm Adamellite is post-Upper Silurian; if the pink dacite porphyry is intrusive, it would be post-Upper Silurian. The southern part of the Greenwood Granite and the adamellite at Belconnen both have pronounced trends in a northwesterly direction, roughly parallel to fold axes in the Deakin Volcanics; the trends may indicate emplacement during the folding of the volcanics probably in the late Silurian or Devonian.

LOWER DEVONIAN

Acid volcanic rocks of the Ainslie/Majura ridge (extending about 13 km north from Mt Ainslie, co-ordinates N6094700, E696200) are known as the Ainslie Volcanics and have been regarded as Lower Devonian (Opik, 1958). The volcanics also occur south of Fyshwick (N6088000, E698000) and east of Canberra airport (N6091000, E699000).

PERMIAN

Patches of partly consolidated gravel on the Canberra plain, known as the Fyshwick Gravel, are considered by Öpik to be Permian. Jennings (1972) and others have suggested an early Tertiary or Pleistocene age.

QUATERNARY

Superficial deposits of alluvium are widespread in low-lying areas; however, only the main areas are shown on the map. The alluvium is thought to be mainly Pleistocene and Recent; it is predominantly clayey with occasional gravelly horizons and minor sandy bands. Dune-like deposits of fine red sand, which are of eolian origin, occur along the Molonglo River valley. Other superficial deposits include fanglomerate on the lower slopes of Black Mountain and clays that have been described as lake bed deposits in the Lyneham area (Öpik, 1958).

STRUCTURE

FOLDING

A decrease in the complexity of folding and in the predominant trend of fold axes is discernible from the oldest to the youngest rocks in the area.

The Ordovician Pittman Formation and Acton Shale are steeply dipping and in places tightly folded; overturned beds are known. In much of the eastern part of Belconnen the Ordovician rocks strike regularly to the northeast; strike of bedding in this apparently less disturbed area is believed to reflect the trends of the primary folds. West of Black Mountain the bedding is variable but the main structure appears to be an anticline trending northeast; the rocks have almost certainly been subjected to more than one generation of folding and associated faulting. An anticline and syncline, both plunging northeast, have been mapped in the Acton Shale northeast of Aranda. In the Queanbeyan/Sutton area folding in the Ordovician rocks appears to be more intense that at Belconnen; recumbent and isoclinal foldings have been recongized (Moore, 1957; Stauffer and Rickard, 1966).

The Lower Silurian Black Mountain Sandstone and State Circle Shale are possibly less strongly folded than the Ordovician rocks; bedding on Black Mountain generally dips at less than 45 degrees, although steeper dips are known in the northeast of Belconnen and in the Capital Hill area. To the northeast of Belconnen the strike of the Lower Silurian rocks is generally similar to that of the Ordovician rocks; in the Black Mountain area, however, there is generally a marked discordance in bedding attitudes between Lower Silurian and adjacent Ordovician rocks. The dominant structure in the Lower Silurian rocks on Black Mountain is a syncline plunging east-northeast; but bedding attitudes discordant with this structure indicate more than one episode of folding; minor folding with some faulting of the more competent quartzites is common. Irregular folding and faulting is present on Capital Hill.

In the Middle to Upper Silurian rocks in the centre of Canberra City the strike of bedding ranges from northeast to northwest. Moderately gentle folds with dips less than 45 degrees are the most common; steeper dips are known but are generally associated with faults. Several broad folds are indicated in the Canberra City area (Öpik, 1958). Smaller folds, which trend north-northeast, have been mapped in the Riverside Formation west of Commonwealth Avenue near London Circuit (N609300, E693000); an anticline plunging south-southeast is visible in the Camp Hill Sandstone exposed in State Circle (N6091000, E693300).

In the Upper Silurian Deakin Volcanics and Yarralumla Formation, the strike of bedding is generally northwest; dips are generally less than 50 degrees. Most of the folds in the Upper Silurian rocks in the Woden and Belconnen areas have been established from recent mapping. The northwesterly trends of the folds contrast with the northeasterly trends of folds in the older rocks northeast of the Deakin Fault.

The Ainslie Volcanics show dips of less than 35 degrees. Mount Ainslie appears to be part of the core of a syncline which trends slightly east of north.

The sequence and pattern of folding in the area can be interpreted as follows. The earliest fold movements were in Ordovician and Lower Silurian rocks which were folded, possibly in several eposides, the last of which occurred in the Middle Silurian; the axes of these folds trend about northeast. After uplift and erosion in the Middle Silurian sedimentation began again with the Camp Hill Sandstone. Fold movements occurred again in the middle of the Upper Silurian with folding that left a pronounced axial plane cleavage trending north-northeast in the fine-grained sediments of the Canberra Group. The next and possibly last major folding occurred after deposition of the Deakin Volcanics and Yarralumla Formation which are the uppermost Silurian rocks; these folds trend northwest. Whether the north-northeast trending syncline is the Lower Devonian Ainslie Volcanics on the Ainslie/Majura Ridge is contemporaneous with the northwest-trending folds, or represents later fold movements, is not clear.

FAULTING

Many faults occur in the area. Major faults include the Deakin Fault and Sullivans Fault on which the displacements are probably over 1000 metres. Faults trend in numerous directions, but those trending north-west and northeast appear to be the most common. Many of the faults are known to be steeply dipping normal faults; others such as the Queanbeyan Fault are possibly high angle reverse faults. A major shallow-dipping thrust fault has been mapped south of Queanbeyan (Stauffer & Rickard, 1966), and minor thrust faults are known in the Canberra area, such as at the National Library site, Scrivener Dam, and Capital Hill.

Many previously unknown faults have been mapped recently, mainly in the Woden and Belconnen areas; some others, not shown on previously published maps, are also indicated on the map. Some have been identified by the presence of quartz or ironstone gossans, and others by shearing and structural discontinuities. The extension of the Winslade Fault (Malcolm, 1954) northeast to the Deakin Fault from the Cotter area is indicated by prominent quartz reefs. Another northeast trending fault separating rocks of the Canberra Group from the Undifferentiated Silurian rocks is believed, for structural reasons, to extend southwest into the Pittman Formation. The northern extension of this fault is inferred from correlation with the geology of the Gundaroo/Nanima area (Smith, 1964). An inferred extension of Sullivans Fault has been mapped south of Fairbairn Avenue, to join with probable reverse faults mapped along the railway line south of the Molonglo River and on the western side of Mount Jerrabomberra.

Faults on Capital Hill were exposed during recent investigations; large displacements are inferred for two of them. Recent mapping on Black Mountain has indicated several additional faults. The Black Mountain Fault is now considered to be two faults - one separating Black Mountain Sandstone from State Circle Shale (fault near junction of Dryandra Street and Belconnen Way (N6096000, E691500), now concealed) and the other separating both Black Mountain Sandstone and State Circle Shale from the Pittman Formation; however, the Black Mountain Sandstone and State Circle Shale may in places be unconformable on, rather than faulted against, the Pittman Formation. Evidence was not found for the South Black Mountain Fault, an inferred fault that was supposed to separate the Black Mountain Sandstone from the State Circle Shale at the southern foot of Black Mountain. Most of the major faults have probably been identified but many faults of small displacement have probably not been detected. Many faults of apparently large displacement have probably not been traced along their full length; others, such as the Acton Fault, may not be a single fault but a number of intersecting faults.

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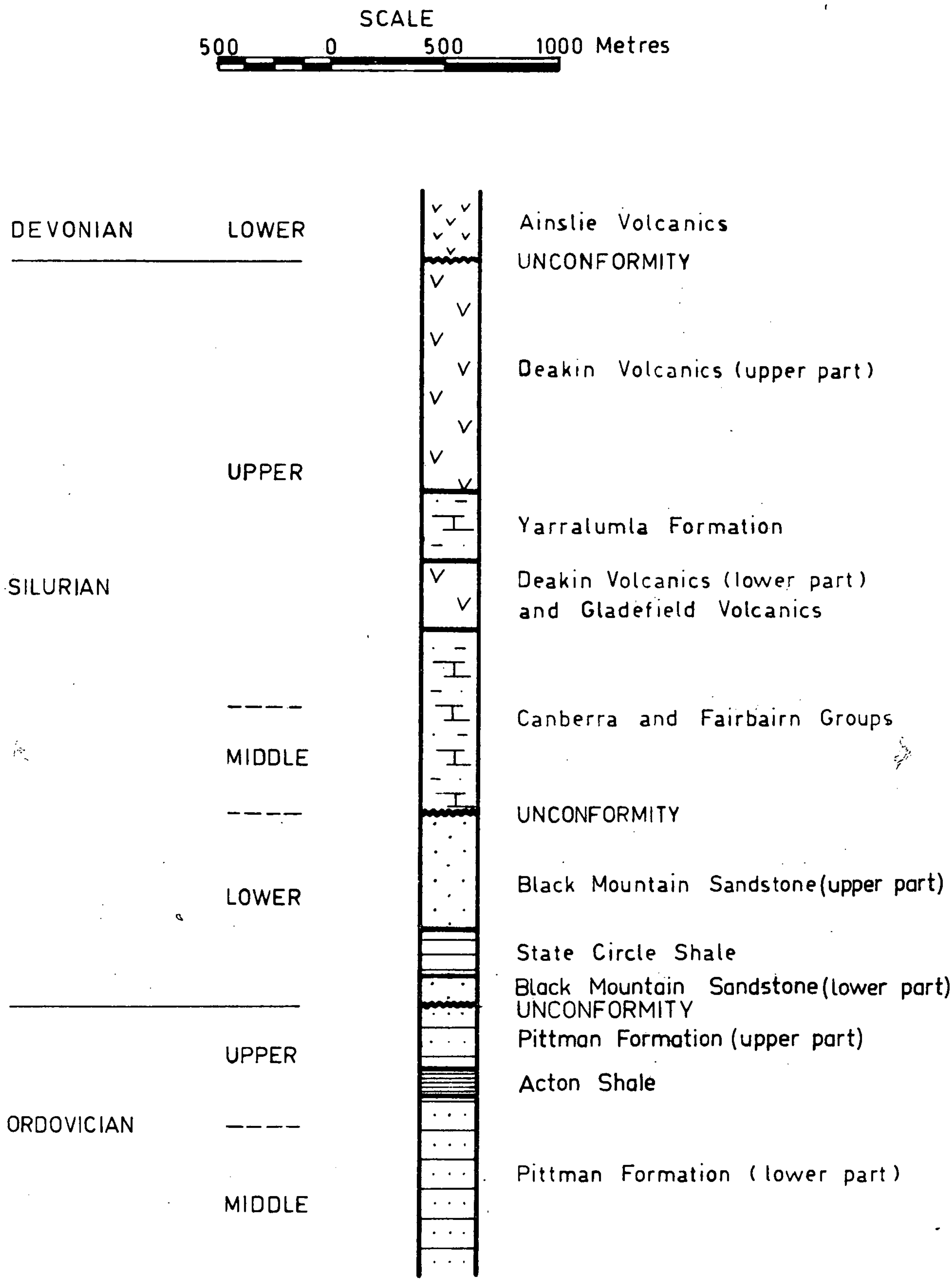
Figure 1

COMPOSITE STRATIGRAPHIC COLUMN OF FORMATIONS IN THE CANBERRA AREA



Stratigraphy as modified (1971) from Öpik (1958)

To accompany Record 1973/11

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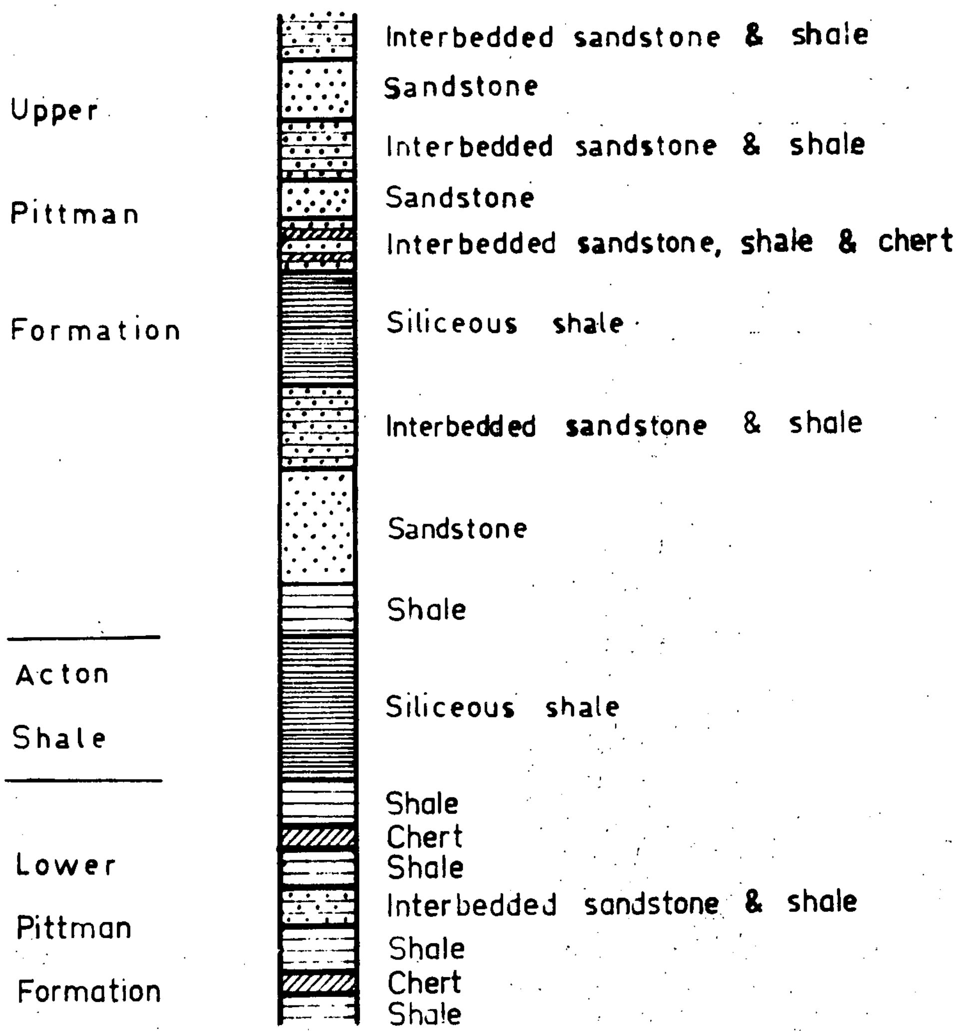
Figure 2

STRATIGRAPHY OF PART OF THE PITTMAN FORMATION AT ARANDA

SCALE

100 0 100 200 Metres



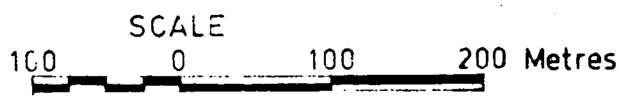
Note: Sandstone includes quartz sandstone and micaceous sandy siltstone. Shale includes mudstone, and silty shale and mudstone.

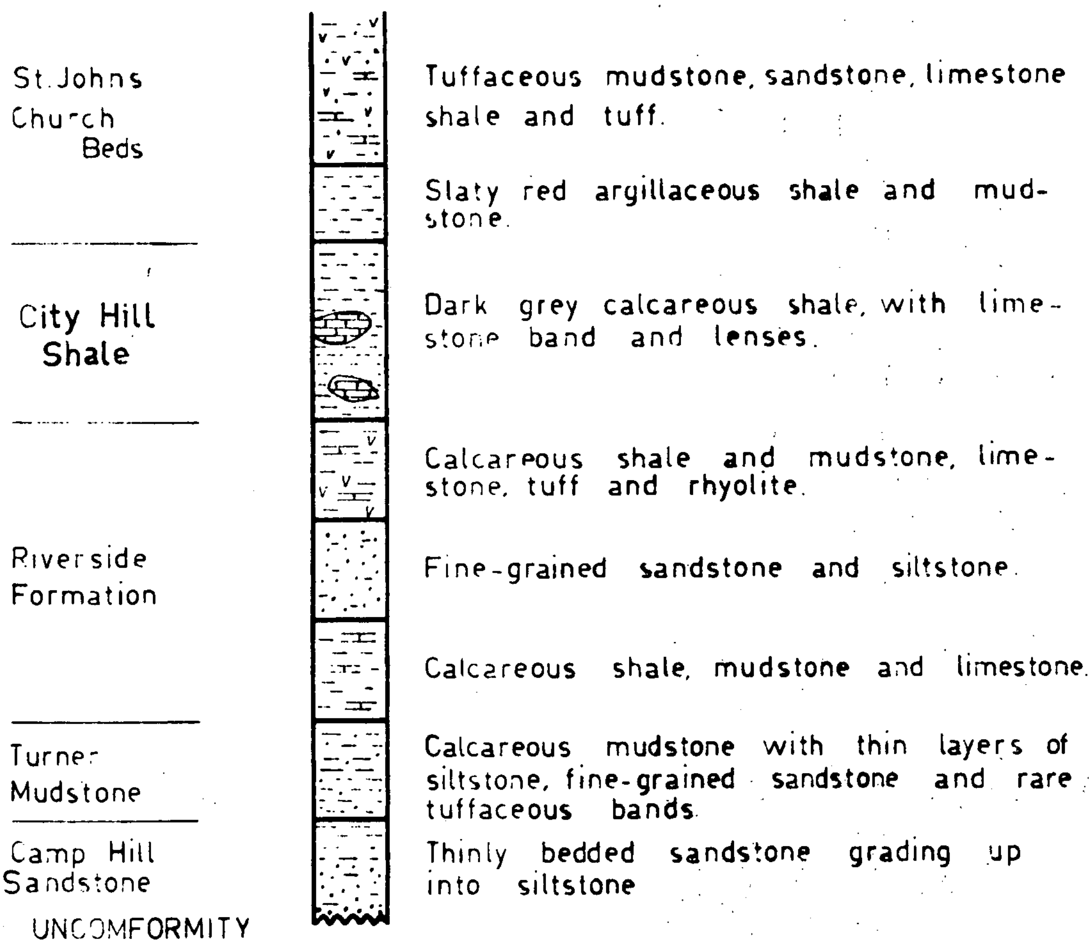
Stratigraphy derived from trench mapping by G.A.M. Henderson

To accompany Record 1973/11

Figure 3

STRATIGRAPHY OF THE CANBERRA GROUP





Stratigraphy as modified (1971) from Öpik (1958) (see text)

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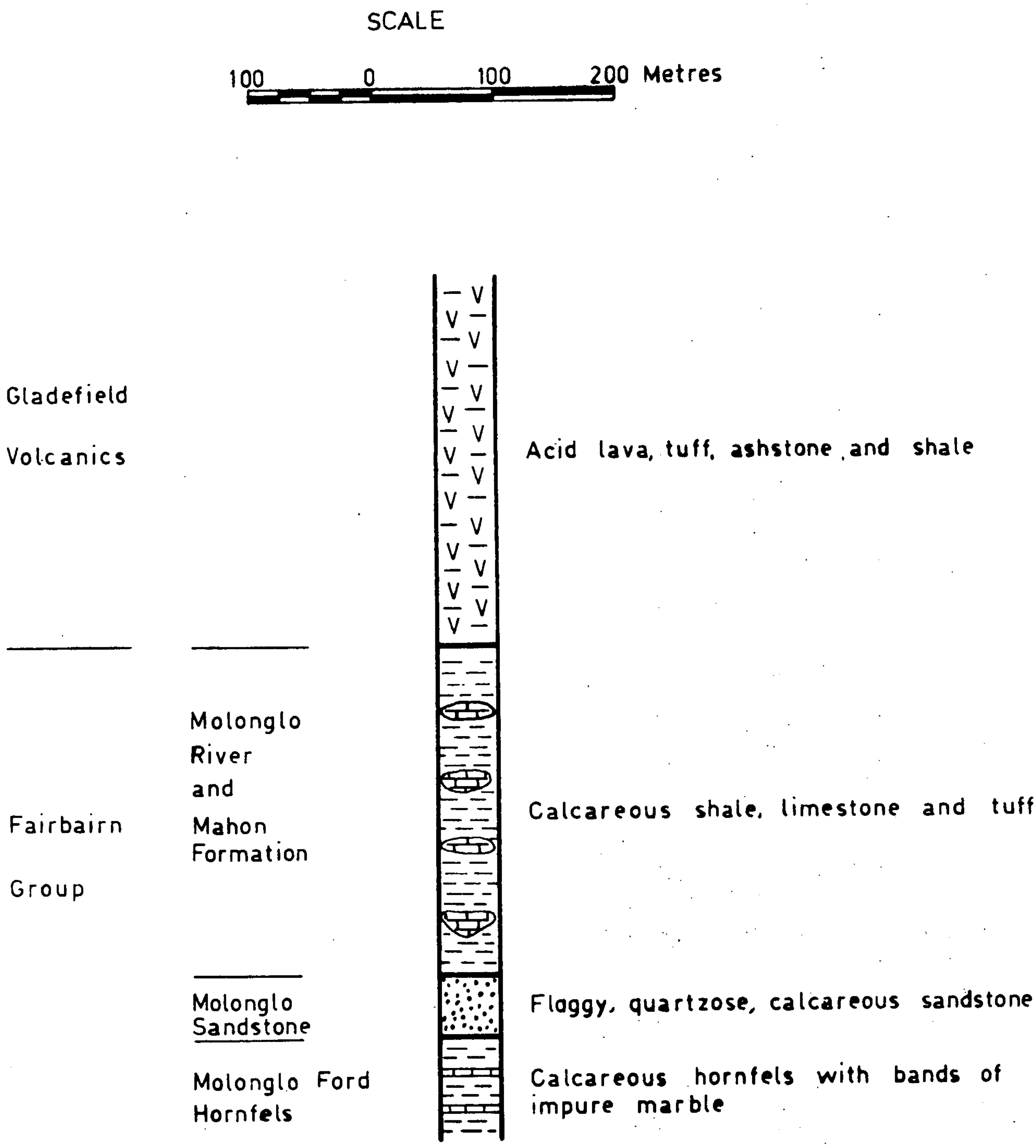
Figure 4

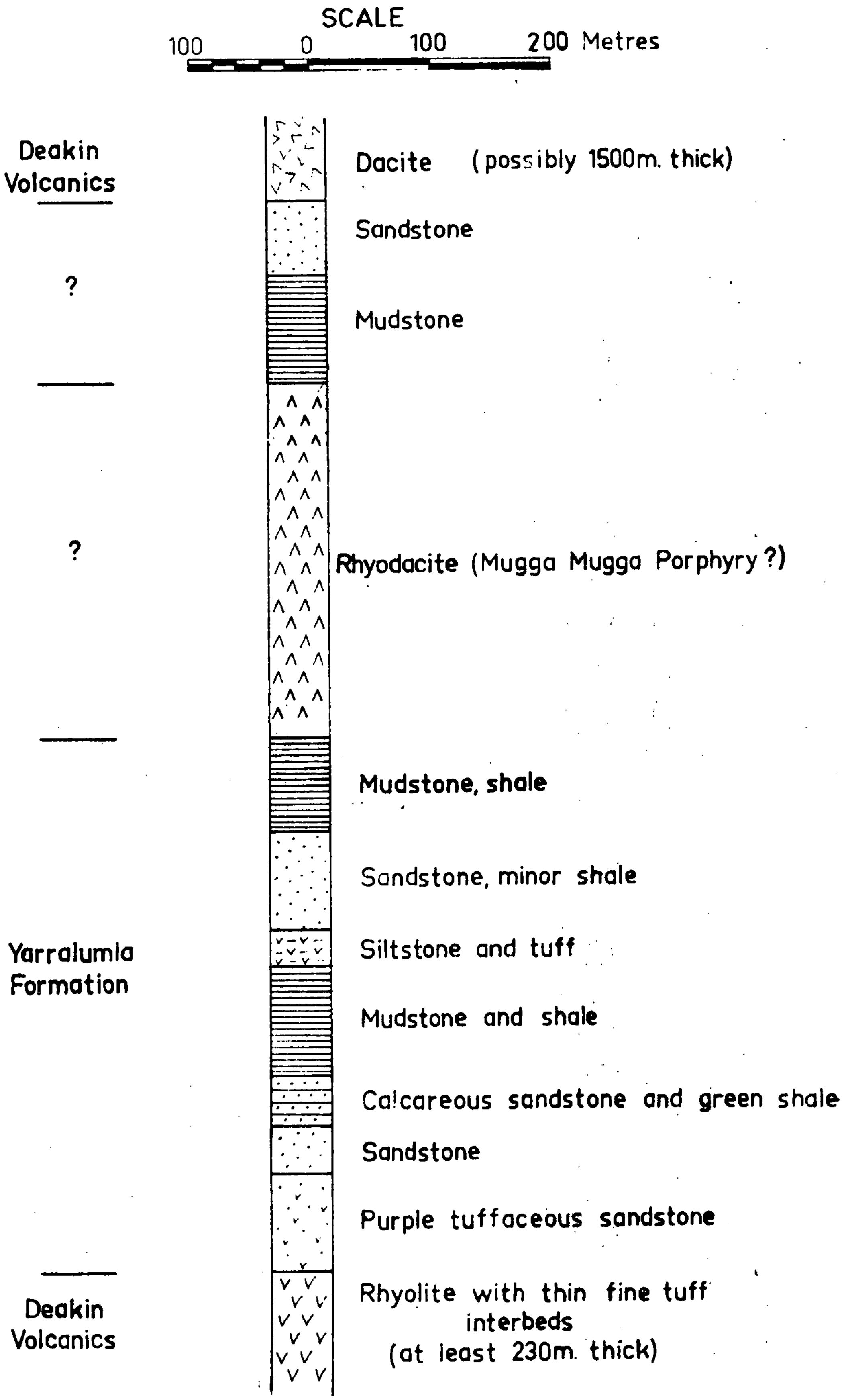
STRATIGRAPHY OF FAIRBAIRN GROUP AND GLADEFIELD VOLCANICS



Stratigraphy after Öpik (1954, 1958) and Moore (1957)

Figure 5

STRATIGRAPHY OF RED HILL GROUP AT WODEN



Stratigraphy interpreted by G.A.M. Henderson from mapping of excavations by D.E. Gardner and D.A. Buchhorn.

To accompany Record 1973/11

1973/11 I55/A16/987