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THE SILESIAN IN AUSTRALIA – A REVIEW

by
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SUMMARY

ABSTRACT: The Silesian in Australia is well defined by faunas at the Viséan – Namurian boundary below, and the Sakmarian above. Between these limits the geology is complicated by tectonism and glaciation, and correlation is hampered by faunal and floral provincialism.

I. *Introduction*

The Upper Carboniferous (Silesian) is poorly represented in Australia. Most sequences are known from eastern Australia, where both marine and non-marine strata are represented. In central and western Australia widespread occurrences of Silesian rocks have been reported. In general the Australian Silesian sequence contains glacigene sediments (CROWELL & FRAKES, 1971).

Carboniferous rocks were first described from Australia by STRZELECKI (1845) from the Hunter Valley, New South Wales, from a sequence now referred to the Silesian. Most of his fossil collection was described by MORRIS (LONSDALE described the polyzoans and corals), who concluded that "the deposits containing them may probably belong to that division of the Palaeozoic series, usually termed carboniferous". STRZELECKI'S (1845, pp. 88-9) observations of the sequence exposed on the steep banks of the River Karuah, west of Stroud, are remarkably accurate, in terms of present-day interpretations. There is no doubt that the tripartite sequence ("siliceous breccia, slaty blue argillaceous rock, and sandstone and conglomerate") which he described as overlying

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greenstones (= Nerong Volcanics), refer to the Karuah, Booral, and Isaacs Formations of CAMPBELL (1961). The rich fauna of gastropods, ostracods, *Spirifer*, and fish remains, which STRZELECKI described from Booral, probably belong to the *Levipustula levis* Zone of the Booral Formation, (CAMPBELL, 1961). STRZELECKI suggested that the "sandstones and conglomerates" of his uppermost unit in the Booral district, (i.e. the Isaacs Formation) "at least in a mineralogical point of view" are similar to those of Raymond Terrace (i.e., Lower Permian Dalwood Group and Branxton Formation of the Maitland Group). It is to his credit that he was aware that such a lithological correlation lacked palaeontological control, "for the absence of natural sections precludes the discovery of the fossils".

Considerable information on the Silesian has been published by various authors; a recent synthesis of the Carboniferous System has been given by BROWN et al., (1968). A detailed account of the sequence and affinities of eastern Australian Carboniferous invertebrates has been provided by CAMPBELL & MCKELLAR (1969).

The present review briefly outlines the geology and fauna of the Silesian of the Australian continent. Not every Silesian outcrop has been considered in detail; rather we have used generalized or typical sections to represent each of the major areas of sedimentation.

These sections are shown on Fig. 2, and the localities appear on the generalized map of the Silesian (Fig. 1).

We thank Dr K.S.W. CAMPBELL (Australian National University) and our BMR colleagues Drs ELIZABETH KEMP and J.M. DICKINS for discussions on various aspects of this paper.

II. *The Viséan — Namurian Boundary*

Palaeontological data are not continuous in those sections which appear to cross the boundary. CAMPBELL & MCKELLAR (1969) have reviewed the evidence and considered that the *Margininugus barringtonensis* Assemblage Zone may span this interval. Their evidence was based on the coral fauna and in addition they pointed out that "*Lissochonetes*, which is found only in the upper part of the zone in one area, is not reliably reported from pre-Namurian rocks anywhere in the world" (op. cit. p. 88). Subsequent faunas are separated by either a stratigraphic break or a disconformity (op. cit. p. 103).

This fauna is extensive in eastern Australia, being known from central Queensland (Baywulla Formation, Yarrol Basin; MCKELLAR, 1965, 1967) to the central coast of New South Wales (uppermost Copeland Road and lowermost Buckets Gap Formations; CAMPBELL & MCKELVEY, 1972). Other Namurian faunas in New South Wales include the sequence with *Cravenoceras* at Kempsey (CAMPBELL, 1962), and possibly the Taree Limestone (PICKETT, 1966).

In eastern Australia sedimentation continued from the Viséan into the Namurian and Westphalian. In Western Australia there is generally a hiatus between the marine Viséan and the dominantly non-marine Upper Carboniferous. In the Bonaparte Gulf Basin VEEVERS & ROBERTS (1968, p. 108) considered that the uppermost beds of the Point Spring Sandstone are Namurian. The Point Spring Sandstone contains *Anthracospirifer milliganensis*, which is close to *A. bisulcatus* Sowerby *sensu stricto*, and its close allies from the Viséan and Namurian of Great Britain and Belgium (THOMAS, 1971, p. 24). ROBERTS (1971, p.22) recognized a subsequent brachiopod fauna, the *Echinoconchus gradatus* Fauna, from sample 458/12. Although this species occurs in the Viséan of eastern Australia it is considered to be Namurian in the Bonaparte Gulf Basin because it is later than *A. milliganensis*. The *Echinoconchus gradatus* Fauna has also been found in Bonaparte No. 1 Well (206-210 m) and Kulshill No. 1 Well (2042-2048 m). The Namurian age is confirmed by the presence of foraminifers indicating the Viséan-Namurian boundary in Bonaparte No. 1 Well in the interval 204-207 m (MAMET & BELFORD, 1968, p. 344).

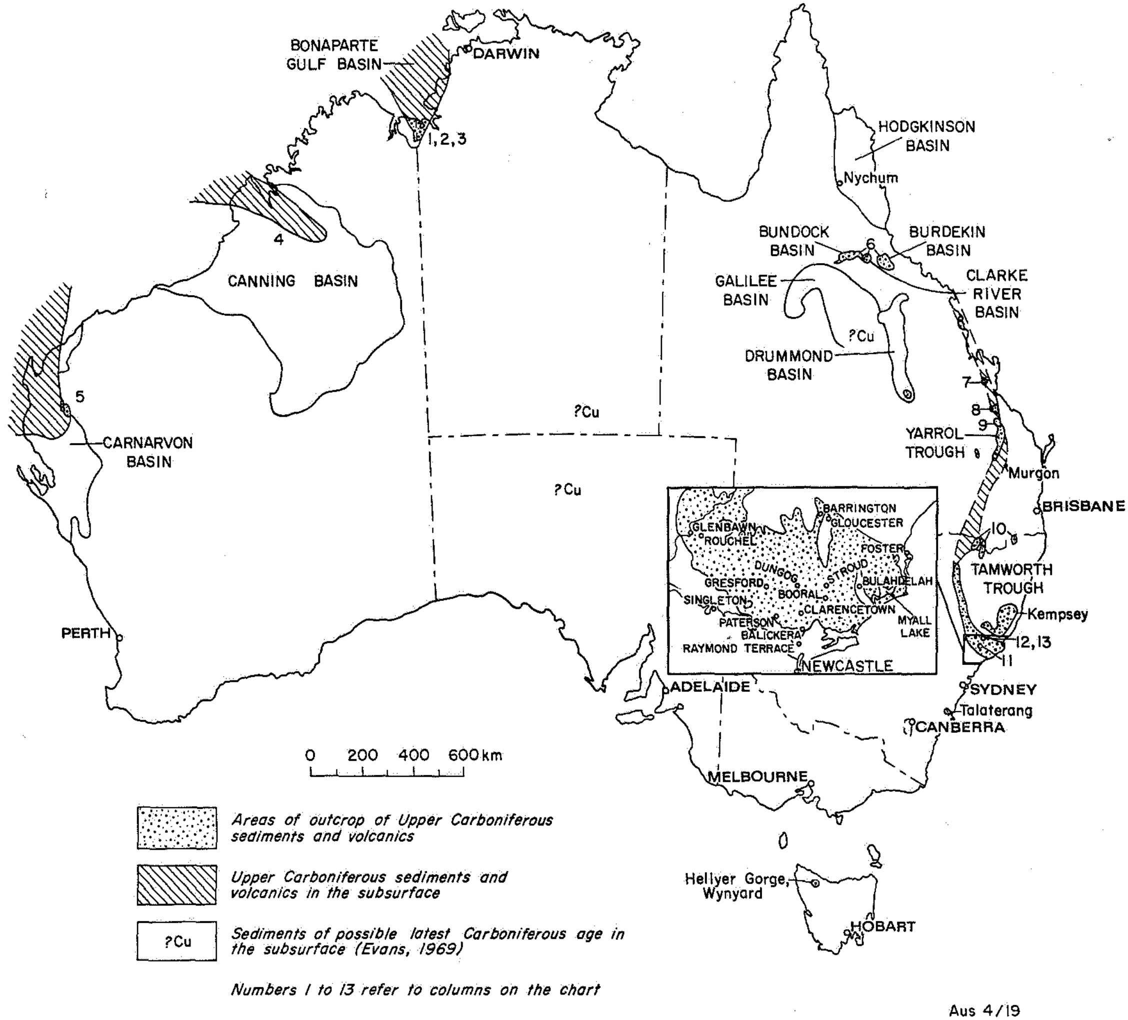

Fig. 1. Silesian localities in Australia.

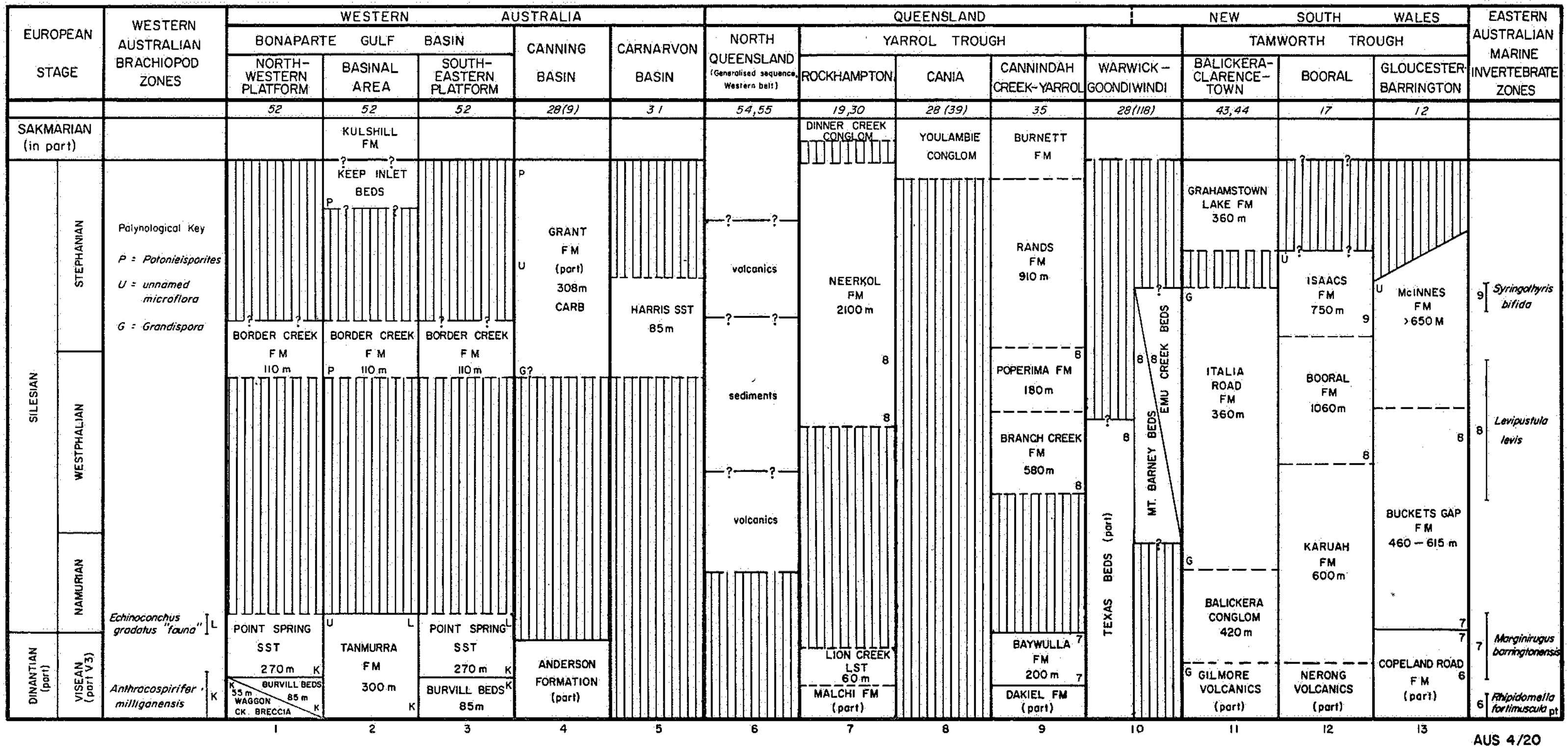

Fig. 2. Generalized or typical sections representing each of the major areas of Silesian sedimentation. The numbers at the top of each column refer to publications cited in the references. Bracketed numbers refer to those in Jones et al. (1973).

In the Canning Basin the top of the Carboniferous Unit A of BISCHOFF has yielded conodonts of either latest Viséan or earliest Namurian age in Barlee No. 1 Well (BISCHOFF, *fide* JONES et al., 1973). This unit is unconformably overlain by the Grant Formation, a non-marine unit which may be as old as Westphalian.

III. *Geological summary*

Eastern Australia

New South Wales

The Upper Carboniferous in New South Wales extends as a U-shaped belt from the Queensland border as far south as Newcastle. Sections in the youngest Carboniferous are developed in the southern part of the Lower and Middle Hunter Valley and in the Stroud-Gloucester area. Three distinct facies are recognized (ENGEL, 1965): the Kuttung, Myall, and Burindi facies.

The Kuttung facies is essentially a non-marine volcanic and glacial sequence, mainly Late Carboniferous (ENGEL, 1966) and laterally equivalent to the Myall facies.

The Myall facies is a mixed sequence of marine and non-marine arenite and mudstone with beds of glacial outwash material and volcanics flows.

The Burindi facies is a marine mudstone-arenite sequence which is virtually confined to the Lower Carboniferous according to ENGEL (1966), and is distinguished from the Myall facies in that it lacks glacial outwash sediments and contains little, if any, volcanic rocks and terrigenous material. However, CAMPBELL & MCKELVEY (1972) consider that the Burindi facies is extensively developed in the Upper Carboniferous and that it is temporally equivalent to both the Kuttung and Myall facies. Some confusion has arisen because these facies names were originally used in a stratigraphic sense and ROBERTS & OVERSBY (1973) suggest that the terms should be abandoned. Though we agree with ROBERTS and OVERSBY that they should not be used in a stratigraphic sense, they are used here strictly as a convenient way of delineating different lithological sequences of the same age.

CAMPBELL & MCKELVEY (1972) illustrate all three facies as being present during the earliest Namurian (*Margininugus barringtonensis* time). The Kuttung facies consists of volcanic rocks separated from the Myall facies by a north-northwest shoreline in the Port Stephens — Dungog area. Farther offshore, to the east, in the area of Myall Lake and Forster, the Burindi facies was developed. This sedimentary pattern continued through the Namurian (*Oriocrassatella* time) and into the Westphalian (*Levipustula levis* time and later), although in the region where the Burindi facies was probably developed after *Levipustula levis* time, no information is available.

The Kuttung facies is well developed in the area north of Raymond Terrace (RATTIGAN, 1967a). Part of the sequence, the Wallaringa Formation and the overlying Gilmore Volcanics, is Lower Carboniferous. The Upper Carboniferous is represented by the Kings Hill Group, comprising the Balickera Conglomerate, the Italia Road Formation, and the Grahamstown Lake Formation (RATTIGAN, op. cit.). The Balickera Conglomerate consists of about 420 m of polymictic boulder conglomerate with two tuff and ignimbrite horizons. Plant fossils are indeterminate. The Italia Road Formation, corresponding to part of the "Glacial Stage" of OSBORNE (1922), contains 360 m of massive lithic arenite with interbeds of fine laminated sandstone, shale, and poor coal (RATTIGAN, 1967a). The formation yields abundant plant material (RATTIGAN, 1967a) and spores (PLAYFORD & HELBY, 1968; HELBY, 1969b). The Grahamstown Lake Formation, corresponding to the "Main Glacial Beds" (OSBORNE, 1922), consists of 363 m of laminated red, green, and mauve claystone, siltstone, fine sandstone with zeolitic sandstone, and pebble conglomerate (RATTIGAN, 1967a). The plant *Rhacopteris* is present. Both RATTIGAN (1967a) and PLAYFORD & HELBY (1968) considered that the Grahamstown Lake Formation is conformable on the Italia Road Formation, however, JONES et al., (1973) have suggested a possible stratigraphic break between the two as an attempt to reconcile the differences between the correlations of NORRIS, and unpublished palynological data of HELBY.

HELBY (*fide* JONES et al. 1973) considers the microflora of the Isaacs Formation to be intermediate between that of the Italia Road Formation and that of the Seaham Formation. The latter has been lithologically correlated with the Grahamstown Lake Formation. However, no floras are known from the Grahamstown Lake Formation (HELBY, pers. comm.) and this break should be considered as questionable.

The Myall facies has been described from the Barrington District by CAMPBELL & McKELVEY (1972), where the Silesian is represented by the Buckets Gap and the McInnes Formations. The Buckets Gap Formation consists of up to 610 m of mudstone, siltstone, and fine sandstone with interbedded lithic sandstones. The unit is fossiliferous, yielding brachiopods, corals, polyzoans, pelecypods, gastropods, and a trilobite (CAMPBELL & McKELVEY, 1972). The McInnes Formation is about 620 m thick, consisting of medium to coarse sandstone and fine conglomerate with interbedded dark siltstone containing plant fossils. The upper part of the unit consists of a volcanic breccia which CAMPBELL & McKELVEY (1972, p. 17) considered to be a separate unit, but the top of the sequence is faulted, and it is not named.

The Burindi facies is developed farther east in the vicinity of Bulahdelah and Port Stephens (ENGEL, 1962) and is conspicuously lacking in glacially derived material. This facies, referred to the Crawford Formation, is about 2440 m thick in the type section and consists of lithic arenite, friable mudstone, and small amounts of conglomerate and tuff beds (ENGEL, 1962). Fossils are rare and occur in bands; they include brachiopods, pelecypods, and gastropods with occasional plant fragments.

On the eastern limb of the Stroud — Gloucester Syncline near Booral, CAMPBELL, (1961) has divided the Crawford Formation into the Karuah, Booral and Isaacs Formations; this locality is probably the one described by STRZELECKI.

Recent studies in the southern Sydney Basin (GOSTIN & HERBERT, 1973) have demonstrated the presence of terrestrial valley-fill sediments (Talaterang Group) which define a palaeodrainage system active during the Late Carboniferous. The basal unit — the Pigeon House Creek Siltstone — contains a microflora closely comparable with that recorded from the Seaham Formation in the Hunter Valley (HELBY & HERBERT, 1971).

Queensland

The scattered outcrops of Upper Carboniferous rocks in Queensland represent marine, mixed and non-marine facies, although nowhere are they seen as an interfingering sequence as in New South Wales. The Carboniferous outcrop consists of two linear belts running north-south. The eastern belt consists of the Yarrol Trough, which is probably a northward extension of the Tamworth Trough. The western outcrop belt consists of the Drummond, Bundock, Clarke River, Burdekin, and Hodgkinson Basins (BROWN et al., 1968, fig. 6, 2). Silesian rocks are rare in the western belt but are relatively more common in the Yarrol Trough.

Terrestrial sediments and volcanics are common in the western outcrop belt to the west and south of Townsville. In most areas the sequence consists of a basalt unit of andesite or rhyolite overlain by sediments, and an upper volcanic unit, with a total thickness of about 3000 m.

The sediments consist of conglomerate, sandstone, subgreywacke, siltstone, and carbonaceous shale. Fossils include palaeoniscid fish and plant remains including cf. *Rhacopteris.* Because of extensive faulting, uplifting, and folding many formation names have been proposed; however, the similarity of lithology and fossils suggests that all the formations are part of a single depositional cycle in the Bundock, Clarke River, and Burdekin Basins. The Drummond Basin is the southerly extension of this outcrop belt and deposition consisted of glacio-lacustrine sediments referred to the Joe Joe Formation, which consists of about 600 m of lithic conglomerate and sandstones with striated polymictic pebbles, grading up into fine sandstone and siltstone, interlaminated siltstone and claystone, carbonaceous beds, and thin coaly beds. Carboniferous plants, *Cardiopteris*, and spores are the only fossils. The sequence was interpreted as fluvioglacial, with tills in the basal part; the upper part is mainly lacustrine (DICKINS & MALONE, 1973, p. 112). Equivalent sediments are developed in the Galilee Basin to the west (OLGERS, 1973.).

The Hodgkinson Basin forms the northern extremity of the outcrop belt; the Nychum Volcanics have yielded a mixed *Glossopteris* — *Cardiopteris* flora and a Rb/Sr age dating of 294 $\pm$ 9 m.y. (BLACK et al., 1972) suggesting a late Carboniferous age. This has been challenged by BALME (1973) who stated that the real interest of this plant fossil assemblage "is not that it is 'mixed', but that it provides the first clear Australian record of cardiopterid fronds in association with diverse elements of the *Glossopteris* flora". Such an association is known from India, South Africa, and Brazil, in strata which most Australian palaeontologists and stratigraphers regard as Early Permian (see full discussion by BALME, op. cit.).

The easternmost deposits in Queensland are in the Yarrol Basin which probably extends south to join the Tamworth Trough in New South Wales. The earliest Silesian is represented by part of the Baywulla Formation; MCKELLAR (1967) considers that his Fauna G (= *Marginirugus barringtonensis* Zone) straddles the Viséan — Namurian boundary.

Unconformably overlying the interbedded limestone and medium grained greywackes of the Baywulla Formation are up to 580 m of subgreywacke, conglomerate, and argillite referred to the Branch Creek Formation (MCKELLAR, op. cit.). The fauna consists of polyzoans, brachiopods (including *Levipustula levis*), coelenterates, molluscs, and a trilobite, *Australosutura gardneri* (MITCHELL).

The upper part of the sequence consists of the Poperima Formation, up to 400 m of mudstone and shale, and the Rands Formation comprising up to 1500 m of subgreywacke with interbeds of conglomerate, shale and mudstone. The fauna of both these formations consists of polyzoans, brachiopods, and molluscs. The Rands Formation is conformably overlain by Lower Permian sediments and MCKELLAR (1967, p. 16) considered that the Boiling Creek Group, which comprises these formations, to include the Westphalian and Stephanian because it overlies, albeit with slight unconformity, the late Viséan-early Namurian Baywulla Formation and is overlain by the Lower Permian (Sakmarian) Burnett Formation.

In the northern part of the Yarrol Basin the Silesian is represented by the 2150 m thick Neerkol Formation (KIRKEGAARD et al., 1970), which disconformably overlies the Rockhampton Group. It is dominated by mudstone and fine grained sandy siltstone with minor amounts of sandstone, conglomerate, and limestone (KIRKEGAARD et al., op. cit.). The fauna consists of polyzoans, brachiopods, and molluscs (FLEMING, 1969) and is similar to that in the central part of the trough; the formation is equivalent to the Poperima and Rands Formations (MCKELLAR, 1967) and possibly to the basal Permian (Sakmarian) Burnett Formation (FLEMING, 1969).

In southern Queensland in an area between the Yarrol and Tamworth Troughs two exposures in areas of structural complexity have yielded Silesian faunas. In the Murgon area, 160 km northwest of Brisbane, limestones of the 'Wondai Series' (thought to be part of the Neranleigh-Fernvale Group) are exposed in a faulted block. PALMIERI (1969) has described a Silesian conodont fauna from them which ranges in age from late Namurian to basal Westphalian (JONES et al., 1973). At Mount Barney 100 km south southwest of Brisbane about 2000 m of sediments occurs; a mudstone 600 m above the base has yielded the *Levipustula levis* fauna (MCKELLAR, 1967).

Central and Western Australia

No undoubted Silesian marine sediments are known from central and Western Australia. However, floral evidence suggests possible widespread non-marine sedimentation in the area, usually including glacigene sediments.

EVANS (1969) reported his Stage 1 microflora, which he regarded as Late Carboniferous, from the Lake Phillipson Bore in the northern part of South Australia (BALME, 1957; LUDBROOK, 1961), the southern part of the Northern Territory, and parts of the Murray Basin. This microflora has since been reported from Tasmania, from Hellyer Gorge in the basal unit of the Wynard Tillite of the Quamby Group (EVANS *fide* BANKS & CLARKE, 1973). GULLINE's (1967, p. 332-3) discovery of '*Rhacopteris*' *ovata* in these sediments provided the first proof of their Late Carboniferous age.

In Western Australia Silesian sediments are known from the Bonaparte Gulf, Canning and possibly the Carnarvon Basins.

In the Bonaparte Gulf Basin the late Viséan — early Namurian Point Spring Sandstone is unconformably overlain by the Border Creek Formation. In outcrop the Border Creek Formation has yielded *Phyllotheca* like plants (VEEVERS & ROBERTS, 1968, p. 110) suggesting a Late Carboniferous or Permian age. In Pelican Island No. 1 well the *Potonieisporites* microflora is present in the unit but in Bonaparte No. 2 Well the Border Creek yielded a Tournaisian — Viséan microflora (JONES et al., 1973). This anomalous result suggests that either the microflora has been recycled, or the sediments have been incorrectly identified.

In the Canning Basin the subsurface Anderson Formation was considered on conchostracan evidence to be Upper Carboniferous (ÖPIK in MCWHAE et al., 1958; BALME, 1960). However conodont evidence from Yulleroo No. 1 Well and Grant Range No. 1 well suggest that it is confined to the Lower Carboniferous (BISCHOFF, *fide* JONES et al., 1973).

The Grant Formation unconformably overlies the Anderson Formation; it consists of up to 3000 m of tillite, sandstone, and shale and is, in large part, Permian in age. However, the lower part contains Late Carboniferous microfloras (BALME, *fide* JONES et al., 1973).

The Harris Sandstone in the Carnarvon Basin is of indefinite age but plants suggest that it is Upper Carboniferous (KRAUSEL, 1961).

IV. *Palaeontological sequences*

The Australian Silesian faunas are markedly provincial (BROWN et al., 1968), and faunal links between Eastern Australia and the northern hemisphere were broken, probably during the Namurian (CAMPBELL & MCKELLAR, 1969). The endemic fauna and flora, including brachiopods, plants, and spores, have been used extensively to subdivide the Late Carboniferous.

Brachiopods

In New South Wales (Tamworth Trough) and Queensland (Yarrol Trough) sequences of marine brachiopod faunas have been described from the Carboniferous (MCKELLAR, 1967; CAMPBELL & MCKELLAR, 1969; CAMPBELL & MCKELVEY, 1972).

MCKELLAR recognized three successive Silesian faunas in the Yarrol Trough, Faunas G-I (1967, p. 28). Fauna G occurs in the Baywulla Formation; the index species are *Marginirugus barringtonensis* (DUN) and *Tylothyris* (?) *multicostatus* MAXWELL. Fauna H includes *Werriea regina* MCKELLAR, *Lissochonetes montinis* MCKELLAR, *Neospirifer campbelli* MAXWELL, *Alispirifer laminosus* CAMPBELL, and *Kitakamithyris booralensis* (CAMPBELL), a fauna with no similarity to Fauna G. It occurs in Unit B of the Branch Creek Formation and is the first appearance of *Levispustula levis* MAXWELL and *Beecheria* aff. *patagonica* AMOS.

The overlying fauna, I, contains two diagnostic species, *Neospirifer pristinus* MAXWELL and *Spinuliplica spinulosa* CAMPBELL, as well as *Levipustula levis*. This fauna is characteristic of the Poperima Formation.

The overlying Rands Formation contains some elements of Fauna I, including *Levipustula levis*, *Spiriferellina neerkolensis* MAXWELL and *Beecheria* aff. *patagonica* AMOS; *Punctospirifer ambiguus* MAXWELL occurs in the upper part. McKELLAR made no attempt to designate these later faunas.

The faunal sequence in New South Wales is closely similar, although CAMPBELL & McKELLAR (1969) have merged Fauna's H and I into a *Levipustula levis* Zone. CAMPBELL & McKELVEY (1972) have added the *Oricrassatella* fauna, which is intermediate between Fauna G and H, to the *L. levis* Zone; they recognized an interval which they call the *Oriocrassatella-Levipustula levis* time (p. 27). McKELLARS Fauna G is equivalent to the *Marginirugus barringtonensis* Zone (CAMPBELL & McKELLAR, 1969).

A post-*Levipustula levis* Zone fauna is recognized in the Tamworth Trough, but is dissimilar to faunas of the same age in the Yarrol Trough. No zones or faunal groupings have been erected for these faunas; they are generally considered to be Carboniferous because they show strong similarity to underlying faunas and little, if any, to the overlying Permian faunas.

Plants

The Silesian in Australia has also been defined florally; it is characterized by the *Rhacopteris* flora and is underlain by the *Lepidodendron* flora of generally lower Carboniferous age (WALKOM, 1920). The upper limit of the Silesian has been taken at the boundary between the *Rhacopteris* and *Glossopteris* floras.

Recently RIGBY (1973) has reviewed the floras and extended the range of *Lepidodendron* upward to a horizon considered to be equivalent to the Westphalian-Stephanian boundary. The range of *Rhacopteris* is unchanged and this interval is called the *Pseudorhacopteris* flora (RIGBY, 1973, p. 5). Overlying this flora is the *Gondwanidium* flora, which is succeeded by the *Gangamopteris/Glossopteris* flora of Permian and questionably latest Carboniferous age. There is still considerable discussion on the taxonomy of Australian Silesian plants, and MORRIS (*fide* JONES et al., 1973) considers that *Lepidodendron* does not extend into the Silesian.

Spores and Pollen

Many petroleum exploration wells have intersected Silesian strata in Australia. The sequence has been divided on palynological data and several schemes have been proposed. The first detailed discussion of Australian pre-Tertiary floras was by BALME (1964), who reported little information from the Carboniferous except that the early Carboniferous was dominated by *Lycospora*. In the Permian he recognized two assemblages in his *Striatites* Microflora, the *Nuskoisporites* and *Vittatina* Assemblages. The lower part of the *Nuskoisporites* Assemblage is now considered to be Silesian because it first appears within the range of the *Rhacopteris* Flora (EVANS, 1969). This interval is Stage 1 of EVANS (op. cit., p. 43) in which *Rhacopteris* is associated with monosaccate pollen; and with the spores *Retusotriletes diversiformis*, *Punctatisporites gretensis* and species of *Verrucosisporites* in the Seaham Formation of New South Wales. This is the *Potonieisporites* Microflora of HELBY (1969).

HELBY (1969b, fig. 30) recognized an earlier *Grandispora* Microflora, first described by PLAYFORD & HELBY (1968), which is long ranging and extends down into the Wallaringa Formation of late Viséan age (JONES et al., 1973). HELBY (*fide* JONES et al., 1973) now recognizes an informal microflora between his *Potonieisporites* and *Grandispora* Microfloras.

The sequence of microfloras above the *Lycospora* Microflora and beneath the upper *Nuskoisporites* Microflora is, in ascending order: *Grandispora*, unnamed, and *Potonieisporites* (= Stage 1 of Evans, and lower *Nuskoisporites* of BALME).

V. *Correlation*

The problems of recognizing boundaries are amplified when the correlation of the Australian Silesian is attempted.

CAMPBELL & MCKELLAR (1969), in considering the macrofaunas, noted that there is little evidence of faunal relationships during the Namurian apart from the occurrence of *Cravenoceras* in New South Wales. The provincial nature of the fauna is due to the establishment of a cool to cold water fauna. There is a close relationship between the Australian and Argentinian faunas. Species in common include the brachiopods *Levipustula levis* MAXWELL, *Alispirifer laminosus* CAMPBELL and *Beecheria* aff. *patagonica* AMOS, the trilobite *Australosutura gardneri* (MITCHELL), and the polyzoans *Fistulamina frondescens* CROCKFORD, *Fenestella anodosa* CAMPBELL, *Polypora neerkolensis* CROCKFORD, *P. septata* CAMPBELL, and ?*Rhombopora bifurcata* CAMPBELL (AMOS & SABATTINI, 1969; CAMPBELL & MCKELLAR, 1969). The Argentinian fauna is much closer to Australian faunas than it is to faunas from the northern part of South America (CAMPBELL & MCKELLAR, op. cit.).

Although the Australian *Levipustula levis* fauna has twelve genera which also occur overseas, CAMPBELL & MCKELLAR (1969, p. 105) concluded that it was not possible to draw any safe conclusions with regard to correlation. The *Levipustula levis* fauna has always been considered to be Westphalian. This conclusion is based on the range of the brachiopod genus *Lissochonetes*, which first appears in the Westphalian (W3a) of Belgium; its close relative, *Eolissochonetes*, occurs in the Pennsylvanian Morrowan and Desmoinesian in North America (MCKELLAR, 1965). CAMPBELL (1961) noted that *Levipustula* occurs in the Westphalian B and basal Westphalian C in the Franco-Belgian coalfield and in Britain.

BÖGER & FIEBIG (1963) also described three species of *Levipustula* from the Silesian of west Germany, the combined range of which is from Westphalian A to the Westphalian B/C boundary (Flöz Ägir). The oldest known species is *L. piscariae* (WATERLOT), from the oberes Sarnsbank-Niveau, i.e., at the Namurian/Westphalian A boundary. Although this evidence strongly supports a Westphalian age for the *Levipustula levis* fauna the picture is complicated by the presence of the *levis* fauna beneath the occurrence of *Cravenoceras* in the Kempsey district (LINDSAY, 1969); however, the area is structurally complex.

The only occurrence of conodonts is in a structurally deformed and metamorphosed area 160 km northwest of Brisbane, Queensland (PALMIERI, 1969). The fauna contains European and North American species of Namurian and Westphalian age, indicating that marine sedimentation was taking place during this time in eastern Australia.

The palynological evidence is tenuous. There is no direct correlation between the *Grandispora* and *Potonieisporites* microfloras and those of the northern hemisphere. The upper limit is set at the incoming of EVANS' (1969) Stage 2, equivalent to the upper of BALME's (1964) *Nuskoisporites* microflora.

The flexibility of correlation of the microfloras is shown by the various ages assigned to the *Potonieisporites* microflora: post-Carboniferous (HELBY, 1969 a, b) to Namurian (HELBY & MCCLUNG, 1973). This microflora occurs above beds yielding the post-*Levipustula levis* fauna within the Isaacs Formation (HELBY, 1969b).

Palynology has been used to correlate the subsurface Silesian but the information remains unpublished.

VI. *Carboniferous/Permian boundary*

The provincial nature of the fauna and flora in the late Carboniferous and early Permian makes the recognition of the Carboniferous/Permian boundary extremely difficult.

Traditionally the boundary has been taken at the incoming of the pelecypod *Eurydesma* and of the *Glossopteris* flora and the extinction of the *Rhacopteris* flora (EVANS, 1969; JONES et al., 1973). However, RUNNEGAR (1969) has pointed out that *Eurydesma* and *Rhacopteris* overlap in sections at Cranky

Corner, 16 km north of Gosford (Seaham Formation) and at Cania in the Yarrol Trough, Queensland (Youlambie Conglomerate).

Palynologists have endeavoured to recognize a change in the microfloras similar to that in the macrofloras. BALME (1964) tentatively suggested that this change could be the incoming of the *Nuskoisporites* Assemblage but, as EVANS (1969, p. 42) pointed out, the incoming of this assemblage is within the upper range of *Rhacopteris*.

EVANS (op. cit.) considered that this interval, between the introduction of monosaccate pollen and the appearance of the *Glossopteris* Flora, is Late Carboniferous.

Palynologically the Carboniferous/Permian boundary has been taken at the base of EVANS' Stage 2, characterized by the first appearance of striate bisaccate pollen and new forms of *Apiculatisporis*, *Lophotriletes*, and certain cingulate mesosporoids (NORVICK, 1971, unpubl.).

The boundary is poorly defined palaeontologically in Europe. JONGMANS & GOTHAN (1937) remarked that SCHMIDT had also noticed GOTHAN's observation that *Callipteris conferta* and *Medlicottia* first appeared at about the same time. JONGMANS & GOTHAN considered that the first appearance of *Medlicottia* in the Krasnofimsk Formation of Russia marked the base of the Permian.

This suggests that the first appearance of *Callipteris conferta* may also mark the beginning of the Permian; "however according to GOTHAN *Callipteris* is very much influenced by the facies of floral association" (JONGMANS, 1952) and it is questionable whether it is restricted to the early Permian.

HELBY (1966) suggested that *Callipteris conferta* may be represented by *Illinites unicus* in dispersed spore assemblages. "*Illinites unicus* is a characteristic component of the assemblage replacing the *Lycospora* Microflora in Western Europe, North America, and the USSR" (HELBY, 1969b, p. 11).

Although *Illinites* has not been found in Australia, HELBY considered the microfloral change from the "Lycosporoid" microflora of BALME (1964) to the *Potonieisporites* Microflora as being a comparable change and that the incoming of *Potonieisporites* marks the top of the Carboniferous. However, this scheme also suggests that some of the Pennsylvanian of North America, nearly all the Uralian of the USSR, and much of the Stephanian C of Western Europe are also post-Carboniferous.

There are obvious problems associated with using the incoming of *Callipteris conferta* to mark the top of the Carboniferous; furthermore the translation of this boundary into Australian terms, when none of the above index species are present, is fraught with danger. This is highlighted by the recent suggestion (HELBY & MCCLUNG, 1973) that the *Potonieisporites* microflora, rather than signifying post-Carboniferous, is in fact Namurian.

At the present time there is no satisfactory solution to recognizing the Carboniferous-Permian boundary; however, the incoming of the *Glossopteris* flora approximates the boundary in Australia.

VII. *Tectonics*

The continent, except for the Tasman Geosyncline, was subjected to mainly vertical movements during the Silesian. In the Western Australian intracratonic basins (Bonaparte Gulf, Canning, and Carnarvon Basins), this resulted in uplift, erosion, and rejuvenation of source areas leading to the accumulation of coarse terrigenous sediments, marking the beginning of a depositional episode extending into the Late Permian. Gentle folding and fairly extensive faulting along the flanks of these basins probably persisted into Permian times.

In the Tasman Geosyncline, intensive diastrophic movements occurred during the Silesian, together with the formation of volcanic and plutonic rocks. These movements affected the Neranleigh Fernvale Group (including the Brisbane Metamorphics), and represent the later phases of the Kanimblan Orogeny (GREEN, 1973). Both in the Yarrol Trough and the northern part of the Tamworth Trough, there is a break between the earliest Namurian and Westphalian. In the lower Hunter Valley, however, marine sedimentation continued, but it was accompanied by widespread volcanicity and the introduction of glacigene sediments.

The faunas became provincial and most genera were new and endemic. This has been attributed to the considerable change in conditions brought about by the relative movement of the continent into a near polar position.

Towards the end of the Silesian nonmarine sedimentation occurred over large areas of Central and Western Australia; in the east, terrestrial sediments interdigitate with volcanics and glacigene sediments including varve-like sequences; marine faunas are rare and are restricted to polyzoans, molluscs, and a few endemic brachiopods.

In the Early Permian there was a transgression with widespread marine deposits in both eastern and Western Australia.

VIII. *Conclusions*

The geology of the Silesian in Australia is complicated by continent-wide tectonic activity and the onset of glaciation which caused faunal and floral provincialism.

The pattern of sedimentation changed from west to east: in the western and possibly the central parts, large areas were covered with continental deposits; on the eastern margin volcanics interfingered with clastics and glacigene deposits which, in turn, interfingered with open marine sediments.

Good biostratigraphic information at the Viséan/Namurian boundary and in the Sakmarian adequatly delineates the Silesian. However, the presence of endemic species and the virtual absence of northern hemisphere forms makes correlation with the type section difficult.

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(The numbers which appear before the references refer to those shown at the top of Fig. 2)

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