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THE LOWER CARBONIFEROUS GEOLOGY OF THE ROUCHEL DISTRICT, NEW SOUTH WALES

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Frontispiece. The northwestern flank of the Albano Syncline.

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SUMMARY

The Rouchel district is in the upper Hunter Valley of New South Wales, about 100 km northwest of Newcastle. The exposed sequence of Lower Carboniferous, and probable Upper Devonian, rocks in the district is between 4000 and 4500 m thick and has been divided into the Goonoo Goonoo Mudstone, Kingsfield Beds (new name), Dangarfield Formation (new name), Waverley Formation, Woolooma Formation (new name), and Isismurra Formation. The Brushy Hill Limestone is a member of the Dangarfield Formation, and the Ayr Conglomerate and Native Dog Member (new name) occur in the Isismurra Formation, the Native Dog Member splits into the Curra Keith and Oakfields Tongues (new names).

The Goonoo Goonoo Mudstone consists mainly of unfossiliferous marine mudstones and greywacke, and is probably of late Devonian and early Carboniferous (Tournaisian) age. Unfossiliferous sandstones and volcanic rocks, probably mainly nonmarine, which occur in the vicinity of Lake Glenbawn, are assigned to the Kingsfield Beds; these are also probably late Devonian and Tournaisian. The Kingsfield Beds are overlain by the early Tournaisian to early Viséan Dangarfield Formation, mainly marine mudstone, siltstones, and limestones; the Brushy Hill Limestone occurs in the lower part of the Dangarfield Formation. Part of the Dangarfield Formation is laterally equivalent to the late Tournaisian to early Viséan Waverley Formation, a unit composed mainly of marine and nonmarine sandstones and conglomerates, which overlies the Goonoo Goonoo Mudstone. The Isismurra Formation, mainly nonmarine zeolitic sandstones, conglomerates and ignimbrites, overlies the Waverley and Dangarfield Formations. Parts of the Isismurra Formation are laterally equivalent to marine mudstones, siltstones and sandstones in the Woolooma Formation. The Ayr Conglomerate occurs at, or near, the base of the Isismurra Formation, and is overlain by ignimbrites of the Native Dog Member in the west-central and southwestern Rouchel district. Eastwards the Native Dog Member splits into the Curra Keith and Oakfields Tongues, both dominated by ignimbrites; unnamed ignimbrites occur higher in the Isismurra Formation. Ignimbrites from the Isismurra Formation give radiometric ages ranging from 308 to 319 million years.

Marine Lower Carboniferous rocks in the Rouchel district contain brachiopods and other fossils of the late Tournaisian to early Viséan *Schellwienella* cf *burlingtonensis* Zone, the early Viséan *Pustula gracilis* Zone (new), the middle Visean *Orthotetes australis* Zone, and part of the late middle Viséan *Delepinea aspinosa* Zone; the early Tournaisian *Spirifer sol* Zone probably also occurs. Data from the Rouchel district indicate that the *sol* Zone should be based on fossils from the upper Tulcumba Sandstone and Lower Namoi Formation, or their equivalents, and the limits of the *australis* Zone have been clarified.

Folds in the Rouchel district define three structural trends. The northwest to north-northwest Brushy Hill Trend and the northeast to north-northeast Woolooma Trend are probably primary; the variable Davis Creek Trend probably results from intersection of folds parallel to the primary trends. Faults in the Rouchel district are all high-angle at the present level of exposure. All faults and folds are geometrically interdependent, suggesting that a regionally constrictive stress deformed the district, presumably during the Hunter-Bowen Orogeny.

INTRODUCTION

The Rouchel district is in eastern New South Wales, about 100 km northwest of Newcastle, and occupies an area of about 1200 km^2 between the towns of Parkville, Scone, Aberdeen, and Muswellbrook in the west, and the Mt Royal Range in the east (Fig. 1). Carboniferous sediments and volcanics in the Rouchel district are part of the New England Belt of the Palaeozoic Tasman Geosyncline (Fig. 2). During the early Palaeozoic the Tasman Geosyncline, an orthogeosyncline as defined by Kay (1951), contained the Lachlan and New England Belts; the Lachlan Belt ceased to be a part of the geosyncline after the Middle Devonian Tabberabberan Orogeny, but geosynclinal conditions persisted in the New England Belt until late in the Palaeozoic. Throughout the late Devonian and early Carboniferous, the Rouchel district occupied a subsiding shelf, previously termed the Tamworth Trough, adjacent to, and east of, the Tabberabberan orogen. Conditions of sedimentation on the shelf were, in general, initially marine but later became progressively non-marine from west to east; a sequence totalling between 4000 and 4500 m in thickness was deposited between the late Devonian or early Carboniferous and the medial early Carboniferous (middle Viséan).

Three main sedimentary facies are recognized in the Rouchel district: (a) marine deepwater mudstone with minor greywacke and lithic sandstone of probably late Devonian to early Carboniferous age; (b) marine shallow water mudstone, lithic sandstone, and limestone of Tournaisian and Viséan age; and (c) terrestrial sandstone, conglomerate, shale, and volcanics of possibly late Devonian to early Carboniferous age, and late Tournaisian to Viséan age. The oldest rocks, which are late Devonian to early Carboniferous in age, comprise deepwater mudstone in the east, and terrestrial sandstone, shale, and volcanics in the west. They are succeeded by early to middle Tournaisian shallow-water marine mudstone, lithic sandstone, and limestone. Regressive terrestrial sediments and volcanics spread eastwards across the region during the late Tournaisian and Viséan, intertonguing with the shallow-water marine sediments, and finally covering the shelf area. Stratigraphic relationships between the various units are indicated in figures 3 and 4.

The Carboniferous rocks in the Rouchel district were deformed by the middle to late Permian Hunter-Bowen Orogeny and now constitute an area of irregular folding between the 'Basin Belt' and the 'Western Belt of Folds and Thrusts' on the southwestern margin of the New England Belt (Fig. 2).

Location and access

The Rouchel district is named after the villages of Rouchel Brook and Upper Rouchel. In this report the term refers to an area of about 1200 km^2 between latitudes 32° 16' and 31° 59' south and longitudes 150° 50' and 151° 15' east (Plate 1). Most of our discussion is concerned with an area of about 950 km^2 which has been mapped in detail. Topographic map coverage is provided by parts of the Wingen, Macqueen, Scone, Woolooma, Muswellbrook, and Camberwell 1:63 360 sheets and parts of the more recent Aberdeen, Scone, Parkville, and Waverley 1:31 680 sheets.

The Rouchel district is drained by the Hunter River and its tributaries; the major streams include the south-flowing Dart Brook, Kingdom Ponds, and Pages River, the west-flowing Stewarts Brook, Back Creek, Rouchel Brook, Davis Creek, Sandy Creek, and Muscle Creek, and the southwest-flowing Foy Brook (Fig. 1). Damming of the Hunter River at Glenbawn has produced Lake Glenbawn, designed for flood mitigation and irrigation. Drainage throughout most of the Rouchel district is in a relatively juvenile state of development; incised meanders and terraces along many of the main watercourses suggest that rejuvenation has taken place. More mature drainage patterns are common in the western part of the district.

The lowest elevations in the Rouchel district, below +250 m, are in the west, between Aberdeen and Parkville where the terrain is undulating. East of the New England Highway and the Main Northern Railway the terrain is rugged, and the summits of Scone Mountain, The Colonel, and Bells Mountain rise to above 650 m. Maximum elevations of above 1 200 m are reached in the Woolooma Range in the eastern Rouchel district. The form and trend of major topographic features are commonly controlled by the underlying strata. Much of the land has been partly or wholly cleared of trees, although there are still heavily timbered ridges and mountains in the west, and rough forest country to the east towards the Mt Royal Range.

The Rouchel district is reached by the New England Highway, which connects sealed minor roads along the valleys of Pages River, Hunter River, Stewarts Brook, Rouchel Brook, Sandy Creek, and Muscle Creek. The sealed minor roads in turn connect a network of unsealed minor roads and tracks throughout the district so that all parts are relatively easily accessable to 4-wheel-drive vehicles. Most of the population in the Rouchel district is concentrated in the west between Aberdeen, Scone, and Parkville. Farms and small villages are scattered throughout the district, but are less common towards the east. Many small villages, notably Davis Creek and Dunbar Creek, no longer exist; they provide useful reference points and are mentioned throughout the text.

Previous investigations

The earliest work in the Rouchel district was that of David (1887), who reported on the limestone and ironstone near the head of Limestone Creek. The most important early work was that of Osborne (1928a, 1928b, 1929), which comprised reconnaissance mapping in the Rouchel district as part of a study of the Hunter-Manning-Myall province; a synthesis of his work was published in 1950 (Osborne, 1950a). Osborne (1950b) also recognized that ignimbrites were present in the 'Kuttung' rocks of the Rouchel district. Most of the geological data on the Rouchel district quoted by recent workers (in Packham, 1969) are from Osborne's publications. Branagan et al. (1970) have recently published a short account of the geology of the Glenbawn area. Palaeontological studies of Lower Carboniferous fossils, mainly from Cameron Bridge at Upper Rouchel, and Stony Creek near Rouchel Brook, have been made by Etheridge (1891), Crockford (1947), Campbell (1955, 1956), and Campbell & Roberts (1964). Manser (1967) mapped the northern part of the Rouchel district as part of a more extensive study of the adjoining Wingen district; his work has so far been published only in the form of a map and explanatory notes (Manser, 1968). The geological setting and evolution of the New England Belt have been outlined by Voisey (1959), Brown, Campbell, & Crook, (1968), and various authors in Packham (1969); Oversby (1971), Solomon & Griffiths (1972), and Scheibner & Glen (1972) have tentatively explained many aspects of the Tasman Geosyncline in terms of plate tectonics.

Purpose and scope of study

Our study of the geology of the Rouchel district was made to clarify the succession of Lower Carboniferous brachiopod zones in New South Wales, and to determine the time relationships between Lower Carboniferous marine and non-marine facies; the project constitutes part of a long-term investigation of the Carboniferous geological history of the New England Belt being carried out by Roberts. The brachiopod zones, which provide the time framework for the Carboniferous marine sediments of the belt, required more precise definition based on an accurate knowledge of the stratigraphic ranges of their constituent species. At the time our study began, the succession of Lower Carboniferous brachiopod zones was well known in only two areas in New South Wales; the Gresford-Dungog district (Roberts, 1965a), and the region surrounding the Werrie and Belvue Synclines west of Tamworth (Campbell & Roberts in Packham, 1969; Campbell et al., 1969). Work in Queensland by McKellar (1967), and a synthesis of eastern Australian Carboniferous marine invertebrate data by Campbell & McKellar (1969) suggested that the zones, and in some cases the stratigraphy of the areas from which they were recognized, required revision; for instance, Campbell & McKellar treated the *Orthotetes australis*, *Delepinea aspinosa* and *Rhipidomella fortimuscula* Zones as a 'natural group', and suggested that they may in the future be relegated to subzonal status. Such a broad group of faunas could not provide the accurate time control required to understand the development of the late Lower Carboniferous portion of the New England Belt; our work was aimed at clarifying the relationships of the lower two zones.

The Rouchel district was chosen for study because of previous reports of abundant faunas (Osborne, 1950a; Campbell & Roberts 1964); because the wider east-west distribution of Lower Carboniferous sediments than elsewhere in the Western Belt of Folds and Thrusts might portray variations in facies; because of abundant easily mappable ignimbrites which would outline the structure and the lateral relationships between marine and non-marine units; and because it was midway between the Gresford-Dungog and Werrie-Belvue areas. New information from the Rouchel district is currently being used by Roberts (in prep.) in a revision of the Gresford-Dungog district and in the study of the country between Salisbury and Brownmore.

Fieldwork totalling approximately 12 man-months was carried out between late 1969 and early 1971. Geological data were plotted on to air-photographs at scales of 1:20 000 and 1:40 000. Stratigraphic sections, many of which are shown on Plate 2, were measured with a tape and Abney level, or a 5-foot (1.524 m) Jacob's staff. Interpretation of the geology from air-photographs preceded, and was concurrent with, field mapping, but the results were found to be unreliable. Air-photo interpretation has been used to locate the boundaries of Tertiary volcanics and Quaternary alluvium, and to locate some of the faults. Most dip measurements were made in the field, and are accurate to $\pm 5^{\circ}$; these were augmented with determinations from air-photographs using floating marks (Maffi, 1969).

Plates 1 and 2 summarize many of the data collected in this study. The brachiopod zones shown in Plate 2 are Concurrent-range Zones in terms of the British Stratigraphic Code (George, et al, 1969); each is characterized by brachiopods with overlapping ranges and is named from a distinctive species. The vertical extent of each zone is shown on Plate 2. Stratigraphic units have been defined in accordance with guidelines laid down in current stratigraphic codes. Some of the formations were originally named by Manser (1967), and are used in the Wingen 1:100 000 Geological Map (Manser, 1968); these units are inadequately defined in terms of the Australian Stratigraphic Code because they lack type sections. In the case of the Waverley Formation, we formally designate a type section for one of Manser's formations.

Clastic sedimentary rocks are described as fine, medium, or coarse-grained according to Wentworth's (1922) grade scale. The description of bedding thicknesses is informal, although close to that proposed by Ingram (1954). Rock colours are also informal; 'olive' refers to olive green, corresponding approximately to 'grayish olive green' in the Geological Society of America's Rock-color Chart. Values for the roundness and sphericity of clastic grains in sedimentary rocks were estimated using the chart in Krumbein & Sloss (1963, p. 111). Field numbers recorded on Plate 2 refer to horizons or localities where data were collected, and in many cases correspond to sample numbers. All fossil collections are identified by field numbers. Samples which have been thin-sectioned, analysed, or dated have, in addition to a field number, a registered BMR number, also shown on Plate 2 where appropriate.

The term 'ignimbrite' is used throughout to mean the same as 'ash-flow tuff' as defined by Ross & Smith (1961). The terms 'arenite', 'sandstone', and 'greywacke' are used as defined by Crook (1960). The compositions of plagioclase feldspars was estimated from the extinction angles of twin lamellae, and the determinations given are preliminary.

Although the work has been done jointly throughout there are some areas of specific responsibility. Roberts has carried out most of the work on the Dangarfield Formation, Waverley Formation, Woolooma Formation, palaeontology, and biostratigraphy; he will report on the systematic palaeontology in the future. Oversby has been largely responsible for the work on the Goonoo Goonoo Mudstone, Kingsfield Beds, Isismurra Formation, undivided Upper Carboniferous and Permian rocks, and structural geology.

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STRATIGRAPHY

INTRODUCTION

Lower Carboniferous rocks in the Rouchel district were mapped by Osborne (1928a & b, 1929, 1950a), on the basis of their inferred deposition in either a marine or non-marine environment, as Burindi or Kuttung 'Series'. We consider that the terms Burindi and Kuttung should be discarded as stratigraphic names because they have become confusing and cannot be applied to detailed local stratigraphy. Where appropriate, we have used the stratigraphic nomenclature established by Crook (1961) and Manser (1967, 1968) in the Wingen district, which adjoins the Rouchel district in the north. Manser named and briefly described the Waverley and Isismurra Formations in the explanatory notes to the Wingen 1:100 000 Geological Map (Manser, 1968). Both formations are, however, inadequately documented because they lack type sections. We have used these names, after an examination of the type areas (Manser, 1967), and have nominated a type section for the Waverley Formation; we have been unable to establish a type section for the Isismurra Formation. The status of the Ayr Conglomerate is changed from that of a formation in Manser's nomenclature to that of a member within the Isismurra Formation. The Goonoo Goonoo Mudstone of Crook (1961) is used in preference to Manser's Glenlawn and Martindale Mudstones.

Newly named stratigraphic units in the Rouchel district include the Kingsfield Beds, Dangarfield Formation, and Woolooma Formation. We define the Brushy Hill Limestone (Osborne, 1950a) as a member of the Dangarfield Formation. The Native Dog Member, Curra Keith Tongue and Oakfields Tongue are also new and are ignimbrite-dominated units within the Isismurra Formation.

GOONOO GOONOO MUDSTONE

In the Rouchel district the Goonoo Goonoo Mudstone (Crook, 1961) comprises an incomplete, poorly exposed succession of olive, brown, and blue mudstones with interbedded arenites (both greywackes and sandstones sensu Crook, 1960). The Goonoo Goonoo Mudstone crops out in the north-central part of the Rouchel district, where it is overlain by the sandstone-dominated Waverley Formation; the top of the Goonoo Goonoo Mudstone is placed at the horizon where sandstone first predominates over mudstone. The base of the Goonoo Goonoo Mudstone is not exposed in the Rouchel district.

The Goonoo Goonoo Mudstone is replaced southwestwards by the lower and middle parts of the Dangarfield Formation, probably by lateral gradation. This gradation is not exposed, but must take place across a north-northwest-trending line between the upper reaches of Lake Glenbawn and Rouchel Brook village (Pl. 1). The Goonoo Goonoo Mudstone probably also passes laterally into the Kingsfield Beds. The minimum exposed thickness of the Goonoo Goonoo Mudstone in the Rouchel district is about 400 m, measured to the south-west of the summit of Benmore (Pl. 2, Section 59); thicker sections may be present near Belltrees, but the paucity of exposure and structural complications in that area prevent the measurement of detailed sections. No diagnostic fossils were found in the Goonoo Goonoo Mudstone, and hence its age must be inferred.

The Goonoo Goonoo Mudstone outcropping around Belltrees was mapped by Manser (1967, 1968) as two separate formations, the Glenlawn Mudstone and Martindale Mudstone. The only obvious difference between rocks assigned to the two formations is that those mapped as Glenlawn Mudstone are more intricately sheared than those of the Martindale Mudstone; this difference is probably explained by their location in a belt of shearing extending from just east of 'Glen Rouchel' to the type area at 'Glenlawn'. Because we were unable to distinguish between the Glenlawn and Martindale Mudstones on an objective basis, we have applied Crook's name Goonoo Goonoo Mudstone to the mudstone succession.

Type section

The type section of the Goonoo Goonoo Mudstone is along Timor Creek and its tributaries, from 15309235 to 19159290 (Timor 1:31 680 sheet); the formation consists predominantly of olive green and brown mudstones, and is 3450 m thick (Crook, 1961). The Goonoo Goonoo Mudstone is underlain by greywacke (sensu Crook, 1960) and conglomerate, with interbedded mudstone, and is overlain by coarse conglomerate and sandstone. Arenite and conglomerate units within the mudstone succession were not named in the type area.

Manser (1967, 1968), working in the type area of the Goonoo Goonoo Mudstone, subdivided the succession into several separate formations (Fig. 5). Manser's Lincount Mudstone, Sutcliffe Conglomerate, Glenlawn Mudstone, Dancing Dicks Conglomerate, Martindale Mudstone, and lowermost Waverley Formation all fall within Crook's type Goonoo Goonoo Mudstone in the Timor district. We are uncertain of the validity of these formations because the conglomerates defining the boundaries of the mudstone units are frequently absent owing to their limited lateral extent.

Section 42

Section 42 extends from near the head of Spring Gully, about 6 km southwest of 'Waverley', to the Isis River near 'Glenugie' (113535 to 043479, Waverley 1:31 680 sheet) (Fig. 8). The base of the section coincides with the base of the Martindale Mudstone of Manser (1968).

The lower 1350 m of Section 42 (Pl. 2) is dominated by olive, brown, and blue mudstone which weathers pale green and buff. The mudstone is poorly fissile, and consists of poorly developed laminae and thin beds of alternately coarse and fine-grained terrigenous material ranging in size from clay to fine sand. Laminae and beds containing relatively coarse material weather to lighter colours than those containing fine material. The mudstone is cut by one or more fracture cleavages, of unknown structural significance, and on weathering tends to break into small chips. Identifiable terrigenous grains in the mudstone are predominantly andesine (approximately An_{36}) and rock fragments, with subordinate orthoclase, microperthite, quartz, biotite, and hornblende. Grains of andesine, orthoclase, microperthite, biotite, and hornblende are commonly altered, and are angular to subrounded (maximum roundness about 0.5) with a sphericity of 0.5 to 0.7. The mudstone has a clay-sized matrix containing scattered carbonaceous fragments and claystone chips. Many of the laminae and thin beds in the mudstone are graded, and locally cross-laminated and slump-folded.

Many of the arenites interbedded with the mudstone are crudely graded, and were probably deposited by turbidity currents; they are thus greywackes as defined by Crook (1960). Arenites which are not graded and which locally contain planar cross-beds are increasingly common towards the top of the Goonoo Goonoo Mudstone; these arenites were probably deposited by traction currents and are thus sandstones, sensu Crook (1960). All arenites in the Goonoo Goonoo Mudstone are fine to coarse-grained, medium to thick-bedded, and green, brown, or blue in colour. The arenites contain the same suite of terrigenous grains as the mudstones, and range from almost pure feldspathic to litho-feldspathic types; they have a variable proportion of clay matrix which is partly replaced by carbonate. Rock fragments in the arenites are devitrified glassy volcanics with andesine phenocrysts, and textural andesites and trachytes, also with andesine phenocrysts. A similar suite of rock fragments, ranging from pebble to cobble size, is present in the conglomerates, as well as clasts of lithic-crystal tuffs, litho-feldspathic sandstones, white and pink micrographic granites, and aplite. Some of the volcanic clasts contain epidote. The plutonic and epidote-bearing volcanic clasts were probably not derived from a local source. The clasts in the conglomerates have a roundness of 0.7 to 0.9, and a sphericity of 0.3 to 0.9.

The Duxford Member of Manser's Martindale Mudstone, between 950 m and 1030 m above the base of Section 42, contains interbedded mudstone, and clasts of crystal lithic tuff and arenites (probably both sandstone and greywacke). The crystal-lithic tuffs contain fresh angular feldspar (predominantly andesine, with subordinate orthoclase and microperthite), rock fragments, up to 2% fresh hornblende, and rare biotite.

The mudstone succession in Section 42 is overlain by conglomerate assigned to the Waverley Formation. The conglomerate probably has an erosional base, but there is no evidence indicating a major disconformity.

Belltrees area

A conglomerate within the Goonoo Goonoo Mudstone, assigned to the Duxford Member of the Martindale Mudstone by Manser (1967, 1968), crosses the Gundy - Belltrees road at 428085 (Waverley 1:31 680 sheet) and dies out about 1 km southwest of the road. Another conglomerate, identical with the 'Duxford Member', appears near the top of the mudstone succession about 1 km southwest of the Gundy - Belltrees road, and can be traced to the Hunter River, where it is about 30 m thick. Small lenses of muddy limestone are present within the Goonoo Goonoo Mudstone in the Belltrees area. Mudstone with interbedded feldspathic greywackes is exposed along the Gundy - Belltrees road,at, and near, 436097 (Waverley 1:31 680 sheet). The greywacke beds are up to 15 cm thick and are crudely graded from medium-grained at the base to fine-grained at the top; they probably represent distal turbidites (K.A.W. Crook, pers. comm., 1971). The Goonoo Goonoo Mudstone in the Belltrees area is rarely well exposed, has no persistant mappable marker horizons, and is cut by many faults; the total stratigraphic thickness is unknown.

Section 59

The Goonoo Goonoo Mudstone is poorly to moderatley well exposed in the lower 390 m of Section 59 (Pl. 2) which was measured from a fault near the Hunter River, 8 km southwest of Belltrees, to the crest of the ridge 3 km southwest of the summit of Benmore (060369 to 080342, Wooloома 1:63 360 sheet). The Goonoo Goonoo Mudstone is overlain with apparent conformity by medium to coarse-grained thick-bedded buff, pink, and green lithic sandstones of the Waverley Formation. The Goonoo Goonoo Mudstone in Section 59 is lithologically identical with that already described from Section 42 and the Belltrees area. Unidentifiable plant fragments are present near the base of Section 59.

About 2.5 km southwest of Section 59 the Goonoo Goonoo Mudstone is cut out by faults. About 1 km farther to the southwest the Dangarfield Formation underlies the Isismurra Formation, in the same stratigraphic position as the Goonoo Goonoo Mudstone and Waverley Formation in Section 59; this suggests that the Goonoo Goonoo Mudstone and Waverley Formation both pass laterally into the Dangarfield Formation (see p. 12).

Age

No diagnostic fossils have been found in the Goonoo Goonoo Mudstone in the Rouchel district; the age of the formation must therefore be inferred from its relationships to fossiliferous formations. In Section 58, measured parallel to and about 2 km southwest of Section 59, the *Schellwienella* cf. *burlingtonensis* and *Pustula gracilis* Zones are tentatively identified in the Waverley Formation (in Plate 2 the positions of the zones have been extrapolated into Section 59). The upper part of the Goonoo Goonoo Mudstone to the southwest of Benmore is thus of *Schellwienella* cf. *burlingtonensis* Zone age, or older. If the Goonoo Goonoo Mudstone in the Rouchel district extends down into the Devonian System below the level of exposure, as in the Timor district and farther north (Crook, 1961), then the succession is laterally equivalent to the lower and middle parts of the Dangarfield Formation, and probably also to the exposed part of the Kingsfield Beds in the Glenbawn area.

Environment of deposition

The fine-grained terrigenous material constituting most of the Goonoo Goonoo Mudstone was probably derived from a distant source area and deposited in a quiet marine environment. Crude lamination and poorly developed sedimentary structures in the mudstone suggest deposition in a low-energy environment below wave base. The absence of a benthonic fauna and the presence of distal turbidites suggest that all except the upper parts of the unit, which contain sandstone and minor limestone, was deposited in deep water, possibly in a situation analogous to the geostrophic contour current deposits on the continental slope of the eastern United States (Heezen et al., 1966). Sandstones near the top of the succession were deposited by traction currents as the area of deposition rose or was progressively filled by sediment. A primary volcanic source for some of the terrigenous material in the Goonoo Goonoo Mudstone is indicated by the local occurrence of unmodified crystal-lithic tuffs. Plutonic and epidote-bearing volcanic clasts in conglomerates indicate additional sources.

KINGSFIELD BEDS

The Kingsfield Beds (new name) comprise an incomplete succession of volcanic rocks, sandstone, and silty shale exposed in the core of the Brushy Hill Anticline between Rouchel Brook, opposite Dangarfield, and the Pages River, 5 km southwest of Gundy (Pl. 1). The beds are named from 'Kingsfield', 2.5 km southwest of Glenbawn Dam.

The Kingsfield Beds are overlain, possibly unconformably by the Dangarfield Formation; the contact between the two units is placed between unfossiliferous purple shale and siltstone, assigned to the Kingsfield Beds, and brown shale and thin-bedded sandstone with marine fossils, assigned to the Dangarfield Formation. The base of the Kingsfield Beds is unknown. Laterally, the Beds are inferred to grade into part of the Goonoo Goonoo Mudstone east and northeast of the Brushy Hill Anticline. The extent of the Kingsfield Beds away from the core of the Brushy Hill Anticline is unknown. No other equivalent volcanogenic units are known from the New England Fold Belt.

Osborne (1928b, 1929, 1950a) assigned rocks of the Kingsfield Beds in the Rouchel district to the Burindi 'Series', although the unit is lithologically typical 'Kuttung' (Branagan et al., 1970). Units 1, 2, and part of 3 described by Branagan et al. are in the Kingsfield Beds as defined herein.

Type Section

The type section of the Kingsfield Beds is in the lower part of Section 1 (Pl. 2), which extends from the axial trace of the Brushy Hill Anticline, 1.5 km south of Glenbawn Dam, to the base of the Dangarfield Formation a few metres south of the outlet tunnel at the base of Glenbawn Dam (997278 to 998290, Scone 1:31 680 sheet). The type section of the Kingsfield Beds is cut by at least one major north-northwest-trending fault, and probably by other faults.

The stratigraphically lowest exposed part of the Kingsfield Beds in the type section consists of at least 30 m of volcanogenic rocks, principally crystal-lithic tuffs. The tuffs are associated with sporadic devitrified volcanics which may originally have been glassy or ignimbritic, and rare porphyritic lavas with a microlithic groundmass. Interbedded sandstones probably represent crystal-lithic tuffs which have been slightly reworked; more intense reworking has produced local lenses of magnetite sandstone. Crystal-lithic tuffs contain angular andesine (An_{35}-An_{40}) which is partly or wholly altered to sericite and clay, up to 25% angular to subrounded (maximum roundness about 0.5) rock fragments, and up to 1% angular green hornblende and clear quartz; the hornblende is altered to chlorite and opaque minerals. Accessory minerals include apatite and opaques. The devitrified volcanics contain up to 40% of altered andesine phenocrysts (again An_{35}-An_{40}) 3% to 5% of carbonate and chlorite pseudomorphs after amphiboles (?), and minor altered hornblende and corroded quartz; the groundmass consists of a mosaic of microgranular quartz and feldspar which has obliterated primary textures. Textural andesites and trachytes in the lower part of the Kingsfield Beds contain the same suite of phenocrysts as those in the associated devitrified volcanics. Lithic fragments in the crystal-lithic tuffs are probably locally derived because they consist of an assortment of devitrified volcanic rocks and porphyritic lavas identical with those described above. The interbedded sandstones contain the same suite of minerals and rock fragments, and probably originated by reworking of the crystal-lithic tuffs; the sandstones are poorly sorted, contain angular grains (roundness 0.5) and are brown, red or green in colour. Opaque minerals derived from tuffs are present in all the sandstones, and locally have been concentrated into lenticular bodies of heavy mineral sandstone. The principal opaque mineral in these concentrations is magnetite, locally altered to hematite; other constituents include ilmenite and rare garnet. An analysis of an opaque mineral sandstone at 065294 (Woolooma 1:63 360 sheet) reveals 55.3% Fe and 8.1% Ti, with traces of vanadium, chromium, nickel, manganese, and cobalt (Appendix 1, sample 70/82/0254).

The upper part of the Kingsfield Beds in the type section consists of about 100 m of coarse to fine-grained poorly sorted crystal-lithic tuff and sandstone, similar to those in the lower part of the section, and interbedded purple shale and siltstone. The sandstones are pebbly, and contain conglomerate lenses. The purple shale and siltstone becomes dominant in the upper 40 m of the Kingsfield Beds; the siltstone contains angular clasts of the purple shale.

North of Glenbawn Dam

The lower portion of the Kingsfield Beds containing volcanic rocks is exposed in cuttings along the road between Glenbawn Dam and Brushy Hill Lookout (982314, Scone 1:63 360 sheet). Northwards, the core of the Brushy Hill Anticline is less deeply eroded than in the south, and only the upper part of the Kingsfield Beds is exposed. Paucity of exposures makes location of the Kingsfield - Dangarfield contact difficult. The many faults in the core of the Brushy Hill Anticline, combined with poor exposure, have made it impossible to determine or map the internal stratigraphy of the Kingsfield Beds.

Age

No fossils have been found in the Kingsfield Beds, but their probable minimum age can be inferred from consideration of the fossils in the Dangarfield Formation. In Section 1, the type section for both the Kingsfield Beds and the Dangarfield Formation, brachiopods tentatively assigned to the *Spirifer sol* Zone and conodonts indicative of an early Tournaisian age (p. 38) are present in the Brushy Hill Limestone, 120 m above the top of the Kingsfield Beds. These indicate that the beds cannot be younger than early Tournaisian (Cu I). We tentatively ascribe a late Devonian to early Carboniferous (Tournaisian) age to the Kingsfield Beds.

Environment of deposition

Most features of the Kingsfield Beds suggest deposition in a fluvial environment close to an active volcanic source, although some may be interpreted as intertidal. The lower part of the sequence is mainly non-marine; it contains volcanic rocks, possibly including ignimbrites, which show no signs of subaqueous deposition, and crystal-lithic sandstone; reworking in a beach environment may explain the concentration of heavy minerals in cross-bedded heavy mineral sandstone. A non-marine environment of deposition is also suggested by the almost total absence of calcite as a cementing mineral in the sandstones; this contrasts with the abundance of calcite cement in sandstones of the overlying marine Dangarfield Formation. Purple siltstone with angular clasts of shale at the top of the Kingsfield Beds may have been deposited on flood plain as an alluvial overbank deposit, or in a protected intertidal environment. Branagan et al. (1970) considered the beds to be entirely non-marine.

Dangarfield Formation

The Dangarfield Formation comprises a thick sequence of mudstone with subordinate lithic sandstone and oolitic and crinoidal limestone which outcrops over an area of about 70 km^2 in the vicinity of Glenbawn Dam. The formation takes its name from the settlement of Dangarfield, 10 km east-northeast of Aberdeen. Outcrops of the Dangarfield Formation are present on the flanks of the Brushy Hill Anticline, and extend from Rouchel Springs in the south to the Pages River in the North (Pl. 1).

The Dangarfield Formation overlies the Kingsfield Beds, and is overlain, probably conformably, by the Isismurra Formation; the abrupt change from purple shale to brown sandstone and mudstone at the junction between the Kingsfield Beds and the Dangarfield Formation may indicate a disconformity. Laterally, the formation passes into other units. To the south near Rouchel Springs, mudstone and limestone in the upper part of the Dangarfield Formation appears to pass laterally into paralic or non-marine coarse-grained zeolitic lithic sandstone, heavy mineral sandstone, and conglomerate identified as Waverley Formation. The actual zone of transition is obscured by soil cover, but because there is no evidence of faulting in adjacent resistant ridges of ignimbrites in the lower part of the Isismurra Formation, which overlies both the Dangarfield and Waverley Formations, we interpret the relationship as a lateral gradation; the boundary is indicated by a serrated line on the geological map. North-eastwards from Lake Glenbawn, the upper part of the Dangarfield Formation passes laterally into the Waverley Formation. Faulting, which separates the block surrounding Lake Glenbawn containing the Dangarfield Formation from one extending southwest from Belltrees containing the Waverley Formation, obscures lithological relationships between the two formations. Palaeontological evidence, however, shows that the Schellwienella cf. burlingtonensis and Pustula gracilis Zones tentatively identified in the Waverley Formation in the Wooloома and Benmore areas are also present in the Dangarfield Formation (Pl. 2). In the 'Belltrees Block' the Waverley Formation becomes thinner towards the southwest, and is underlain by the Goonoo Goonoo Mudstone. A precise age cannot be assigned to the mudstones, because of the lack of fossils. Because the upper part of the Dangarfield Formation is laterally equivalent to the Waverley Formation, it follows that the lower part of the Dangarfield Formation may be equivalent to that part of the Goonoo Goonoo Mudstone immediately beneath the Waverley Formation.

Osborne (1928b, 1950a) mapped sediments now assigned to the Dangarfield Formation, and volcanics now known to belong to the Isismurra Formation, as Lower Burindi Series. He was responsible for naming the Brushy Hill Limestone member. Branagan et al. (1970) presented a disgrammatic stratigraphic section, and briefly described the succession in the Glenbawn area.

Type Section

The type section of the Dangarfield Formation (Pl. 2, Section 1) is measured from the basal contact with the Kingsfield Beds, a short distance downstream from the outlet tunnel of Glenbawn Dam (998290 Scone 1:31 680 Sheet), eastwards to the contact with the overlying Isismurra Formation located just below the top of Trig. 2290 (030289, Wooloома 1:63 360 Sheet) (Fig. 6). The thickness of the type section is 1010 m.

The base of the section is taken at the junction between thinly bedded brown lithic sandstone, assigned to the Dangarfield Formation, and purple shale and siltstone of the Kingsfield Beds. Sandstone in the lower part of the Dangarfield Formation contains interbeds of fossiliferous mudstone, lenses of fossiliferous limestone, and occasional pebbles of grey intermediate volcanics. The sandstone is medium to coarse-grained, green to brown in colour, moderately well sorted, and in places cross-bedded. It contains fresh angular to subangular fragments of andesite, devitrified volcanics, micrographic granite, plagioclase (An_{35}-An_{50}), orthoclase and minor plutonic quartz in a muddy calcareous to coarsely crystalline sparry calcite cement. Allochemical carbonate fragments, particularly oolites, become common towards the top of the sandstone succession, and the unit grades upwards into the Brushy Hill Limestone member.

The Brushy Hill Limestone member consists dominantly of thinly bedded and cross-bedded grey oolitic limestone, with a middle part of reddish impure fossiliferous and oolitic limestone. Angular to subangular fragments of feldspar and devitrified volcanics are present throughout the limestone, particularly the reddish beds, and frequently form nuclei of oolites. Both oolites and uncoated terrigenous fragments are set in a cement of sparry calcite. In the type section, the Brushy Hill Limestone member is approximately 12 m thick. Northwards along Brushy Hill, the limestone thickens and splits into two units separated by beds of calcareous lithic sandstone. The upper beds of the Brushy Hill Limestone grade into fossiliferous calcareous mudstone.

A thick sequence of mudstone overlies the Brushy Hill Limestone, and comprises the greater part of the Dangarfield Formation. The mudstones contain in their middle and upper parts interbeds of lithic sandstone and impure crinoidal limestone. Lithologically the mudstones are dark grey to brown in colour and thinly bedded, and when weathered break down into small cleavage chips. At the top of the succession the mudstone is silty, and in places is abundantly fossiliferous.

The incoming of sandy sediments is marked by thinly bedded, fine-grained, well sorted, ripple-cross stratified lithic sandstone. Terrigenous fragments in the sandstone consists mainly of angular to subangular devitrified volcanics, plagioclase (An_{35}-An_{65}) and orthoclase feldspar, minor plutonic quartz, andesite, magnetite, and epidote; these are bound by a chlorite and calcite cement. In some sandstones the cement is associated with a fine chloritic matrix. A colourless zeolite (heulandite group) is a minor constituent in the cement of one sample (1-13).

Pebbly, poorly sorted coarse-grained lithic sandstone becomes dominant in the upper part of the succession. The composition of the sandstone ranges from lithic to feldspathic: some beds are essentially a plagioclase sandstone. Terrigenous fragments are angular to subangular (0.1 - 0.3; pebbles 0.5), have a sphericity of 0.5 - 0.7, and consist of andesite, devitrified volcanics, micrographic granite, feldspar (mainly plagioclase with a composition of An_{30}-An_{50}), and minor plutonic quartz. The fragments are set in a cement of calcite, supplemented in some cases by a matrix. In sandstone at the top of the succession a colourless to pale pink zeolite (mordenite or clinoptilolite) replaces a matrix of volcanic ash.

Limestones in the upper half of the type section are dark grey, have a muddy calcareous cement, and contain crinoid columnals, corals, brachiopods, polyzoans, ammonoids, bivalves, and gastropods. The limestones are thin and lensoidal; Branagan et al. (1970) mapped three limestones within the upper half of the Dangarfield Formation.

In the type section, the boundary between the Dangarfield and Isismurra Formations is taken at the transition from brown to pink crossbedded lithic sandstone. The pink sandstone is succeeded by the Ayr Conglomerate member. Elsewhere, the base of the Isismurra Formation is usually conglomeratic.

<u>Other sections and localities</u>

Incomplete sections through the Dangarfield Formation have been measured along the Isis River, from the core of the Brushy Hill Anticline eastwards towards Gundy, and on the flanks of the Albano syncline near Dangarfield (Fig. 6).

Section 13 (Fig. 7), from along the Isis River, is cut by a fault and lacks some of the upper part of the succession. In comparison with the type area, lithic sandstone is more prominent in the lower part of the section. With the exception of a conglomerate at 219 m above the Brushy Hill Limestone, the sandstones are fine-grained and are comparable with those in the type section. Impure crinoidal limestone and medium to coarse-grained lithic sandstone between 481 and 561 m above the Brushy Hill Limestone are lithologically similar to those at a comparable level in the type section.

Near Dangarfield, the upper part of the formation contains coarse to medium-grained lithic sandstone, interbedded oolitic and crinoidal limestones, and silty mudstone. A fauna, identified as Pustula gracilis Zone, from mudstone at locality 4-2 indicates a correlation with mudstone in the upper part of the type section (Pl. 2, Section 4). The oolitic and crinoidal limestones in Section 4 are absent from the type section, probably because of non-deposition. The limestones can be traced a short distance to the southwest but disappear beneath alluvium. The relationship between the Dangarfield Formation and the Waverley Formation in this area has already been discussed (p. 12).

Coralline and algal limestone at Kingsfield, on the western side of the Brushy Hill Fault, is present in the uppermost part of the Dangarfield Formation (Branagan et al., 1970). The limestone has a discontinuous and mound-like outcrop which may be due either to the growth of bioherms or to disruption caused by minor faulting. Branagan et al. (1970) have tentatively correlated the limestone at Kingsfield with one in the type area of the Dangarfield Formation. Because of its position near the top of the formation it seems more likely that the limestone at Kingsfield is equivalent to one of the younger limestones in Section 4.

Fauna and Age

Marine invertebrate faunas are present throughout a number of horizons in the Dangarfield Formation. They comprise assemblages of brachiopods, corals, polyzoans, bivalves, gastropods, ammonoids, crinoids, blastoids, and conodonts. Plate 2 indicates the location of brachiopod zones in most of the measured sections, and illustrates correlations between the sections.

In and near the type section, three brachiopod zones are recognized: the Spirifer sol Zone is tentatively identified from locality 1-9 in the Brushy Hill Limestone Member; the Schelwienella cf. burlingtonensis Zone from localities 1-27 and 1-28; and the Pustula gracilis Zone from localities 1-22 and 1-23. The section therefore ranges in age from early Tournaisian to early Viséan, or from the base of the gap between CuI and CuIIα to the middle of the gap between CuIIγ and CuII δ in terms of the German ammonoid zones as interpreted by Campbell, Jones, & Roberts (in prep.) (Fig. 4).

Conodonts identified by Jenkins (in Branagan et al., 1970) from the Brushy Hill Limestone Member (L3 of Branagan et al.), and the Dangarfield Formation (L2) support this age determination. Those from the Brushy Hill Limestone indicate an age equivalent to the upper half of CuI and the lower half of the gap between CuI and CuII , and those from a limestone at L2, on the same horizon as brachiopods of the Schellwienella cf. burlingtonensis Zone, are considered to be CuII in age (Campbell, Jones, & Roberts, in prep.).

Corals from limestone near the top of the Dangarfield Formation at Kingsfield have been tentatively assigned to the Orthotetes australis Zone and dated as ?Lower to Middle Viséan (Branagan et al., 1970). We have seen no evidence of brachiopods of the australis Zone in the Dangarfield Formation, and suggest that the corals are older than australis Zone.

Environment of deposition

The Dangarfield Formation was deposited in a shallow marine environment, the lower part eastwards of a possibly linear north-northwesterly shoreline near Scone and Aberdeen (Fig. 13A), and the upper part in a protected embayment (Fig. 13B&C). Sediments in the lower-most part of the formation are interpreted as near-shore 'transgressive' sands derived from a volcanic terrain, probably exposed Kingsfield Beds. The presence of limestone lenses and oolite grains within the sandstone succession suggests that the influx of terrigenous sediment was low. The Brushy Hill Limestone, an oolitic limestone immediately overlying the sandstones, was deposited on a carbonate bank which received little terrigenous material. Mudstones succeeding the Brushy Hill Limestone were probably deposited in slightly deeper water.

The upper part of the Dangarfield Formation, which is laterally equivalent to the Waverley Formation, was deposited in a protected marine embayment, and comprises silty mudstone, lithic sandstone, and limestone. The sandstone is mostly finer-grained than those in the Waverley Formation, and reflects periodic influxes of sand-sized detritus into an embayment which received mainly silty muds. Oolitic and skeletal limestone accumulated in shallow water during occasional periods of low sediment influx.

Waverley Formation

Waverley Formation is the name first used by Manser (1968) to describe a sequence of lithic sandstone, conglomerate, and siltstone in the Wingen area, immediately north of the Rouchel Map Sheet. The Waverley Formation overlies the Goonoo Goonoo Mudstone (Martindale Mudstone of Manser, 1968), and is overlain by the Isismurra Formation. It has already been shown (p. 11) that in the area around Lake Glenbawn the Waverley Formation passes laterally into the Dangarfield Formation. Manser has not formally defined a type section for the formation, but gives the maximum thickness as 4 650 feet (about 1550 m).

To gain a better understanding of the Waverley Formation a section (42) was measured from near the head of Spring Gully, 5.6 km southwest of Waverley Homestead, to Glenugie Station (Fig. 8). Because section 42 is in the vicinity of the nominate area, we designate it the type for the Waverley Formation.

Type Section

In section 42, the Waverley Formation reaches a thickness of 622 m, and consists of thick-bedded pinkish-brown to green lithic sandstone, occasional black cross-bedded heavy mineral sandstone, and conglomerate. The section is cut by one possible fault 360 m above the base of the Waverley Formation.

At the base of the formation a conglomerate 75 m thick overlies, possibly unconformably, thinly bedded brown to olive Goonoo Goonoo Mudstone. The conglomerate is succeeded by a sequence of mainly thick to medium-bedded lithic sandstones. These are poorly to very poorly sorted, and have grains which are coarse to frequently pebbly, angular to subangular (0.3-0.5), and with a sphericity averaging 0.7. Rock fragments consist mainly of two andesites, one with andesitic texture and the other with sub-trachytic texture, devitrified glassy volcanics, and minor brown ignimbrite and micrographic granite. Other terrigenous fragments comprise both orthoclase and plagioclase (An_{40}-An_{60}) feldspar, minor plutonic quartz, magnetite, hornblende, augite, epidote, and biotite. The lithic sandstones are cemented by a colourless zeolite and chlorite, and occasionally by sparry calcite; in some sandstones the cementing minerals partly replace a brown matrix.

At a height of 515 m, towards the top of the formation, there is a well sorted black cross-bedded heavy mineral sandstone which we interpret as a beach deposit. It consists mainly of magnetite but also has abundant ferromagnesian minerals, epidote, and garnet, and minor amounts of devitrified volcanics, micrographic granite, and plutonic quartz. Sediments above the heavy mineral sandstone are conglomeratic and pebbly lithic sandstone.

The boundary between the Waverley and Isismurra Formations is defined by the incoming of purple conglomerate of the Ayr Conglomerate member.

Fossiliferous marine siltstone, not observed in section 42, is present on the roadside west of the section line (Fig. 8). The virtual absence of marine beds, and the nature of the lithic sandstone and conglomerate suggests that sediments in section 42 represent an area of non-marine to possibly littoral deposition. For example, the conglomeratic and pebbly sandstone overlying the heavy mineral sandstone may represent non-marine conditions of sedimentation resulting from a marine regression after deposition of beach sediments.

<u>Other Sections</u>

The Waverley Formation is predominantly non-marine to paralic in the west, but becomes entirely marine in the east. In the west, sediments consist of lithic sandstone and conglomerate, as in the type section, and minor interbedded fossiliferous mudstone; towards the east, lithic sandstone remains dominant, but there are increasing amounts of fossiliferous mudstone, siltstone, and limestone. In the following discussion we deal with sections of the Waverley Formation from west to east.

<u>Benmore - sections 58 & 59</u>. Sections 58 and 59 are measured in the 'Belltrees Block' west of Benmore, the region in which the Waverley Formation becomes thinner and appears to pass laterally into the Dangarfield Formation. The Waverley Formation is 290 m thick in section 59, and only 2 km to the southwest in section 58 measures approximately 130 m (Fig. 9).

Sediments in both sections consist dominantly of thick-bedded buff-pink to green lithic sandstone, with subordinate interbeds of olive to brown mudstone. Both the Schellwienella cf. burlingtonensis and Pustula gracilis Zones have been tentatively identified in section 58, suggesting that the Waverley Formation in this area was originally thin, and was not extensively eroded before the deposition of the Ayr Conglomerate. Plate 2 shows the positions of the zones extrapolated from section 58 into section 59. In both sections the Waverley Formation is underlain by the Goonoo Goonoo Mudstone and overlain by lithic sandstone and conglomerate of the Isismurra Formation.

Rouchel Springs - Dunbar Creek area (including section 47). At Rouchel Springs lithic sandstone of the Waverley Formation appears to pass laterally into the upper part of the Dangarfield Formation (p. 11). In this area, and to the south around Sandy Creek, the Waverley Formation consists of thick beds, some cross-stratified, of pebbly and conglomeratic pinkish-brown to purple lithic sandstone, with minor intercalations of mudstone and heavy mineral sandstone. The succession is exemplified by section 47 at Sandy Creek. The environment of deposition of sediments in section 47 is interpreted as a fluvial piedmont close to a shoreline. The change from the piedmont to a beach is indicated by the presence of cross-bedded heavy mineral sands.

Deformed impure limestone in a fault block farther westwards along Sandy Creek is probably older than the sandstones in section 47. In the vicinity of Dunbar and Limestone Creeks the limestone becomes richer in calcium carbonate and consists of a grey thinly bedded oolite. The presence of the limestone implies that a marine regression in the southwestern part of the Rouchel area produced non-marine conditions of sedimentation in the upper beds of the Waverley Formation.

Wooloома Gully - Back Creek area - sections 24 & 39. Wholly marine sequences of Waverley Formation are present in the eastern part of the Rouchel Map Sheet. In sections from Woolooma Gully (24) and Back Creek (39) the Waverley Formation contains the Schellwienella cf. burlingtonensis Zone at high levels, and is overlain by the Ayr Conglomerate member; the absence of the Pustula gracilis Zone, which elsewhere typifies the upper beds of both the Waverley and Dangarfield Formations, suggests that some Waverley Formation may have been eroded before deposition of the Ayr Conglomerate.

Section 24. Lithic sandstone at the base of section 24 appears to conformably overlie poorly exposed Goonoo Goonoo Mudstone. Sandstones in the lower part of the section are fine to medium-grained, green, blue, or grey in colour, and in some instances contain crinoid columnals; they are poorly sorted, and have fragments of andesite, devitrified volcanic glass, micrographic granite, plagioclase (An_{30}-An_{50}) and orthoclase feldspar, and plutonic quartz set in a chloritized matrix; the matrix is partly replaced by a cement of chlorite and minor colourless zeolite. Higher in the section, the lithic sandstones become coarse - grained and conglomeratic, and are cemented by chlorite and minor zeolite and calcite; matrix is less prominent than in lower parts of the section.

A succession of 115 m of thinly bedded fossiliferous mudstone and interbedded sandstone is present 500 m above the base of the section. Fossils from the mudstone have been identified as Schellwienella cf. burlingtonensis Zone. Faulting disrupts the section between the interbedded mudstone and sandstone unit and conglomerates of the Isismurra Formation, apparently cutting out a sequence of lithic sandstone (Pl. 2, Section 24). The interbedded mudstone and sandstone unit is repeated at the confluence of Wooloома Gully and a major tributary at 145327 Wooloома 1:63 360 Sheet, and is overlain by buff to pink coarse-grained lithic sandstone constituting the upper part of the formation. The lithic sandstone is moderately well sorted, and contains angular to subangular fragments set in a cement of chlorite and colourless zeolite; terrigenous fragments comprise andesite, micrographic granite, plagioclase (An_{40}-An_{50}) and orthoclase feldspar, and plutonic quartz. Brachiopods in a fine-grained interbed near the top of the formation (locality 24-15) are assigned to the Schellwienella cf. burlingtonensis Zone. The burlingtonensis Zone is identified in the interbedded mudstone and sandstone beneath the lithic sandstone, supporting the suggestion that the former unit is repeated.

Conglomerate overlying the buff to pink beds of lithic sandstone is identified as the Ayr Conglomerate member of the Isismurra Formation.

The thickness of the Waverley Formation in the Wooloома Gully area is estimated to be 840 m.

Section 39. A sequence similar to that in the Wooloома Gully area, but containing a greater proportion of siltstone, is present to the east along Back Creek (Pl. 2, Section 39). The lower part of the section contains interbedded siltstone and fine to medium-grained lithic sandstone. Lithologically the sandstones are identical with those in the lower part of section 24. Coarse-grained pebbly and conglomeratic sandstones characterize the upper part of the formation, and like those in section 24 have cements of chlorite, colourless zeolite, and calcite. Interbeds of siltstone between 450 m and 810 m in the section contain brachiopods referable to the Schellwienella cf. burlingtonensis Zone. Siltstone containing the burlingtonensis Zone is overlain by conglomerate tentatively identified as Ayr Conglomerate.

Stewarts Brook - Wooloома Range Area. The Waverley Formation crops out extensively between the Wooloома Range and Stewarts Brook. In this vicinity it consists of thinly bedded fossiliferous siltstone, some of which is cleaved and has previously been mapped as Glenlawn Formation (Manser, 1968), thickly bedded green lithic sandstone, and conglomerate. The lithic sandstone is usually coarse-grained, poorly to moderately well sorted, and contains angular grains of volcanic rocks, micrographic granite, plagioclase (An_{30}-An_{50}), orthoclase, and minor plutonic quartz cemented by chlorite and colourless zeolite; the volcanic rock fragments are partly devitrified glass, ignimbrite, and andesite. Some of the sandstones have a dark matrix. The lithic sandstones in the eastern part of the Rouchel area are slightly richer in chlorite than those in the type area, possibly reflecting the stronger marine influence in the east. Siltstone from locality 63-5 (216402 Wooloома 1:63 360 Sheet), 3 km north of Mt Wooloома, contains the Pustula gracilis Zone.

A sequence of mainly thinly bedded fine-grained fossiliferous lithic sandstone identified as Waverley Formation is exposed along the upper reaches of Back Creek, south of Woolooma Range. The sandstone contains some coarser beds, and interbedded siltstone. Brachiopods and particularly polyzoans are scattered throughout the sequence, the brachiopods belong to either the Schellwienella cf. burlingtonensis or the Pustula gracilis Zone.

At Conical Hill and on the dip slope to the southeast into Rouchel Brook, there are outcrops of coarse-grained grey skeletal calcarenite. The calcarenite consists of rounded but poorly sorted skeletal fragments of crinoid columnals, fenestellid polyzoans, solitary corals, and occasional brachiopods, set in a coarsely crystalline calcite cement. Some of the skeletal fragments have rims, possibly of algal origin, consisting of brown calcareous material with scattered tubular filaments. Stratigraphically, the calcarenite is situated approximately 210 m below the top of the Waverley Formation.

Malumla - section 30. Rib-forming sandstones cropping out on the lower slopes of Malumla, on the southern bank of Rouchel Brook, are assigned to the top of the Waverley Formation. In the Malumla area the Waverley Formation is wholly marine and passes upwards into the Woolooma Formation. The Ayr Conglomerate, which overlies the Waverley Formation in most localities in the Rouchel area, is absent and has been replaced by marine sediments. Volcanism and the associated abundant supply of terrigenous detritus which characterized the incoming of the Isismurra Formation in the west may be represented in the Malumla area by a sequence of sandstone, with an interbedded devitrified tuff, which succeeds the skeletal calcarenite (Pl. 2, Section 30). Lithologically, the sandstones are medium to coarse-grained or pebbly, and contain angular to subangular fragments of andesite, partly devitrified ash flow tuffs, devitrified volcanic glasses, micrographic granite, plagioclase (An_{30}-An_{50}) and orthoclase feldspar, and plutonic quartz; the terrigenous grains are set in a glassy matrix which may be replaced by colourless zeolite or a cement of zeolite and chlorite. The boundary between the Waverley and Woolooma Formations is taken at the top of the succession of thickly bedded coarse-grained lithic sandstone.

The sandstones are interpreted as marine equivalents of the Ayr Conglomerate and the Curra Keith Tongue, and are probably younger than sediments at the top of the Waverley Formation in the western part of the Rouchel district. Two faunas from the Malumla area should be considered in a discussion on the correlation of the sandstone unit constituting the upper part of the Waverley Formation. The first, from locality 31-1 on the bank of Rouchel Brook at 'Brookdale' (198288, Woolooma 1:63 360 sheet) lies stratigraphically beneath the calcarenite at the base of section 30. Brachiopods from locality 31-1 are assigned to the gracilis Zone on the basis of the occurrence of Schellwienella sp. B; other species are longer-ranging and are present in both the burlingtonensis and gracilis Zones (Tables 6, 7). This part of the section is therefore equivalent to the upper part of the Dangarfield and Waverley Formations to the west and northwest.

A stratigraphically higher fauna from within the upper sandstone unit of the Waverley Formation is present at two localities at Malumla: locality 15-3 (207282, Woolooma 1:63 360 Sheet), and locality 30-2 near the base of section 30. The fauna is regarded as transitional between the gracilis and australis Zones, containing Syringothyris cf. principalis North, Antiquatonia cf. insculpta Muir-Wood, Rugosochonetes sp. A, terebratuloid n.gen. and Schuchertella sp. ?A in association with Orthotetes australis (Campbell) and Fluctuaria campbelli Roberts. The composition of the 'transitional' fauna confirms that the sandstone at the top of the Waverley Formation at Malumla is younger than that in the uppermost parts of the formation elsewhere in the district, and supports our contention that the sandstone is laterally equivalent to the lower part of the Isismurra Formation. Additional evidence supporting correlation with the lower part of the Isismurra Formation is provided by the identification of the Orthotetes australis Zone in the overlying Woolooma Formation at Malumla, and in sediments (Woolooma Formation) overlying the lower part of the Isismurra Formation in section 17 at Back Creek (Fig. 4).

Scrumlo Area. A sliver along a major fault extending east-northeast at Davis Creek contains thinly bedded silty mudstone and lithic sandstone identified as Waverley Formation. To the west, the succession is faulted against the upper part of the Isismurra Formation, and to the east it is overlain by the lower part of the Isismurra Formation. Fossils from locality 38-7 (152199, Woolooma 1:63 360 Sheet), approximately 400 m stratigraphically beneath the Curra Keith Tongue of the Isismurra Formation, belong to the Pustula gracilis Zone.

The Pustula gracilis Zone is also present in outcrops of mudstone and siltstone at Cameron Bridge, spanning Rouchel Brook (075268, Woolooma 1:63 360 Sheet), and on Rouchel Brook immediately west of Rouchel Brook Post Office. In both localities the succession is complicated by faulting, but at Rouchel Brook it is likely that the mudstone containing the gracilis Zone underlies the Ayr Conglomerate member. Both outcrops are too small to be accurately portrayed on the geological map.

Age of the Waverley Formation

The Schellwienella cf. burlingtonensis and Pustula gracilis zones have both been identified within the Waverley Formation. In some sections the Pustula gracilis Zone is absent from the top of the formation, probably because of erosion beneath the Ayr Conglomerate member. The age of the greater part of the Waverley Formation, in terms of the German ammonoid zones (after Campbell, Jones, & Roberts, in prep.) is therefore CuIIα to CuIIγ (late Tournaisian to early Viséan). The age of the sandstone unit at Malumla, which contains a fauna transitional with the younger Orthotetes australis Zone, is probably equivalent to the gap between CuIIγ and CuIIδ (early Visean).

Manser (1968) reported brachiopods of middle Viséan age from the Waverley Formation near Green Creek in the north of the Wingen 1:100 000 Map Sheet. The fauna is assigned to the Orthotetes australis Zone, which suggests either that the Waverley Formation extends into the middle Viséan in the north, or that the fauna is a marine intercalation into sediments which may be more precisely mapped as Isismurra Formation.

Environment of deposition

The Waverley Formation was deposited in response to uplift and volcanism in a source area west or northwest of the Rouchel district. Sediments, which comprise mainly coarse-grained lithic sandstone, were deposited in both non-marine and marine environments. Non-marine sandstones are usually pink to brown in colour and have a cement dominated by a zeolite (mordenite or clinoptilolite), and marine sandstones are usually green in colour and have a cement dominated by chlorite. The sandstones of both environments are poorly to moderately well sorted, moderately well-washed, and have angular grains, all features indicative of rapid sediment influx and rate of deposition. The non-marine sediments, usually coarse-grained pebbly and conglomeratic sandstones, were deposited by probably braided streams flowing across a piedmont area. In the Rouchel district, the piedmont prograded eastwards in two main regions separated by a marine embayment (Fig. 13B & C) which received finer sediments (Dangarfield Formation) and which must have been protected from the main currents distributing coarse marine sediments. Beach zones, on the flanks of the piedmont plain, are indicated by cross-stratified heavy mineral sandstone. Offshore, sediments were deposited on a shelf which was shallow in the west near the piedmont areas, and slightly deeper in the east. The marine sediments consist of coarse-grained lithic sandstone and conglomerate in the west, and medium to fine-grained sandstone, siltstone, and occasional skeletal limestone in the east. An oolitic limestone, indicative of a shallow bank environment, was deposited on one part of the shelf, probably during a period of low sediment influx.

Woolooma Formation

The Woolooma Formation is a sequence of marine siltstone, mudstone, lithic sandstone, and minor limestone that derives its name from Woolooma Gully, a major tributary of Back Creek. In the east, the Woolooma Formation succeeds the Waverley Formation, and is overlain by the upper part of the Isismurra Formation, and in the west the formation intertongues with the Isismurra Formation. Two periods of westward marine transgression are recognized within the Woolooma Formation (Fig. 10): the first during the upper part of the Orthotetes australis Zone, and the second during the Delepinea aspinosa Zone. In areas of intertonguing with the Isismurra Formation, Woolooma Formation containing the upper part of the australis Zone replaces the Oakfields Tongue and terrestrial lithic sandstone. Transgressive deposits containing the aspinosa Zone extend farther westwards, and replace terrestrial lithic sandstone between the Oakfields Tongue or Native Dog Member and the red ignimbrites in the upper part of the Isismurra Formation.

Osborne (1950a) previously recognized a marine phase in the 'Lower Kuttung Series' at Rouchel. He considered the fossiliferous marine sediments to extend as one horizon from Back Creek, to Cameron Bridge, and south to Fish Hole Creek. All three localities are at different stratigraphic levels: the Cameron Bridge locality, in rocks identified as Waverley Formation, contains a fauna referable to the Pustula gracilis Zone; the Back Creek locality, in the Woolooma Formation, contains a fauna identified as Orthotetes australis Zone; and the Fish Hole Creek horizon, apparently within the Isismurra Formation, is probably Delepinea aspinosa Zone.

Type Section - section 17 Back Creek

The type section of the Woolooma Formation is measured westwards along Back Creek from a small anticlinal closure (143293, Woolooma 1:63 360 Sheet) to the hill north of the closure of the Davis Creek Syncline (117287, Woolooma 1:63 360 Sheet). The thickness of the type section is 560m; a minor fault disrupts the sequence 380 m above the base of the formation.

At the base of section 17 there is a transition from coarse-grained pink to grey plant-bearing conglomeratic sandstone of the Isismurra Formation to fine-grained grey lithic sandstone and interbedded siltstone of the Woolooma Formation. The base of the Woolooma Formation is taken at the incoming of interbeds of siltstone. Well sorted sandstone with small-scale cross-stratification outlined by stringers of heavy minerals, below the base of the Woolooma Formation at locality 17-3, is interpreted as a beach deposit indicative of the middle Visean marine transgression.

Much of the lower half of the type section consists of hard grey to blue thinly bedded fossiliferous siltstone and interbedded fine to coarse-grained lithic sandstone. The siltstone contains a large proportion of glassy material probably derived from nearby volcanic activity. The lithic sandstone is poorly sorted and contains angular grains of andesite, devitrified ignimbrite, granite, plagioclase (An_{30}-An_{40} : mainly zoned andesine), and minor plutonic quartz in a dark ?glassy matrix; chlorite and colourless zeolite replace parts of the matrix. At locality 17-9 an unusual pink coarse-grained tuffaceous rock consisting of fragments of glassy ignimbrite and plagioclase (An_{35}-An_{60}) set in a matrix of partly zeolitized glass shards and volcanic ash indicates close proximity to an active volcanic source. Similar tuffaceous horizons have been identified at comparable stratigraphic levels in section 30 at Malumla (below 30-10) and section 68 in the Scrumlo-Mullee area (locality 68-3). Rich brachiopod faunas from the lower part of the type section (localities 17-5 to 17-11) all belong to the Orthotetes australis Zone.

In the upper half of the type section the succession contains thicker beds of coarse to medium-grained grey lithic sandstone interbedded with brown mudstone; there is one thin unit of blue-grey siltstone. Terrigenous components of the lithic sandstone are mainly of volcanic origin and include glassy and partly devitrified ignimbrites, devitrification mosaics formed from volcanic glass, andesite, micrographic granite, plagioclase (An_{33}-An_{55}) and orthoclase feldspar, and plutonic and minor volcanic quartz; accessory minerals include magnetite, epidote, hypersthene, hornblende, augite, and sphene. Grains are angular to subangular, and are set in a cement of chlorite, zeolite, or calcite which either grades into or replaces a dense brown matrix. Mudstone and sandstone near the top of the section (locality 17-14) contain a fauna assigned to the Delepinea aspinosa Zone. The boundary between the Woolooma Formation and the upper part of the Isismurra Formation is taken at the top of the last brown lithic sandstone beneath the first red ignimbrite in the Isismurra Formation; the contact is usually poorly exposed.

Other Sections

Malumla - Mt Scrumlo - sections 30 & 32 At Malumla, thinly bedded medium-grained green fossiliferous lithic sandstone containing lenses of crinoidal calcarenite overlies the Waverley Formation (Pl. 2, Section 30). The sandstone is predominantly composed of devitrification mosaics after volcanic glass, orthoclase and plagioclase (An_{28}-An_{45}) allochemical calcite, and minor micrographic granite, andesite, and plutonic quartz; grains are angular, and are set in a cement of calcite, chlorite, and colourless zeolite. Overlying the basal sandstone is a sequence, nearly 200 m thick, of richly fossiliferous mudstone and interbedded siltstone; in some beds zeolites extensively replace glass shards and volcanic ash. Brachiopods in this interval belong to the Orthotetes australis Zone. The composition of the assemblage below horizon 29-7 in section 30 suggests that the incoming of the australis Zone may have occurred slightly earlier at Malumla than in the type area 7 km to the west (Table 3).

Lithic sandstone, approximately 490 m thick, succeeds the mudstone and siltstone beds; it is exposed towards the top of Malumla, on dip slopes on the southern flank of Malumla, and on the lower slopes of Mt Scrumlo. Sorting in the sandstone is extremely poor, and in many specimens the grains range in size from pebbles 3.5 mm in diameter to silt-size fragments 0.04 mm in diameter; grains are angular to subangular. Many of the sandstones have a brownish-green chloritic matrix which is partly replaced by chlorite, colourless zeolite, and patches of calcite; in some, the zeolite also replaces feldspars. Terrigenous fragments are dominated by glassy to partly devitrified ignimbrites, devitrified ignimbrites, devitrification mosaics after volcanic glass, and plagioclase (An_{28}-An_{60}, mainly An_{35}-An_{50}) and orthoclase feldspar. Minor constituents include andesite, micrographic granite, plutonic quartz, magnetite, epidote, hypersthene, hornblende, augite, biotite, zircon and sphene.

The uppermost beds of the Woolooma Formation on Scrumlo comprise 90 m of interbedded mudstone and medium to fine-grained grey lithic sandstone. Brachiopods from locality 32-10 (202236 Woolooma 1:63 360 Sheet) are assigned to the Delepinea aspinosa Zone. Overlying the mudstone are thick-bedded coarse-grained lithic sandstones identified as Isismurra Formation.

Scrumlo - Mullee - section 68 Southwest of Scrumlo the Wooloome Formation intertongues with the Isismurra Formation, lying stratigraphically between the Curra Keith Tongue and red ignimbrite in the upper part of the Isismurra Formation. The sequence in the Scrumlo-Mullee area is exemplified by section 68. Thinly bedded grey-green crinoidal mudstone and lithic sandstone overlie coarse-grained conglomeratic sandstone identified as Isismurra Formation. Between 170 and 235 m above the base of the formation there is a succession of hard blue-grey siltstone and interbedded sandstone containing abundant brachiopods of the Orthotetes australis Zone. A coarse-grained red-green tuff 200 m above the base of the Wooloome Formation in section 68 indicates volcanism in the source area to the west contemporaneous with deposition of the hard blue-grey siltstone. Glassy fragments and volcanic ash derived from the volcanic source are probably responsible for the hard resistant properties of the siltstone.

The upper part of the section is poorly exposed. Sediments include conglomeratic sandstone or conglomerate, medium to coarse-grained lithic sandstone, and interbedded mudstone and lithic sandstone containing the Delepinea aspinosa Zone. Coarse-grained lithic sandstone and an interbedded red ignimbrite identified as Isismurra Formation overlie the mudstone and sandstone unit.

Campbell Creek - Fal Brook area. Outcrops of Wooloome Formation are present in the Campbell Creek - Fal Brook area, south and southeast of the Brothers. The sequence is similar to that in section 68 at Scrumlo - Mullee, the Wooloome Formation intertonguing with the Isismurra Formation. At the base of the Wooloome Formation, hard blue-grey fossiliferous siltstone overlies thickly bedded coarse-grained lithic sandstone and conglomerate. The Curra Keith Tongue is represented by one small outcrop, stratigraphically above a conglomerate, and appears to have nearly lensed out. Fossils from siltstone at locality 66-21 (229097 Camberwell 1:63 360 Sheet) and locality 66-22 (232100 Camberwell 1:63 360 Sheet) are from the Orthotetes australis Zone. Overlying the siltstone is a sequence of thinly bedded mudstone and lithic sandstone; faulting along Fal Brook and Timor Creek then disrupts the succession. The Delepinea aspinosa Zone is present at locality 67-12 (254132, Wooloome 1:63 360 Sheet) on Fal Brook: a little farther east, the succession passes upwards into the upper part of the Isismurra Formation. A similar transition from Wooloome Formation to upper Isismurra Formation is present immediately east of Campbell Creek; the aspinosa Zone is identified at locality 66-4 (198091, Camberwell 1:63 360 Sheet).

Stony Creek - section 6. The second phase of transgression in the Wooloome Formation is portrayed in Section 6 (Pl. 2, section 6), measured along Stony Creek; marine sediments intertongue between the Oakfields Tongue and the upper part of the Isismurra Formation containing red ignimbrites. Both the upper and lower contacts of the Wooloome Formation are disrupted by faults, but the displacement is insufficient to change the overall succession significantly. West of Stony Creek the Wooloome Formation wedges out into the Isismurra Formation (Pl. 1). Brachiopods from throughout the succession are referred to the Delepinea aspinosa Zone.

Sediments in the Stony Creek section consist mainly of thin-bedded olive mudstone and grey siltstone with subordinate lithic sandstone and calcarenite. The lithic sandstone is fine to medium-grained, and frequently contains skeletal carbonate debris. Terrigenous fragments comprise andesite, devitrification mosaics, glassy or partly devitrified ignimbrites, micrographic granite, orthoclase and plagioclase (An_{30}-An_{55}) feldspar, minor plutonic and volcanic quartz, and accessory minerals. Fragments are set in cements of calcite, chlorite, and minor zeolite; the cementing minerals frequently replace a matrix. Calcarenites are present as lenses or continuous beds, and contain abundant skeletal material as well as a small amount of terrigenous material. Most of the detrital grains are coated with algal overgrowths consisting of brown concentric rims and ramifying tubules. The grains are set in a granular to sparry calcite cement.

On the eastern side of Stony Creek, siltstone and interbedded sandstone containing the Delepinea aspinosa Zone are overlain by the upper part of the Isismurra Formation (Pl. 2, section 44). Southeastwards, on the flanks of the Davis Creek Syncline thick ridge-forming marine lithic sandstone replaces terrestrial sandstone and possibly the Oakfields Tongue present beneath the Woolooma Formation in the Stony Creek area.

Benmore - Rouchel area. Southwest of Benmore, a wedge of Woolooma Formation within the Isismurra Formation encloses the Oakfields Tongue. The succession above the Oakfields Tongue contains siltstone, lithic sandstone, and limestone similar to those in section 6 at Stony Creek, but also has thin beds of red ignimbrite. It is not known whether the tuffs are local ash falls within the upper part of the Woolooma Formation, or whether they are correlates of the red ignimbrites in the upper part of the Isismurra Formation. Marine sediments overlying the ignimbrites in section 101 (Plate 2) suggest either that the ignimbrites are older than those in the upper part of the Isismurra Formation, or that the marine regression and change to non-marine sedimentation represented by the base of the upper Isismurraaffected areas in only the western and southern parts of the Rouchel district, and marine sedimentation continued in the northeast. Support for the second alternative is provided by the presence of a red partly devitrified ignimbrite beneath the Delepinea aspinosa Zone in the upper parts of section 39 (Plate 2). The tongue of Woolooma Formation at Benmore wedges out near Gum Flat Gully. A similar tongue is present in a region of complex faulting west of Upper Rouchel.

Age of the Woolooma Formation

The Woolooma Formation contains the Orthotetes australis and Delepinea aspinosa Zones, and in terms of the German ammonoid zones (after Campbell, Jones & Roberts, in prep.) is dated as CuII δ to CuIII α, or middle Viséan in age. In areas of intertonguing, the youngest part of the australis Zone is absent, but we cannot indicate the interval of time in terms of the German zones. Faunas in the aspinosa Zone represent the lower part of that zone.

Limestone in the *aspinosa* Zone at Stony Creek (localities 6-9, 6-11 and 6-12) have yielded an assemblage of foraminifers and algae. B.L. Mamet (pers. comm.) has identified these as *Aoujgalia* sp., *Archaediscus* sp., *Brunsia* sp., *Calcisphaera* sp., *Cornuspira* sp., *Earlandia* sp., *Endothyra* sp., *Girvanella* sp., *Globoendothyra* sp., *Kamaena* sp., *Septabrunsiina* sp., *Stacheoides* sp., and *Tetrataxis* sp.; he suggests that they indicate 'a late Early or Middle Viséan age (around Zones 11-12 or perhaps younger)'.

Environment of deposition

The Woolooma Formation was deposited on a shallow marine shelf offshore from an extensive piedmont complex. Deposition, particularly in the lower part of the formation, was influenced by intense volcanism to the west of the Rouchel district. Showers of ash, mainly glassy material, formed a nearshore zone of silt which has since been lithified into hard blue-grey siltstone. Farther offshore, thinly bedded mud was deposited below wave base. Crystal lithic tuffs are interbedded with the siltstone and occasionally with the mudstone successions. Sandstones in the Woolooma Formation are poorly sorted, poorly washed, and contain angular grains; they were deposited as the result of a rapid influx of coarse volcanogenic detritus on to the marine shelf. Algal limestone was deposited close to the shore during occasional periods of low sediment influx.

Isismurra Formation

The Isismurra Formation, named after 'Isismurra' (053606, Timor 1:31 680 sheet), was mapped throughout the adjoining Wingen district by Manser (1968). As yet, no type section has been nominated, but we assume it will be located close to 'Isismurra'. According to Manser, the Isismurra Formation comprises 3400 feet (about 1100m) of lithic sandstone siltstone, conglomerate, and volcanics, mainly vitric tuffs; this sequence did not include the underlying Ayr Conglomerate, which we have reduced in status to a member in the lower parts of the Isismurra Formation.

In the Rouchel district the formation contains a named conglomerate member and three ignimbrite units interspersed throughout a sequence of conglomeratic lithic sandstone: these are the Ayr Conglomerate, the Native Dog Member, the Curra Keith Tongue, and the Oakfields Tongue. In the vicinity of 'Albano' the upper part of the formation contains four informally designated ignimbrite units.

The Isismurra Formation overlies, probably disconformably, both the Waverley and Dangarfield Formations; it is overlain, apparently conformably, by quartz-bearing sandstone and conglomerate identified as Upper Carboniferous Rossmore Formation (Manser, 1968). In the eastern half of the district the lower and especially the middle parts of the formation are replaced by marine sediments of the Waverley and Woolooma Formations. The thickness of the Isismurra Formation is greater than 1150 m; there is no unbroken section through the formation.

Lithologically the Isismurra Formation is typical of the Kuttung Series of early workers, and was mapped as such in the Rouchel district by Osborne (1928a & b, 1929, 1950a). Branagan et al. (1970) assigned rocks which we map as Isismurra Formation to their units 6 and 7. Before defining the new ignimbrite units the internal sequence and stratigraphic relationships of the Isismurra Formation in different parts of the Rouchel district will be examined (Fig. 11).

The Isismurra Formation in the western part of the Rouchel district

The western part of the Rouchel district contains the most complete sequence of Isismurra Formation. The formation overlies either the Waverley Formation or, in the Glenbawn area, the Dangarfield Formation. A coarse conglomerate, the Ayr Conglomerate, is usually present at the base of the Isismurra Formation, and is overlain by ignimbrites of the Native Dog Member or Curra Keith Tongue; the base of the ignimbrites is probably a time-parallel plane. The Native Dog Member splits eastwards and northwards into two ignimbrite tongues, the Curra Keith and Oakfields Tongues. In measured sections, the Native Dog Member is up to 340 m thick (Plate 2, section 4), although it is estimated to be more than 500 m thick in the Dangarfield-Segenhoe area, where many of the ignimbrites were originally more thoroughly welded than elsewhere. The Curra Keith and Oakfields Tongues are each never more than 80 m thick and are separated by about 200 m of terrigenous sediments (Plate 2, section 100a). In the 'Albano' area, above the stratigraphic level of the Native Dog Member and the Oakfields Tongue, there are four ignimbrite units a , b , c , and d which can be lithologically differentiated from one another. Elsewhere, thin nonwelded red ignimbrites, which are lithologically identical with one another, are present at about the same stratigraphic levels as ignimbrites a , b , and c . Sedimentary rocks in the Isismurra Formation near Gundy are coarser than elsewhere in the Rouchel district, suggesting that at least one major source of terrigenous material lay to the northwest.

The Isismurra Formation in the central and eastern parts of the Rouchel district

Towards the east, the middle and lower parts of the Isismurra Formation are replaced by the marine Woolooma Formation, and the upper part of the Waverley Formation. Lower units, comprising the Ayr Conglomerate and the Curra Keith Tongue, extend into the southeastern part of the district around 'Scrumlo', but are replaced by the uppermost marine sandstones of the Waverley Formation at Malumla, in the central eastern part of the district (Pl. 2, section 30). A progressive westward marine transgression, which followed deposition of the Curra Keith Tongue, resulted in the Woolooma Formation intertonguing with the middle part of the Isismurra Formation. In the east, the Oakfields Tongue and its associated alluvial sediments are replaced by shard-rich siltstone containing the Orthotetes australis Zone, and occasional vitric-lithic tuffs (Pl. 2, section 68). In the central part of the district, the Oakfields Tongue, or an equivalent vitric-crystal tuff, is both interbedded with and overlain by marine sediments, the uppermost of which contain representatives of the Delepinea aspinosa Zone (Plate 2, section 6). The upper part of the Isismurra Formation, which in the eastern part of the district overlies the Woolooma Formation, consists of about 700 m of zeolitic lithic sandstone and conglomerate, and up to three thin nonwelded red ignimbrites (Pl. 2, section 37).

East of Foy Brook, in the southeastern corner of the Rouchel district, sandstone and conglomerate of the Isismurra Formation pass upwards into a succession of quartzose lithofeldspathic sandstone and pebble conglomerate. The sandstone contains up to 20 percent quartz, lacks a zeolite cement, and is better sorted than those in the Isismurra Formation. The associated pebble conglomerate is well sorted, and contains clasts of pale quartz-bearing 'felsites', some of which are devitrified ignimbrites. The quartzose sediments are identified as Rossmore Formation (Manser, 1968), and are mapped in a unit of undivided Upper Carboniferous and Permian rocks in Plate 1.

Terrigenous sediments of the Isismurra Formation

Terrigenous sediments in the Isismurra Formation comprise lithic sandstone, conglomerate, and minor siltstone and shale. The conglomerates include fan and channel fill deposits, and are exemplified by the Ayr Conglomerate member; they are described below.

Lithic and lithofeldspathic sandstone comprises the bulk of the Isismurra Formation, and is also present in the matrix of, and as lenses within, the conglomerates. The sandstones are thickly bedded, sometimes with planar cross stratification, coarse-grained to pebbly, poorly sorted and pink, purple or brown in colour. Terrigenous grains are angular (roundness 0.1 - 0.3; sphericity 0.5 - 0.9) and consist of up to 50% oligoclase and andesine (An_{28}-An_{50}), rare orthoclase and microperthite, minor quartz, hornblende, biotite, epidote and magnetite, and up to 50% rock fragments. The rock fragments include ignimbrites showing eutaxitic texture, devitrified glassy volcanics some of which contain recognizable vitroclastic textures, textural andesites and trachytes, and micrographic granite. Sand-sized grains are cemented by an ironstained zeolite of the heulandite group (mordenite or clinoptilolite) which frequently pseudomorphs glass shards. The zeolite gives the rocks a distinctive salmon pink or red colour which becomes brown on weathering.

Shale and siltstone are rarely exposed, and appear to constitute a minor part of the formation. They are purple to buff in colour, and contain plant debris including rootlets penetrating laminated bedding planes.

Ayr Conglomerate

The Ayr Conglomerate mostly occupies the basal part of the Isismurra Formation, and disconformably overlies older marine or non-marine units. At Glenbawn and Benmore (Pl. 2, sections 1 and 59), however, the conglomerate is underlain by pink lithic sandstone, identified as Isismurra Formation, which may be conformably with the Dangarfield Formation.

The thickness of the Ayr Conglomerate is variable, reaching a maximum of 180 m in section 59 at Benmore (Pl. 2). The conglomerate is poorly sorted, indistinctly bedded, and has a sandy matrix and interbeds or lenses of sandstone; the matrix and interbedded sediments usually consist of pink or purple zeolitic lithic sandstone. Clasts range in size from pebbles to boulders; are well rounded (0.7 - 0.9), and have a variable sphericity (0.3 - 0.7). Rock-types represented in the clasts include devitrified glassy volcanics, pink and white micrographic granite and aplite, and lithic arenites.

In most places the Ayr Conglomerate is interpreted as a fluvial piedmont conglomerate. On the banks of the Pages River near Gundy, however, the conglomerate contains interbeds of well bedded siltstone and sandstone, and has a matrix of green-grey rather than pink lithic sandstone; these features may indicate a near-shore marine environment of deposition.

Native Dog Member

The Native Dog Member (new name) consists of ignimbrites with interbedded sediments in the lower part of the Isismurra Formation to the west and south of Lake Glenbawn. The member is named after Native Dog mountain (021181, Woolooma 1:63 360 sheet). The type section is in the lower part of section 104 (Pl. 2), and was measured on the ridge east of Limestone Creek, 1 km southeast of Dunbar Creek village.

Type section

In the type section the Native Dog Member overlies the Ayr Conglomerate, and the base of the member coincides with the base of the lowest ignimbrite in the Isismurra Formation. The Native Dog Member is about 300 m thick; a minor fault is present at about 190 m above the base of the type section.

The lower 70 m of the Native Dog Member consists of massive, cliff-forming, lithoidal ignimbrite identical with that in the Curra Keith Tongue (p. 31). Ignimbrites in the upper 230 m of the Native Dog Member are purple and lithoidal, and are a little less massive than the ignimbrite in the lower 70 m. Red lithoidal ignimbrites are present locally in the upper part of the Native Dog Member. The purple ignimbrites contain up to 25 percent of orange and white phenocrysts of unzoned andesine (An_{30} - An_{36}) which are corroded, and invariably altered to sericite and clay; the rare orthoclase and microperthite phenocrysts are altered to a lesser degree. All of the feldspar phenocrysts are angular, and anhedral to subhedral. Other constituents consist of minor phenocrysts of clear quartz, altered biotite and hornblende, and fragments of rock and coarsely recrystallised pumice. The microcrystalline groundmass is charged with opaque mineral dust which probably gives the rocks their colour. Opaque mineral grains are concentrated at the axes and rims of original glass shards which show mild deformation, presumably reflecting a moderate degree of welding of the ignimbrites at their time of deposition. In places (e.g. locality 104-7) devitrification of the groundmass shards and dust has produced spherulites which have destroyed the original vitroclastic texture. Associated with the purple ignimbrites in the upper part of the Native Dog Member are sporadic interbeds of friable, poorly exposed, red lithoidal vitric-crystal-lithic tuffs up to 5 m thick. The red tuffs are unsorted and unstratified, and are interpreted as nonwelded ignimbrites. They contain up to 50 percent fresh andesine phenocrysts (An_{30}-An_{40}), some of which are normally zoned and corroded. The groundmass consists of undeformed glass shards pseudomorphed by ironstained zeolite (mordenite or clinoptilolite) and iron oxide, associated with small shards and glass dust which have recrystallized to a fine microcrystalline mosaic of potassium feldspar and quartz, or been altered to clay and chlorite. The red nonwelded ignimbrites also contain rare phenocrysts of orthoclase, up to 2% altered biotite, up to 10% hornblende which is commonly fresh, pumice, and up to 5% of other rock fragments. Sandstone and conglomerate interbedded with the ignimbrites in the Native Dog Member are identical with those elsewhere in the Isismurra Formation.

South of Section 104 the outcrop belt of the Native Dog Member trends south-southeast to the edge of the Rouchel district. The Native Dog Member has the same characteristics as in Section 104, but the Ayr Conglomerate is locally absent and the ignimbrite directly overlies the Waverley Formation.

The purple and red ignimbrites in the Native Dog Member of Section 104 are types which recurr throughout the Isismurra Formation.

Other Sections of the Native Dog Member

Section 4 (Pl. 2) was measured south of Rouchel Brook, about 2 km east of Dangarfield. The Native Dog Member overlies the Ayr Conglomerate, and is about 340 m thick; the lower 110 m contains buff ignimbrite with orange andesine phenocrysts, and locally has green and purple patches. Above the buff ignimbrite is a succession of welded purple and green ignimbrites, sporadic red nonwelded ignimbrites, and interbedded sandstone and conglomerate.

Near the road from Aberdeen to Rouchel, close to section 4, the purple and red ignimbrites in the middle part of the Native Dog Member die out, and are replaced by sediment. The buff ignimbrite in the lower part of the Native Dog Member persists, and is present to the north of the road as the Curra Keith Tongue. Red and purple ignimbrites near the top of the Native Dog Member also persist northwards as the Oakfields Tongue. The two tongues are separated by conglomerate and sandstone.

Dangarfield - Segenhoe area

Thick sections of the Native Dog Member containing buff and purple ignimbrites with rare nonwelded red ignimbrites are present on and around Logans Mountain, Thunderbolt Hill, Page Mountain, and Sugarloaf. The ignimbrites are poorly to moderately well exposed, and underlie steep country which has been cleared of timber. The Native Dog Member in the Dangarfield - Segenhoe area overlies either thin Ayr Conglomerate or the Waverley Formation. The member is at least 500 m thick, but the top is not exposed. About 2 km north of Thunderbolt Hill the Native Dog Member splits into the Curra Keith and Oakfields tongues in the same manner as near Section 4.

The Native Dog Member in the Dangarfield - Segenhoe area contains buff devitrified ignimbrite at the base, and purple ignimbrites throughout the remainder of the succession; red nonwelded ignimbrites are rarely exposed. Most of the purple ignimbrites have shards which are more deformed than those in the purple ignimbrites farther east in the type section and in Section 4. This suggests that the purple ignimbrites in the Dangarfield - Segenhoe area were originally more thoroughly welded than those elsewhere, implying that they were deposited closer to the source. Ignimbrites with intensely deformed shards are denser and more compact than those with less deformed shards, and have a subvitreous lustre and subconchoidal fracture.

<u>Muscle Creek</u>. Near the head of Muscle Creek, in the south-western corner of the Rouchel district, the Native Dog Member overlies the Waverley Formation, and consists of a thick succession of predominantly purple ignimbrites, with a buff ignimbrite in the lower part, sporadic red nonwelded ignimbrites, and interbedded sandstone and conglomerate. Some of the purple ignimbrites have intensely deformed shards. Osborne (1950b) inferred the presence of a local volcanic centre at Muscle Creek from what he thought was a neck of volcanic breccia. We suggest the breccia is in a fault zone because there is no other evidence consistent with the existance of a volcanic centre at Muscle Creek.

The thoroughly welded nature of the ignimbrites at Dangarfield, Segenhoe, and Muscle Creek suggests a volcanic source west or southwest of the Rouchel district. This inference is supported by the splitting of the Native Dog Member into the Curra Keith and Oakfields Tongues towards the east and north.

Curra Keith and Oakfields Tongues

Mappable ignimbrite tongues split off from the upper and lower parts of the Native Dog Member east and north of Dangarfield. The upper tongue is the Oakfields Tongue (new name), and the lower one the Curra Keith Tongue (new name). The tongues are separated by sandstone and conglomerate similar to those found elsewhere in the Isismurra Formation; ignimbrites are absent from this wedge of sediment. The Curra Keith Tongue contains predominantly buff devitrified ignimbrite corresponding to the buff ignimbrite in the lowermost part of the Native Dog Member. The base of the Curra Keith Tongue is continuous with the base of the Native Dog Member, and is probably a time-parallel plane. The Oakfields Tongue contains purple and red ignimbrites corresponding to ignimbrites between 200 m and 250 m above the base of the Native Dog Member.

The Curra Keith Tongue is named form Curra Keith Creek, on the eastern side of Lake Glenbawn about 2 km north of Glenbawn Dam. The Oakfields Tongue is named from Oakfields hill (058268, Woolooma 1:63 360 sheet). The type sections of both tongues are in Section 100a (Pl. 2), measured near Curra Keith Creek.

<u>Type sections</u>

Section 100a (Pl. 2) extends from 015307 to 051329 (Woolooma 1:63 360 Sheet) subparallel to Curra Keith Creek. The Curra Keith Tongue overlies the Ayr Conglomerate, and is at least 70 m thick; the base is obscured by scree. The tongue contains two lithologically distinct ignimbrites separated by pink and brown sandstone and conglomerate, and purple shale. The lower unit is a massive cliff-forming lithoidal ignimbrite at least 25 m thick, and usually buff in colour, rarely purple, green and red. It contains up to 25 percent unzoned orange and white andesine phenocrysts (An_{30} - An_{36}), altered to sericite and clay and frequently ironstained, and rare orthoclase and microperthite phenocrysts which are less altered than the andesine; feldspar phenocrysts are angular, anhedral to subhedral, and generally corroded. Rare biotite phenocrysts are partly or wholly altered to opaque minerals. Rock and pumice fragments are rare. The groundmass consists of coarsely devitrified glass shards and dust; large shards have devitrified in a different way from small shards and dust, and are outlined by clay and opaque dust, portraying a vitroclastic texture. The upper ignimbrite in the Curra Keith Tongue is 27 m thick, and is lithologically similar to the lower unit; it is distinguished by a content of about 1 percent corroded quartz phenocrysts which are up to 1 mm across and are visible in hand specimen. Both ignimbrites in the Curra Keith Tongue contain shards which are slightly deformed, suggesting that the rocks were slightly welded as they were deposited. The coarseness of the recrystallization products in the ignimbrites indicates that they were originally rich in volatiles; they may have been cemented by vapour-phase minerals which have recrystallized and can no longer be identified. Separating the two ignimbrites are 18 m of pink and brown litho-feldspathic pebbly sandstone and conglomerate, and mottled purple shale with plant fragments; the plant-bearing shale may be a palaeosol (D.F. Branagan, pers. comm. 1971).

The base of the Oakfields Tongue in section 100a is about 180 m above the top of the Curra Keith Tongue. The Oakfields Tongue is 30 m thick, and consists of two ignimbrites separated by sandstone. The lower is about 5 m thick, friable, poorly exposed, lithoidal, and red with white phenocrysts; it contains up to 50 percent fresh, rarely corroded and zoned, andesine phenocrysts (An_{30} - An_{40}) and rare phenocrysts of orthoclase and biotite. The groundmass consists of large undeformed glass shards pseudomorphed by ironstained zeolite, and finely devitrified and altered shards and glass dust. The ignimbrite also contains abundant coarsely recrystallized pumice fragments and occasional rock fragments some of which are identifiable as textural andesites. Overlying the red ignimbrite is 5 m of pebbly lithofeldspathic sandstone with a cement of bright green celadonite (?) and pink zeolite (mordenite or clinoptilolite). The upper ignimbrite, which overlies the sandstone, is 20 m thick, purple to buff in colour, lithoidal, and is locally cliff-forming; it contains up to 25 percent orange and white andesine phenocrysts (An_{36}) altered to sericite and clay, rare altered biotite, coarsely recrystallized pumice, and rock fragments. The groundmass contains slightly deformed shards which have been devitrified to a fine microcrystalline mosaic of quartz and feldspar, and a large amount of opaque dust.

Northwest and northeast of the Curra Keith area the Curra Keith and Oakfields Tongues persist unchanged except for the disappearance of the upper ignimbrite unit in the Curra Keith Tongue south of MacIntyres Mountain (983368, Scone 1:31 680 sheet). Southeast of Curra Keith Creek the Woolooma Formation replaces part of the Isismurra Formation including the Oakfields Tongue.

<u>Other sections of the Curra Keith and Oakfields Tongues</u>

In section 101 (Pl. 2), measured near Gum Flat Gully, the Curra Keith Tongue overlies the Ayr Conglomerate, and is 40 m thick. The tongue contains only the lowermost buff ignimbrite unit. Between the Curra Keith and Oakfields Tongues are about 200 m of sandstone and conglomerate.

The Oakfields Tongue is about 30 m thick and contains two ignimbrites, as in the type section. The upper purple ignimbrite in the Oakfields Tongue is abruptly overlain by about 5 m of laminated and thin bedded red vitric-crystal tuff with 8 percent angular sand-sized feldspar grains in a matrix of undeformed devitrified and zeolitized glass shards and pumice fragments. The tuff is cross-laminated, and is probably a waterlaid equivalent of part of the upper purple ignimbrite in the Oakfields Tongue; it is mapped as the basal unit of the Woolooma Formation in the area near section 101.

Along the outcrop belt of the lower part of the Isismurra Formation to the north-northeast of section 101, the base of the Woolooma Formation lies below the stratigraphic level of the Oakfields Tongue, which is represented by waterlain vitric-crystal tuff within the Woolooma Formation.

The Curra Keith Tongue in section 118, measured near Native Dog Gully, is 80 m thick, and overlies the Ayr Conglomerate; the tongue contains both of the ignimbrite units present in the type section. The Oakfields Tongue is about 160 m above the Curra Keith Tongue, and, as in section 101, is overlain by a laminated vitric-crystal tuff interpreted as Woolooma Formation.

Northeast of section 118 the upper ignimbrite unit in the Curra Keith Tongue thins, and eventually dies out near Rouchel Brook village; only the lower ignimbrite unit is present in the tongue in section 6 (Pl. 2), measured along Stoney Creek.

Hornblende from a red nonwelded ignimbrite at the top of the Oakfields Tongue near 'Arkana' (037198, Woolooma 1:63 360 sheet) gives K/Ar ages of 308 ± 6 and 309 ± 6 m.y. (Appendix 4).

<u>Unnamed ignimbrites</u>

In the country around 'Albano' (096188, Woolooma 1:63 360 sheet) we have mapped four unnamed ignimbrites in the Isismurra Formation, above the Native Dog Member. Each unit is lithologically distinctive, and they have been identified informally as ignimbrites <u>a</u>, <u>b</u>, <u>c</u>, and <u>d</u>.

Elsewhere in the Rouchel district thin red nonwelded ignimbrites are present in the Isismurra Formation at about the same stratigraphic levels as ignimbrites <u>a</u>, <u>b</u>, and <u>c</u>. These red ignimbrite units are lithologically indistinguishable from one another, so that although they have been mapped they are not individually identified. The red nonwelded ignimbrites may be lateral equivalents of ignimbrites <u>a</u>, <u>b</u>, and <u>c</u>, but this cannot be proved.

<u>Section 4</u>

A red nonwelded ignimbrite, about 5 m thick, and designated <u>a</u> is present about 110 m above the top of the Native Dog Member. Ignimbrite <u>a</u> has the same characteristics as other red nonwelded ignimbrites in the Isismurra Formation. Ignimbrite <u>a</u> is overlain by 90 m of pink zeolitic sandstone and conglomerate, which in turn are overlain by a second ignimbrite unit, <u>b</u>. Ignimbrite <u>b</u> is 10 m thick and consists of a lower thin nonwelded red ignimbrite, which is poorly exposed, and an upper resistant purple ignimbrite; the two ignimbrites in <u>b</u> are separated by about 2 m of sandstone and conglomerate. The upper purple ignimbrite in <u>b</u> has moderately deformed shards, and is typified by about 5 percent of conspicuous pale green biotite phenocrysts up to 4 mm long. Ignimbrite c, which is about 10 m thick, is present at the top of section 4, capping the hill at 033223 (Woolooma, 1:63 360 sheet), and also contains a lower red nonwelded unit and an upper purple moderately welded unit. The purple ignimbrite in c contains about 5% corroded quartz phenocrysts up to 2 mm across.

Ignimbrite units a, b, and c are also present in sections 104 and 118 (Pl. 2).

Section 139

Section 139 (Pl. 2) was measured subparallel to Hilliers Creek, from its confluence with Sandy Creek near 'Albano (115176, Woolooma 1:63 360 sheet) east-southeast to 136169 (Woolooma 1:63 360 sheet). Both the base and top of the section are faulted.

Ignimbrite b is about 20 m thick and is deformed and altered because of its proximity to the fault at the base of the section. Ignimbrite c is about 40 m above b, and is up to 25 m thick. Red nonwelded ignimbrites are sporadically exposed both above and below the purple moderately welded ignimbrite in c. Ignimbrite d is present about 300 m above ignimbrite c and is dark olive to blue-grey, weathering to buff or white; it forms conspicuous ridge. Ignimbrite d contains up to 40 percent intensely altered andesine (An_{45} - An_{50}) phenocrysts, 15 percent altered hornblende, and rare corroded quartz and altered biotite. The groundmass is finely devitrified and altered; the few vitroclastic textures preserved indicate that the ignimbrite was originally thoroughly welded. In section 139 ignimbrite d is 20 m thick.

Southwards towards Bowmans Creek village (150097, Camberwell 1:63 360 sheet) ignimbrite d thickens and is exposed in a conspicuous cliff. Osborne (1928a) correlated ignimbrite d with the Martins Creek Andesite on lithological grounds, but the validity of this correlation is uncertain.

Hornblende from ignimbrite d at 130140 (Woolooma 1:63 360 sheet) gives a K/Ar age of 319 $\pm$ 9 m.y. (Appendix 4).

Section 100a

Two thin, poorly exposed, red nonwelded ignimbrites are present above the Oakfields Tongue in section 100a. The lower is 80 m above the Oakfields Tongue, and the other is 90 m higher. Both are about 5 m thick, are lithologically identical, and hence can be differentiated only by their stratigraphic position. The ignimbrites may be lateral equivalents of ignimbrites a and b, but this cannot be demonstrated from present data.

Davis Creek - Scrumlo area

In the area round Davis Creek village and Scrumlo mountain at least three thin red ignimbrites are present in the upper part of the Isismurra Formation (section 103, Pl. 2). The three ignimbrites cannot be traced far east of 'Mullee' (196190, Woolooma 1:63 360 sheet), probably because they die out; they may be lateral equivalents of ignimbrites a, b, and c.

Age

Apart from plant fragments, no fossils have been found in the Isismurra Formation. The age of the lower and middle parts of the formation can be inferred from the underlying and intertonguing marine formations, but the upper part cannot be precisely dated. An isotopic age of 319 ± 9 m.y. from ignimbrite d in the upper part of the formation does not conflict significantly with ages of 308 ± 6 and 309±6 m.y. from the Oakfields Tongue in the middle part of the formation.

The lower part of the Isismurra Formation overlies sediments containing the Schellwienella cf. burlingtonensis and Pustula gracilis Zones. The gracilis Zone is present beneath the Isismurra Formation in sections 1 and 4 in the Dangarfield Formation, section PS in the Waverley Formation, and tentatively in section 58 in the Waverley Formation (Pl. 2). These occurrences form a broad belt extending northwest and southeast of Rouchel Brook village. Northeast of Rouchel Brook village, in section 24, the Ayr Conglomerate overlies, probably unconformably, sediments of the Waverley Formation containing the burlingtonensis Zone; the same zone is overlain by conglomerate identified as Ayr Conglomerate in section 39 (Pl. 2). The absence of the gracilis Zone may indicate substantial erosion beneath the Ayr Conglomerate in the area northeast of Rouchel Brook village.

The upper part of the Isismurra Formation, containing the four informally designated ignimbrites and their possible equivalents, overlies the Woolooma Formation. A fauna near the top of the Woolooma Formation at Stony Creek (section 6), Rouchel (section 44), 'Scrumlo' (section 32), and 'Mullee' (section 68) is identified as being low in the Delepinea aspinosa Zone. The lower and middle parts of the Isismurra Formation are therefore early to middle Viséan in age, or, in terms of the German ammonoid zones (after Jones, Campbell & Roberts, in prep.), from the middle of the gap between CuIIγ and CuIIδ to about the middle of CuIIIα. The upper part of the Isismurra Formation is younger than middle Visean but older than the overlying late Carboniferous Rossmore Formation.

Environment of deposition

Most features of the Isismurra Formation indicate deposition in a non-marine environment. These include the association of coarse-grained zeolitic lithic sandstone and conglomerate with siltstone and shale, some of which is penetrated by rootlets, and the abundance of ignimbrites. The formation was deposited over a relatively flat piedmont plain which sloped gently eastwards; the flat nature of the plain is demonstrated by the constant thickness of individual ignimbrites, and the eastward-dipping palaeoslope by the lateral gradation of the Isismurra Formation into marine sediments.

The onset of deposition of the Isismurra Formation, particularly deposition of a widespread basal conglomerate (Ayr Conglomerate member), was probably directly related to uplift preceding volcanism west of the district. We suggest that the Ayr Conglomerate was deposited in an alluvial fan in front of a strongly uplifted mountain range to the west of the Rouchel district; in some instances, for example near Gundy, the fan may have reached the sea. After an initial period of erosion, and the volcanism which followed the deposition of the Ayr Conglomerate, the source in the west was lowered, and no further fan-like bodies of conglomerate were deposited.

The remainder of the sediments in the Isismurra Formation were probably deposited in a complex of braided streams which continually changed their courses across the piedmont plain. Sandstones and conglomerates form lenticular bodies, and are regarded as channel deposits. The sandstone is coarse-grained, poorly sorted, contains stringers of pebbles, and in some cases has planar cross-bedding. A small number of overbank deposits of plant and root-bearing shale and laminated siltstone are interbedded with the sandstone. Ignimbrites extruded from a source in the west periodically buried the depositional surface. The volcanic region in the west was probably the major source area, but the presence of plutonic and epidote-bearing volcanic rocks indicates another, probably more distant, source.

UNDIVIDED UPPER CARBONIFEROUS AND PERMIAN ROCKS

Upper Carboniferous and Permian rocks are present in the western part of the Rouchel District, and probable Upper Carboniferous rocks are mapped between Foy Brook and Campbell Creek, in the southeastern corner of the district. We have not mapped these rocks in detail and they are undivided on Plate 1; the distribution of the Upper Carboniferous and Permian Formations is shown in a diagrammatic geological map in Figure 12.

Upper Carboniferous rocks on Scone Mountain, the Colonel, Bells Mountain, and north of Sugarloaf were originally mapped as undivided Kuttung Series by Osborne (1928b, 1929, 1950a); they are lithologically identical with the Rossmore Formation, mapped throughout the Wingen district by Manser (1968). The volcanic and sedimentary rocks in the Rossmore Formation are similar to those in the Isismurra Formation except that sediments in the Rossmore Formation contain a larger amount of quartz. Conglomerate and sandstone in the Rossmore Formation on The Colonel and Bells Mountain are better sorted than those in the Isismurra Formation. *Rhacopteris* sp., which indicates a late Carboniferous age, has been recorded from the Rossmore Formation on Scone Mountain by Branagan et al. (1970). Throughout the western part of the Rouchel district the Rossmore Formation is separated by faults from Lower Carboniferous rocks.

Between Foy Brook and Campbell Creek, rocks identified as Rossmore Formation are apparently conformable with the Isismurra Formation. The Rossmore Formation in this area contains moderately well sorted sandstone and conglomerate.

Permian rocks in the extreme western part of the Rouchel district are faulted against the Rossmore Formation, except in the Dangarfield - Segenhoe and Muscle Creek areas, where they are faulted against Lower Carboniferous rocks. The Permian succession includes the Gyarran Volcanics (equivalent to the Dalwood Group), Greta Coal Measures, Branxton Formation, Mulbring Siltstone and Singleton Coal Measures (equivalent to the Tomago and Newcastle Coal Measures). The Murulla Beds, mapped in the vicinity of Parkville by Manser (1968), may be equivalent to the Singleton Coal Measures. The stratigraphy of the Permian rocks is discussed by various authors _in_ Packham (1969).

FAUNAL ZONES

In New South Wales, Carboniferous brachiopod zones were first established from Lower Carboniferous faunal sequences in the Gresford-Dungog district by Roberts (1965a); the zones were used to correlate marine Lower Carboniferous rocks throughout the state, and provided the basis of preliminary correlations with the Yarrol Trough in Queensland. Campbell & Roberts (1969) later established additional zones, and extended the zonal sequence to cover most of the Carboniferous. For the First International Gondwana Symposium held in Buenos Aires in 1967, Campbell, Dear, Rattigan, & Roberts (1969) drew up a correlation chart for the Carboniferous system in Australia. The eastern Australian Carboniferous marine sequence was correlated on the basis of nine brachiopod zones. In superpositional order these zones are the _Tulcumbella tenuistriata_, _Spirifer sol_, _Schellwienella_ cf. _burlingtonensis_, _Orthotetes australis_, _Delepinea aspinosa_, _Rhipidomella fortimuscula_, _Marginirugus barringtonensis_, _Levipustula levis_, and _Syringothyris bifida_ Zones. Campbell & McKellar (1969) documented the ranges of the numerous genera and species within the zones, and also dealt with the affinities of the fauna. The ages of the zones have been re-examined by Jones, Campbell & Roberts (in prep.), in the light of new interpretations of the standard German goniatite succession (Matthews, 1969, 1970); except where there is new information from the Rouchel district, the ages of the zones will not be discussed.

Faunal zones recognized in marine sediments in the Rouchel district (Table 1) are possibly the _Spirifer sol_ Zone, and the _Schellwienella_ cf. _burlingtonensis_, _Pustula gracilis_, _Orthotetes australis_, and _Delepinea aspinosa_ Zones. New information from this area has made it possible to recognize a new zone, the _Pustula gracilis_ Zone, between the _burlingtonensis_ and _australis_ Zones; to clarify the upper and lower limits of the _australis_ Zone; and to recognize that the _aspinosa_ Zone at Rouchel constitutes the oldest part of that zone.

Spirifer sol Zone

The Spirifer sol Zone is tentatively identified from the Brushy Hill Limestone member of the Dangarfield Formation. Brachiopods in the Brushy Hill Limestone include Rhipidomella australis (M'Coy), Leptagonia analoga (Phillips), Rugosochonetes kennedyensis magnus Maxwell, Prospira prima Maxwell, Unispirifer sp., Brachythyris davidi (Dun), 'Dimegelasma' elegante Maxwell, and?Pentremoblastus sp. The brachiopods cannot be conclusively referred to a zone, but it is noteworthy that Prospira prima and the cosmopolitan species Rhipidomella australis and Leptagonia analoga elsewhere first appear in the sol Zone (Campbell & McKellar, 1969, Tables 6.2 and 6.3).

A species of Patrognathus close to P. andersoni Klapper has been identified from the Brushy Hill Limestone by T.B.H Jenkins (pers. comm.). Klapper (1971) has reported P. andersoni in association with late Kinderhookian species of Siphonodella in the United States, and with S. cooperi in the Hastière Limestone (Tn1b) of Belgium. According to P.J. Jones (pers. comm.) these occurrences indicate that the range of Patrognathus andersoni corresponds to the upper half of CuI and the lower part of the gap between CuI and CuII α in terms of Matthews (1969, 1970) interpretation of the German ammonoid zones. The association of a conodont likely to have this range with the brachiopod fauna suggests that the Brushy Hill Limestone may be situated low in the sol Zone.

Work in the Rouchel district indicates that the concept of the sol Zone portrayed by Campbell & McKellar (1969, Table 6.2) requires modification, and that the zone should be based on species occurring in the upper part of the Tulcumba Sandstone and lower part of the Namoi Formation or their equivalents. Species described from Lewinsbrook in the Gresford-Dungog district by Roberts (1963), and formerly assigned to the sol Zone, are now known to come from a stratigraphically younger unit and are placed in the lower part of the Orthotetes australis Zone. The reasons for this modification and a list of the species concerned are given on page 40.

Schellwienella cf. burlingtonensis Zone

The Schellwienella cf. burlingtonensis Zone is widespread throughout the Rouchel district, and is present in both the Dangarfield and Waverley Formations. In addition to many of the species listed by Campbell & McKellar (1969) the zone at Rouchel contains two species of Rugosochonetes, one a characteristic small globose species, Productina globosa Roberts, Spirifer sol Campbell, Kitakamithyris rouchelensis (Campbell), Cleiothyridina segmentata Roberts, Crurithyris sp. A., and a retzioid brachiopod (Table 6). Productina globosa and Spirifer sol, originally considered to be restricted to the sol Zone, have longer stratigraphic ranges than previously recognized. Most brachiopod species in the burlingtonensis Zone range into the younger gracilis Zone (Table 1).

A goniatite identified as Muensteroceras cf. oweni (Hall), which is different from the form in the sol Zone, is present with brachiopods of the burlingtonensis Zone at locality 1-27 in the Dangarfield Formation. From a slightly higher level within the zone, Branagan et al. (1970) have listed a conodont fauna of late Tournaisian age (T.B.H. Jenkins, pers. comm. in Jones, Campbell, & Roberts, in prep.).

Pustula gracilis Zone

The Pustula gracilis Zone is characterized by an assemblage consisting of the nominate species, Schellwienella sp. A which has coarser ribs than S. cf. burlingtonensis, and Schuchertella sp.A, in association with a large number of species which have extended up from the burlingtonensis Zone; Marginatia patersonensis first appears in the gracilis Zone. Important species common to both the gracilis and burlingtonensis Zones include Rugosochonetes sp. A, Antiquatonia cf. insculpta Muir-Wood, Brachythyris cf. solida Campbell, Kitakamithyris rouchelensis (Campbell), Syringothyris cf. principalis North, Crurithyris sp. A, 'Camarotoechia' cf. chouteauensis Weller, and terebratuloid n. gen. Other species are listed in Table 7.

The base of the gracilis Zone is defined by the incoming of Pustula gracilis, Schellwienella sp. A, Schuchertella sp. A, and Marginatia patersonensis, and the absence of Schellwienella cf. burlingtonensis. In its uppermost part, the zone is transitional with the Orthotetes australis Zone. At localities 15-3 and 30-2 (Section 30 at Malumla) in the upper sandstone unit of the Waverley Formation, Orthotetes australis (Campbell) and Fluctuaria campbelli Roverts are associated with Antiquatonia cf. insculpta Muir-Wood, Syringothyris cf. principalis North, Schuchertella ?sp. A, Rugosochonetes sp. A, and Delepinea sp. This assemblage is assigned to the gracilis Zone, the base of the australis Zone being signalled by the incoming of a large number of new species and the apparent extinction of most forms characterizing the gracilis and burlingtonensis Zones (Table 3).

The gracilis Zone is identified near the top of the Dangarfield Formation in Section 1 at Glenbawn; near the top of the Dangarfield Formation in Section 4 at Dangarfield; in the uppermost sandstone of the Waverley Formation in Section 30 at Malumla; towards the top of the Waverley Formation in Section 68 (locality 38-7) at Scrumlo (Plate 2); and at scattered localities including the Cameron Bridge locality of Osborne (1950a) at Upper Rouchel (Table 7).

Age of the gracilis Zone. There is little internal evidence on which to base the age of the gracilis Zone. The zone is, however, bracketed by two well dated units, the Schellwienella cf. burlingtonensis Zone which covers most of the interval CuIIα to CuIIγ ; and the Orthotetes australis Zone which covers most of CuIIδ and the lower part of CuIIIα of Germany (Jones, Campbell, & Roberts, in prep.). The gracilis Zone therefore lies within the gap between CuIIγ and CuIIδ of Germany (Fig. 4) and can be considered early but not earliest Visean in age.

Orthotetes australis Zone

The Orthotetes australis Zone was established by Roberts (1965a) in the Gresford-Dungog district, New South Wales, and subsequently has been recognized throughout eastern Australia (Campbell et al., 1969; Campbell & McKellar, 1969; Jones, Campbell, & Roberts, in prep.). The present biostratigraphical study in the Rouchel district has clarified the stratigraphic ranges of many species associated with the lower part of the australis Zone, and indicates errors in correlations between the main stratigraphic sequence and fault blocks in the Gresford-Dungog district, and between that area and the Werrie Syncline (Roberts, 1965a; Campbell et al., 1969). Hence it is necessary to briefly discuss the succession of faunas and stratigraphy of the Gresford-Dungog district before emending the australis Zone.

A preliminary revision of the geology suggests that sediments in fault blocks between Lewinsbrook and Trevallyn previously mapped as Bingleburra Formation (Roberts, 1961, 1963, 1965a, 1965b) are referable to younger units. At Lewinsbrook a rich fauna similar to that in the lower part of the Woolooma Formation at Malumla (localities 30-13, 30-9, 29-6, 29-2, 29-1) is present in grey siltstone identified as Bonnington Siltstone. A fault, mainly concealed by alluvium, separates this block from the Trevallyn fault block, which contains a sequence extending through the Ararat Sandstone and the overlying Bonnington Siltstone; faunas from Trevallyn resemble those from higher in the Woolooma Formation at Malumla (locality 29-7) and at Back Creek (localities 17-5 to 17-11). We have identified both groups of faunas in the Woolooma Formation as australis Zone.

New evidence from the reference section in the Lewinsbrook Syncline supports the re-interpretation of the stratigraphy of the Lewinsbrook and Trevallyn fault blocks: a fauna tentatively identified as Schellwienella cf. burlingtonensis Zone is present in the upper beds of the Bingleburra Formation; a second poorly preserved fauna from oolitic limestone member A of the Ararat Sandstone (Roberts, 1961) belongs to either the burlingtonensis or Pustula gracilis Zones (probably the latter because it contains a coarsely ribbed species of ?Schellwienella); and the Bonnington Siltstone contains the Orthotetes australis Zone. Stratigraphically, therefore, the Lewinsbrook fauna is younger than the burlingtonensis and ?gracilis Zones.

The Lewinsbrook assemblage had previously been equated with faunas in the upper part of the Tulcumba Sandstone and lower part of the Namoi Formation in the Werrie Syncline because it contained species such as Productina globosa Roberts and Crassumbo voisevi (Roberts); these faunas were referred to the Spirifer sol Zone (Campbell et al., 1969). Newly recognized extensions to the ranges of Productina globosa and Crassumbo voisevi at Rouchel, and stratigraphic evidence from Gresford, indicate that the Lewinsbrook fauna should be transferred to the lower part of the australis Zone. The species transferred from the sol to the australis Zone include: Bibucia tubiformis Roberts, Streptorhynchus spinigera (M'Coy), Pustula multispinata Roberts, Acuminothyris triangularis

Roberts, Delthyris? papilionis Roberts, Brachythyris elliptica Roberts, Asyrinxia lata (M'Coy), Cleiothyridina segmentata Roberts, Coledium laevis (Roberts), Fenestella brownei Roberts, Ptilopora konincki Crockford, and Conophillipsia brevicaudata Roberts. Cleiothyridina segmentata ranges from the burlingtonensis to the aspinosa Zones at Rouchel; Brachythyris elliptica may have a similar lower limit to its range (Campbell & McKellar, 1969), but at Rouchel ranges from the australis to the aspinosa Zones.

At Rouchel, stratigraphic sections are relatively continuous when compared with those at Gresford, and the australis Zone is associated with both older and younger zones. The australis Zone is characterized by a large influx of new species, two of which, Orthotetes australis (Campbell) and Fluctuaria campbelli Roberts, are present in a fauna transitional with the older Pustula gracilis Zone. Important species marking the incoming of the zone include: Schuchertella concentrica Roberts, Streptorhynchus spinigera (M'Coy), Eomarginifera tenuimontis Roberts, Krotovia sp., Acuminothyris triangularis Roberts, Brachythyris elliptica Roberts, Kitakamithyris triseptata (Campbell), Asyrinxia lata (M'Coy), Cleiothyridina australis Maxwell, Punctospirifer amblys Cvancara, Coledium laevis (Roberts), and Dielasma picketti Roberts. Many of these species range throughout the australis Zone, and some extend into the lower part of the Delepinea aspinosa Zone.

The faunal succession within the australis Zone is displayed in two main sections in the Rouchel district, section 17 at Back Creek, and section 30 at Malumla (Plate 2; Table 1). At Malumla, the sequence is wholly marine and the australis fauna succeeds one transitional with the gracilis Zone. The incoming of the australis fauna may have occurred slightly earlier at Malumla than at Rouchel because the sediments immediately beneath the australis Zone at Back Creek are non-marine, and the fauna resembles that at locality 29-7 near the top of section 30.

Delepinea aspinosa Zone

The Delepinea aspinosa Zone was established by Roberts (1965a) from faunas in the Wiragulla Beds and sediments identified (erroneously) as Ararat Sandstone on the flanks of the Wallarobba Syncline, south of Dungog. At the time, it appeared that Delepinea aspinosa had a short stratigraphic range, and hence all faunas containing D. aspinosa were referred to the aspinosa Zone, regardless of associated species. Stratigraphic studies north of Dungog (Roberts, in prep.) now show that D. aspinosa has a much longer stratigraphic range than previously recognized, rendering it a singularly unfortunate choice as index species. There is also the added complication that a species of Delepinea closely resembling aspinosa is present in the burlingtonensis, gracilis, and possibly the australis Zones.

Recent work in the Dungog district shows that the marine sediments beneath the Wallaringa Formation, on the flanks of the Wallarobba Syncline, are part of a sequence which extends through a faulted terrain northwards to Brownmore. The sequence of faunas at Brownmore indicates that the assemblages at Wiragulla and Cangon, on which the zone was originally based, in fact constitute the upper part of the zone in terms of its present broad interpretation. At Brownmore, faunas containing D. aspinosa extend 1040 m stratigraphically below an horizon containing Gigantoproductus tenuirugosus Roberts in association with D. aspinosa. It must be noted here that this same horizon, present at locality 235 at Cangon, lies stratigraphically above locality 234 at Wiragulla which contains Inflatia elegans Roberts and D. aspinosa, and therefore cannot be located within the Ararat Sandstone (see Roberts, 1964, 1965a).

For the purpose of this bulletin the aspinosa Zone will be used in the broadest sense, but it is likely from work in hand at Brownmore that the zone will eventually be subdivided. Faunas from Rouchel assigned to the aspinosa Zone (Section 6, Stony Creek; Section 44, Upper Rouchel; Tables 1, 4, 5) are characterized by the association of Schuchertella sp. B, Delepinea aspinosa (Dun), Productina margaritacea (Phillips), and Brachythyris sp. with a number of species also present in the australis Zone. Species which have extended from the australis Zone into the aspinosa Zone include: Streptorhynchus spinigera (M'Coy), Waagenoconcha delicatula Campbell, Marginatia patersonensis Roberts, Eomarginifera tenuimontis Roberts, Asyrinxia lata (M'Coy), Voiseyella anterosa (Campbell), Brachythyris elliptica Roberts, Cleiothyridina australis Maxwell, and Punctospirifer amblys Cvancara. The overall assemblage should be regarded as typical of the lowest part of the aspinosa Zone.

A fauna from locality 32-10, near the top of Scrumlo, contains species of Pustula and Rugosochonetes that are unknown elsewhere in New South Wales. The association of Delepinea aspinosa, Eomarginifera tenuimontis, and a distinctive trilobite pygidium suggests that the fauna can be correlated with those at Stony Creek and Rouchel.

The upper part of the Delepinea aspinosa Zone, characterized by the association of Gigantoproductus tenuirugosus Roberts, Chonetes cangonensis Roberts, Delepinea aspinosa (Dun), Echinoconchus gradatus Campbell, and Balanoconcha elliptica Campbell, is not known in the Rouchel District.

PALAEOGEOGRAPHY

Late Devonian

With the possible exception of the Kingsfield Beds and the lower part of the Goonoo Goonoo Mudstone there are no units of late Devonian age in the Rouchel district. The Kingsfield Beds comprise a terrestrial to possibly intertidal volcanogenic succession, and may represent either the remnants of a volcanic island or the eastern margin of the Tabberabberan orogen. Northeast of the Rouchel district, late Devonian sediments consisted initially of deep water muds with interbedded turbidites, conglomerate and a lithographic carbonate, and later of unfossiliferous mud, silt and greywacke, again probably of deep-water origin.

Early Tournaisian: Spirifer sol Zone (Fig. 13A)

Early in the Carboniferous the sea transgressed westwards, possibly as far as Scone, across a terrain of previously exposed Kingsfield Beds. Shallow-water marine sand containing carbonate lenses and minor interbedded muds (Dangarfield Formation) were deposited during this westward movement. Following the transgression, a carbonate bank became established in the Brushy Hill - Glenbawn area. Conditions appear to have been favourable for carbonate deposition during both the transgression and the period of oolite deposition on the carbonate bank. The presence of interbedded sand within the Brushy Hill Limestone in the northern part of Bushy Hill suggests that, at this time, terrigenous sediment was derived from an area northwest of the carbonate bank.

The sol Zone is not recognized in the Goonoo Goonoo Mudstone northeast from Glenbawn, probably because of deep-water conditions of sedimentation. We postulate that mud, silt, and minor greywacke accumulated in relatively deep-water contemporaneously with deposition on the carbonate bank near Glenbawn. The deep-water marine area northeast of the Rouchel district later became shallower because of either uplift prior to volcanism in the source area of the Waverley Formation, or infilling by sediment. Traction current sands and lenses of oolitic and crinoidal carbonate were interbedded with muds constituting the upper part (in this region) of the Goonoo Goonoo Mudstone.

Continued subsidence allowed muds similar to those in the Goonoo Goonoo Mudstone to be deposited in the Glenbawn region during the interval between the sol and burlingtonensis Zones.

Late Tournaisian - early Viséan: Schellwienella cf. burlingtonensis Zone (Fig. 13B)

Towards the end of the Tournaisian, immediately before the burlingtonensis Zone, the pattern of sedimentation changed because of increased volcanic activity in the west and northwest, and the associated uplift of a granitic hinterland; detritus derived from these sources consisted of andesite, devitrified volcanic glass, plagioclase and orthoclase feldspar, and minor amounts of granite, plutonic quartz, and ignimbrite. The upsurge of volcanism was reflected in the deposition of coarse-grained lithic sand (Waverley Formation) over much of the region. In the west, the influx of sediment built a non-marine piedmont plain eastwards across the shelf, and caused a regression of the sea. Sediments deposited on the piedmont plain comprised coarse-grained lithic sand and gravel. Offshore, sediments consisted of lithic sand which was particularly coarse and gravelly in a region northeast of Rouchel Brook village (section 39) but which elsewhere was coarse to medium-grained, grading eastwards into silt and mud. The presence of coarse sediments northeast of Rouchel Brook suggests derivation from a bulge in the shoreline in the Waverley area. In the vicinity of Glenbawn the coastline developed an embayment which, for the most part, was protected from currents transporting coarse detritus and received mud and at times shelly carbonates. The great influx of sand into areas adjacent to the embayment is reflected in the interbeds of at first fine-grained and then coarse-grained lithic sand. Sediments within the embayment comprise the Dangarfield Formation.

Early Viséan: *Pustula gracilis* Zone (Fig. 13C)

During the early Viséan a pattern of sedimentation similar to that in the late Tournaisian prevailed over the Rouchel district. The embayment in the coastline remained a protected area of sedimentation and received shelly silty mud and, in some areas, carbonate. A carbonate bank on the southeastern margin of the embayment generated sediment ranging in composition ranging from coralline and algal carbonate to oolitic and crinoidal carbonate. On the southern margin of the embayment the marine sediments passed laterally into a beach zone, represented by well sorted cross stratified heavy mineral sand (Waverley Formation). Landward of the beach zone, the heavy mineral sand passed into alluvial fan deposits consisting of coarse-grained cross-bedded gravelly lithic sand with sporadic beds of purple silt. A similar transition from a marine to non-marine environment is present on the northeastern flank of the embayment where the beach zone is again represented by heavy mineral sand, and the terrestrial sediments by gravelly lithic sand. Offshore, fine to medium-grained sand and interbedded silty mud were deposited in shallow water, and in the east around Malumla, skeletal calcarenite accumulated on a carbonate bank, probably during a period of low influx of terrigenous detritus.

Late in the early Viséan there were a second major uplift and period of volcanism in the source area to the west. The first event, preceding the volcanism, was a period of arching or uplift which effected an area extending from the Liverpool Range in the north to Mount Olive and Carrow Brook (Camberwell 1:63 360 Sheet) in the south. A thick piedmont gravel (Ayr Conglomerate) was built out over the shelf, causing the shoreline to migrate eastwards; in most areas the gravel was fluvial , but in a few places it may have penetrated into the marine environment. Uplift in the vicinity of Back Creek and Wilson Gully appears to have caused substantial erosion of Waverley Formation prior to the deposition of the Ayr Conglomerate. Simultaneously with the accumulation of the piedmont gravel, thickly bedded coarse-grained lithic sand was deposited on the marine shelf area in the eastern part of the Rouchel district.

Following the uplift, and probably as a result of subsequent rifting, there was a period of intense volcanism which spread ignimbrites and volcanogenic debris over the piedmont plain and to a certain extent into the marine shelf. The ignimbritic style of volcanism of the late early Viséan appears, from a study of detrital grains, to be markedly different from the dominantly andesitic volcanism of the Tournaisian and late Devonian source areas, and may reflect a major change in the development of the New England Folt Belt.

<u>Middle Viséan</u> (Fig. 13D): a. <u>Orthotetes australis Zone</u>

In the middle Viséan during a period of intense outpouring of volcanic ash, a marine transgression caused the shoreline to move a short distance (6 km) westwards. Onshore, repeated ash flows built up a large thickness of ignimbrite (Oakfields Tongue and Native Dog Member). Ash and glass shards from the volcanism were carried offshore and deposited in a quiet marine environment containing a rich benthonic fauna; when lithified, the volcanogenic fragments produced a hard blue-grey resistant siltstone. Farther offshore, and presumably out of reach of the most intense ash showers, thinly bedded fossiliferous muds accumulated in a shallow marine environment. Periodically, ash showers now represented by zeolitized siltstone and crystal-lithic tuffs extended as far as the muddy environment.

In the period following the intense volcanism, mud and then medium to coarse-grained lithic sand were deposited offshore. The sand was poorly sorted and, with the exception of a greater proportion of glassy ignimbritic fragments, resembled that previously deposited on the marine shelf (Waverley Formation). Non-marine gravelly lithic sands continued to be deposited on the piedmont area in the landward part of the region.

b. <u>Delepinea aspinosa Zone</u>

Later in the middle Viséan a second marine transgression pushed the shoreline a short distance farther westwards (Fig. 10). Sediments deposited at this time varied from coarse-grained fluvial lithic sand on the western piedmont, to interbedded mud and fine-grained lithic sand on the marine shelf; skeletal and algal calcarenite accumulated in areas near the shoreline.

<u>Late middle Viséan - ?late Viséan</u> (Fig. 13e)

A second phase of intense ignimbritic vulcanism commenced late in the middle Viséan, causing a major regression of the sea; the late middle Viséan age for the regression is suggested by the presence of only the lower part of the <u>aspinosa</u> Zone in the Rouchel area. Onshore, a sequence of four ignimbrites was interbedded with coarse-grained fluvial lithic sand and tuffaceous sand.

The embayment in the shoreline is based on the presence of red vitric tuffs within marine sediments. Little is known of the late Visean stratigraphy north-northeast of the Rouchel district because of erosion of strata from the Timor Anticline. The position of the shoreline is conjectural because there are only two known occurrences of red tuffs within marine sediments. From meagre evidence we suggest that the shoreline extended eastwards from Rouchel to Barrington Tops and then curved southwards to Gresford; support for this suggestion is provided by geological mapping in the Camberwell 1:63 360 Sheet by students of Newcastle University, and the recognition of red tuffs in the Carrow Brook area by Dr G. Jones (pers. comm.).

STRUCTURAL GEOLOGY

INTRODUCTION

The Rouchel district is located at the northern end of the 'Basin Belt' (Voisey, 1959), a structural province which extends from Maitland to Scone near the southwestern edge of the New England Belt (Fig. 2). The Basin Belt is characterized by several shallow downfolds with discontinuous axes, traditionally described as basins. The so-called 'Rouchel Basin' is a misnomer, and is more complex than originally envisaged by Osborne (1950a).

Carey & Osborne (1938) outlined an evolutionary model for the structures in the 'Basin Belt', many of which were poorly defined at the time. According to their model the area of the Basin Belt was deformed by a horizontal shear stress which initially produced a single set of folds in association with several sets of faults of different types. As deformation progressed, the structures were rotated and fold axes became sinusoidal; upfolds were eventually eliminated by faulting, leaving downfolded 'basins'.

Three distinct structural trends in and adjacent to the Rouchel district (Fig. 14) are defined by folds and followed by many faults. Two of the trends are probably primary and the third may have originated as a geometrical consequence of the intersection of folds parallel to the two primary trends. The northwest to north-northwest Brushy Hill Trend is probably primary; it is named from the Brushy Hill Anticline and is conspicuous in the western part of the Rouchel district. The northeast to north-northeast Woolooma Trend is probably also primary and is defined by the Woolooma Anticlinorium and the adjacent Bowmans Gully Syncline. The Woolooma Trend intersects the Brushy Hill Trend near Dangarfield, where faults and enclosing strata change strike markedly. The Davis Creek Syncline defines the David Creek Trend, which may be secondary; the trend is variable, although consistently more easterly than either the Brushy Hill or Woolooma Trends. The Scrumlo and Albano synclines follow the Davis Creek Trend. The Muscle Creek Syncline is the marginal portion of a structure centred on the Owens Mount Basin (Osborne, 1928a), to the south of the Rouchel district, which also follows the Davis Creek Trend. The geometry of folds along the Davis Creek Trend can be explained most simply in terms of the intersection of elements belonging to Brushy Hill Trend and Woolooma Trend folds.

North of the Rouchel district the north-plunging Sandy Creek Syncline (Manser, 1968), which is part of the 'Scone-Gundy Syncline' of Osborne (1950a), and the south-plunging Timor Anticline (Osborne, 1950a) are approximately parallel to the Brushy Hill Trend (Fig. 14). Both the Sandy Creek Syncline and Timor Anticline are cut by cross-folds subparallel to the Woolooma Trend. Faults between the Sandy Creek Syncline and Timor Anticline follow the Brushy Hill Trend. The nose of the Sandy Creek Syncline persists as far south as Gundy, where it merges into the northern limb of the Brushy Hill Anticline and the northwestern limb of the Bowmans Gully Syncline. The Timor Anticline merges into the Belltrees Structure (Osborne, 1950a) which consists of a series of ill-defined folds and faults between the Timor Anticline, Bowmans Gully Syncline, and Woolooma Anticlinorium. To the east of the Belltrees Structure is the southeast-plunging Moonan Syncline (Osborne, 1950a).

Structures in the Basin Belt and adjacent structural provinces are thought by most workers to have formed mainly during the late Palaeozoic Hunter-Bowen Orogeny; we have no reason to dispute this because we cannot precisely date the time of the folding in the Rouchel district.

FOLDS

Brushy Hill Trend

The Brushy Hill Anticline trends northwest to north-northwest from Dangarfield to the Pages River, about 4.5 km southwest of Gundy. The anticline plunges northwards at between 5° and 10° (Fig. 15a) and is regionally symmetrical, having limbs which dip at 20° to 30°, with local oversteepening along faults. The western limb is markedly oversteepened, and locally overturned, adjacent to the Brushy Hill Fault, as noted by Branagan et al. (1970). The eastern limb of the Brushy Hill Anticline is preserved north of Pages River, but the continuation of the axial portion of the fold is occupied by faults along, and parallel to, Glen Creek. The western limb of the Brushy Hill Anticline north of Pages River is probably present to the west of Glen Creek as part of a shallow syncline noted by Osborne (1950a) at Scone Mountain (Fig. 14). At Dangarfield, the Brushy Hill Anticline is disrupted by faults and southeasterly-dipping strata following the Woolooma Trend and forming the northwestern limb of the Bowmans Gully Syncline. South of Dangarfield the Brushy Hill Trend reappears in the southwestern limb of the shallow Albano Syncline.

Synclinal closures are present west of the Brushy Hill Anticline, on Logans Mountain, Page Mountain, and Sugarloaf; the closure at Sugarloaf forms the Segenhoe Basin of Osborne (1928b). The synclines plunge to the north-northwest and may be parts of a single structure which has been cut by faults, or they may be discrete structures separated by faults rather than anticlines. A shallow syncline with a warped axis which trends north-northeast underlies The Colonel and Bells Mountain (Osborne 1928b, 1950a).

The Kingsfield Beds and Dangarfield Formation appear to be restricted to the area of the Brushy Hill Anticline. It is possible that there is some direct genetic connection between the location of the anticline and the two formations.

Woolooma Trend

The Woolooma Anticlinorium is an open structure, part of which is located in the Woolooma Range in the northeastern part of the Rouchel district. The anticlinorium trends north-northeast and along the upper reaches of Rouchel Brook plunges southwards at about 5° (Fig. 15b). Several subsidiary folds are present in the axial portion of the anticlinorium, but are difficult to trace in the undivided strata of the Woolooma Formation which they fold. Many of these subsidiary folds appear to merge into faults along strike and are lost. South of Rouchel Brook the Woolooma Anticlinorium merges into the transverse Davis Creek and Scrumlo synclines, although a fault-bounded 'corridor' about 1 km wide between Davis Creek village and 'Scrumlo' contains rocks dipping east-southeast. The south-plunging nose of the Woolooma Anticlinorium forms the northern limbs of the Davis Creek and Scrumlo Synclines.

West of the Woolooma Anticlinorium the Bowmans Gully Syncline has an axial trace extending 5 km northeast to north-northeast along Bowmans Gully from the confluence of the gully and Back Creek (101306, Woolooma 1:63 360 sheet). The Bowmans Gully Syncline plunges south at between 5° and 10° and is a symmetrical structure, tighter than the Woolooma Anticlinorium, with limbs which dip at 25° to 30° except where they are oversteepened along faults. The western limb of the syncline is better developed than the eastern limb because of the open form of the Woolooma Anticlinorium. The axial trace of the Bowmans Gully Syncline merges into a fault near the head of Rainbow Creek (126384, Woolooma 1:63 360 Sheet) but probably reappears to the north as the axial trace of a syncline mapped by Manser (1968) in the Belltrees Structure. The northwestern limb of the Bowmans Gully Syncline persists as far south as Dangarfield, forming the northwestern limb of the Albano Syncline. At Dangarfield the limb intersects strata parallel to the Brushy Hill Trend.

Davis Creek Trend

The Davis Creek, Scrumlo, and Albano synclines are shallow structures with curved axial traces present in areas where folds along the Brushy Hill and Woolooma Trends intersect with one another. The Muscle Creek Syncline is part of a similar structure centred on the Owens Mount Basin to the south of the Rouchel district.

The Davis Creek Syncline lies between Upper Rouchel and Davis Creek villages, and is almost completely surrounded by faults. The western end of the syncline's axial trace merges into faults about 1 km east of Upper Rouchel, and is not quite continuous with the axial trace of the Bowmans Gully Syncline. The eastern end of the Davis Creek Syncline is bounded by a major north-northeast-trending fault at Davis Creek village (160231, Woolooma 1:63 360 sheet). From Upper Rouchel the axial trace of the Davis Creek Syncline strikes southeast and east-southeast, and is subparallel to strata in the western limb and nose of the Woolooma Anticlinorium. In the axial portion of the Davis Creek Syncline strata dip at 5° or less; away from the axis dips increase to about 20° to 25°, and are greater adjacent to faults. The structure is almost horizontal except in the east, where it is folded 15° to 20° to the east-southeast along a north-northeast-trending line about 1.5 km west of Davis Creek village.

The Davis Creek and Scrumlo synclines are separated by a 1 km-wide fault-bounded 'corridor' containing strata which dip towards the east-southeast. The axial trace of the Scrumlo Syncline, which is bounded by faults on all sides except the north, runs along Davis Creek valley to 'Mullee' (196190, Woolooma 1:63 360 Sheet), and then along Hartletts Creek. Strata in the syncline dip at 10° to 15° except where they are oversteepened along faults. In the Malumla Range, between Davis Creek and Rouchel Brook, the northern limb of the Scrumlo Syncline merges with the nose of the south-plunging Woolooma Anticlinorium.

The Albano Syncline is made up principally of two intersecting fold limbs, the northeastern limb of the Brushy Hill Anticline and the southeastern limb of the Bowmans Gully Syncline, both of which dip at about 20°. The axial trace of the Albano Syncline strikes southeast to east-southeast from the head of Rouchel Gully, about 2 km south of Dangarfield, to 'Albano' (097188, Woolooma 1:63 360 Sheet), and it is sub-parallel to the axial trace of the Davis Creek Syncline. The Albano Syncline does not persist east of the Rouchel Brook - Bowmans Creek road, where it is replaced by strata dipping east-northeast to southeast. The northern part of the Albano Syncline is separated from the Davis Creek Syncline by faults.

The Muscle Creek Syncline, in the southwestern part of the Rouchel district, is a marginal portion of a shallow downfold which centres on the Owens Mount Basin about 10 km southeast of the head of Muscle Creek (Camberwell 1:63 360 Sheet). The Muscle Creek - Owens Mount structure is a shallow warped syncline whose axial trace strikes from southeast and south-southeast at the head of Muscle Creek to east-northeast at Owens Mount (Osborne, 1928a, 1929, 1950a; Carey & Osborne, 1938).

FAULTS

Individual faults in the Rouchel district are never continuously exposed, but major faults can be located accurately in areas where stratigraphic markers provide good control, notably in areas containing the Isismurra Formation. Where stratigraphic control is poor, for example in the Woolooma Formation, parts of many faults have been located approximately along linear drainage channels and other topographic features.

Where exposed, the faults contain zones of sheared and brecciated rocks up to tens of metres wide. These zones contain sporadic veins of carbonates and zeolites, and around Stewarts Brook, in the northern part of the Rouchel district, veins of auriferous quartz. Silicified mudstone breccia is present in fault zones about 3 km southeast of Glenbawn Dam, and has weathered to form long narrow ridges. Strata adjacent to fault zones are commonly oversteepened, and locally folded. All the faults mapped in the Rouchel district are vertical or nearly vertical at the present level of exposure, as indicated by the fault traces being independent of topography.

Faults in the Rouchel district strike in many different directions (Fig. 16), although the strike of most major faults is approximately parallel to that of the enclosing strata. In areas where strata change strike markedly, for example around Dangarfield, major faults commonly do the same. Along the Brushy Hill Anticline and the southwestern limb of the Albano Syncline major faults, for example the Brushy Hill Fault (defined below), are approximately parallel to the Brushy Hill Trend, striking between northwest and north-northeast. In most cases strata on the western side of these major faults have moved down relative to strata on the eastern side. The fault inferred to be present beneath Lake Glenbawn, and its northern and southern continuations along Courigans Creek and to Rouchel Brook, is unique in the area because the relative sense of movement along it has been east side down. The axial portion of the Brushy Hill Anticline thus occupies a north-northeast-trending horst between this fault and the Brushy Hill Fault. Major faults along the Brushy Hill Anticline are joined, and rarely cut, by subsidiary cross faults, some of which are subparallel to the Woolooma Trend. Major faults associated with the Bowmans Gully Syncline and the Woolooma Anticlinorium strike northeast to north-northeast, approximately parallel to the Woolooma Trend. The relative sense of movement on these faults is west side down, the same as that on faults along the Brushy Hill Trend. Many cross faults, and parts of some major faults, are subparallel to the Brushy Hill Trend. Faults with an east-northeast to east-southeast strike are uncommon in the Rouchel district; locally they cut strata which follow the Davis Creek Trend. The relative sense of movement along at least some of these faults has been south side down.

None of the faults in the Rouchel district show evidence of an important strike-slip component of movement, and such movement cannot be inferred on stratigraphic or other grounds. Many faults are characterized by decreased throw along their strikes, indicating that strata on the opposite sides of the faults have rotated relative to one another. Many of the faults along which rotation has taken place die out in areas of sheared and warped strata. Rotation of blocks of strata relative to one another probably took place as a result of the juxtaposition and intersection of growing folds with different trends or geometries, or both. As deformation progressed intense strains between folds would be dissipated by the formation of faults which might almost completely isolate some blocks of folded strata. The Davis Creek Syncline is in one such isolated block.

No single set of faults in the Rouchel district consistently cuts and displaces any other set. In addition, individual faults commonly change trend markedly along strike; such faults cannot be assigned to a single set on a basis of their trend. Because of these facts we are unable to infer the relative ages of different sets of faults. The facts are consistent with all the faults being of about the same age; alternatively they are also consistent with all faults having been rejuvenated together after the main period or periods of deformation in the Rouchel district.

Brushy Hill Fault

Osborne (1928a, 1928b, 1929) mapped and named the Brushy Hill Fault as a single structure trending north-northeast to west-northwest from 'Greylands' (183972, Camberwell 1:63 360 Sheet), about 12 km south-southeast of Bowmans Creek village, to the Pages River Valley 5 km west of Gundy. Later he traced the fault northwards to Murrurundi as the composite Brushy Hill - Murrurundi Fault (Osborne, 1950a). Osborne originally interpreted the Brushy Hill Fault as a normal fault developed during the late Palaeozoic Hunter-Bowen Orogeny. Carey & Osborne (1938) tentatively regarded the Brushy Hill Fault as one of a system of conjugate shears (implying possible transcurrent movement) developed in the Basin Belt during the Hunter-Bowen Orogeny. Osborne (1950a) later interpreted the Brushy Hill - Murrurundi Fault as a steep normal fault of post-Triassic, pre-Tertiary age, developed in response to post-orogenic 'isostatic sag'. Branagan et al. (1970) inferred that the Brushy Hill Fault to the west of Lake Glenbawn was a high-angle 'thrust' (reverse fault).

We define the Brushy Hill Fault as the high-angle (vertical or nearly vertical) fault trending roughly north-northwest to the west of, and subparallel to, the axial trace of the Brushy Hill Anticline from Dangarfield to the Pages River about 6 km southwest of Gundy (Pl. 1). In this definition the Brushy Hill Fault is bounded at both ends by north-northeast- to northeast-trending cross faults, and does not continue beyond as a single structure. Strata to the west of the fault have been downthrown relative to those on the east; the direction of dip of the fault plane as a whole is not known so that it cannot be termed normal or reverse. We prefer to limit the term 'thrust' to faults with low dips, and hence do not classify the Brushy Hill Fault as a thrust at its present level of exposure; the attitude of the fault plane at depth is unknown.

The Brushy Hill Fault has the same characteristics as the other faults in the Rouchel district, and there is no evidence to suggest that it has a different age.

Hunter Fault System

The Hunter Fault System (Hunter Thrust of many workers) is part of a structural 'line' or 'front' along the Hunter River valley which separates relatively undeformed Upper Palaeozoic rocks in the west from a more intensely deformed sequence in the east. In this respect the Hunter Fault System is equivalent to the Mooki Fault System ('Mooki Thrust') farther north (Fig. 2). We have not examined the Hunter Fault System, but suspect that at least between Muswellbrook and Scone it consists of several intersecting high-angle (at the present level of exposure) faults of different trends.

Osborne (1928b, 1929, 1950a) mapped a single low-angle fault between Scone and Muswellbrook, the Hunter Thrust. As mapped by Osborne there were marked re-entries in the trace of the fault where it crossed Rouchel Brook, and also about 1 km north of Muscle Creek. In these two areas the trace of Osborne's Hunter Thrust is made up of intersecting high-angle faults subparallel to the Brushy Hill, Woolooma, and Davis Creek trends (Pl. 1). The relative sense of movement along most of these faults has been west or south side down. The faults are similar to others in the Rouchel district.

It would be desirable for detailed mapping to be extended west from the Rouchel district to define the Hunter Fault System in the region, and to determine the nature of the structural change across the Hunter Line.

DISCUSSION

The Rouchel district is characterized by an intricate structural pattern consisting of several sets of folds and faults which are geometrically interdependent. Many workers have followed Osborne (1950a) in referring to the 'Rouchel Basin', but such a structure does not exist. Other parts of the Basin Belt may have a structural pattern equally as intricate as the one in the Rouchel district; if so, the belt is misnamed.

Carey & Osborne (1938) attributed the structures in the Basin Belt to the action of a regional shear stress which produced a single set of folds associated with sets of faults of different kinds. The model cannot be applied to the Rouchel district because there are at least two sets of folds which are probably primary (parallel to the Brushy Hill and Woolooma Trends) and because faults of different kinds cannot be identified.

The complete geometrical interdependence of all folds in the Rouchel district and the absence of a single predominant set are consistent with all the folds having been initiated at, or about, the same time. Folds and faults are intimately associated throughout the district, and the formation of many of the faults can be explained as a response to rotation of blocks of strata deformed into folds of different geometries and orientations. These data are consistent with all structures having formed at, or about, the same time, presumably during the Hunter - Bowen Orogeny.

We tentatively conclude that the Rouchel district was deformed by a regional constrictive stress field. The strata of the district constitute an inhomogeneous medium in which local stress fields could be expected to develop within the hypothesized regional constrictive field in response to local variations in the geometries and physical characteristics of different rock bodies. As deformation progressed the appearance and growth of folds and faults would further localise stresses, which might either emphasise early-formed structures, or destroy them. The end product would be an intricate and unpredictable structural pattern, like the one in the Rouchel district, whose evolution was impossible to analyse in detail. The conclusions outlined above have wide regional significance and should be evaluated carefully elsewhere in, and adjacent to, the Basin Belt.

SUGGESTIONS FOR FUTURE WORK

Our principal aim in this study has been to establish the Lower Carboniferous biostratigraphy in the Rouchel district. There are many aspects of the geology which we have not studied in as much detail as they warrant. A few specific suggestions for desirable future work have been made throughout the text, and these are added to below.

The depositional environments recorded by the rocks in the Rouchel district have not been analysed in detail, although preliminary conclusions have been presented. A detailed examination of the clasts in the sedimentary rocks could be made with a view to interpreting the nature of the source area or areas contributing terrigenous material to the Rouchel district during early Carboniferous time. In particular, the plutonic and epidote-bearing volcanic clasts would probably provide significant data concerning regional tectonics during early Carboniferous time. The Kingsfield Beds and Dangarfield Formation, which are restricted to the Rouchel district, should be studied in detail. The age of the Kingsfield Beds is uncertain, although the formation contains volcanic rocks with relatively small amounts of fresh hornblende which could probably be dated isotopically. We have suggested that the localization of the Kingsfield Beds and Dangarfield Formation to the area of the Brushy Hill Anticline might be genetically significant and that the anticline might have been an active structure at the time of deposition. A study of the zeolites in the Rouchel district could be undertaken with a view to determining whether they formed in response to burial metamorphism, low-grade thermal metamorphism (either regional or local), or by reaction of volcanic glass with saline groundwater.

The ignimbrites in the Rouchel district are a potential source of much information. Detailed study of ignimbrite chemistry, mineralogy and textures could be used to define individual flows and cooling units. We have little information on the chemistry of the ignimbrites, but that available (Appendices 1 and 2) suggests extrusion from more than one source. The erratic soda and potash values in the ignimbrites are peculiar and suggest that the rocks reacted with saline groundwater at the time of deposition; this may also be significant in terms of the origin of the zeolites in the Isismurra Formation. Trace elements in the ignimbrites might be used to correlate them in detail. It would be interesting to know the detailed differences in chemistry between individual, precisely defined and correlated, ignimbrites and their marine equivalents. Regional and local flow directions of ignimbrites could be determined by the method used by Elston & Smith (1970) and would aid in the location of possible source areas and the recognition of local topographic features on the depositional surface. Ignimbrite source areas could contain mineral deposits, especially of base metals, of mineable size and grade.

The K/Ar geochronology of some ignimbrites (Appendix 4) should be supplemented by Rb/Sr whole-rock dating of suitable material, which is certainly present in the Rouchel district. Whole-rock dates would be precise and could be compared with similar dates from European type sections. The resulting chronostratigraphic correlation could thus provide a check on the validity of long-distance biostratigraphic correlation.

The structural significance of the fracture cleavages in the Goonoo Goonoo Mudstone is unknown, and should be investigated. A regional study is required of the nature of the Hunter Fault System and of the structural change across the Hunter Line. The constrictive stress field which we tentatively suggest affected the Rouchel district during late

Palaeozoic time could have operated over a wide area, and should be carefully evaluated because of its significance in terms of the evolution of the New England Belt.

In general there is a need for stabilization of the stratigraphic nomenclature and a critical examination of traditional interpretations and inferences which have become axiomatic through repetition.

Appendix 1

Analyses of opaque mineral sandstones from the Kingsfield Beds and Waverley Formation:

BMR Sample No.	% Fe	% Ti	% V	% Cr	% Ni	% Mn	% Co
69/82/0059	33.6	6.3	0.18	0.01	<0.01	0.1	0.01
70/82/0227	37.1	6.9	0.19	0.01	<0.01	0.2	0.01
70/82/0254	55.3	8.1	0.19	0.01	<0.01	0.2	0.01

69/82/0059 from the Waverley Formation, Back Creek (182300, Wooloома 1:63 360 sheet).

70/82/0227 from locality 42-17, section 42 (Plate 2), 'Waverley' district.

70/82/0254 from the Kingsfield Beds 3 km east of Thunderbolt Hill (065294, Woolooma 1:63 360 sheet).

Analysis by D. O'Neill, AMDEL, by direct-reading emission spectrography.

Appendix 2

Chemical analyses of ignimbrites from the Isismurra Formation:

%	70/82/0104	..0262	..0263	..0514	..0515	..0516	BMR Sample No.
SiO_2	78.0	73.0	69.0	69.6	71.3	78.6	
Al_2O_3	11.3	12.8	14.8	12.4	14.0	11.5	
Fe_2O_3	1.7	2.2	2.25	0.50	1.50	<0.5	
CaO	0.51	0.54	2.15	3.65	0.52	0.39	
MgO	0.12	0.16	1.20	1.25	0.12	0.04	
MnO	0.02	0.07	0.05	0.02	0.02	<0.01	
K_2O	0.30	4.05	4.4	2.05	6.85	3.7	
Na_2O	5.65	5.75	4.4	0.85	3.6	3.45	
P_2O_5	0.05	0.10	0.11	0.04	0.09	0.04	
TiO_2	0.27	0.39	0.41	0.21	0.28	0.11	
BaO	0.01	0.06	0.06	0.06	0.08	0.07	
H_2O+	1.72	0.64	1.00	6.9	1.22	1.68	
H_2O-	0.22	0.11	0.30	2.50	0.22	0.19	
Rb	0.002	0.007	0.012	0.005	0.016	0.008	
Sr	0.005	0.01	0.03	0.06	0.004	0.004	
U	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Th	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
ppm							
Y	30	30	30	10	30	20	
Sc	--	--	50	--	--	--	

70/82/0104 from the red nonwelded ignimbrite in the lower part of the Oakfields Tongue near Spring Gully, 2.5 km southwest of Rouchel Brook village (057230, Woolooma 1:63 360 sheet).

70/82/0262 from near the top of the Curra Keith Tongue near Spring Gully (057233, Woolooma 1:63 360 sheet).

70/82/0263 from ignimbrite d near the head of Fish Hole Creek (130140, Woolooma 1:63 360 sheet).

70/82/0514 from ignimbrite a near Native Dog Gully, 4 km southwest of Rouchel Brook village (033227, Woolooma 1:63 360 sheet).

70/82/0515 from the purple welded ignimbrite at the top of ignimbrite unit b near Native Dog Gully (033225, Woolooma 1:63 360 sheet).

70/82/0516 from the purple welded ignimbrite at the top of ignimbrite unit c near Native Dog Gully (033223, Woolooma 1:63 360 sheet).

Analysis by R.F. Lomman and G.R. Holden, AMDEL, by direct-reading emission spectroscopy, wet chemical analysis and x-ray flourescence spectroscopy, Sc and Y determined by semi-quantitative emission spectroscopy by R.R. Robinson, AMDEL.

Appendix 3

Chemical analysis of devitrified glass separated from laminated vitric-crystal tuff (BMR Sample No. 70/82/0421) in the Woolooma Formation, Back Creek, near Upper Rouchel (077272, Woolooma 1:63 360 sheet).

%	
SiO_2	66.5
Al_2O_3	13.0
Fe_2O_3	0.90
CaO	5.30
MgO	0.66
MnO	0.04
K_2O	0.80
Na_2O	0.15
P_2O_5	0.08
TiO_2	0.41
BaO	0.15
H_2O+	10.1
H_2O-	2.88
U	<0.005
Th	<0.005
ppm	
Rb	16
Sr	800
Y	30

Separation and analysis by B.G. Stevenson, AMDEL.

Appendix 4

Geochronology of ignimbrites, Isismurra Formation:

(a) BMR Sample No. 70/82/0107; nonwelded ignimbrite from the top of the Oakfields Tongue near the transition into the Native Dog Member, Sandy Creek, near 'Arkana' (036198, Woolooma 1:63 360 sheet):

mineral	hornblende
% K	0.508; 0.513
radiogenic Ar^{40}/K^{40}	0.01957; 0.01964
% atmospheric Ar^{40}	5.5; 7.4
age	308 ± 6 my; 309 ± 6 my

(b) BMR Sample No. 70/82/0263; ignimbrite "d" from near the head of Fish Hole Creek (130140, Woolooma 1:63 360 sheet):

mineral	hornblende
% K	0.7428; 0.7401
radiogenic Ar^{40}/K^{40}	0.02028
% atmospheric Ar^{40}	10.4
age	319 ± 9 my

Constants used:

$K^{40} = 0.0119$ atom. %

$\lambda\beta = 4.72 \times 10^{-10}/yr$

$\lambda\epsilon = 0.584 \times 10^{-10}/yr$

Geochronology by A.W. Webb, AMDEL.

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Table I

?sol	cf burlington ensis	gracilis	australis	aspinosa	
- -					Rossirhynchus sp.
—					?Pentremoblastus sp.
—	- -				Brachythyris davidi (Dun)
—	—	—			Prospira prima Maxwell
—	—	—			'Dimegelasma' elegante Maxwell
—	—	—	—	—	Rhipidomella australis (M'Coy)
—	—	—	—	—	Leptagonia analoga (Phillips)
—	—	—	—	—	Rugosochonetes kennedyensis magnus Maxwell
- -	—	—	—	—	Unispirifer striatoconvolutus (Benson & Dun)
	—				Schellwienella cf. burlingtonensis Weller
	—				Muensteroceras cf. oweni (Hall)
	—	—			Rugosochonetes sp. A.
	—	—			Antiquatonia cf. insculpta Muir-Wood
	—	—			Prospira sp.
	—	—			Spirifer cf. sol Campbell
	—	—			Brachythyris cf. solida Campbell
	—	—			Kitakamithyris rouchelensis (Campbell)
	—	—			Crurithyris sp.A.
	—	—			Syringothyris cf. principalis North
	—	—			'Camarotoechia' cf. chouteauensis Weller
	—	—			Terebratuloid n. gen.
	—	—	—		Delepinea sp.
	—	—	—		Productina globosa Roberts
	—	—	—		Retzioid gen & sp.
	—	—	—	—	Schizophoria verulamensis Cvancara
	—	—	—	—	Cleiothyridina segmentata Roberts
		—			Schuchertella sp. A.
		—			Schellwienella sp. A.
		—			Pustula gracilis Campbell
		—			rugose productoid gen & sp.
		—			Ammonelipsites sp.
		—	—		Crassumbo voiseyi (Roberts)

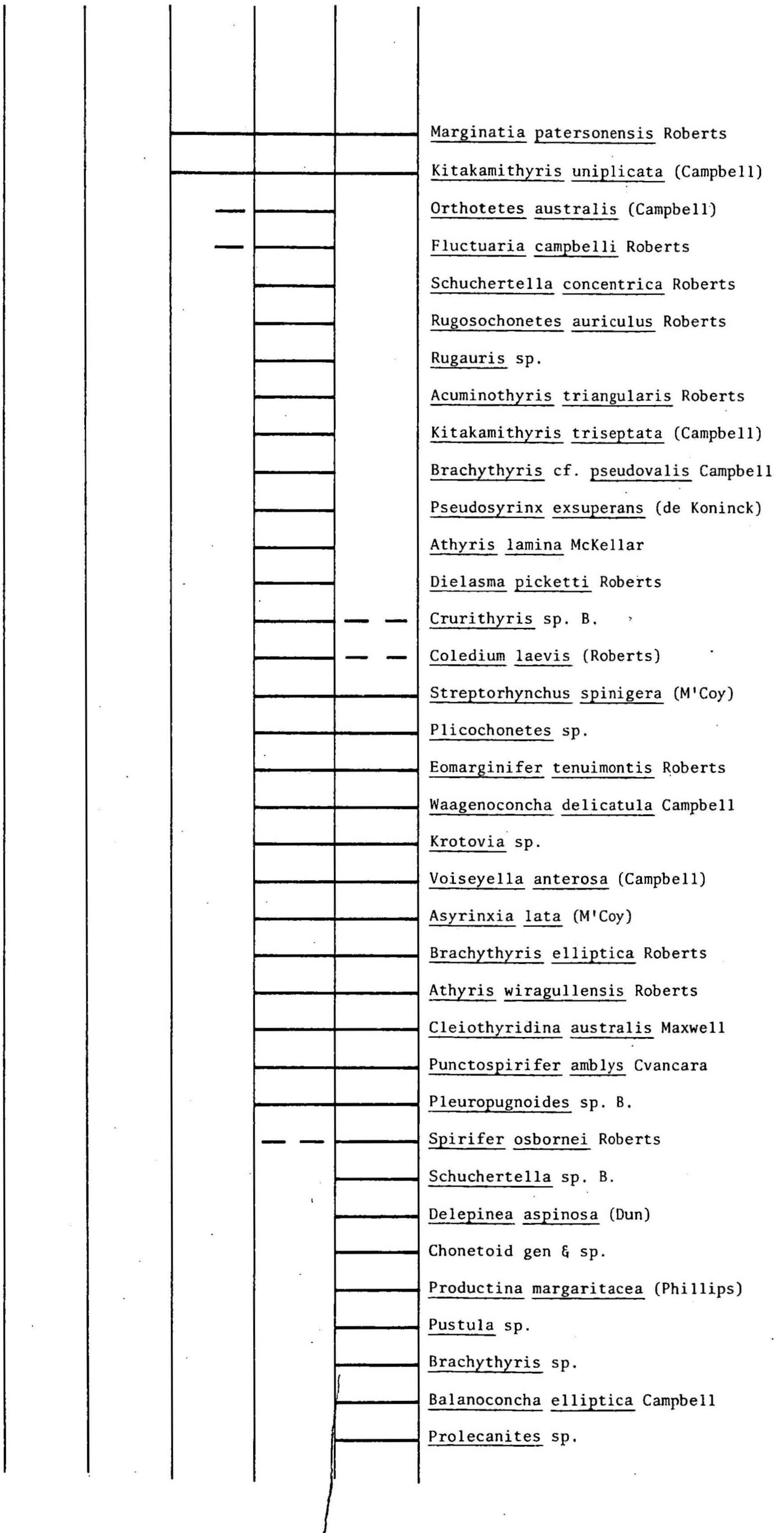

Marginatia patersonensis Roberts
Kitakamithyris uniplicata (Campbell)
Orthotetes australis (Campbell)
Fluctuaria campbelli Roberts
Schuchertella concentrica Roberts
Rugosochonetes auriculus Roberts
Rugauris sp.
Acuminothyris triangularis Roberts
Kitakamithyris triseptata (Campbell)
Brachythyris cf. pseudovalis Campbell
Pseudosyrinx exsuperans (de Koninck)
Athyris lamina McKellar
Dielasma picketti Roberts
Crurithyris sp. B.
Coledium laevis (Roberts)
Streptorhynchus spinigera (M'Coy)
Plicochonetes sp.
Eomarginifer tenuimontis Roberts
Waagenoconcha delicatula Campbell
Krotovia sp.
Voiseyella anterosa (Campbell)
Asyrinxia lata (M'Coy)
Brachythyris elliptica Roberts
Athyris wiragullensis Roberts
Cleiothyridina australis Maxwell
Punctospirifer amblys Cvancara
Pleuropugnoides sp. B.
Spirifer osbornei Roberts
Schuchertella sp. B.
Delepinea aspinosa (Dun)
Chonetoid gen & sp.
Productina margaritacea (Phillips)
Pustula sp.
Brachythyris sp.
Balanoconcha elliptica Campbell
Prolecanites sp.

Table 2.

SECTION 1, GLENBAWN

Species	1-5	1-9	1-27	1-28	1-22	1-23
Rhipidomella australis (M'Coy)		●	●			
Schizophoria verulamensis Cvancara					●	
Leptagonia analoga (Phillips)		●	●	—	—	●
Schellwienella cf. burlingtonensis Weller			●			
Rugosochonetes sp A.						
Rugosochonetes kennedyensis magnus Maxwell		?●	●			
Productina globosa Roberts			●	●	●	●
Antiquatonia cf. insculpta Muir-Wood			●			
Marginatia patersonensis Roberts					●	●
Unispirifer striatoconvolutus (Benson & Dun)		?●	- -	- -	●	
Spirifer cf. sol Campbell			●	●		
Prospira prima Maxwell		●	?●	—	—	●
Prospira sp.			●	—	●	
Brachythyris davidi (Dun)		●				
Brachythyris cf. solida Campbell			●	●	—	●
Kitakamithyris rouchelensis (Campbell)			●	—	●	
Cleiothyridina segmentata Roberts						●
'Dimegelasma' elegante Maxwell		?●	●			
Retzioid gen & sp.			●	—	●	
Rossirhynchus sp.	●					
?Pentremoblastus sp.		●				
Muensteroceras cf. oweni (Hall)			●			
Zone	?sol Zone		cf. burlingtonensis Zone		gracilis Zone	

Table 3

SECTION 30, MALUMLA

Species	31-1	30-2 15-3	29-6	30-9	30-13	29-2	29-1	29-7
Rhipidomella australis (M'Coy)				●	●	●		●
Schizophoria verulamensis Cvancara	●	●			●		●	●
Leptagonia analoga (Philliph)			●		●	●		●
Schellwienella sp. A.	●							
Schuchertella sp. A.		●						
Schuchertella concentrica Roberts			●					●
Orthotetes australis (Campbell)		●						●
Streptorhynchus spinigera (M'Coy)					●	●		●
Rugosochonetes sp A.	●	●						
Rugosochonetes auriculus Roberts								●
Rugosochonetes kennedyensis magnus Maxwell		●			●	●	●	●
Plicochonetes sp.				●				
Delepinea sp.	●	●						?●
Antiquatonia cf. insculpta Muir-Wood	●	●						
Eomarginifer tenuimontis Roberts			●	●	●			●
Marginatia patersonensis Roberts			●	●	●	●		●
Fluctuaria campbelli Roberts		●				●		●
Rugauris sp..							●	
Waagenoconcha delicatula Campbell								●
Productina globosa Roberts								●
Krotovia sp.					●			●
Unispirifer striatoconvolutus (Benson & Dun)	●	●	●		●	●		●
Spirifer cf. osbornei Roberts								●
Acuminothyris triangularis Roberts					●			●
Brachythyris elliptica Roberts			?●		●		●	●
Brachythyris sp.	●	●						
Kitakamithyris uniplicata (Campbell)	●	●						
Kitakamithyris triseptata (Campbell)			●			?●		●
Syringothyris cf. principalis North	●	●						
Asyrinxia lata (M'Coy)								●
Pseudosyrinx exsuperans (de Koninck)								●

(Table 3 cont.)

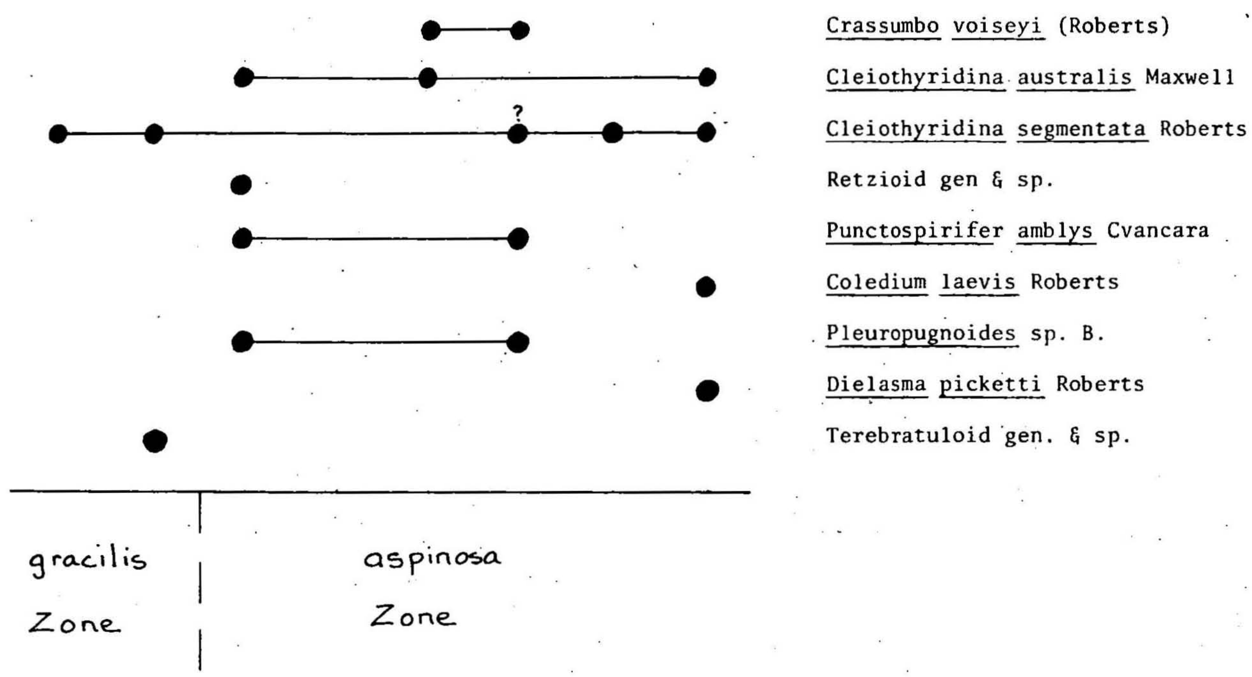
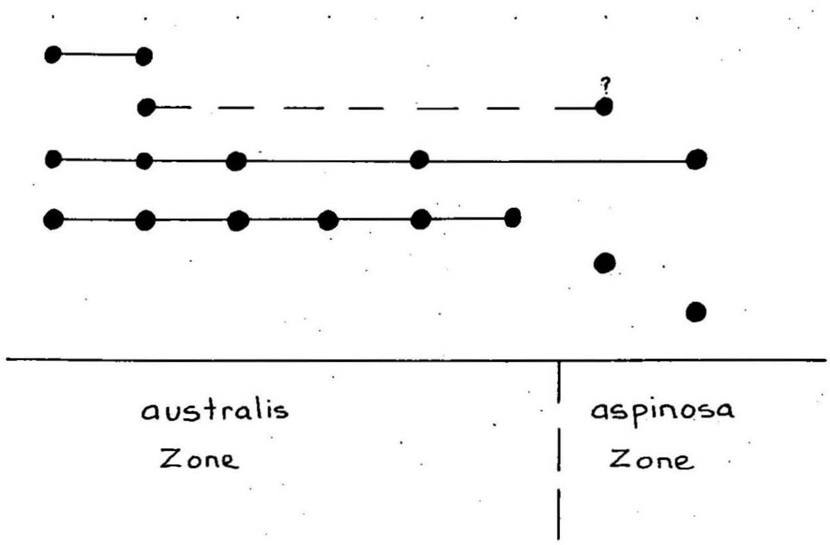

Crassumbo voiseyi (Roberts)
Cleiothyridina australis Maxwell
Cleiothyridina segmentata Roberts
Retzioid gen & sp.
Punctospirifer amblys Cvancara
Coledium laevis Roberts
Pleuropugnoides sp. B.
Dielasma picketti Roberts
Terebratuloid gen. & sp.
?
gracilis Zone
aspinosa Zone

Table 4

SECTIONS 17, BACK CREEK AND 41 UPPER ROUCHEL

17-5	17-6	17-7	17-8	17-9	17-11	41-1	41-2	41-4	Species
●	●	●	●	●		●	●	●	Rhipidomella australis (M'Coy)
●	●	●	●	●	●	●	●	●	Schizophoria verulamensis Cvancara
●	●	●	●	●		●	●	●	Leptagonia analoga (Phillips)
●	●	●	●						Orthotetes australis (Campbell)
●	●	●	●		●				Schuchertella concentrica Roberts
						●	●	●	Schuchertella sp. B.
	●						●		Streptorhynchus spinigera (M'Coy)
●				●					Rugosochonetes auriculus Roberts
●	●	●	●	●		●	●	●	Rugosochonetes kennedyensis magnus Maxwell
								●	Plicochonetes sp.
●									Delepinea sp.
							●		Delepinea aspinosa (Dun)
			●	●	●	●			Eomarginifera tenuimontis Roberts
●	●	●	●	●	●	●	●	●	Marginatia patersonensis Roberts
●					●				Fluctuaria campbelli Roberts
●	●	●	●		●	●	●		Waagenoconcha delicatula Campbell
	●	●	●	●		●			Krotovia sp.
						●	●		Productina margaritacea (Phillips)
●	●	●	●	●	●	●		●	Unispirifer striatoconvolutus (Benson & Dun)
				? ●		●	? ●		Spirifer osbornei Roberts
			●	●				●	Asyrinxia lata (M'Coy)
	? ●	? ●	●	●		●			Kitakamithyris uniplicata (Campbell)
					●				Kitakamithyris triseptata (Campbell)
●	●		●			●			Voiseyella anterosa (Campbell)
					●	●	●		Brachythyris elliptica Roberts
	●	●							Brachythyris cf. pseudovalis Campbell
							●		Brachythyris sp.
				●	●		●	●	Cleiothyridina australis Maxwell
●	●	●			●	●			Cleiothyridina segmentata Roberts
								●	Athyris wiragullensis Roberts
	●	●							Athyris lamina McKellar
	●			●	- - -	- - -	? ●		Crurithyris sp. B.

(Table 4 cont.)



Punctospirifer amblys Cvancara

Coledium laevis (Roberts)

Pleuropugnoides sp. B

Dielasma picketti Roberts

Balanoconcha elliptica Campbell

Prolecanites sp.

Table 5

SECTION 6, STONY CREEK

Species	6-10	6-11	6-13
Rhipidomella australis (M'Coy)	●	●	●
Schizophoria verulamensis Cvancara	●	●	●
Leptagonia analoga (Phillips)	●	—	●
Schuchertella sp. B.	●	●	●
Streptorhynchus spinigera (M'Coy)			●
Delepinea aspinosa (Dun)	●	●	●
Rugosochonetes kennedyensis magnus Maxwell	●		
Productina margaritacea (Phillips)	●	●	●
Eomarginifera tenuimontis Roberts			●
Marginatia patersonensis Roberts	●	? ●	●
Waagenoconcha delicatula Campbell	●	—	●
Unispirifer striatoconvolutus (Benson & Dun)		●	●
Brachythyris sp.	●	●	●
Kitakamithyris uniplicata (Campbell)		●	●
Cleiothyridina segmentata Roberts	●	●	●
Athyris wiragullensis Roberts			●
Crurithyris sp.		●	
Pleuropugnoides sp.B.	●	—	●

aspinosa Zone (6-10 to 6-13)

Table 6

SCHELLWIENELLA cf BURLINGTONENSIS ZONE

1-27	1-28	24-7	24-8	24-12	24-15	39-13	39-16	39-18	58-3	
●								●		Rhipidomella australis (M'Coy)
		●			●	●	●		●	Schizophoria verulamensis Cvancara
●					●					Leptagonia analoga (Phillips)
●		●	●	●	●	●	●			Schellwienella cf. burlingtonensis Weller
		●	●		●	●	●			Rugosochonetes sp. A.
●		●	●					●	●	Rugosochonetes kennedyensis magnus Maxwell
		●					●	●		Delepinea sp.
●		●			●		●	●		Antiquatonia cf. insculpta Muir-Wood
●	●									Productina globosa Roberts
		●								Unispirifer striatoconvolutus (Benson & Dun)
●	●									Spirifer cf. sol Campbell
●										Prospira prima Maxwell
●							●			Prospira sp.
●	●						●	●		Brachythyris cf. solida Campbell
		●			●					Brachythyris cf. davidi (Dun)
●		●						●		Kitakamithyris rouchelensis (Campbell)
		●			●		●	●	●	Cleiothyridina segmentata Roberts
							●	●		Syringothyris cf. principalis North
●										'Dimegelasma' elegante Maxwell
●					? ●					Retzioid gen & sp.
		●	●							Crurithyris sp. A.
					●		●		●	'Camarotoechia' cf. chouteauensis Weller
		●			●	●	●			Terebratuloid n.gen.
●										Muensteroceras cf. oweni (Hall)

Table 7

PUSTULA GRACILIS ZONE

1-22	1-23	4-2	4-3	15-3	31-1	38-7	41-3	58-12	63-5	
			●			●	●			*Rhipidomella australis* (M'Coy)
●				●	●					*Schizophoria verulamensis* Cvancara
	●	●	●			●	●	●		*Leptagonia analoga* (Phillips)
		●			●		? ●			*Schellwienella* sp.A.
				? ●		●				*Schuchertella* sp.A.
				●						*Orthotetes australis* (Campbell)
				●	●	●				*Rugosochonetes* sp.A.
		●		●		●	●	●	●	*Rugosochonetes kennedyensis* magnus Maxwell
				●	●					*Delepinea* sp.
●	●								? ●	*Marginatia patersonensis* Roberts
				●	●		●			*Antiquatonia* cf. *insculpta* Muir-Wood
		●				●	●		●	*Pustula gracilis* Campbell
●	●					●	●		●	*Productina globosa* Roberts
		●				●		●		rugose productoid
				●						*Fluctuaria campbelli* Roberts
●		●	●	●	●	●	●		●	*Unispirifer striatoconvolutus* (Benson & Dun)
	●	●				●				*Prospira prima* Maxwell
●									●	*Prospira* sp.
								●		*Spirifer* cf. *sol* Campbell
	●	●	●			? ●		●	? ●	*Brachythyris* cf. *solida* Campbell
●						●	●		? ●	*Kitakamithyris rouchelensis* (Campbell)
				●	●					*Kitakamithyris uniplicata* (Campbell)
							●			*Crassumbo voiseyi* (Roberts)
	●	●	●		●	●	●		●	*Cleiothyridina segmentata* Roberts
				●	●				●	*Syringothyris* cf. *principalis* North
		●								'*Dimegelasma*' *elegante* Maxwell
●							●			Retzioid gen & sp.
						●				*Crurithyris* sp. A.
●					●	●	●			'*Camarotoechia*' cf. *chouteauensis* Weller
				●			●			Terebratuloid gen & sp.
●		●								*Ammonelipsites* sp.

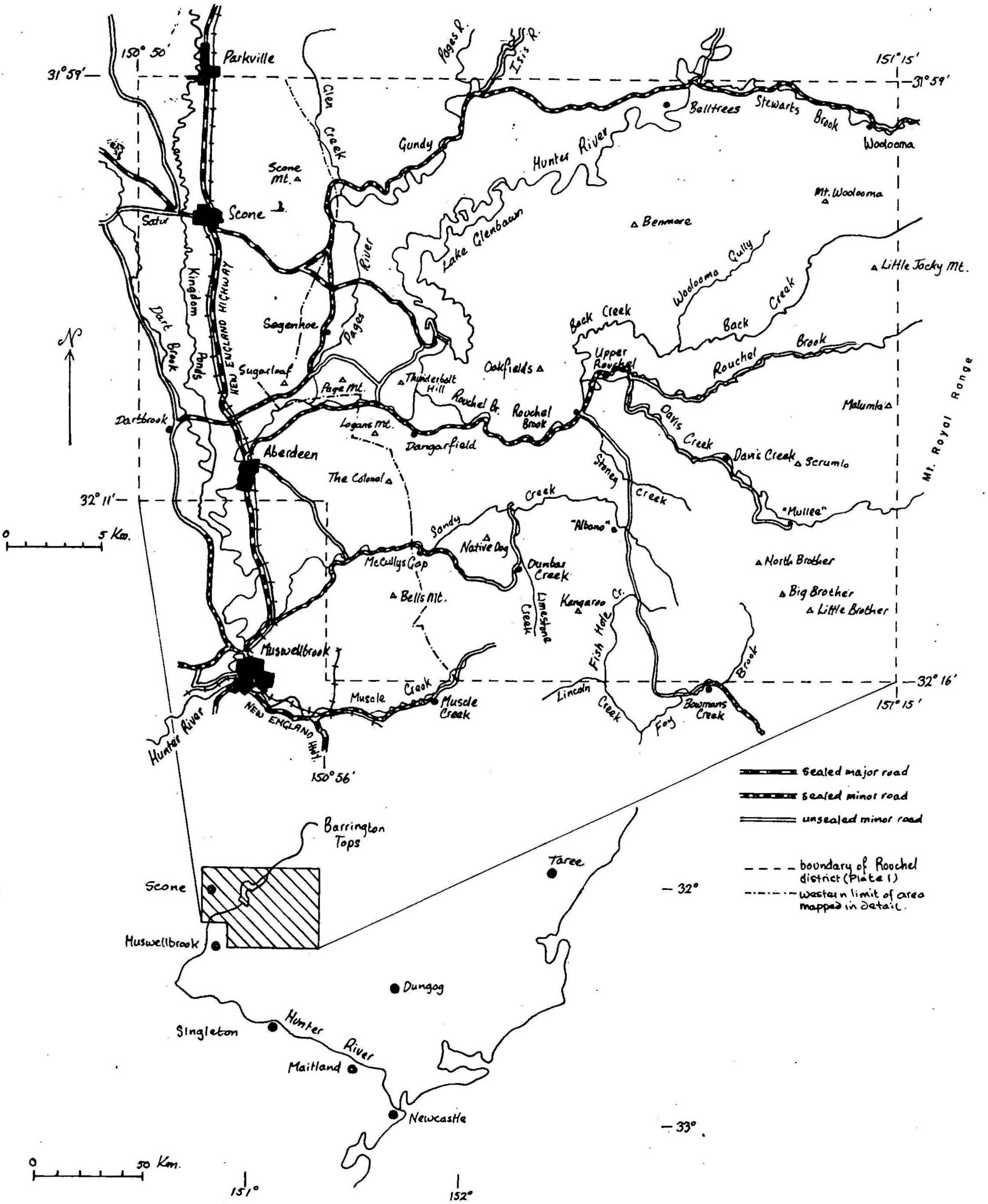


FIGURE 1- LOCALITY MAP

To accompany Record 1972/119

156/A1/3

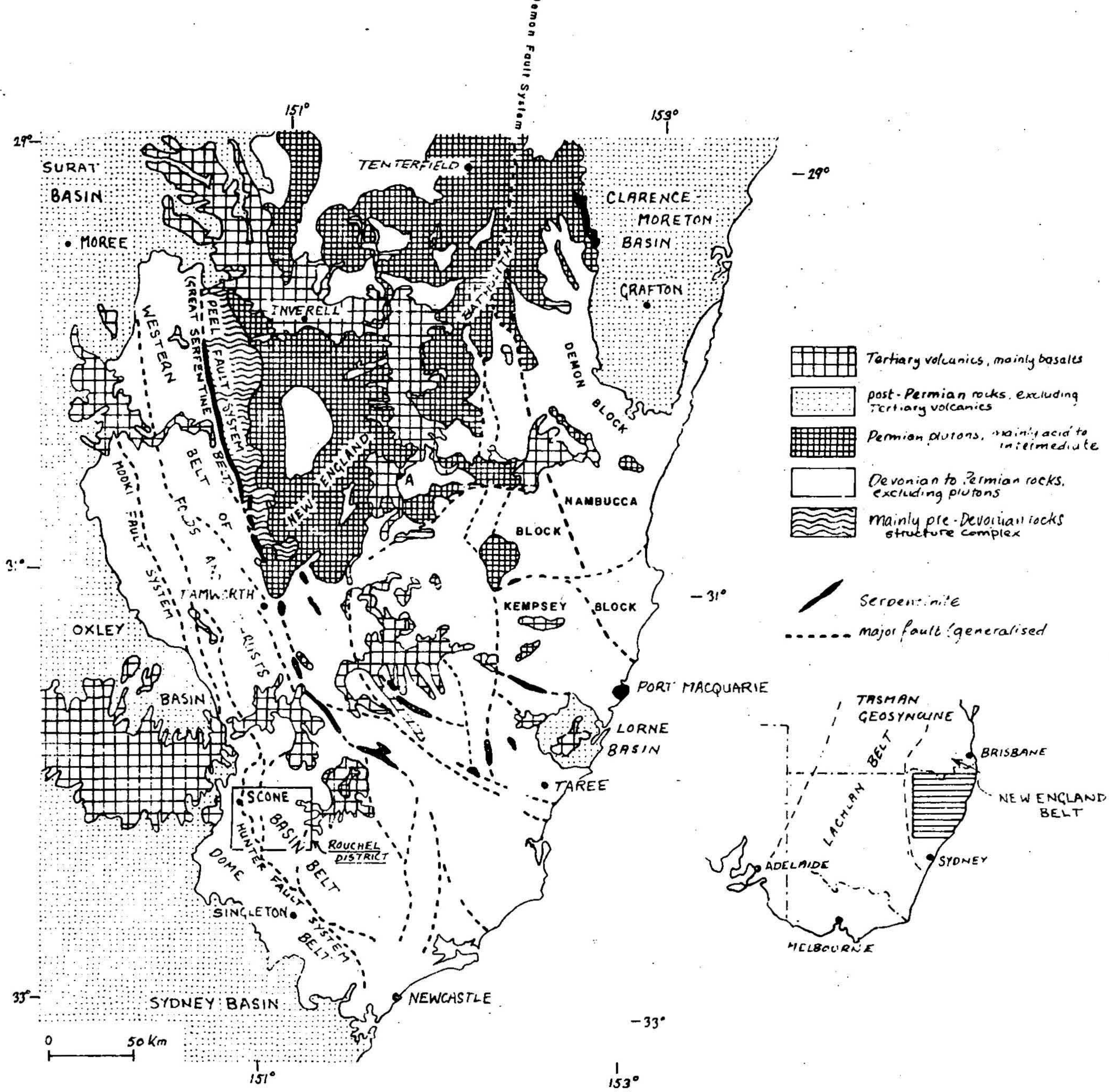
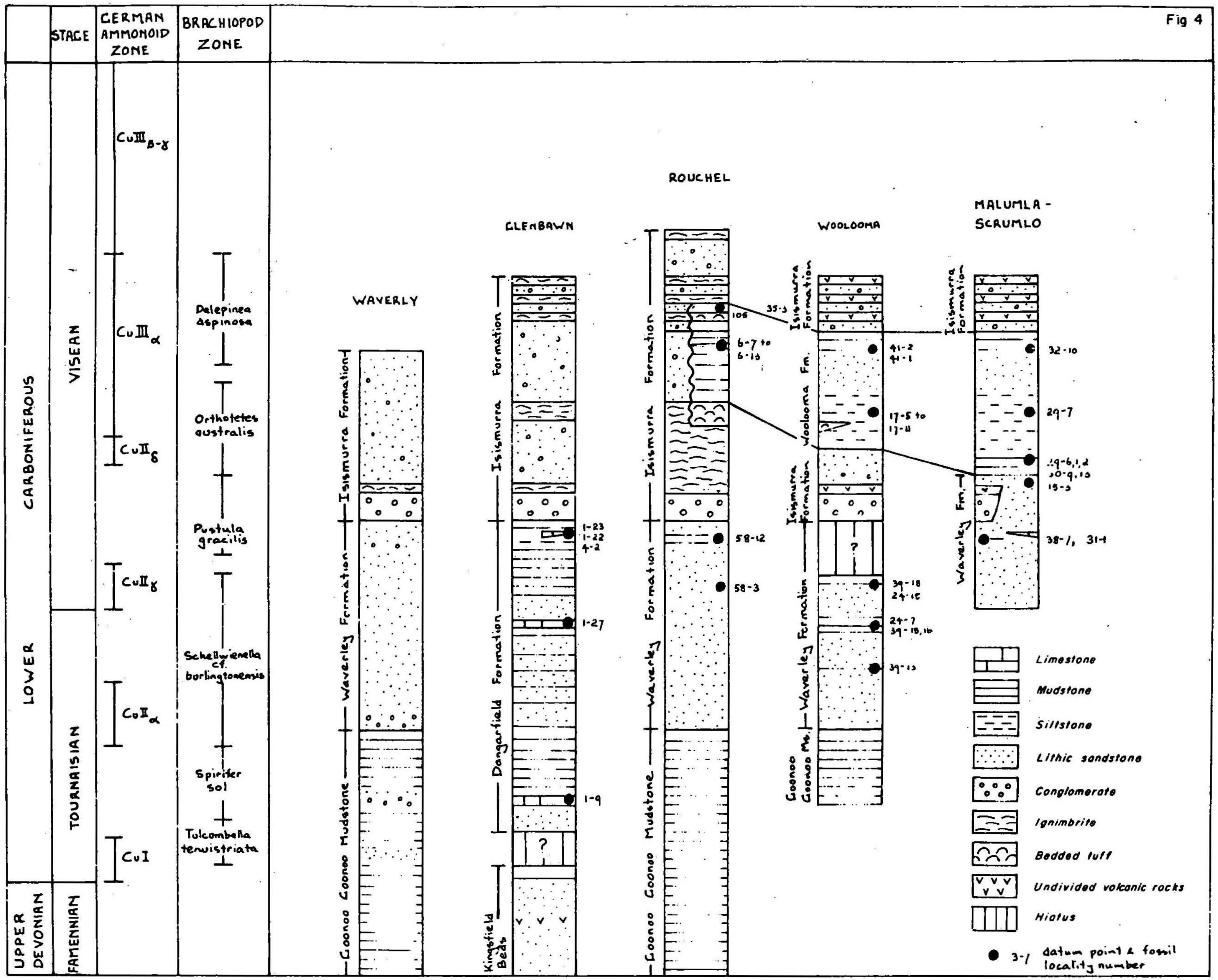


FIGURE 2 - GEOLOGICAL SETTING OF THE ROUCHEL DISTRICT; MODIFIED FROM VOISEY (1959)
THE TECTONIC MAP OF AUSTRALIA AND NEW GUINEA (1971) AND SCHEIBNER (1972)
A = ARMIDALE

To accompany Record 1972/119 I 56/A1/4

Figure 3
volcanics, mainly ignimbrite
conglomerate
sandstone
mudstone and siltstone
limestone
unconformity
Waverley
Glenbawn
Woolooma
Back Creek - Scrumlo
Rouchel Springs - Sandy Creek
Mullee
Cli
Clw
D-Cg
Clo
Cld
Clk
151° 10'
151° 20'
151° 22'
31° 50'
151° 00'
150° 50'
32° 00'
32° 10'
32° 20'
Pages River
Hunter River
Scone
Aberdeen
Sandy Creek
Muswellbrook
Foy Brook
Campbells Creek
2000'
1000'
J. Roberts 7, 2, 72
I 56/AI/5
To accompany Record 1972/119

Fig 4



STAGE
GERMAN AMMONOID ZONE
BRACHIOPOD ZONE
UPPER DEVONIAN
FAMENNIAN
LOWER CARBONIFEROUS
TOURNAISIAN
VISEAN
CuI
CuII α
CuII γ
CuII δ
CuIII α
CuIII β-γ
Tulcumbella tenuistriata
Spirifer sol
Schellwienella cf. burlingtonensis
Pustula gracilis
Orthotetes australis
Delepinea aspinosa
WAVERLY
GLENBAWN
ROUCHEL
WOOLOOMA
MALUMLA - SCRUMLO
Goonoo Goonoo Mudstone
Waverley Formation
Isismurra Formation
Kingsfield Beds
Dangarfield Formation
Goonoo Goonoo Ms.
Woolooma Fm.
Waverley Fm.
Limestone
Mudstone
Siltstone
Lithic sandstone
Conglomerate
Ignimbrite
Bedded tuff
Undivided volcanic rocks
Hiatus
3-1 datum point & fossil locality number

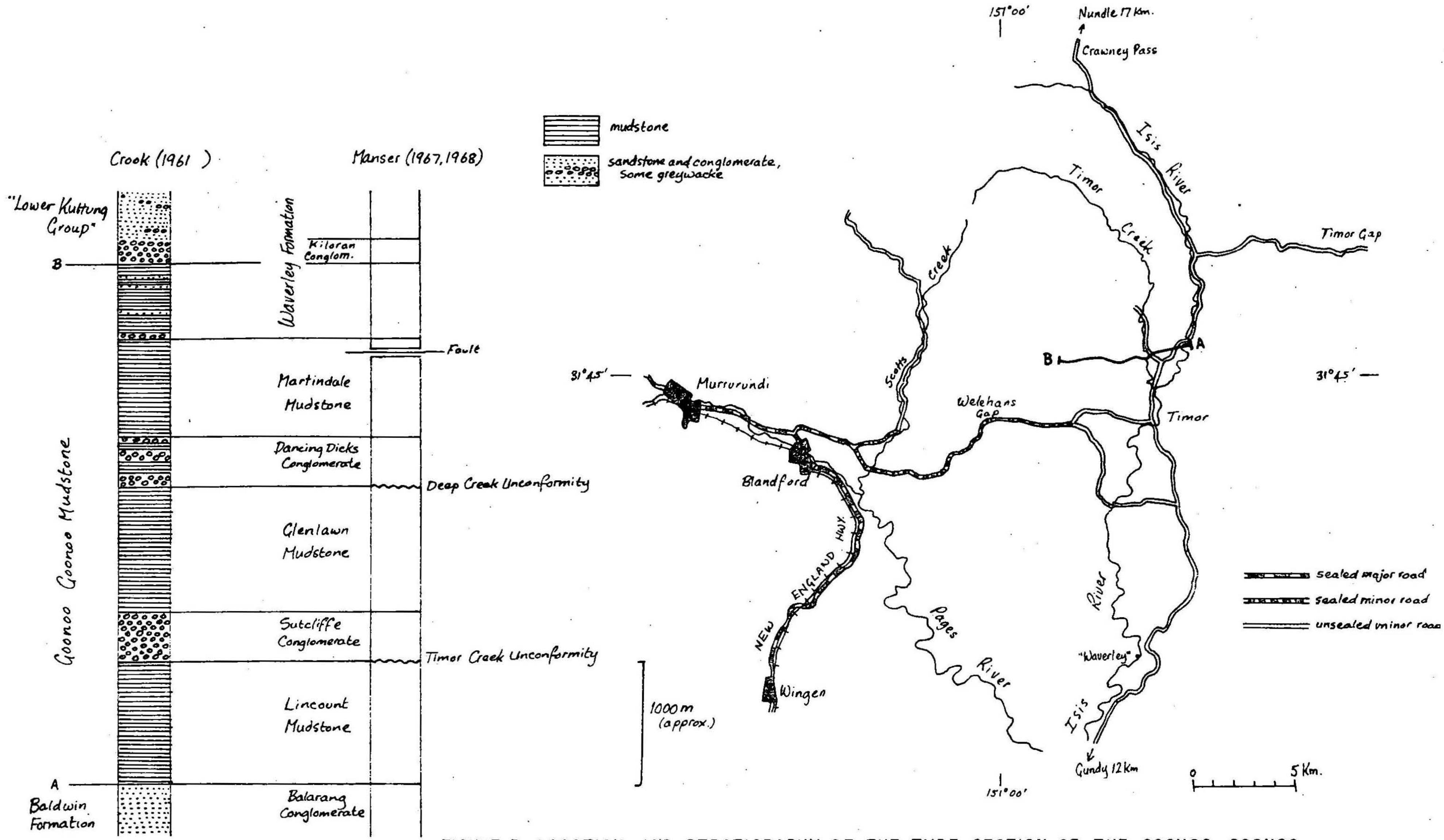
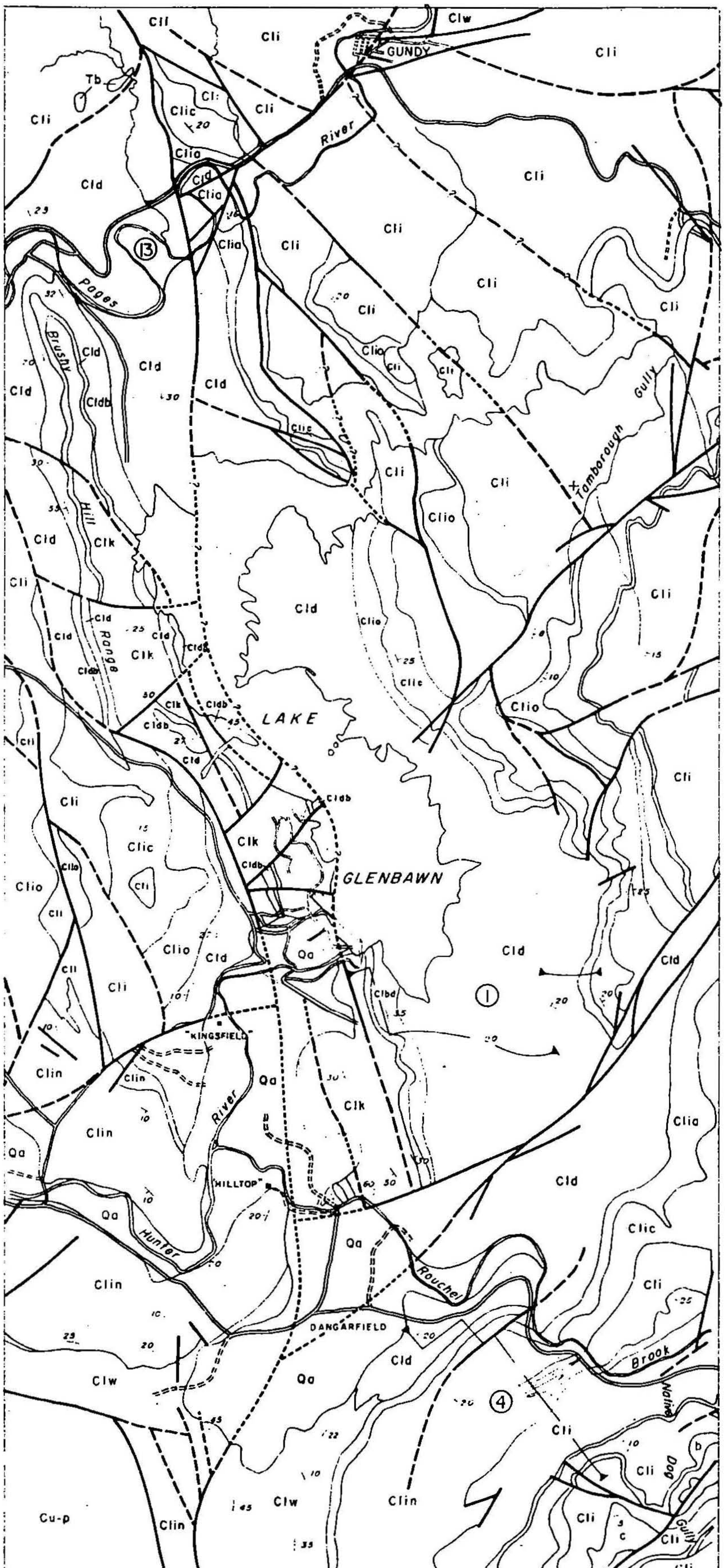


FIGURE 5 - LOCATION AND STRATIGRAPHY OF THE TYPE SECTION OF THE GOONOO GOONOO MUDSTONE; AFTER CROOK (1961) AND MANSER (1968)

To accompany Record 1972/119

156/A1/7

FIG 6 - LOCATION OF MEASURED SECTIONS THROUGH THE DANGARFIELD FORMATION



Qa	Alluvium
Tb	Basic lavas and intrusives
Cu-p	Undivided
Cli	Isismurra Formation
d, c, b, a	Unnamed tuffs near 'Albano'
Clin	Native Dog Ignimbrite Member
Clio	Oakfields Ignimbrite
Clic	Curra Keith Ignimbrite Member
Clia	Ayr Conglomerate Member
Clw	Waverley Formation
Cld	Dangarfield Formation
Cldb	Brushy Hill Limestone Member
Clk	Kingsfield Beds

Geological boundary

Fault

Where location of boundary is approximate, line is broken; where inferred, queried, where concealed, faults are shown by short dashes

Strike and dip of strata

Horizontal strata

Measured section

Road

Track

'HILLTOP' Homestead

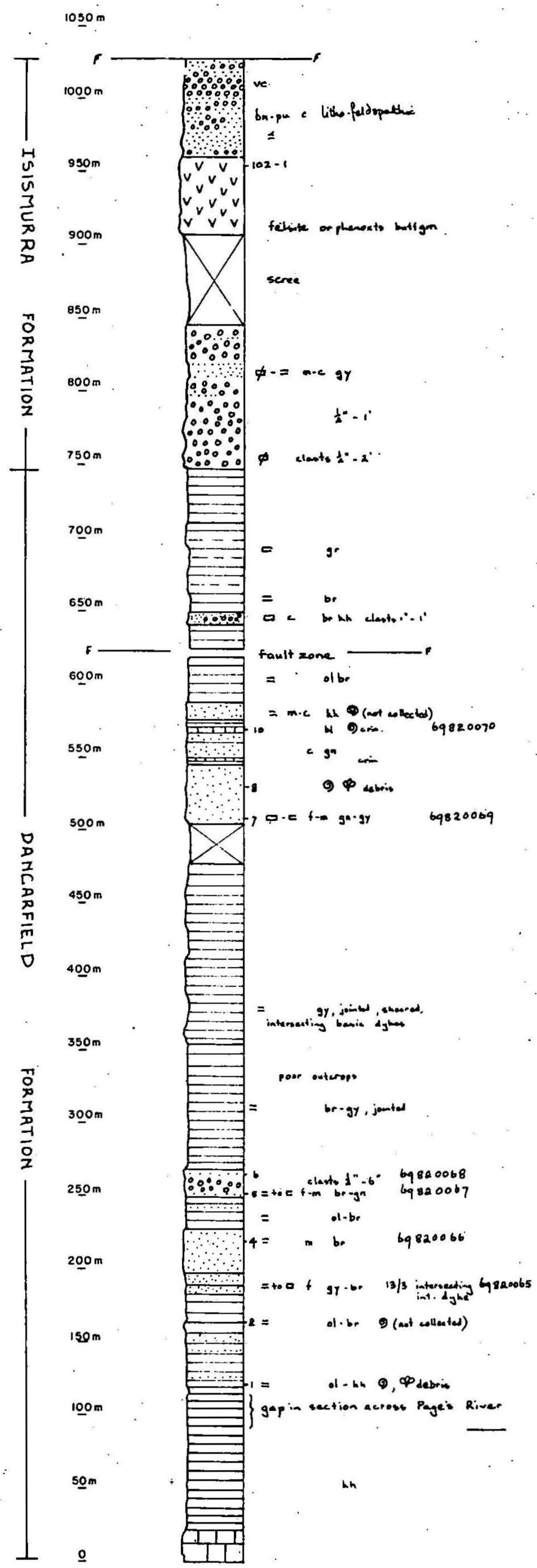
To accompany Record 1972/119

I 56/A1/8

Figure 7

1100 mètres

SECTIONS 13 AND 102
BRUSHY HILL - GUNDY



John Roberts - B.S. Oversby
16.12.69 18.3.71
18.2.70
10.6.70

To accompany Record 1972/119

156/A1/9

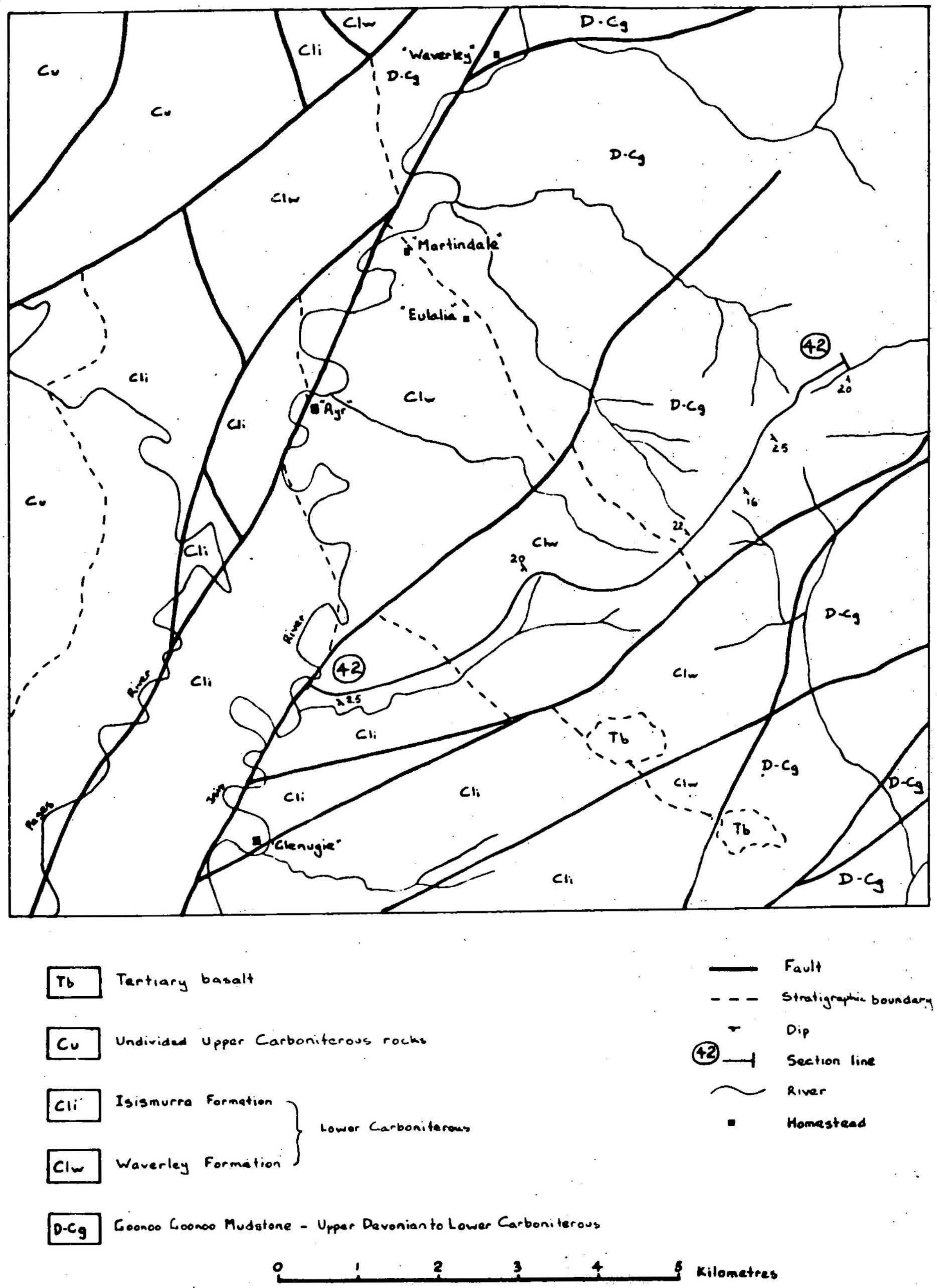


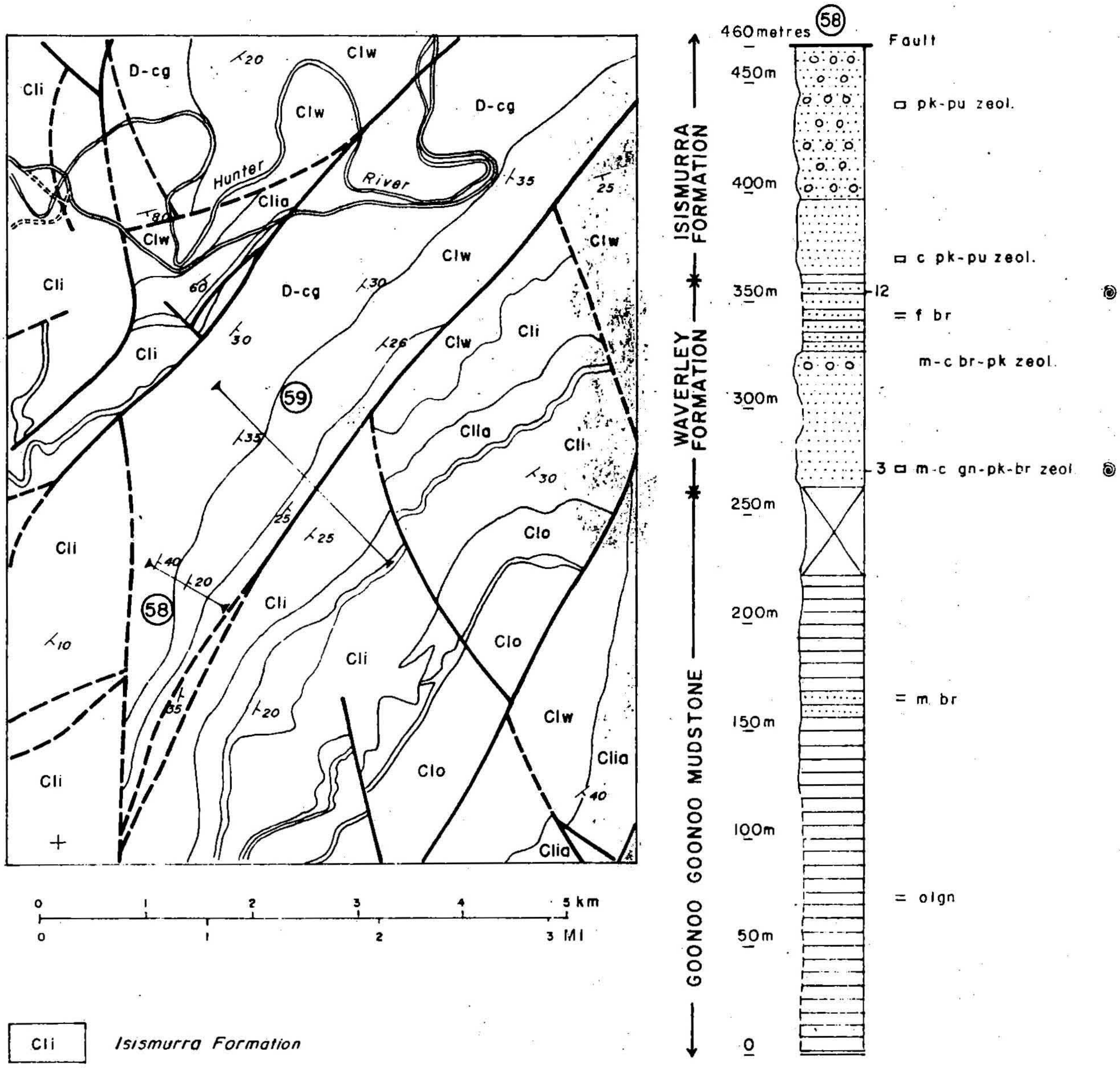
Fig 8. Location of Section 42 near Waverley. Geology modified from Manser (1968)

J.Roberts 31.1.72

To accompany Record 1972/119

I56/AI/19

FIG 9 - LOCATION AND STRATIGRAPHY OF SECTION 58, MEASURED SOUTHWEST OF BENMORE



Cli	*Isismurra Formation*
Clia	*Ayr Conglomerate Member*
Clo	*Woolooma Formation*
Clw	*Waverley Formation*
D-Cg	*Goonoo Goonoo Mudstone*

Geological boundary

Fault.
Where location of boundary is approximate, line is broken; where inferred, queried; where concealed, faults are shown by short dashes

Strike and dip of strata (20)

Horizontal strata (+)

Measured section

Road

Track

To accompany Record 1972/119

I 56/A1/11

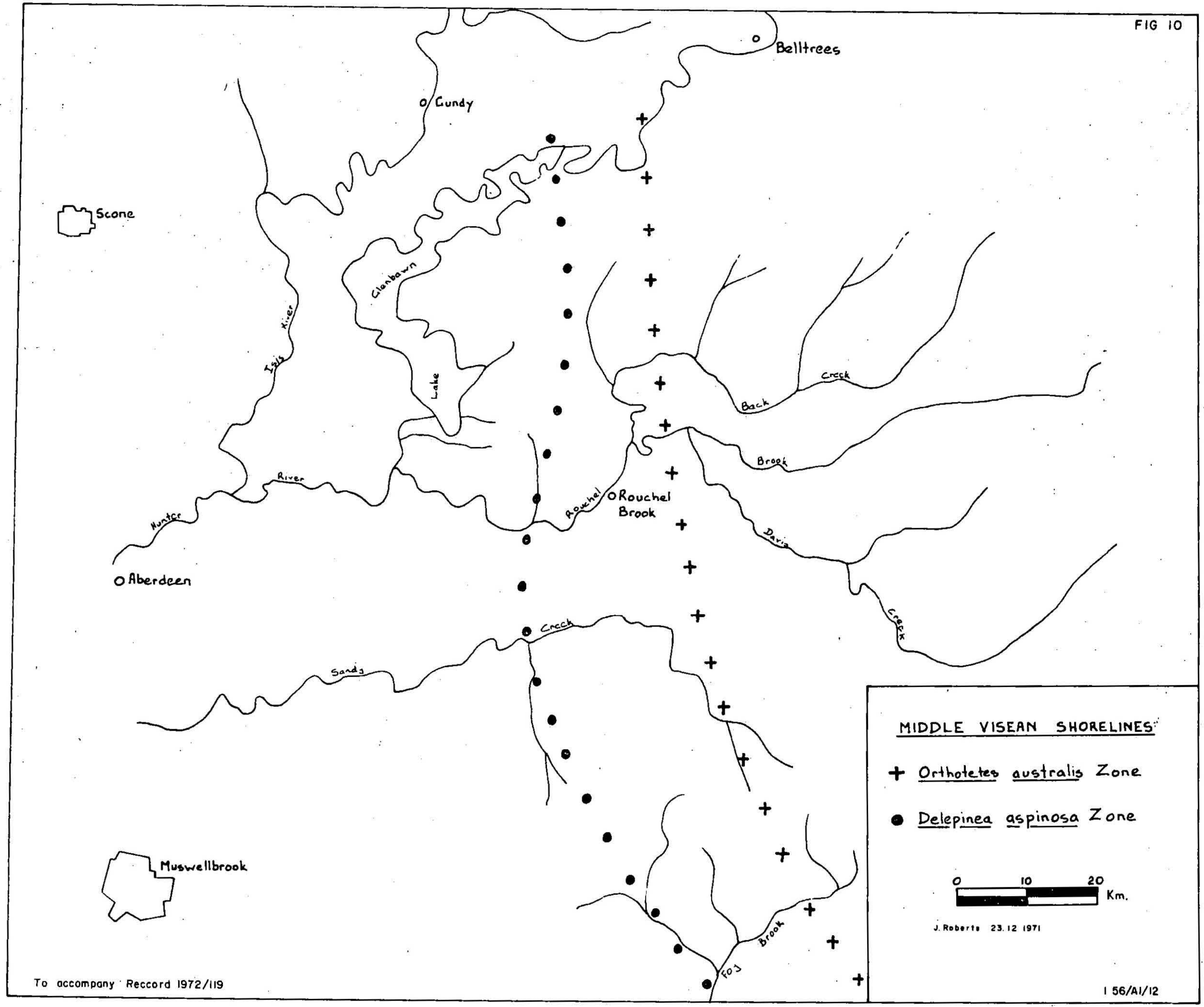

Belltrees
Cundy
Scone
Clanbawn
Lake
Isis
River
Hunter
River
Aberdeen
Rouchel
Rouchel Brook
Back
Creek
Brook
Davis
Creek
Sands
Creek
Muswellbrook
Brook
MIDDLE VISEAN SHORELINES
+ Orthotetes australis Zone
● Delepinea aspinosa Zone
0
10
20
Km.
J. Roberts 23.12 1971
To accompany Reccord 1972/119
I 56/A1/12

FIG 10

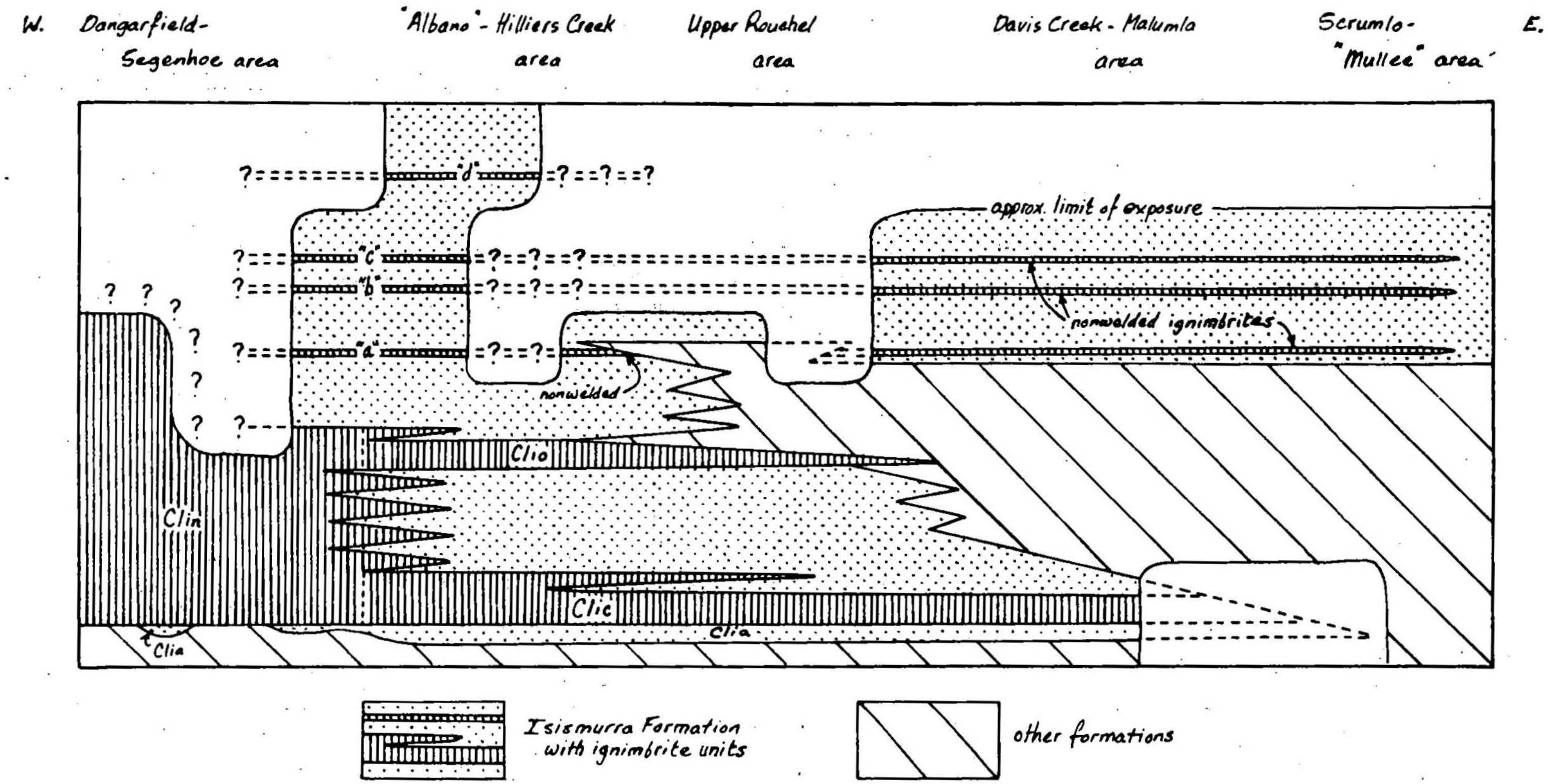


FIGURE 11 - STRATIGRAPHIC RELATIONSHIPS OF UNITS WITHIN THE ISISMURRA FORMATION; NOT TO SCALE

To accompany Record 1972/119

I 56/A1/13

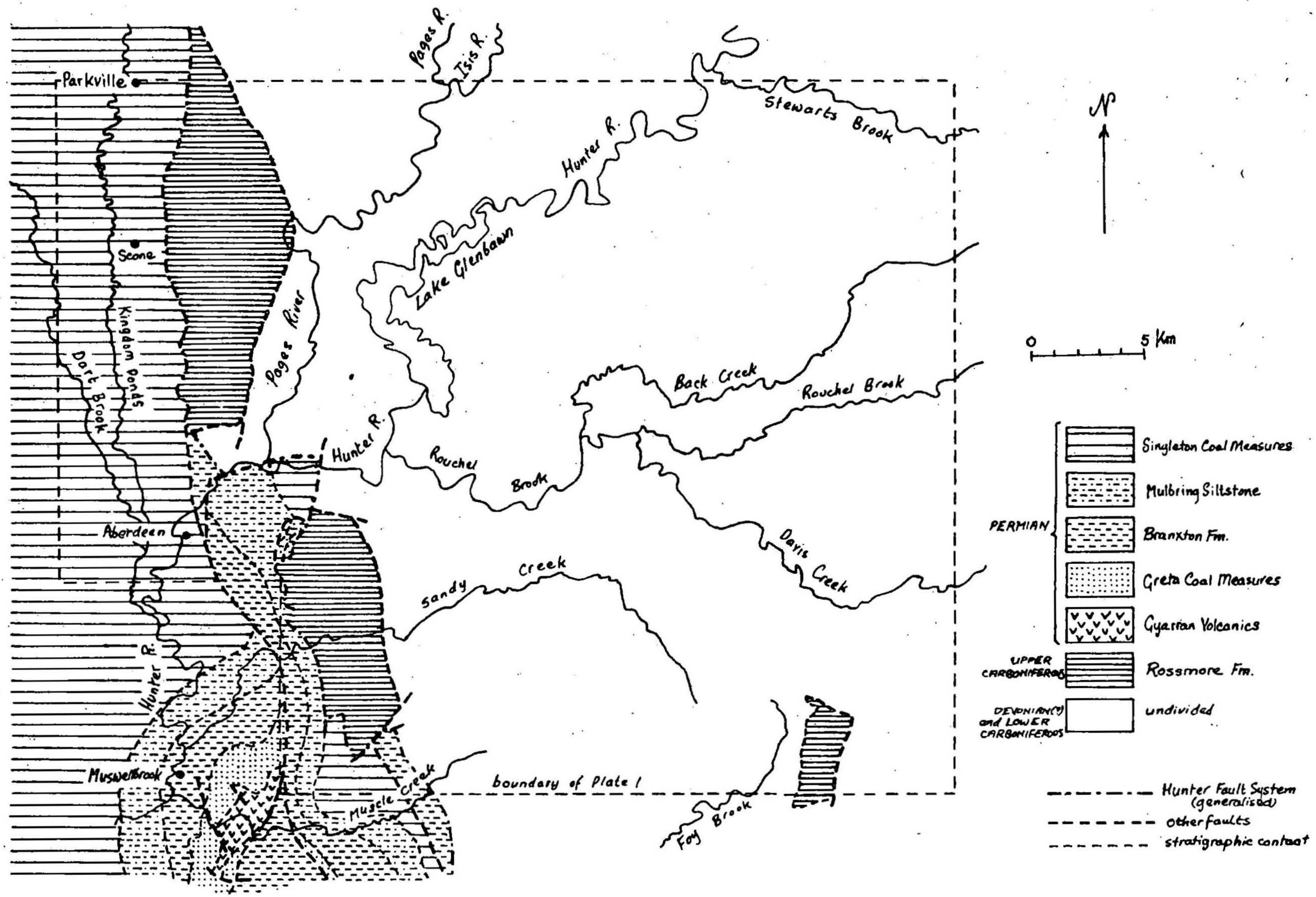


FIGURE 12 - SIMPLIFIED GEOLOGY OF UPPER CARBONIFEROUS AND PERMIAN ROCKS IN AND ADJACENT TO THE ROUCHEL DISTRICT; MODIFIED FROM PACKHAM (1969, p. 314)

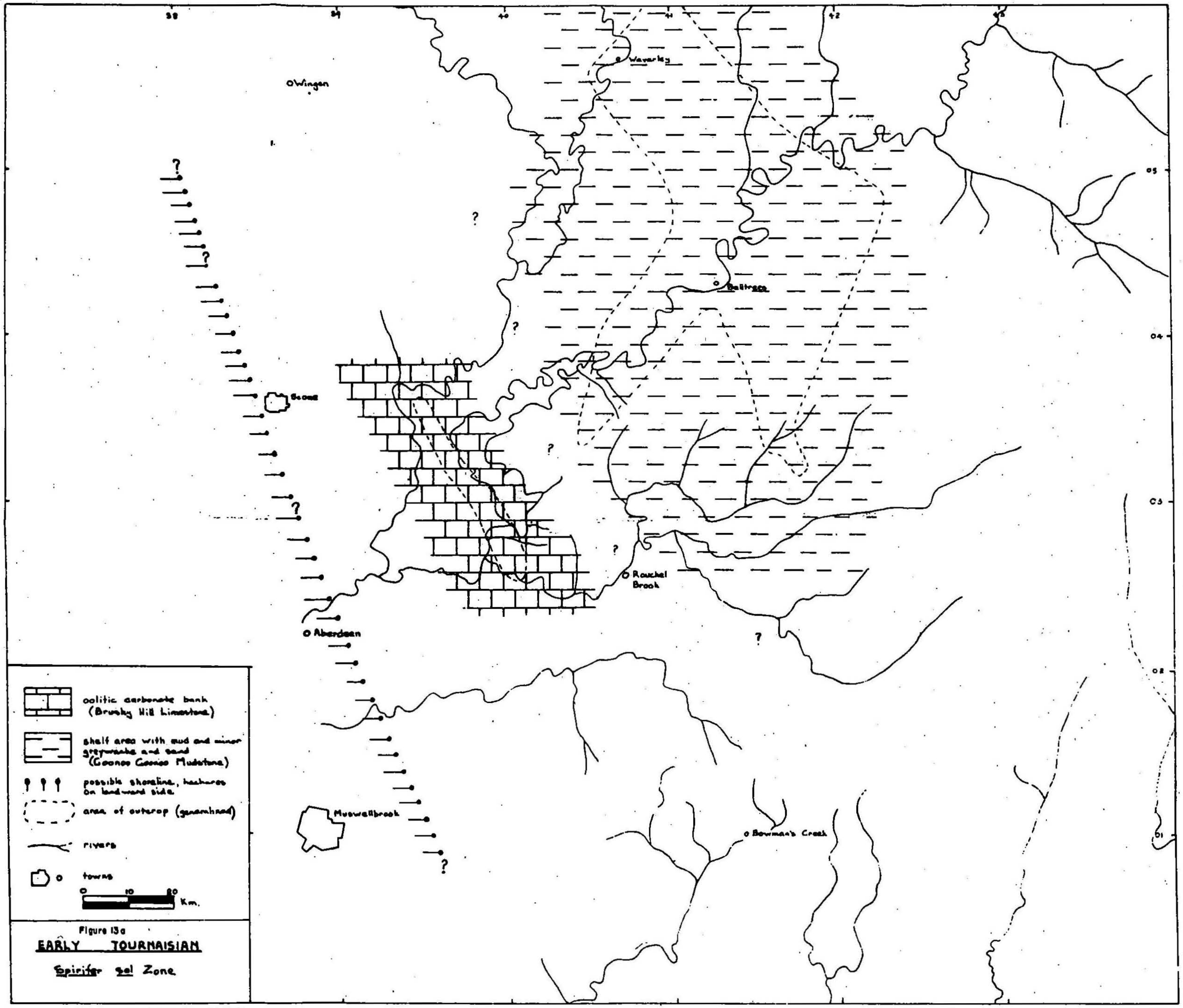


Figure 13a
EARLY TOURNAISIAN
Spirifer sol Zone

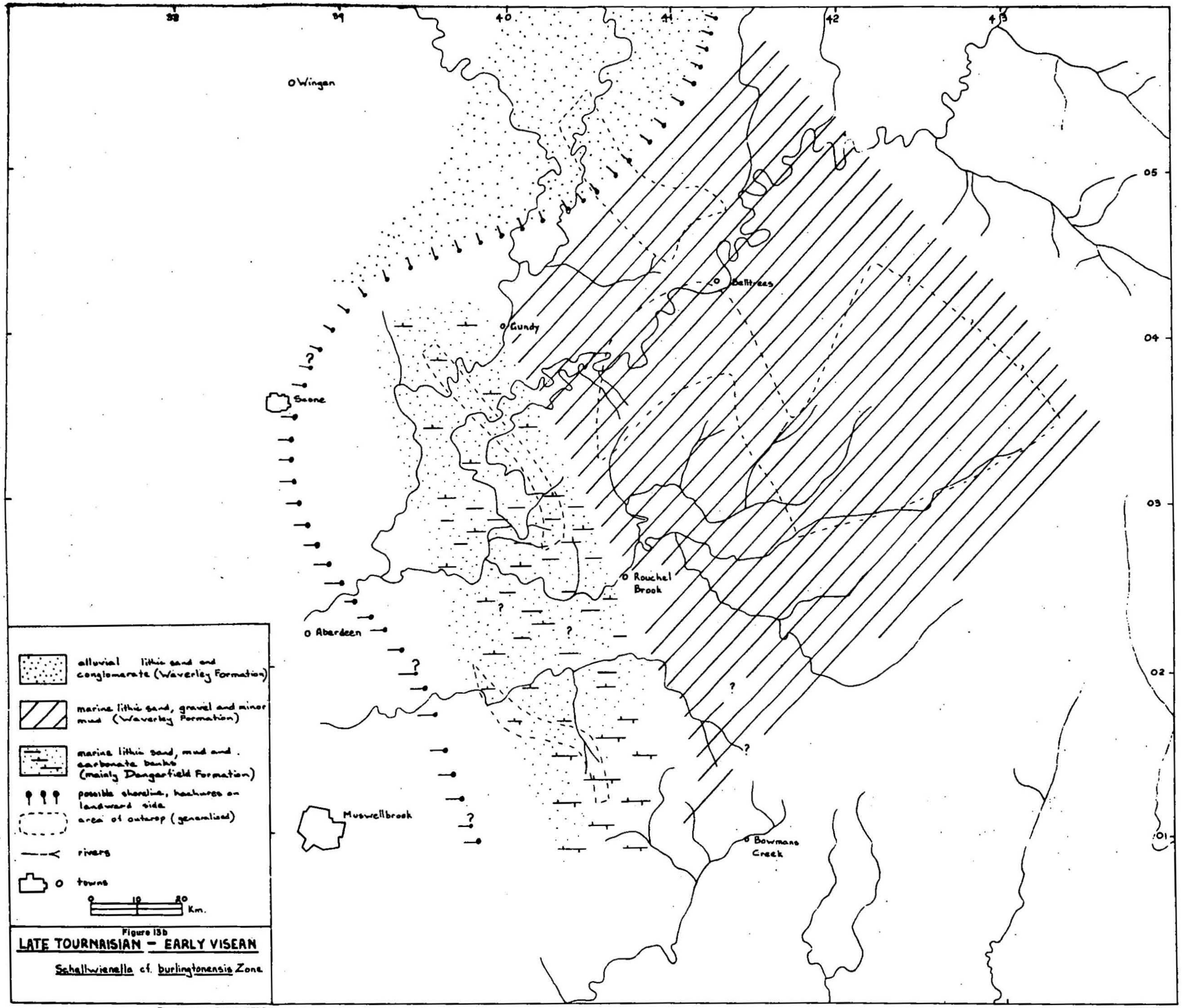


Figure 13b

LATE TOURNAISIAN — EARLY VISEAN

Schellwienella cf. burlingtonensis Zone

To accompany Record 1972/19

I56/A1/15

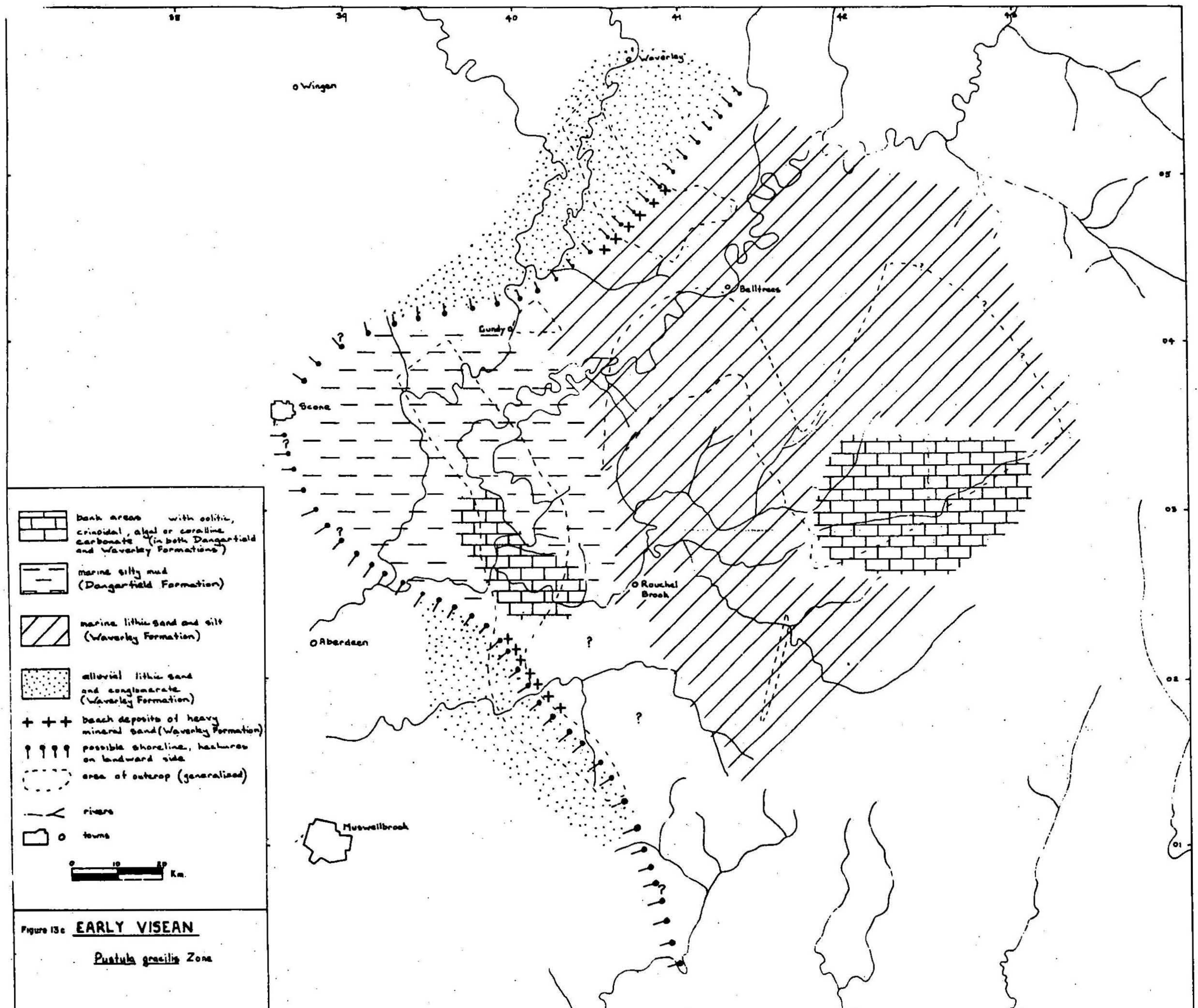
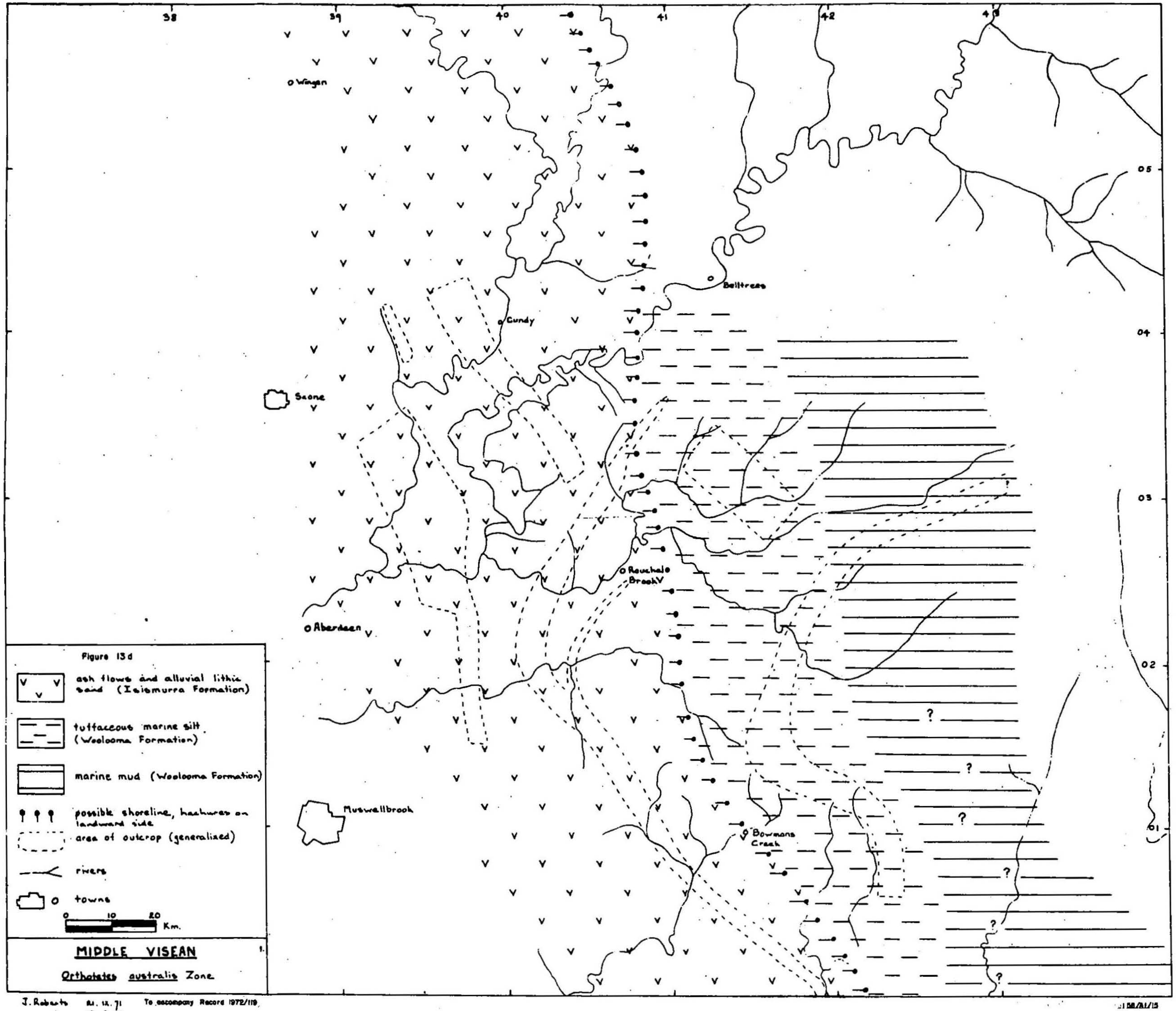


Figure 13c **EARLY VISEAN**

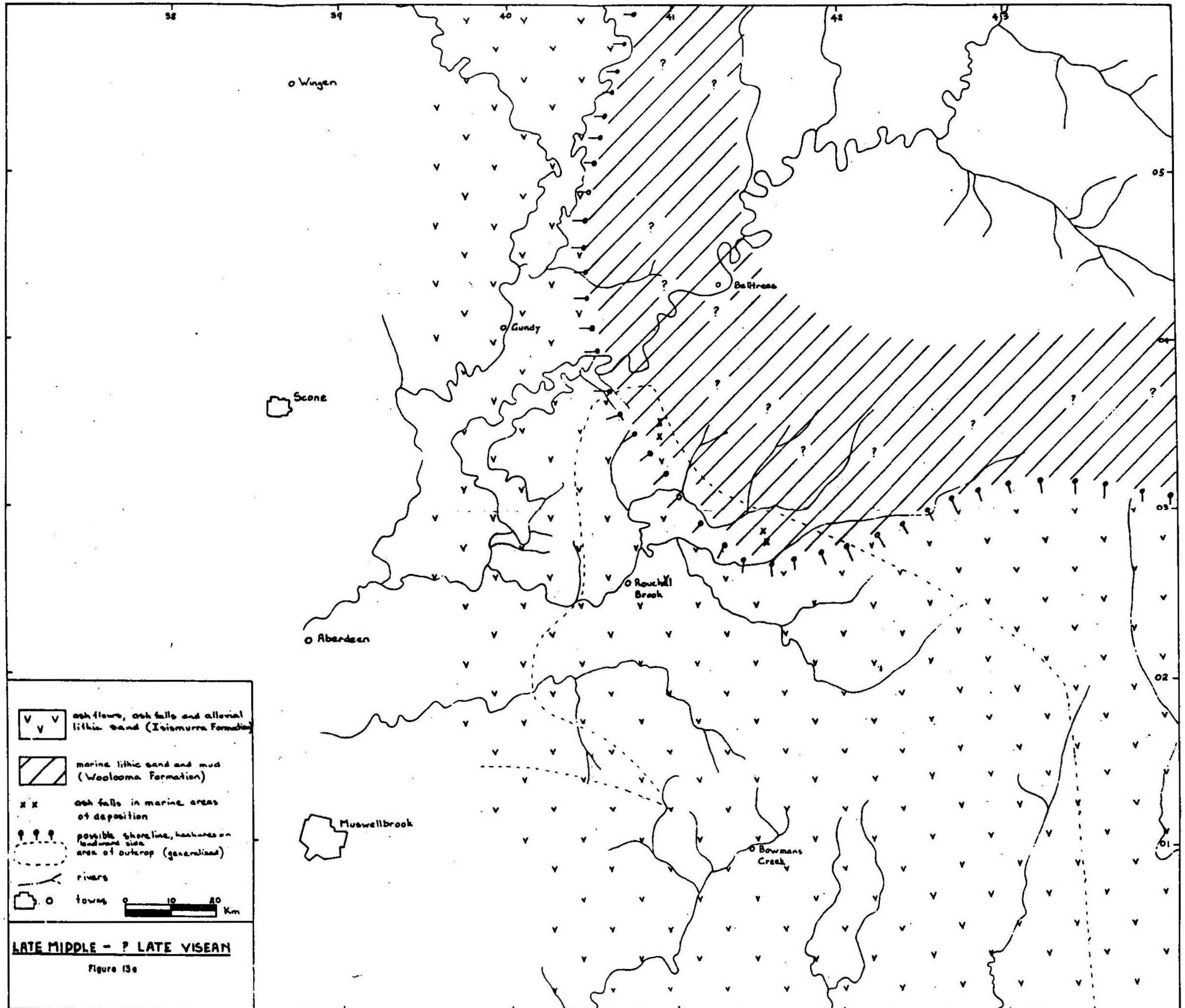
Pustula gracilis Zone

To accompany Record 1972/119

156/A1/15



J. Roberts 21. IX. 71 To accompany Record 1972/119



LATE MIDDLE - ? LATE VISEAN

Figure 13e

To accompany Record 1972/119

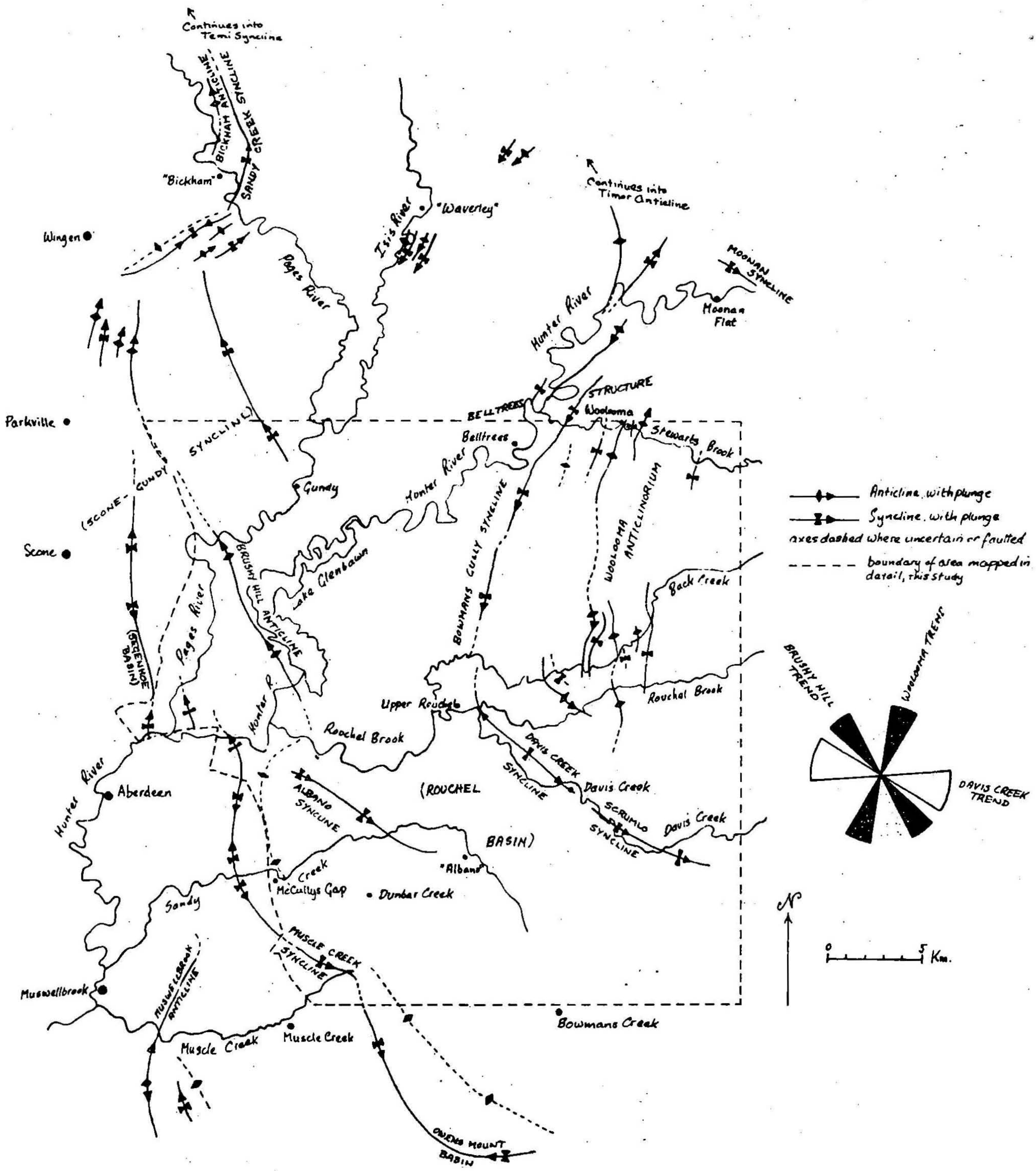


FIGURE 14 - STRIKE AND PLUNGE OF MAJOR FOLDS IN AND ADJACENT TO THE ROUCHEL DISTRICT; COMPILED MAINLY FROM OSBORNE (1929, 1950a) AND MANSER (1968). NAMES IN BRACKETS WERE USED BY OSBORN, BUT ARE NOW CONSIDERED INAPPROPRIATE.

To accompany Record 1972/119 | I 56/A1/16

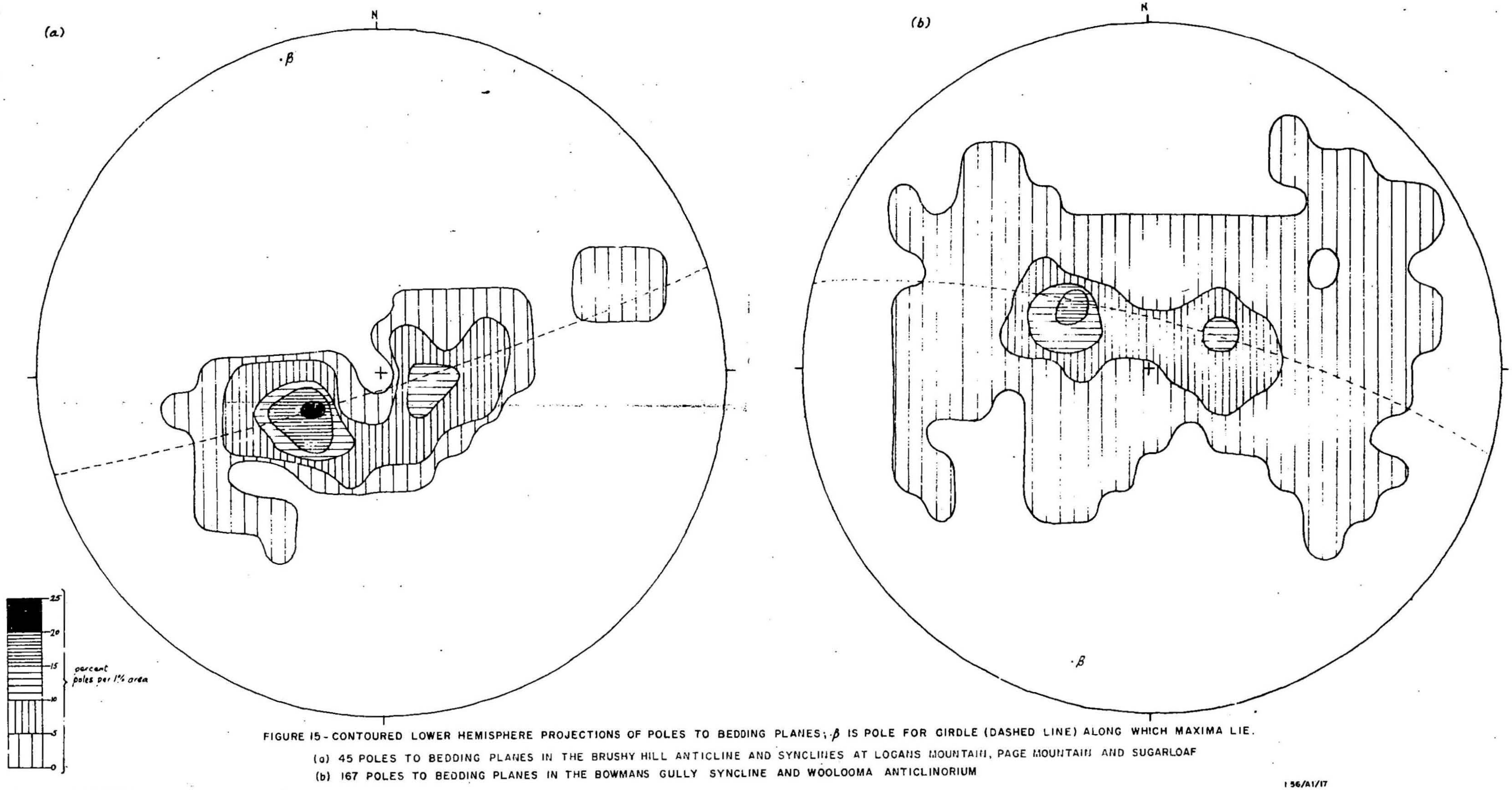


FIGURE 15 - CONTOURED LOWER HEMISPHERE PROJECTIONS OF POLES TO BEDDING PLANES; β IS POLE FOR GIRDLE (DASHED LINE) ALONG WHICH MAXIMA LIE.

(a) 45 POLES TO BEDDING PLANES IN THE BRUSHY HILL ANTICLINE AND SYNCLINES AT LOGANS MOUNTAIN, PAGE MOUNTAIN AND SUGARLOAF

(b) 167 POLES TO BEDDING PLANES IN THE BOWMANS GULLY SYNCLINE AND WOOLOOMA ANTICLINORIUM

To accompany Record 1972/119

I 56/A1/17

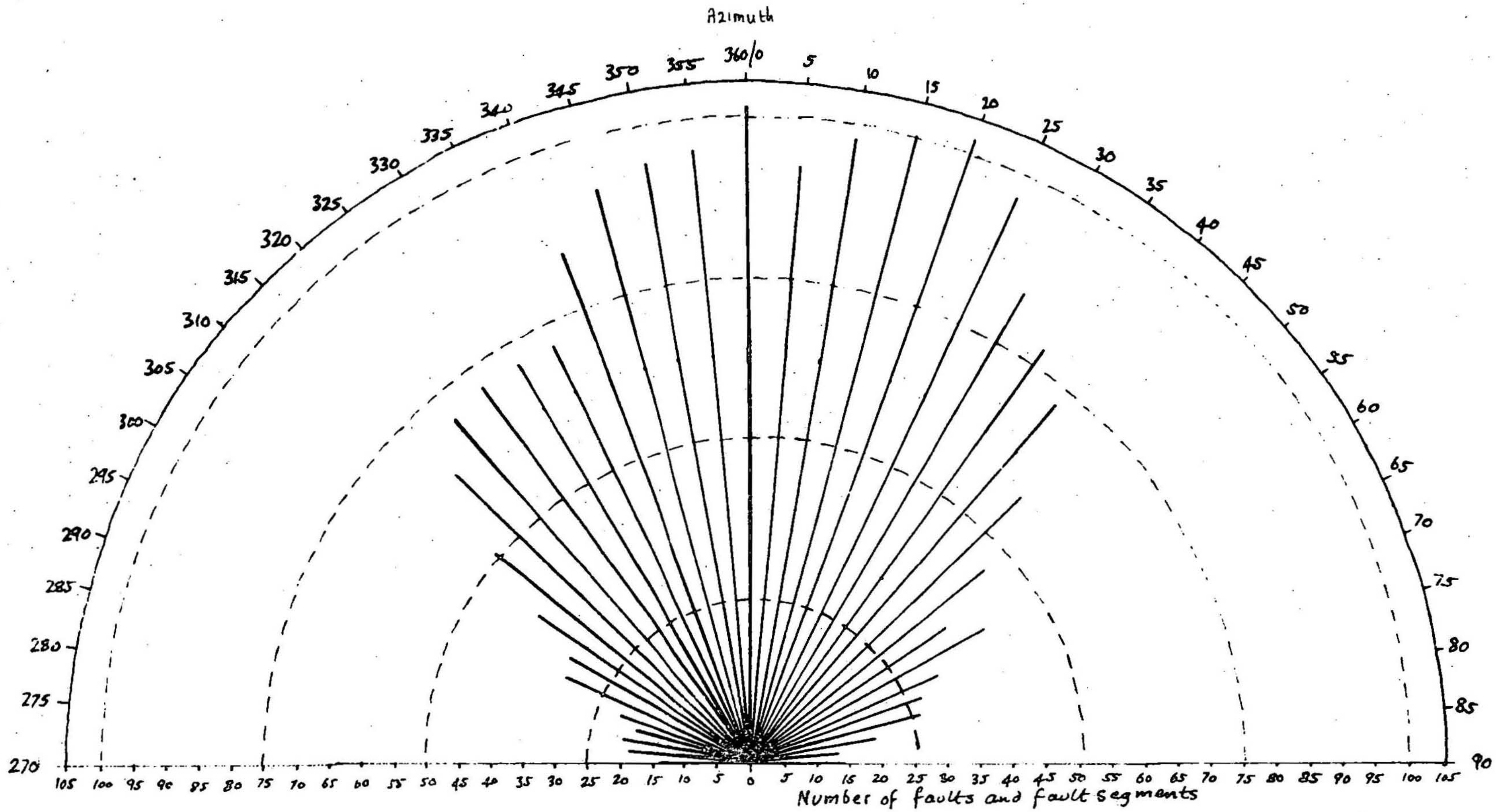


FIGURE 16 - STRIKE OF 2.090 FAULTS AND FAULT SEGMENTS PLOTTED AT 5-DEGREE CLASS INTERVALS

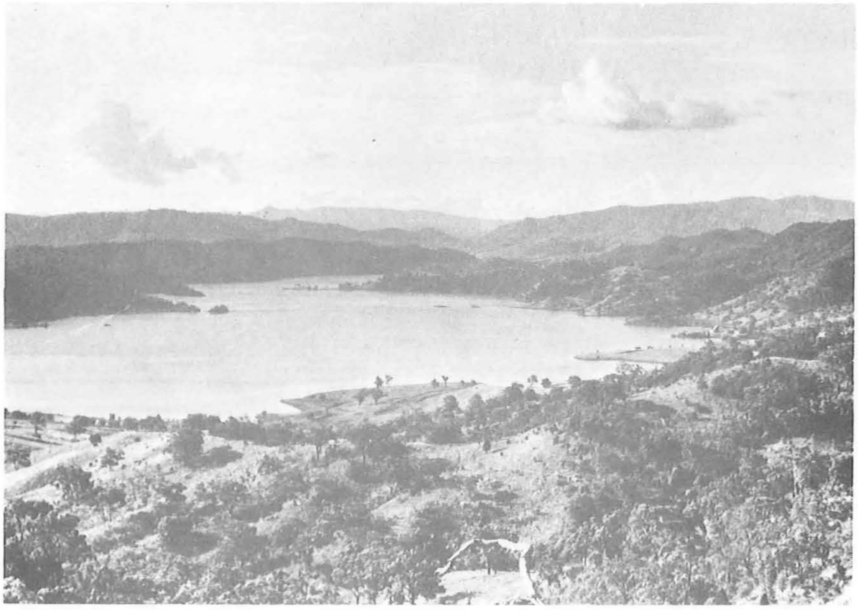


Plate 1. Figure 1. Looking north-northwest from Curra Keith across Glenbawn Dam to the Brushy Hill Anticline.

Plate 1. Figure 2. Cleaved siltstone in the Goonoo Goonoo Mudstone at Lapstone Gully.

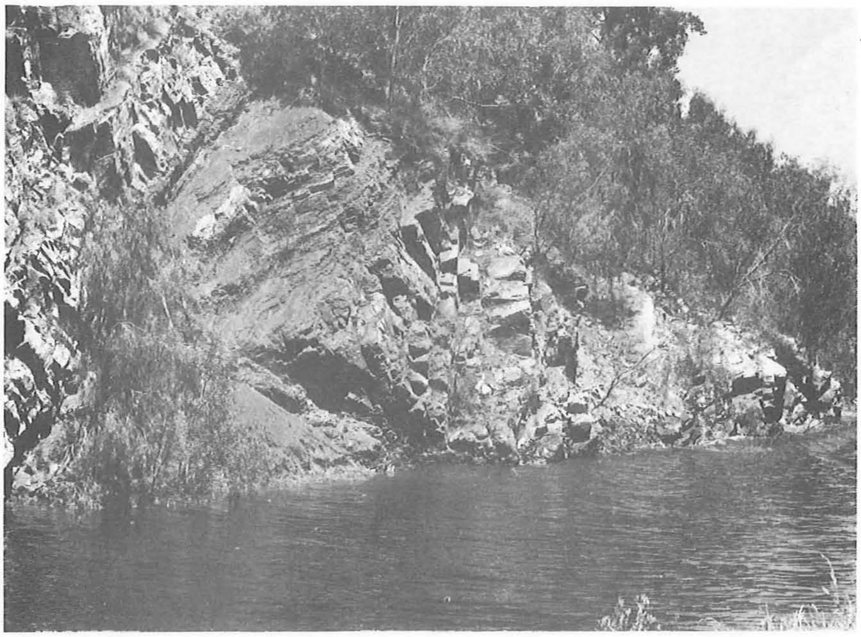


Plate 2. Figure 1. Interbedded purple shale and tuffaceous sandstone in the type section of the Kingsfield Beds, immediately downstream from the outlet of Glenbawn Dam.

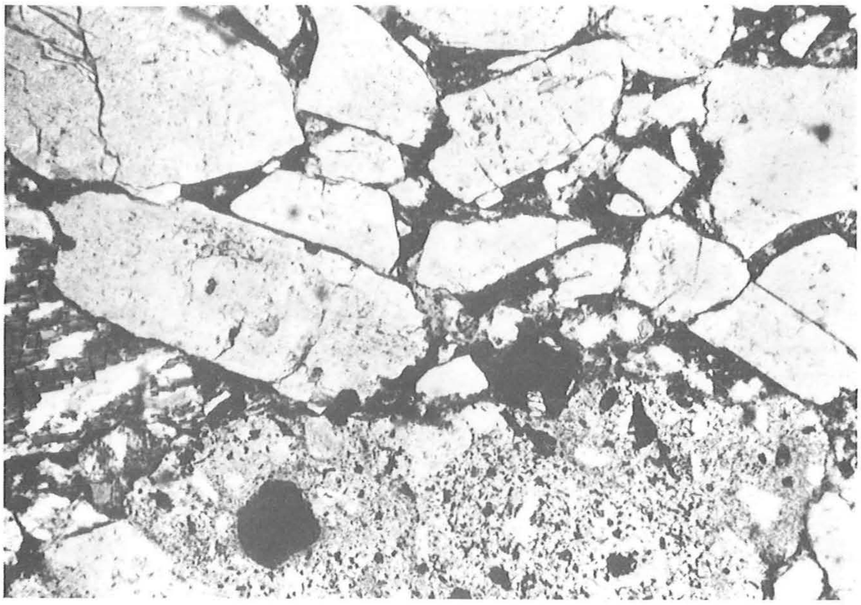


Plate 2. Figure 2. An unreworked airfall crystal-lithic tuff from locality 1-1, Kingsfield Beds. 69/82/0001, plain-polarized light, X 60.

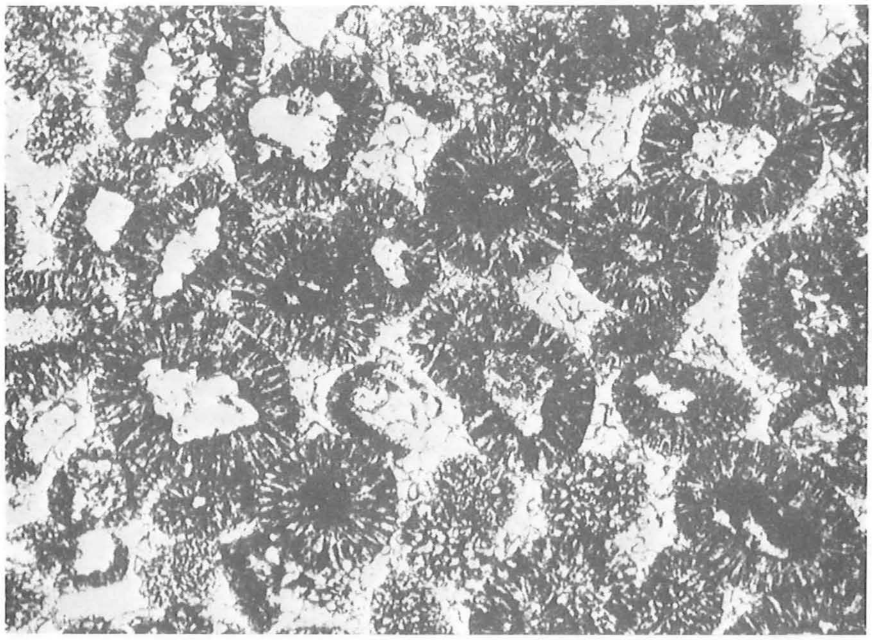


Plate 3. Figure 1. Oolites with nuclei of terrigenous fragments in the Brushy Hill Limestone Member of the Dangarfield Formation; 69/82/0008, locality 1-9, plain-polarized light, X 73.

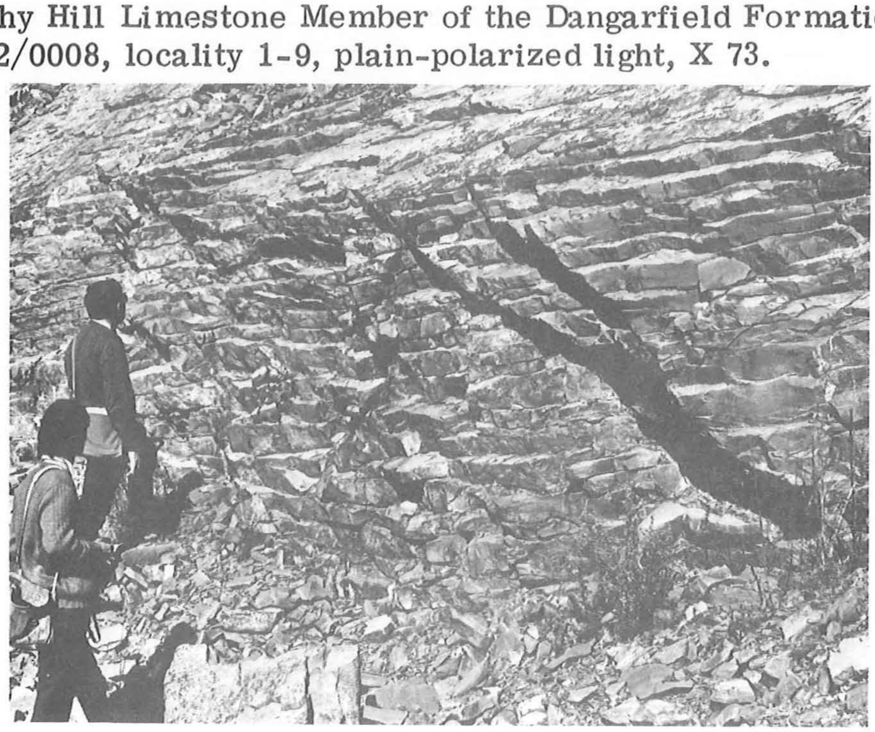


Plate 3. Figure 2. An exposure of the Brushy Hill Limestone Member south of the wall of Glenbawn Dam.

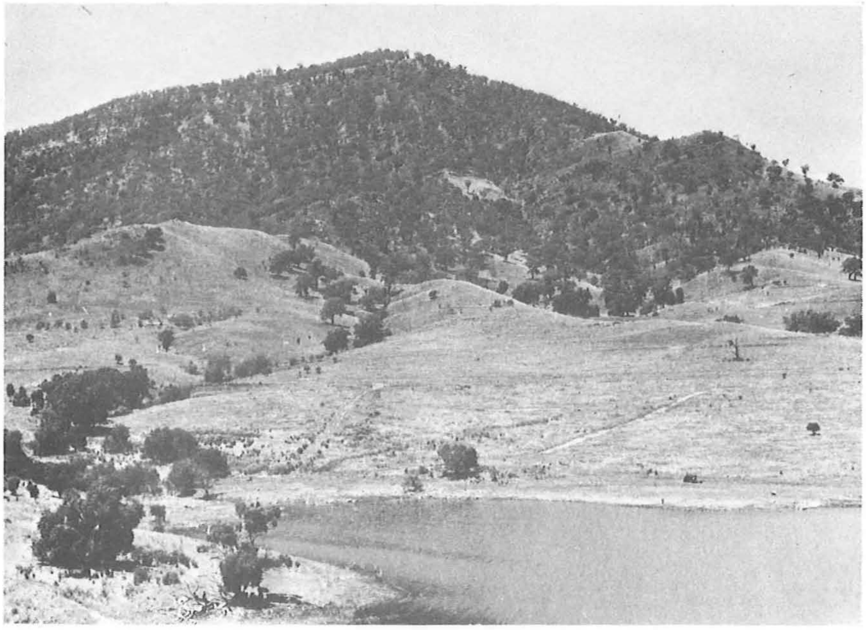


Plate 4. Figure 1. Looking east across Glenbawn Dam. The Dangarfield Formation, comprising soft mudstones (foreground) and resistant sandstones, is overlain near the top of the scarp by the Isismurra Formation.

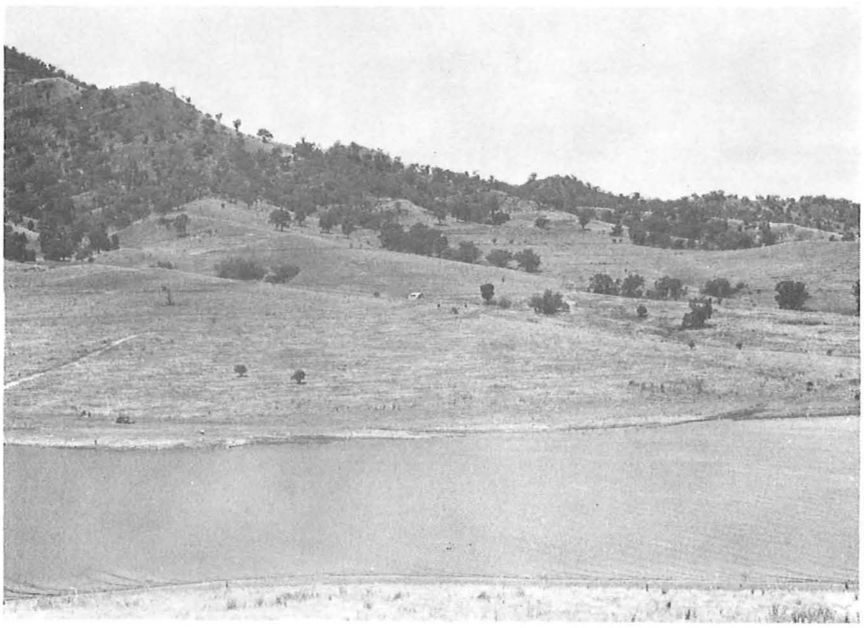


Plate 4. Figure 2. A view south of the previous figure showing mudstone and a resistant ridge of sandstone in the Dangarfield Formation.

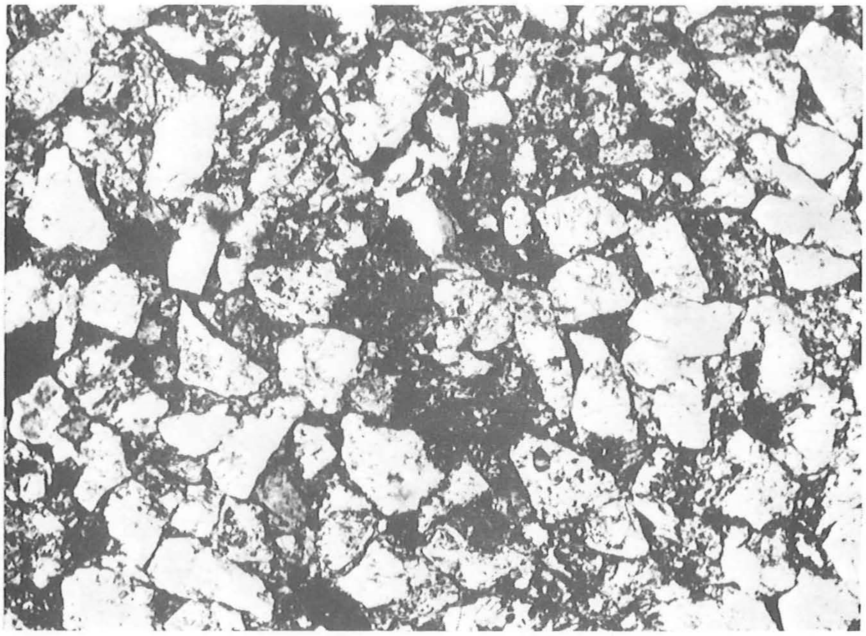


Plate 5. Figure 1. Fine-grained lithic sandstone with a chloritic matrix, locality 1-13, Dangarfield Formation. 69/82/0011, plain-polarized light, X 73.

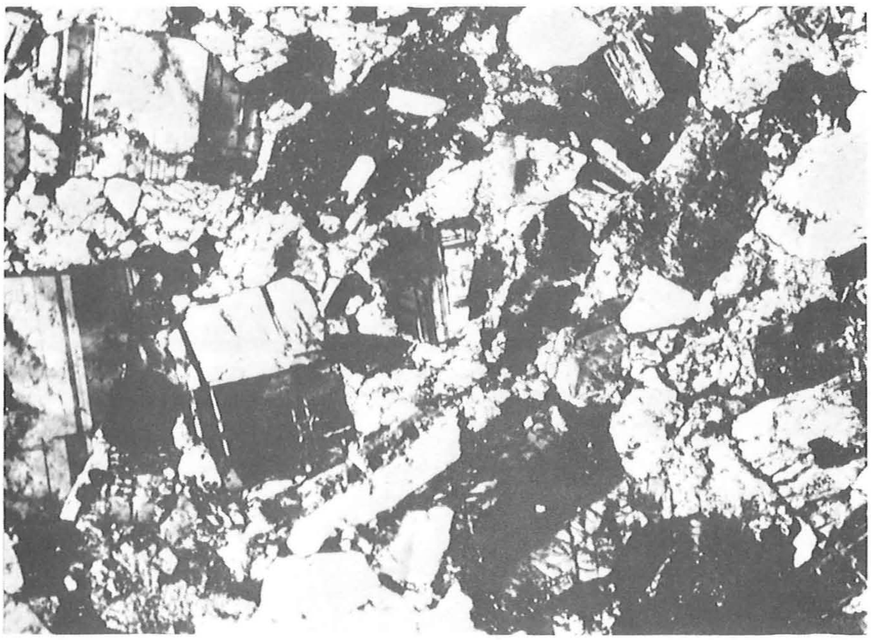


Plate 5. Figure 2. Coarse-grained feldspathic sandstone with a cement of calcite from resistant ridge-forming beds at locality 1-20, Dangarfield Formation. 69/82/0016, crossed nicols, X 44.

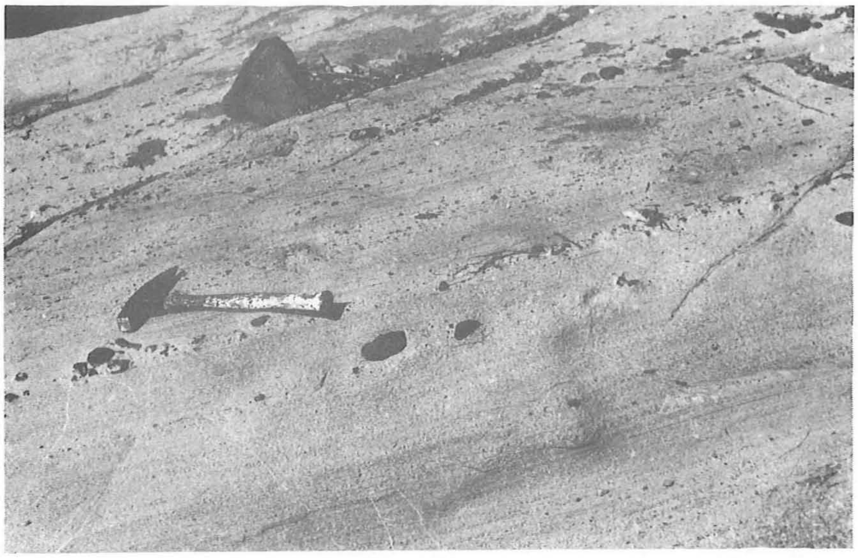


Plate 6. Figure 1. Plain-bedded pebbly sandstone in the Waverley Formation (Section 47) at Sandy Creek.

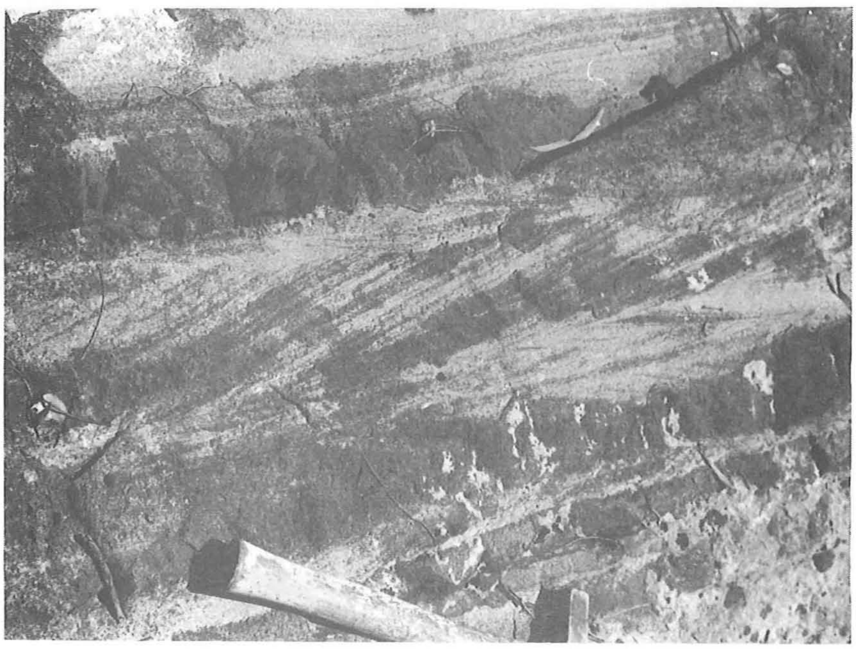


Plate 6. Figure 2. Epsilon cross-bedding in the Waverley Formation, locality 39-11, Back Creek.

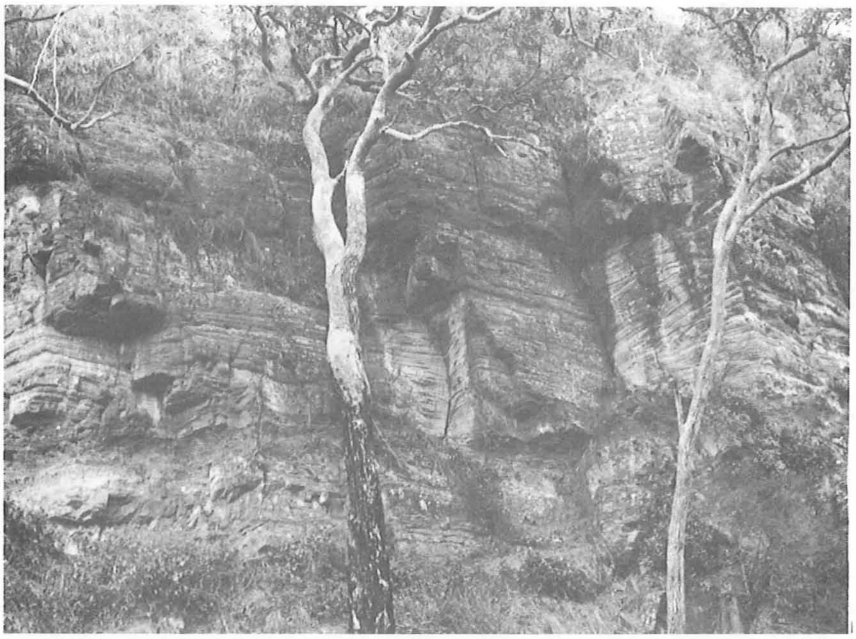


Plate 7. Figure 1. A cliff of sandstone in the Waverley Formation on the southern bank of Rouchel Brook at the eastern extremity of the map sheet.

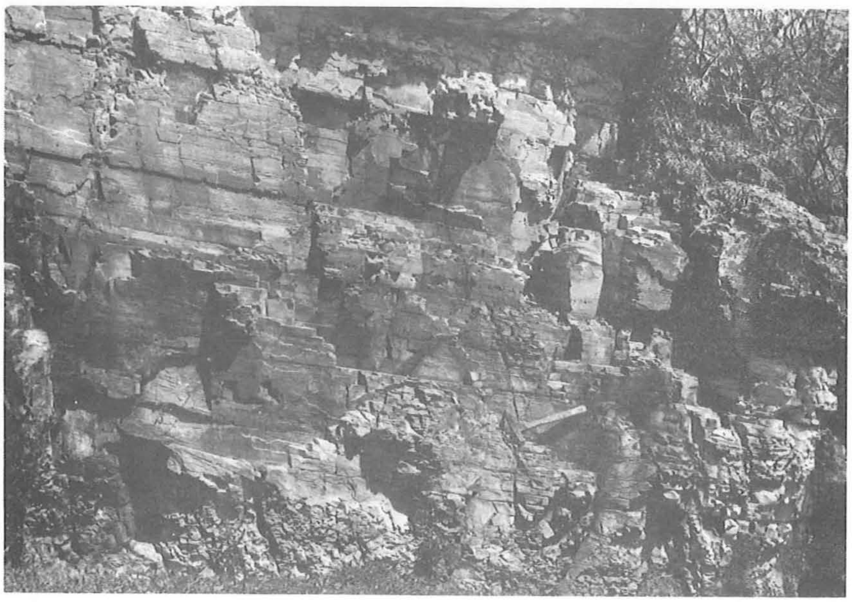


Plate 7. Figure 2. Thinly bedded siltstone towards the top of the Waverley Formation, Section 39, Back Creek.

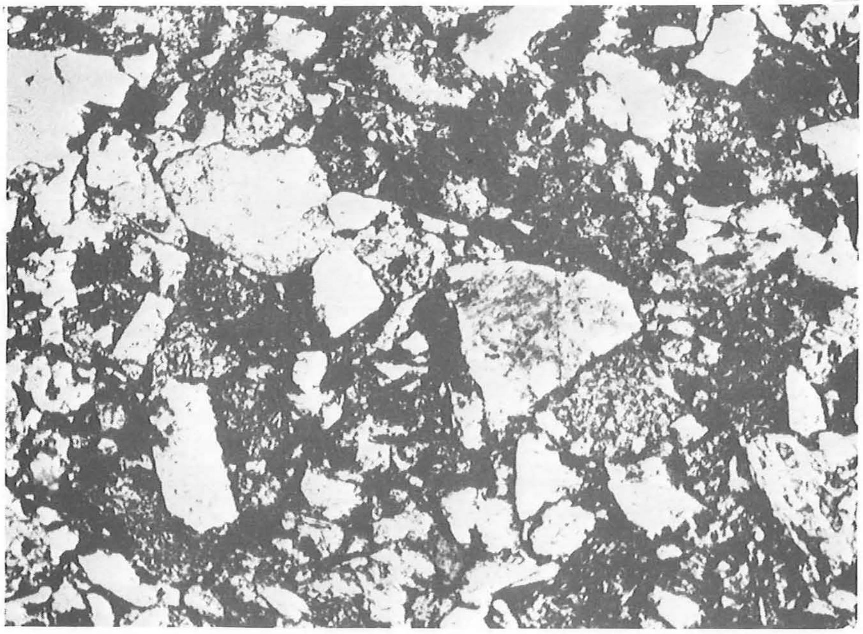


Plate 8. Figure 1. Poorly sorted lithic sandstone with a chloritic matrix from the base of the Waverley Formation; 70/82/0121, Locality 24-1, plain-polarized light, X 73.

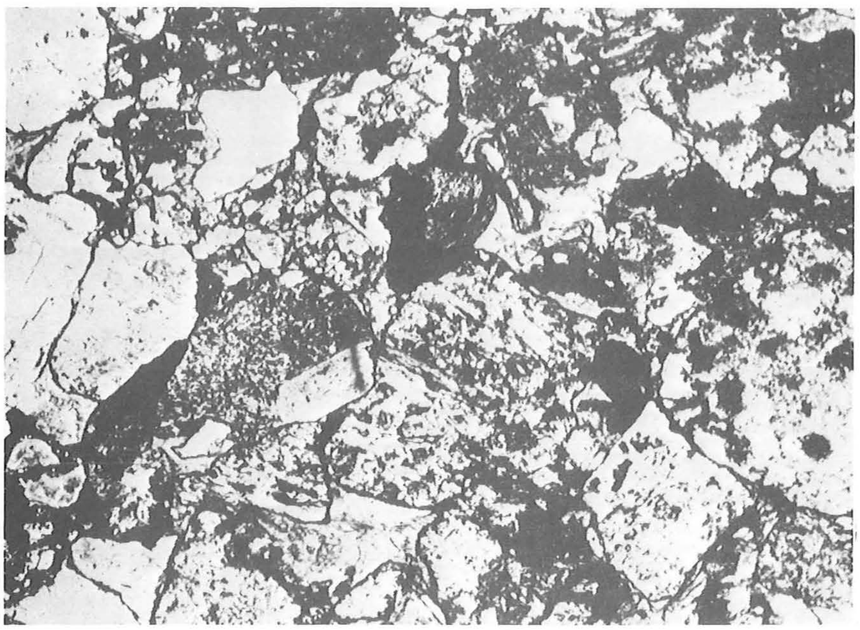


Plate 8. Figure 2. Lithic sandstone with cements of chlorite and heulandite, locality 24-10, Isismurra Formation: 70/82/0136, plain polarized light, X 57.

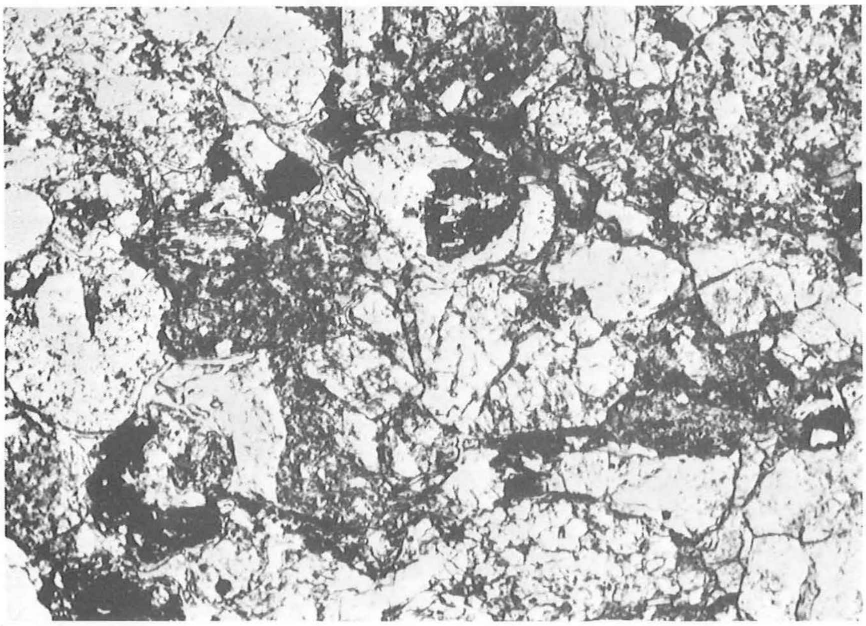


Plate 9. Figure 1. Coarse-grained lithic sandstone from near the top of the Waverley Formation in Section 42 at 'Waverley'. The cement consists of pale-green chlorite, heulandite, and minor calcite. 70/82/0228, plain polarized light, X 57.

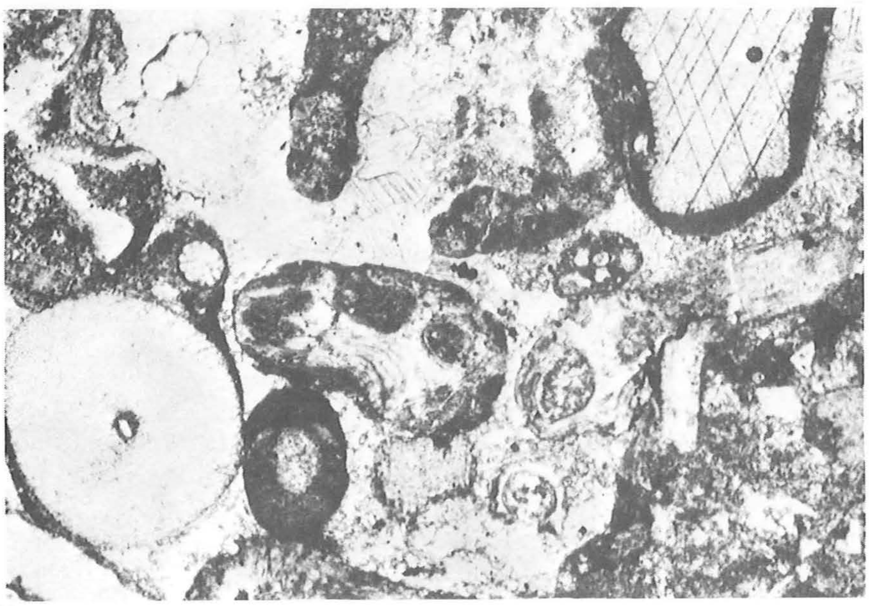


Plate 9. Figure 2. Skeletal calcarenite from the Waverley Formation (basal part of Section 30) in the eastern part of the Rouchel district. 70/82/0147, locality 30-1, plain-polarized light, X 60.

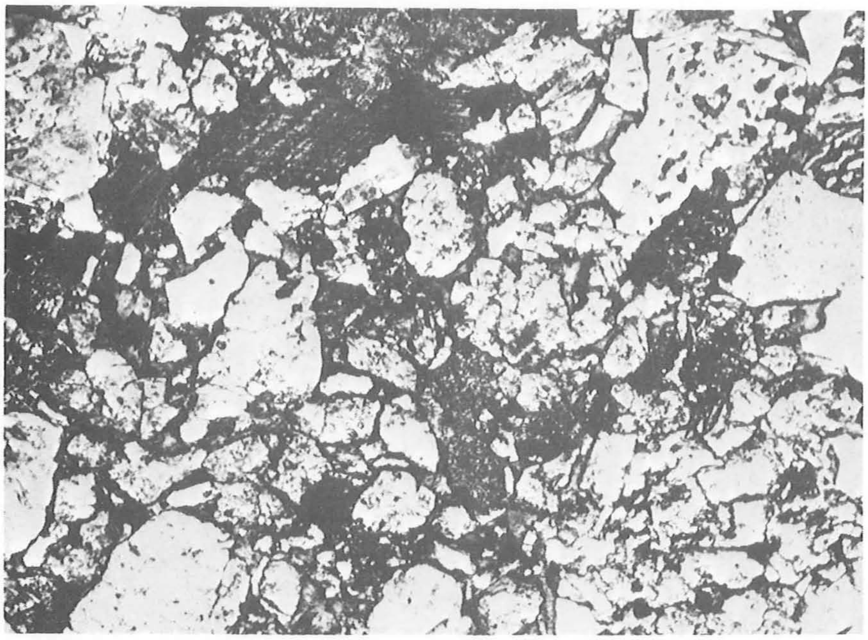


Plate 10. Figure 1. Lithic sandstone with detrital calcite and fragment of micrographic granite from the lower part of the Woolooma Formation at Malumla (Section 30); calcite, chlorite and heulandite replace a fine-grained matrix. 70/82/0153, locality 30-8, plain-polarized light, X 44.

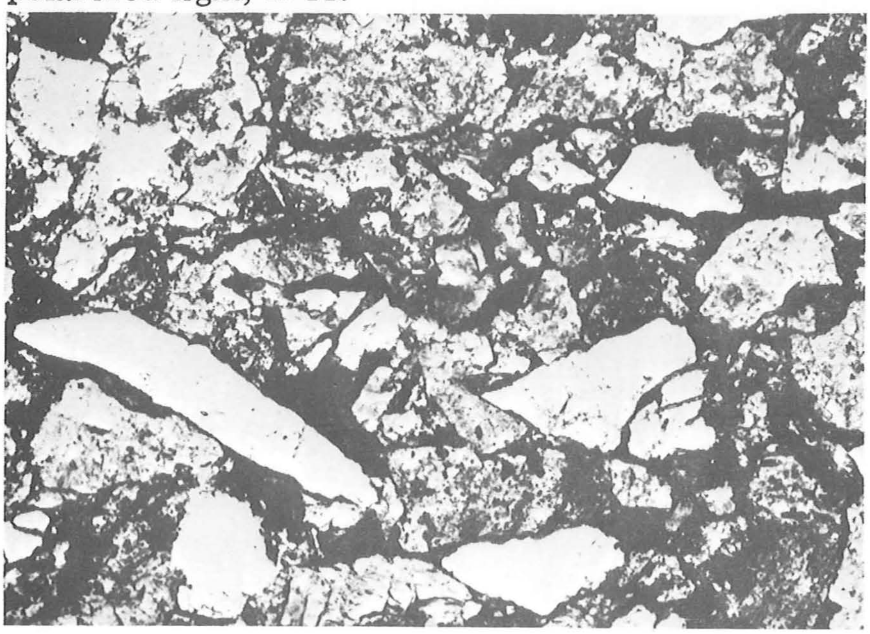


Plate 10. Figure 2. Poorly sorted lithic sandstone from near the top of the Woolooma Formation at Mt. Scrumlo 70/82/0160, locality 32-5, plain-polarized light, X 73.

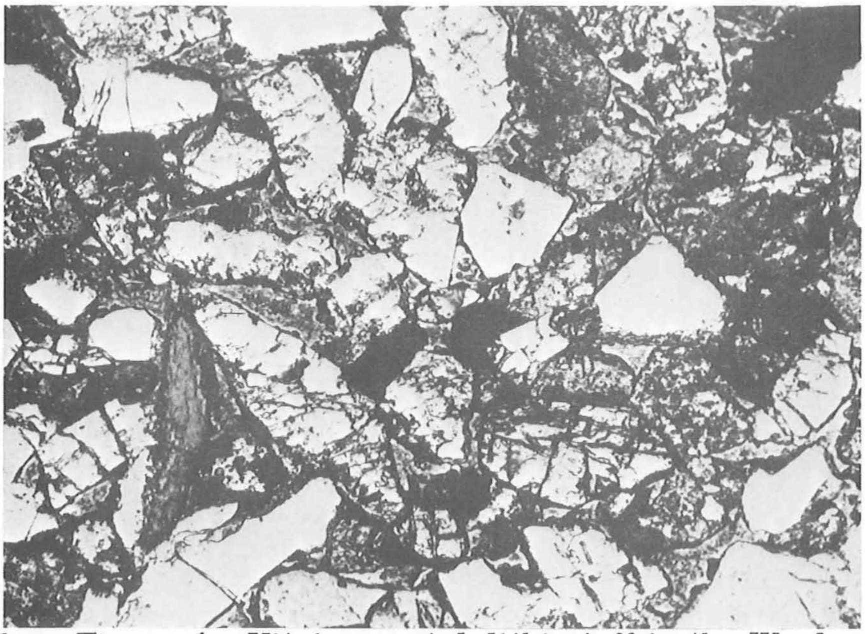


Plate 11. Figure 1. Vitric crystal-lithic tuff in the Woolooma Formation at Back Creek (Section 17). The tuff is interbedded with fossiliferous siltstone and may be a lateral equivalent of the Oakfields Ignimbrite tongue of the Isismurra Formation. 70/82/0141, locality 17-9, plain-polarized light, X 73.

Plate 11. Figure 2. Sandy skeletal calcarenite from the Woolooma Formation (Section 6) at Stony Creek. Allochemical grains are rimmed by dark brown algal layers. 69/82/0050, locality 6-12, plain polarized light, X 44.

Plate 12. Figure 1. Ayr Conglomerate Member of the Isismurra Formation exposed in a road cutting 4 km southeast of Rouchel Brook village.

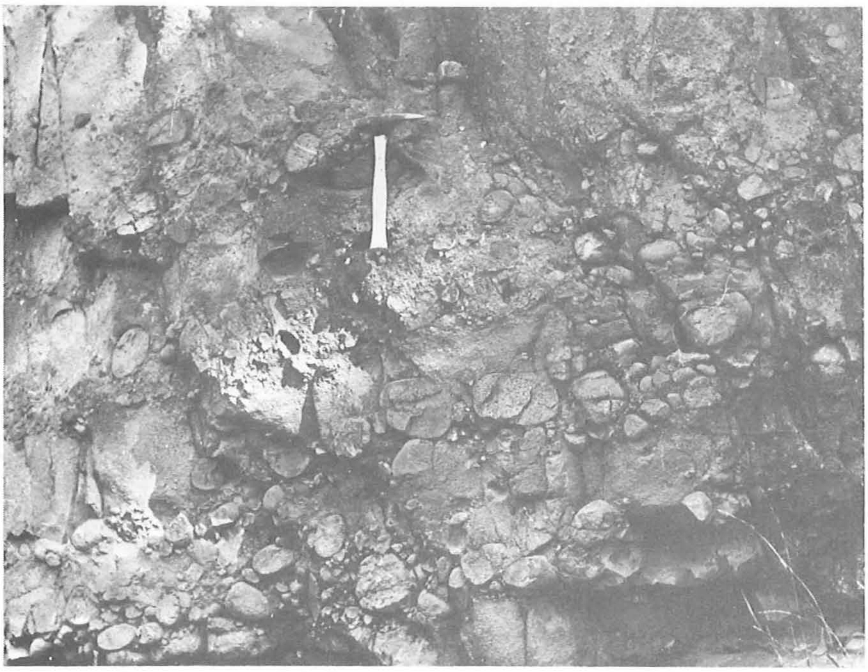


Plate 12. Figure 2. Stringers of conglomerate in zeolitic lithic sandstone in the Isismurra Formation at the base of Section 17, Back Creek. Locality 17-2, western side of anticlinal nose.

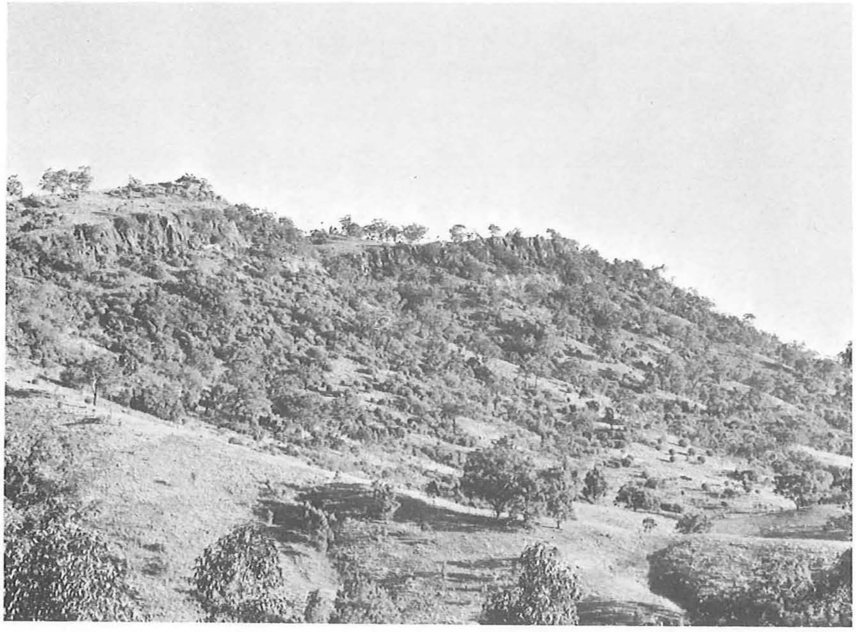


Plate 13. Figure 1. Cliffs of Curra Keith Ignimbrite Tongue on the north-western slope of Benmore.

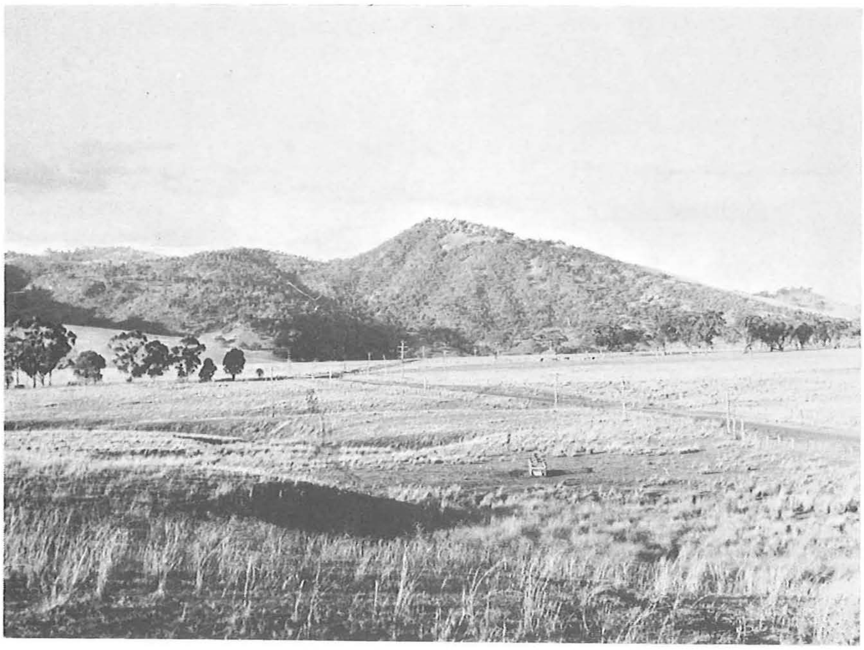


Plate 13. Figure 2. The Oakfields Ignimbrite Tongue forming the dip-slope on Wallaby between Aberdeen and Rouchel Brook village.

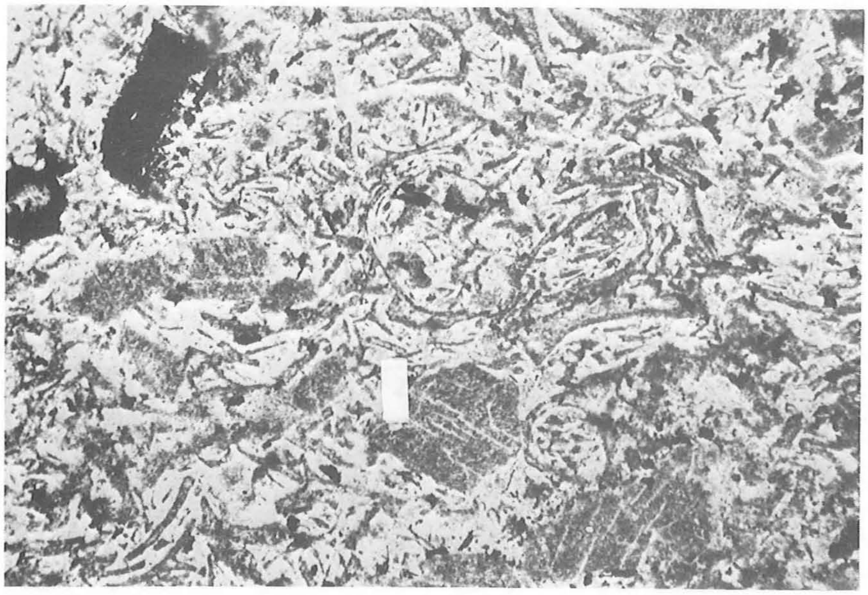


Plate 14. Figure 1. Non-welded ignimbrite from the Curra Keith Tongue, Isismurra Formation. 70/82/0072, from section 100, eastern side of Lake Glenbawn, plain-polarized light, X 60.

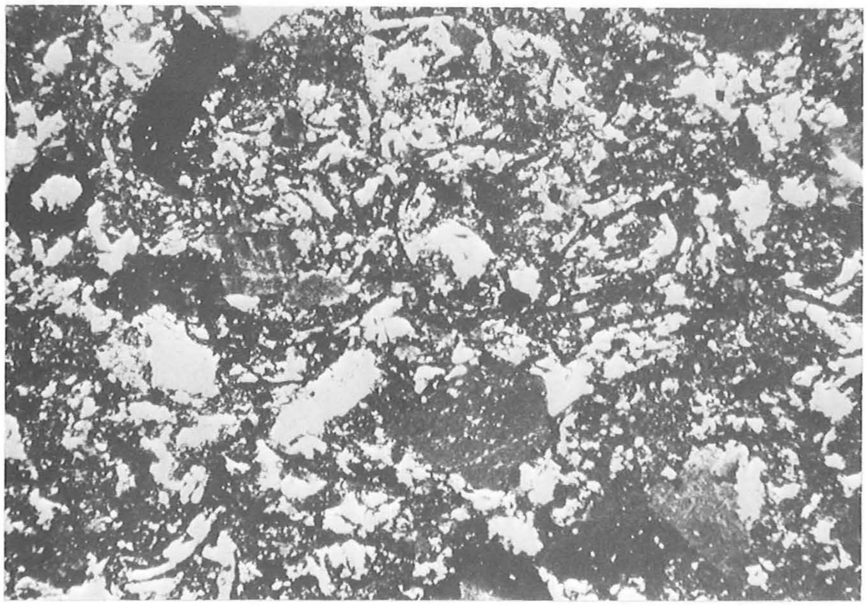


Plate 14. Figure 2. The same, showing relatively coarse microcrystalline groundmass, some of which may be vapour-phase crystallization which originally cemented the rock. Crossed nicols.

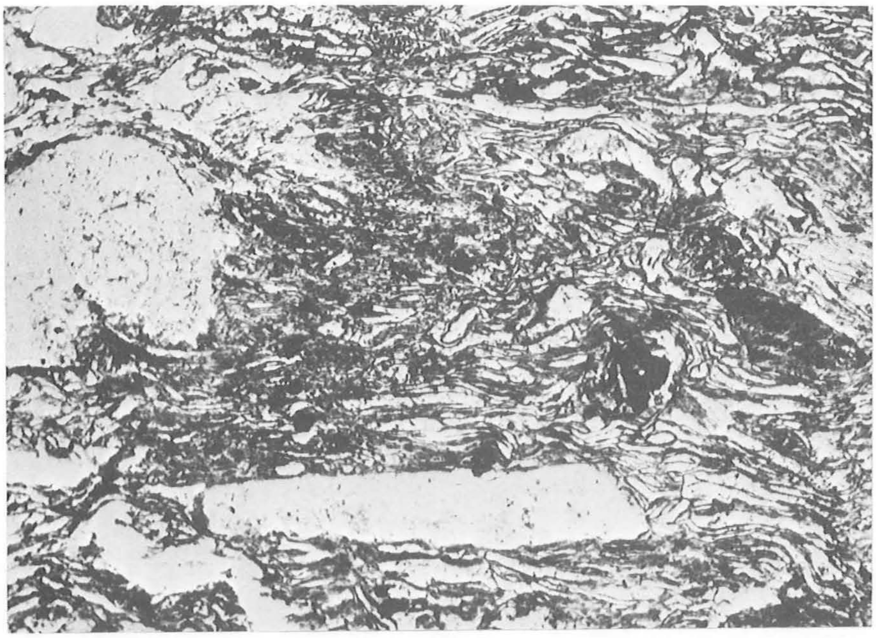


Plate 15. Figure 1. Thoroughly welded ignimbrite from the Oakfields Tongue, Isismurra Formation, near Native Dog Gully. 70/82/0106, plain-polarized light, X 57.

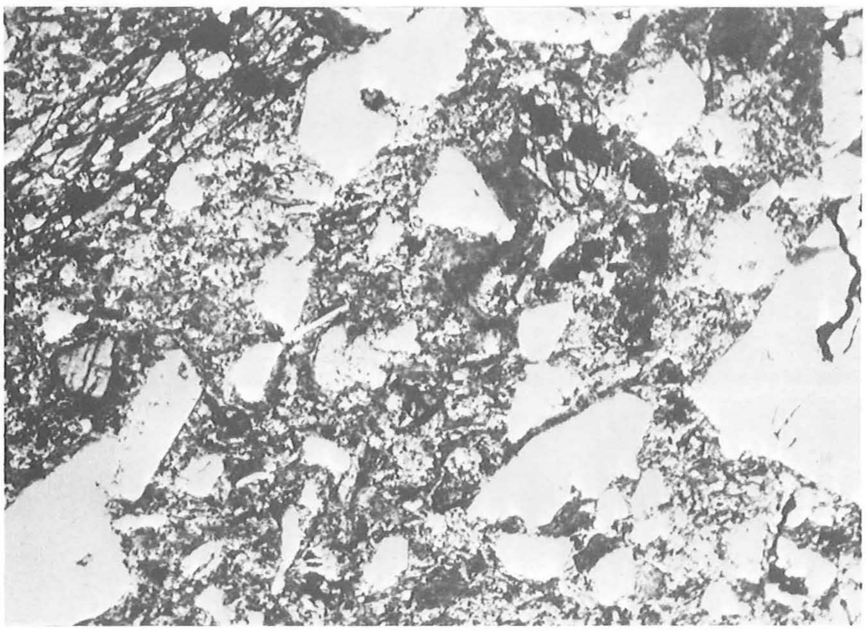


Plate 15. Figure 2. Non-welded ignimbrite from the Oakfields Tongue, Isismurra Formation; hornblende in this rock has given K/Ar dates of 308 $\pm$ 6 my and 309 $\pm$ 6 my (Appendix 4), 70/82/0107 from Sandy Creek near "Arkana", plain-polarized light, X 44.

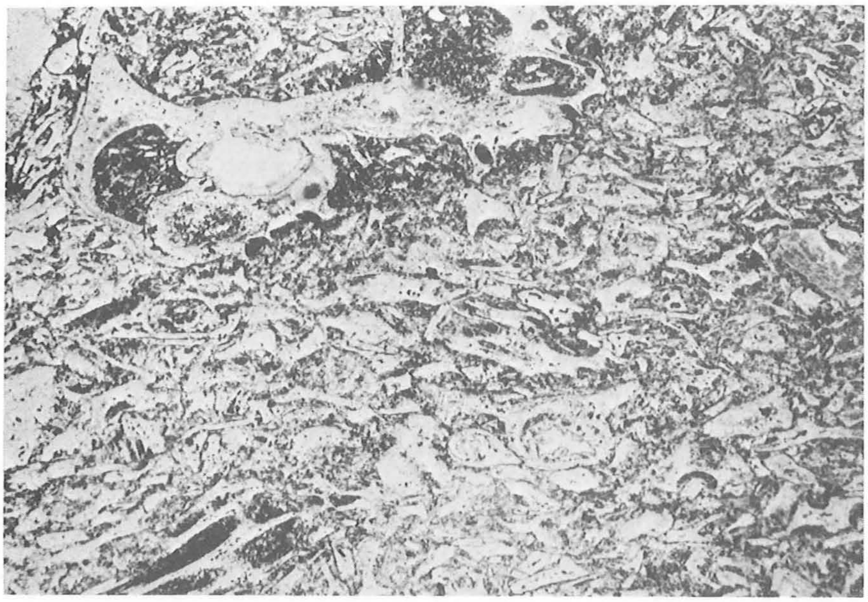


Plate 16. Figure 1. Slightly welded ignimbrite from ignimbrite "b", Isismurra Formation. 70/82/0204, near Bowmans Creek village, plain-polarized light, X 60.

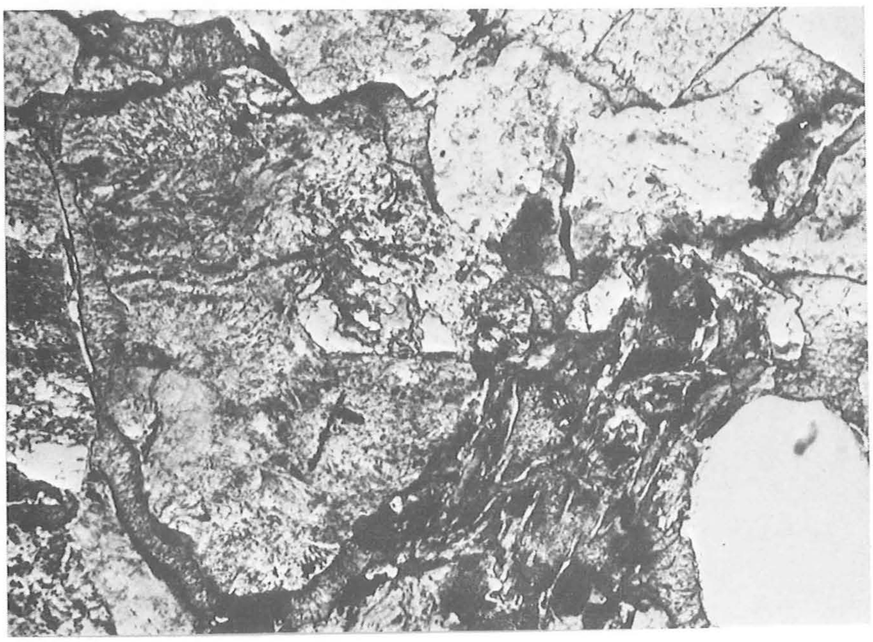


Plate 16. Figure 2. Zeolitic lithic sandstone from the Isismurra Formation (Section 37) at "Mullee". 70/82/0169, locality 37-5, plain-polarized light, X 73.

Plate 17. Figure 1. Native Dog Ignimbrite Member, Isismurra Formation, at Darkie near McCullys Gap.

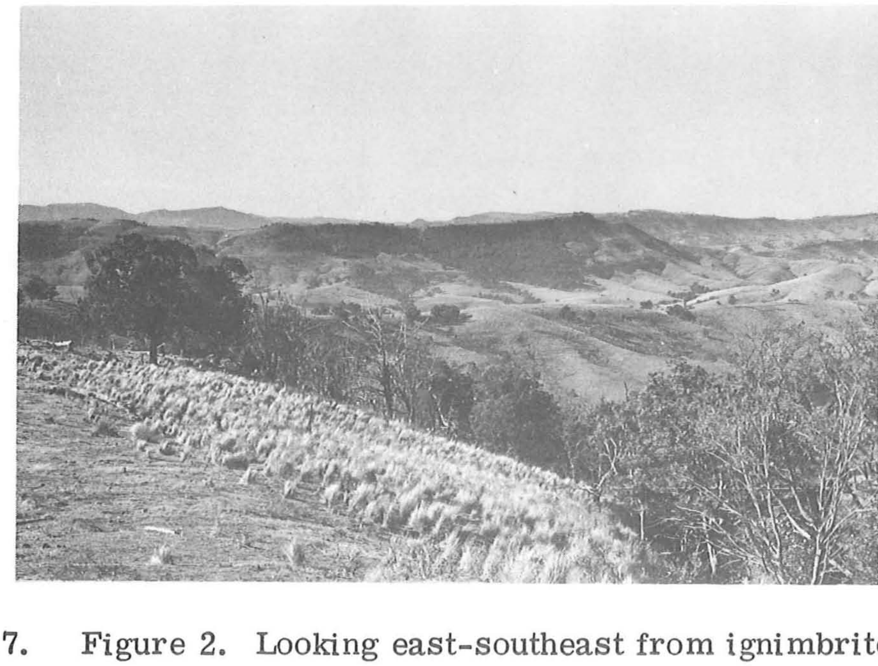


Plate 17. Figure 2. Looking east-southeast from ignimbrite D, near the Rouchel Brook - Bowmans Creek Road, towards undifferentiated Upper Carboniferous sediments which overlie the Isismurra Formation.

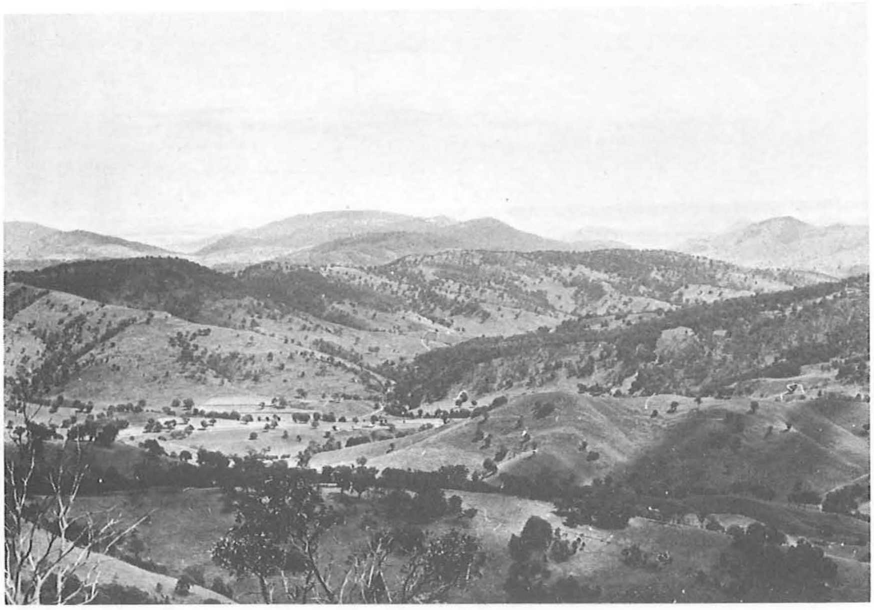


Plate 18. Figure 1. The Davis Creek Syncline viewed from Mt. Scrumlo. The strongly ribbed ridge in the middle distance is a fault block containing Isismurra Formation.

Plate 18. Figure 2. The southern margin of Brushy Hill Anticline exposing volcanics in the Kingsfield Beds, and the overlying Brushy Hill Limestone Member of the Dangarfield Formation; looking north from the axis of the Albano Syncline.

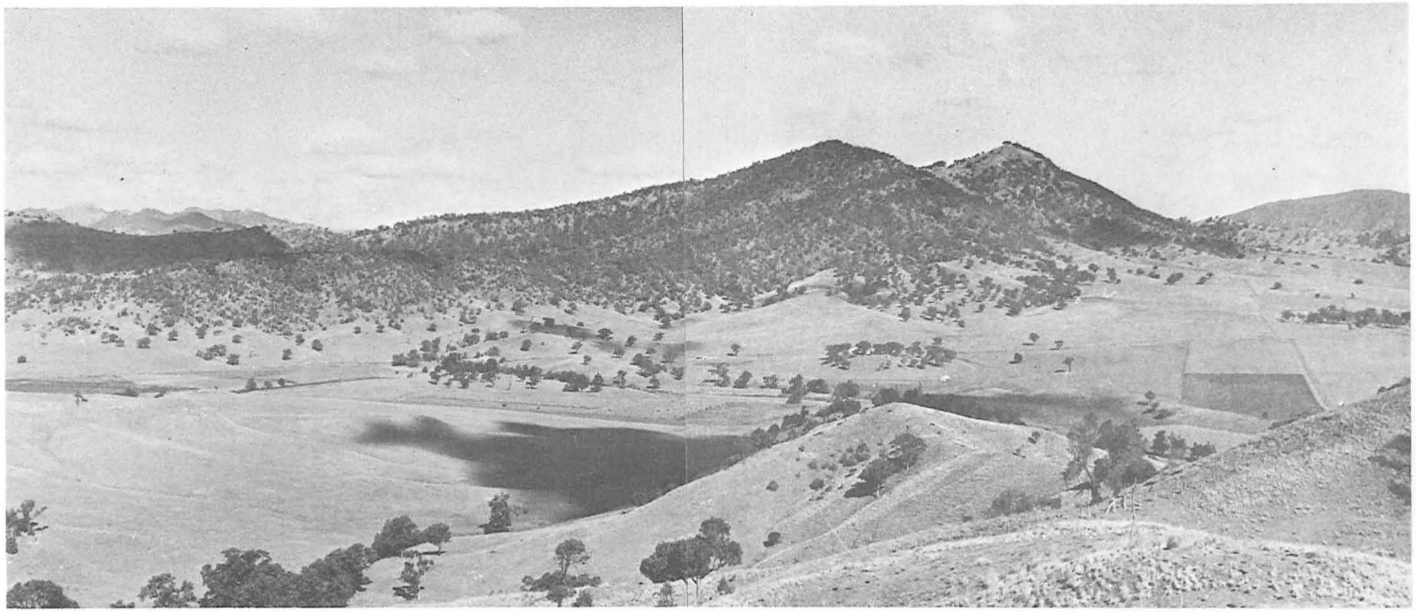
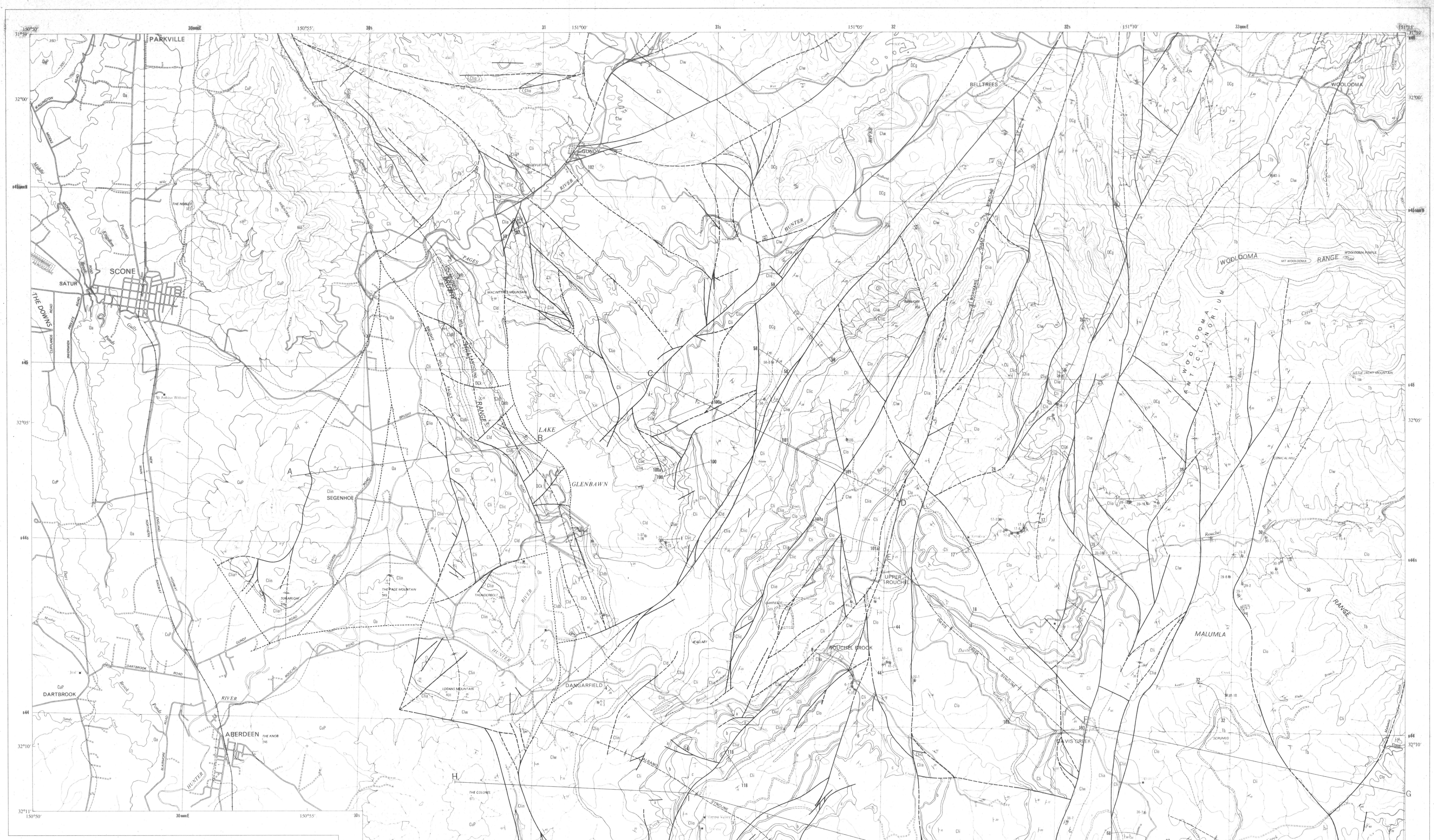


Plate 19. Looking south from the southern margin of the Brushy Hill Anticline to the closure of the Albano Syncline.



Reference

CAINOZOIC	QUATERNARY		Qa	Alluvium
	TERTIARY		Tb	Basic lavas and intrusives
PALAEOZOIC	UPPER CARBONIFEROUS AND PERMIAN		CuP	Undivided
	LOWER CARBONIFEROUS	Isismurra Formation	Cli	Coarse lithic sandstone and conglomerate, welded and nonwelded tuffs
		Unnamed tuffs near "Albano"	d	Dark grey welded tuff
			c	Purple welded tuff, red nonwelded tuff
			b	Purple welded tuff, red nonwelded tuff
			a	Red nonwelded tuff
		Unnamed tuffs North and East of "Albano"		Red nonwelded tuff
		Native Dog Member	Clin	Purple and buff welded tuff, red nonwelded tuff
		Oakfields Tongue	Clio	Purple welded tuff and red nonwelded tuff
		Curra Keith Tongue	Clic	Buff welded and nonwelded tuff
		Ayr Conglomerate	Clia	Coarse lithic conglomerate
		Woolooma Formation	Clo	Siltstone, mudstone, sandstone
				Laminated red nonwelded tuff
		Waverley Formation	Clw	Lithic sandstone and conglomerate
		Dangarfield Formation	Cld	Mudstone, lithic sandstone, limestone
		Brushy Hill Limestone	Cldb	Oolitic limestone
	UPPER DEVONIAN? AND LOWER CARBONIFEROUS	Kingsfield Beds	DCk	Mudstone, sandstone, volcanics
		Goonoo Goonoo Mudstone	DCg	Mudstone, sandstone

- Geological boundary
- Anticline
- Syncline
- Fault
- Fault, showing relative movement (Sections only)

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, folds and faults are shown by short dashes

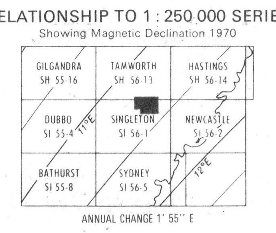
- 35 Strike and dip of strata
- Horizontal strata
- Vertical strata
- 41-2 Macrofossil locality with reference number
- 6 — 6 Measured section

- Highway
- Road
- Vehicle track
- Railway with station
- "Albano" Homestead
- 500 Topographic contour. Contour interval 50 metres
- 246 Elevation in metres—approximate

GEOLOGY OF THE ROUCHEL DISTRICT,
HUNTER VALLEY, NEW SOUTH WALES

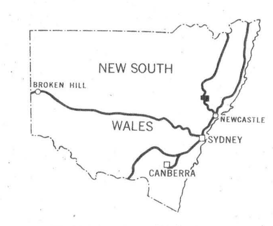
Scale 1 : 50 000

RELATIONSHIP TO 1 : 250 000 SERIES
Showing Magnetic Declination 1970

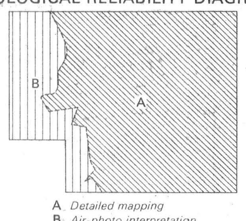


ANNUAL CHANGE 1′ 55″ E

TRANSVERSE MERCATOR PROJECTION
GREY NUMBERED LINES ARE 5000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 56
HORIZONTAL DATUM : AUSTRALIAN GEODETIC DATUM, 1966



GEOLOGICAL RELIABILITY DIAGRAM



A Detailed mapping
B Air-photo interpretation

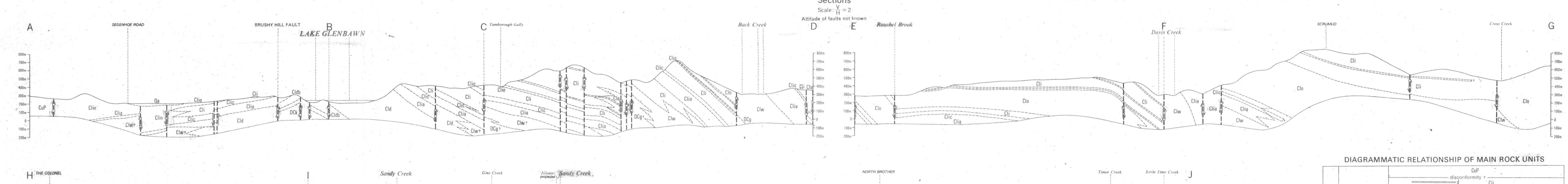
Published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Minister for National Development
Base map compiled by B.M.R. from New South Wales Department of Lands Standard 1 : 31 680 Map Series Aberdeen, Parkville, Scone and Waverley and Royal Australian Army 1 : 63 360 Map Series Camberwell, Muswellbrook and Woolooma. Metric contours interpolated

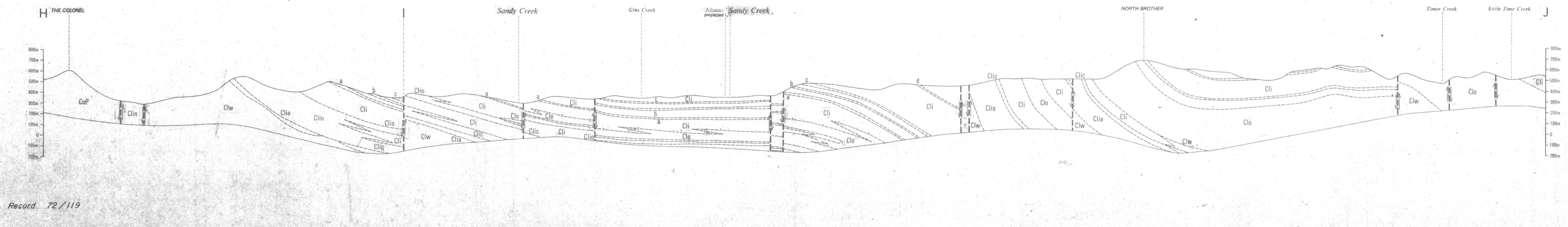
Geology 1969-71 by B. S. Oversby, J. Roberts
Compiled 1971 by B. S. Oversby, J. Roberts, M. R. Moffat
Cartography by Geological Branch, B M R
Drawn 1972 by M. R. Moffat

Sections

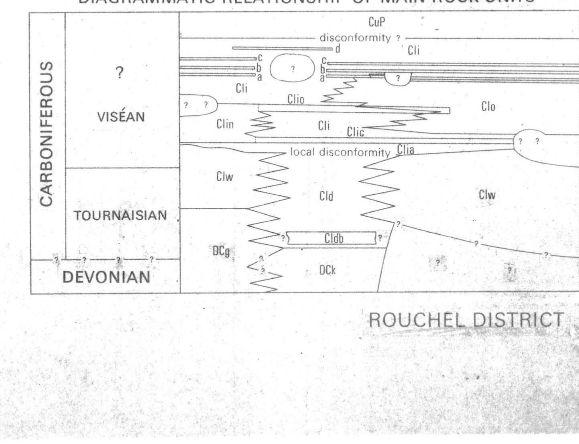
Scale: $\frac{V}{H} = 2$

Attitude of faults not known





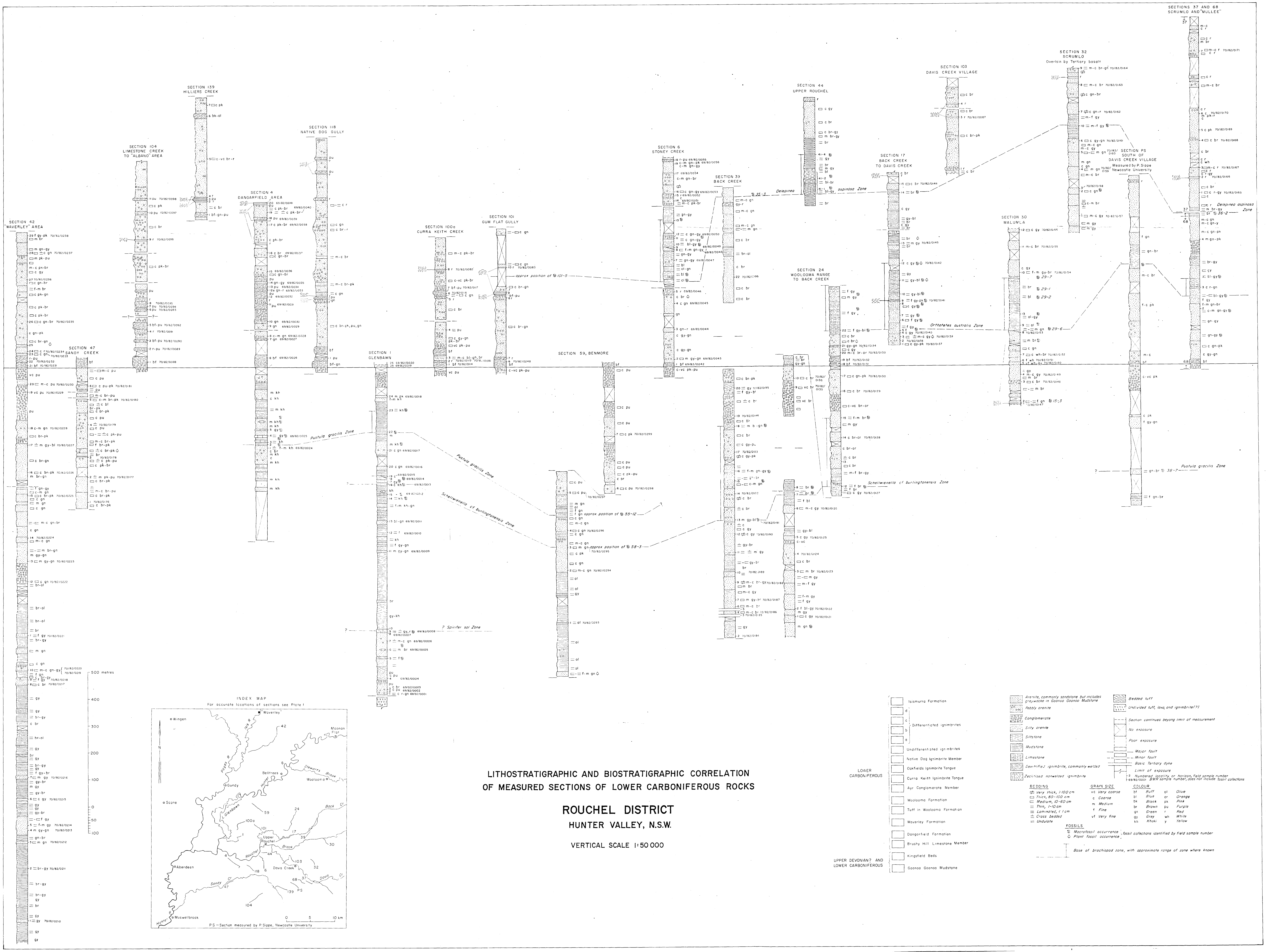
DIAGRAMMATIC RELATIONSHIP OF MAIN ROCK UNITS



ROUCHEL DISTRICT 1 : 50 000, 1972

To Accompany Record 72/119

I56/A1/22



LITHOSTRATIGRAPHIC AND BIOSTRATIGRAPHIC CORRELATION OF MEASURED SECTIONS OF LOWER CARBONIFEROUS ROCKS

ROUCHEL DISTRICT

HUNTER VALLEY, N.S.W.

VERTICAL SCALE 1:50 000

To Accompany Record 72/119