**REVIEW OF THE CARBONIFEROUS STRATIGRAPHY, TECTONICS AND PALÆOGEOGRAPHY OF NEW SOUTH WALES AND QUEENSLAND.**

By S. W. Carey, M.Sc.,
and W. R. Browne, D.Sc.

(Manuscript received, March 11, 1938. Read, April 6, 1938.)

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I. Stratigraphy.

Proposed Classification.

In a recent paper(7) by one of us (S.W.C.) it was shown that for the Babbinboon area north of Currabubula, on the western limb of the Werrie Syncline, there was amid the freshwater Carboniferous Lower Kuttung beds an intercalation of marine limestone containing a *Lithostroton* coral-fauna of Viséan aspect; also that some distance above the base of the Burindi Series there was a fauna including the ammonoid *Protocanites* cf. *lyoni* M. & W., a fossil characteristic of a zone low in the Tournaisian.
There is a distinct lithological and facies break at the base of the Lower Kuttung and another break a short distance above the limestone; it is permissible therefore, to regard the Burindi beds at Babbinboon as approximately equivalent to the Tournaisian and the Lower Kuttung to the Viséan. The Barraba beds, immediately underlying the Burindi, are Upper Devonian.

The Upper Kuttung Series, almost entirely glacial and volcanic, contains in great abundance the *Rhacopteris* flora. The exact time-range of this series is a matter beyond the scope of the present paper, but on the evidence of the plants there appears to be no warrant for supposing it to ascend above Middle Carboniferous. There is thus reason to believe that the sequence commonly called Carboniferous in eastern Australia is equivalent only to a portion of the European Carboniferous system.

The known occurrence of the Viséan coral *Lithostrotion* elsewhere in the State in beds of definite Burindi facies prompted us to examine the records of the Carboniferous sequence. Hitherto it has been generally assumed that a Burindi epoch of marine sedimentation was followed by a Kuttung epoch of terrestrial deposition, but we have been led to the conclusion that during Viséan time in New South Wales marine and terrestrial deposition were going on side by side.

Some revision of the classification is called for, and we propose to modify the generally accepted divisions of the Carboniferous as follows:

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<thead>
<tr>
<th>Terrestrial</th>
<th>Marine</th>
<th>European Equivalents</th>
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<tbody>
<tr>
<td>Upper Kuttung Series.</td>
<td>—</td>
<td>Middle Carboniferous (Moscovian).</td>
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<tr>
<td></td>
<td>—</td>
<td>Lower Carboniferous</td>
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<tr>
<td></td>
<td>Lower Burindi Series.</td>
<td>Tournaisian.</td>
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</tbody>
</table>

The names *Kuttung* and *Burindi* are so well known and so entrenched in Australian geological literature that it seems inadvisable to change them; the former name, too,
CAREY AND BROWNE. limestones of the Great Serpentine Belt. Dr. Ida Brown has kindly furnished the following list of forms present:

- *Litjnostrotion arundineum* Eth. fil.,
- *Amygdalophyllum etheridgei* D. and B.,
- *Aphrophyllum foliaceum* Hill,
- *Symplectotyllum cf. mutatum* Hill.

It is clear from the above that, in the type-area at least, the Eocky Creek Series is Upper Kuttung, the Lower Kuttung is absent and the marine beds embrace both the Upper Burindi and the Lower Burindi Series.

Though there has been as yet but little attempt at zoning the marine beds by their fossil content, it appears to us that most, if not all, of the known Carboniferous in the State can be fitted into the scheme defined above. It will be convenient now to examine this proposition.

New South Wales Correlations.

1. Great Serpentine Belt.

The separation of the Carboniferous sequence into a marine (Burindi) and a terrestrial (Rocky Creek) series was one result of Benson's brilliant and extensive field-studies in what he termed the Great Serpentine Belt, stretching along the western margin of New England. Benson showed that on the one hand the Burindi beds merged downwards into the Barraba Series, and that on the other they enclosed lenses of limestone containing a Viséan fauna including species of *Lithostroton*. The Rocky Creek strata he did not investigate in any detail, they being on the western fringe of the area examined. On a recent visit to the type-area, some 20 miles south-west of Bingara, one of us (W.R.B.) observed the series to be composed mainly of conglomerates and tuffs, with varve-shales on more than one horizon, while near the base an unmistakable tillite was discovered. Incidentally, this is the furthest north point to which Kuttung tillites have been traced. On the eastern side of the Rocky Creek syncline the basal rocks of the series are coarse conglomerates.

In the same area, through the kindness of Mr. Wilfred Crowley, of Pine Cliffs Station, it was possible to examine a small but highly fossiliferous lens of limestone among typical Burindi shales, and probably not more than 200 feet below the base of the Rocky Creek Series. This limestone is from its fossils the stratigraphical equivalent of the Babbinboon limestone and the other Burindi coral-
limestones of the Great Serpentine Belt. Dr. Ida Brown has kindly furnished the following list of forms present:


It is clear from the above that, in the type-area at least, the Rocky Creek Series is Upper Kuttung, the Lower Kuttung is absent and the marine beds embrace both the Upper Burindi and the Lower Burindi Series.

2. Werrie Syncline.

The details of the succession have already been described. The Lower Burindi Series is followed by the Lower Kuttung, and the northern end of the syncline is the most northerly point in the State where the Lower Kuttung has been recognized. Where it gives place to the Upper Burindi Series we do not know.

It is of interest to note that recently some fossils collected by Miss E. Basnett from the Lower Burindi beds in por. 179, par. Somerton, have been found by Dr. Ida A. Brown to include the following:

Zaphrentis (Caninia) sumphuens Eth. fil., Z. sp., Spirifer striata Sow., Schizophoria resupinata Martin, Productus spp., Loxonema (?) babinboonensis Eth. fil. and a Euomphalid. In Europe, the genus Caninia makes its first appearance in the Syringothyris zone at the top of the Tournaisian, a fact which sets a downward limit to the age of the Somerton beds.

3. Hunter Valley.

Both Upper and Lower Kuttung beds have been traced without interruption from a point north of Babinboon to the southern extremity of the Werrie Syncline at Wallabadah. From here to Scone various elements of both series have been recognized at intervals, and there is no doubt of their continuity. From Scone in a south-east direction to Lamb's Valley and thence eastward to Paterson and Clarendecotown the Carboniferous rocks have been mapped and investigated in more or less detail by Osborne and other workers. It is thus possible to assert the physical continuity of both Upper and Lower Kuttung Series over a distance of 150 miles. The most detailed work has been done in the Lower Hunter Valley, and a close comparison is possible between the
stratigraphical units developed there and those of the Werrie Syncline, which may be indicated as follows:

<table>
<thead>
<tr>
<th>Werrie Syncline</th>
<th>Lower Hunter Valley</th>
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<tbody>
<tr>
<td><strong>Upper Kuttung Series:</strong></td>
<td><strong>Kuttung Series:</strong></td>
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<tr>
<td>Upper Glacial Stage.</td>
<td>Seaham Beds.</td>
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<tr>
<td>Lower Glacial Stage.</td>
<td>Mt. Johnstone Beds.</td>
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<tr>
<td>Lower Kuttung Series</td>
<td>Martin's Creek Beds.</td>
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<tr>
<td>Lower Burindi Series</td>
<td>Wallaroo Ba Beds.</td>
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<td></td>
<td>Burindi Series.</td>
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<tr>
<td><strong>Sussmilch.</strong></td>
<td><strong>Osborne.</strong></td>
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<tr>
<td>Kuttung Series :</td>
<td>Kuttung Series :</td>
</tr>
<tr>
<td>Main Glacial Beds.</td>
<td>Main Glacial Beds.</td>
</tr>
<tr>
<td>MAIN CLASTIC</td>
<td>Glacial Stage.</td>
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<tr>
<td>Zone.</td>
<td>Volcanic Stage.</td>
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<tr>
<td>Basal Stage.</td>
<td>Basal Stage.</td>
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<tr>
<td>Burindi Series.</td>
<td>Burindi Series.</td>
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</table>

The name *Kuttung* was first applied by Sussmilch and David, and the subdivisions of the series for the Lower Hunter Valley were first made by them. These were later renamed by Osborne.

The subdivisions of Osborne's Glacial Stage are closely comparable with those of the Upper Kuttung of the Werrie Syncline. In the latter there are two stages of definitely glacial and fluvio-glacial strata separated by a stage, chiefly tuffaceous, from which glacial evidences are absent. In the Lower Hunter Valley neither Sussmilch nor Osborne definitely recognized a glacial unit in the Mt. Johnstone beds (though the latter noted a horizon of varve-rock at Glenoak), but in the Gosforth area, both to the north of Drinan's Mount and between Winder's Hill and Lochinvar, it is possible to recognize the equivalents of the Upper and Lower Glacial and the Interglacial Stage. Further north, in the Muswellbrook area, the Lower Glacial beds are well-developed, and it would seem that all three divisions of the Upper Kuttung Series may be represented.

Of particular interest is the coarse heavy conglomerate, definitely fluvio-glacial or tillitic in places, which everywhere marks the base of the Upper Kuttung Series in the Hunter Valley and which is clearly the counterpart of the "Porphyry Boulder Horizon" in the Werrie Syncline and the heavy basal conglomerates at Rocky Creek.

Nowhere have lava-flows been observed in the Upper Kuttung Series except in the Upper Glacial Stage. The acid lavas in the Werrie Syncline on this horizon may be correlated in a general way with the Paterson tosacanite and the felsites which occur at the base of the stage in the
Hunter Valley. The rhyolites and andesites of Pokolbin and Mt. Bright and the Paddy’s Hill rhyolite north-east of Raymond Terrace apparently belong to the same epoch.

Within the Lower Kuttung Series there is no persistent sedimentary formation which might be used as a datum. In the Lower Hunter Valley the sequence between the Glacial Stage and the Burindi Series has been divided into a Volcanic and a Basal Stage, the former composed mainly of lavas and tuffs, the latter of clastic sediments, chiefly conglomerate. Further up the Hunter Valley the proportion of tuffs to lavas in the Volcanic Stage appears to increase, and the order of succession and relative proportions of the various lava-flows change, so that the distinctive characters of the stage are somewhat obscured. It is possible, however, that some degree of correlation throughout the Lower Kuttung belt may be effected with the aid of the pyroxene-andesite flows which are so very persistent and widespread. They have been traced for 30 miles in a S.S.E. direction in the Werrie Syncline, and have been observed, though not mapped, beyond its southern limit. From the other direction they are known to occur more or less continuously from the Clarencetown area to the neighbourhood of Muswellbrook and Aberdeen. As explained in a previous paper, it is believed that the Lower Kuttung Series as exposed at Babinboon comprises both Volcanic and Basal Stages of the Lower Hunter. In regard to the Burindi beds of the latter area, although systematic collecting and examination of fossils have not been done, it is of interest to note that the highest of the marine beds, those calcareous mudstones which at Hilldale immediately underlie the basal (Wallarobba) conglomerate of the Lower Kuttung Series, are relatively rich in the distinctive brachiopod Syringothyris exsuperans. In Europe this genus gives its name to the zone within which the boundary between Tournaisian and Viséan Series is drawn, and its occurrence in the topmost Burindi beds at Hilldale is in harmony with, and indeed supports, the view that only the Lower Burindi Series is present in this area.

4. Lower and Middle North Coast.

But little detailed work has been published in regard to the stratigraphy of this region, but it is known that Carboniferous rocks extend at intervals from a little south of Port Stephens to beyond Kempsey.
(a) Gloucester.

In 1921 Sussmilch\(^{17}\) divided the Carboniferous rocks of this district into (a) the Kuttung Series (1,750 feet) consisting of rhyolites with some *Rhacopteris* beds and conglomerates; and (b) the Burindi marine series (10,860 feet), mostly mudstones and tuffs, with conglomerates, oolitic limestones and acid lava-flows. Subsequently to the discovery of the marine limestone in the Lower Kuttung at Babbinboon, and to the conclusion stated by one of us (S.W.C.) in regard to the Myall Lakes area, as detailed below, Sussmilch\(^{20}\) tentatively suggested that the upper portion of the marine series might be contemporaneous with the Lower Kuttung of other areas. He based his suggestion apparently on the unusual thickness of the marine series. A recent hurried reconnaissance of portion of the area by one of us (W.R.B.) in company with Mr. A. H. Voisey, M.Sc., made it clear that the sequence as given by Sussmilch requires revision. The following is offered as an alternative interpretation of the section on the eastern wall of the valley of Barrington River north-west of the Gloucester Buckets:

Upper Kuttung

("Kuttung" of Sussmilch).

- Felsite flow.
- Tuff, conglomerate and cherty plant-beds (thick).
- Rhyolite.
- Plant-beds (?).

Lower Kuttung

("Upper Burindi" in part of Sussmilch).

- Bed with marine fossils.
- Rhyolite.
- Marine bed with brachiopods.
- *Productus barringtonensis* bed.
- Tuff.
- Rhyolite.
- Tuff.
- Rhyolite.

Lower Burindi.

Great thickness of shale, mudstone, etc., with oolitic limestones.

This sequence is qualitative only, and is based on a rapid traverse, so that some units may have been missed. The beds here grouped as Lower Kuttung consist predominantly of tuffs and lavas. In contrast to the characteristic hard and compact bluish-green Burindi types the tuffs are light-coloured and contain, as Sussmilch notes, "abundance of quartz and felspar grains, more rarely a little biotite and..."
occasional fragments of rhyolite". Anyone familiar with the Carboniferous lithology of the Hunter Valley would immediately pronounce this to be a typical freshwater Kuttung and not a Burindi sequence, though the absence of andesite and the prominence of acid types among the lavas are unusual. The marine beds are all thin, but the quantity of colluvial débris on the steep slopes gives a deceptive appearance of thickness. It seems most fitting to interpret this as essentially a terrestrial series with narrow marine intercalations.

No detailed work has been done on the palaeontology of these marine beds, apart from the identification and description of the large brachiopod *Productus barring-tonensis*, which is very abundant in one bed. This is an endemic species, but is not improbably the Australian representative of some of those large Productids which flourished in Europe near the close of Viséan time.

The boundary between Upper and Lower Kuttung is somewhat arbitrary, but is perhaps justified by the fact that the greatest development of the *Rhacopteris* flora is elsewhere found in the Upper Kuttung beds. The chemical composition of the topmost lava-flow as given by Sussmilch separates it sharply from the lower rhyolites and allies it very closely to the Upper Kuttung rhyolite of Mt. Bright. The thickness of this Upper Kuttung Series seems to have been considerably underestimated.

No glacial or fluvio-glacial rocks were noted in this section, but a cutting on the Rawdon Vale Road, about 6 or 8 miles south of Gloucester, reveals definite varveshales, with conglomerates and other rocks, underlying rhyolite.

It would appear, then, that conditions at Gloucester were somewhat similar to those obtaining at Babbinboon, though none of the marine transgressions resulted in the formation of coral-limestone.

Incidentally it may be recalled that many years ago Jaquet[10] described alternations of marine and freshwater beds in the Carboniferous between Claracentown and Gloucester. Both Sussmilch and Osborne have explained the apparent interbedding by faulting, but in view of what is now known there seems a possibility that the original interpretation was in part correct, and that the Lower Kuttung Series may include some marine beds.
Interglacial stages. From the Burindi beds no distinctive fossils have been recorded.

Queensland Correlations.

Australian geologists are under a deep debt of gratitude to J. H. Eeid for his able and sustained efforts to unravel the stratigraphical tangle of the Upper Palaeozoic of Queensland. Some years ago his views on the succession and correlation were set forth in a comprehensive and thoughtful paper,(15) in which, among other things, he sought to link up the Carboniferous beds in Queensland and New South Wales. Eeid's admirable pioneer work has made possible the more precise correlation here attempted.

On fossil evidence very similar to that adduced for Babbinboon Br. F. W. Whitehouse has been able to demonstrate(24) that the Eockhampton Series, including the Lion Creek limestone at the top, comprises both the Visean and the Tournaisian. It is in fact the exact equivalent of the Upper and Lower Burindi Series of New South Wales. The resemblance extends to the considerable developments of oolitic limestone in both States, pointing to a great uniformity of conditions through a very big range of latitude.

By the contained Lithostrotion fauna it has been possible to show that Vise'an beds are present in a number of localities between the latitude of Eockhampton and the New South Wales border. (9) It is extremely probable that much of south-eastern Queensland was covered by strata of the Eockhampton Series, of which only a few isolated remnants survive.

Much further to the west and occupying the Drummond Range is a considerable area of freshwater beds which apparently are Upper Devonian at the base with Lepidodendron australe, but grade up into beds with the Carboniferous plants L. Veltheimianum and Aneimites austrina. Eeid(15) argues that the upper part of the Drummond Range Series is Lower Carboniferous and the terrestrial time-equivalent of the Eockhampton Series. On the evidence of the Aneimites it might be regarded as extending into Middle Carboniferous, but there appear to be tectonic reasons against this.

The Star Beds farther north are believed to be in part Lower Carboniferous.

(b) Myall Lakes.

One of us (S.W.C.) during the course of a short survey in 1934(6) formed the opinion that the Lower Kuttung Series was missing. There is an extraordinary thickness of marine beds, which may comprise both Lower and Upper Burindi Series, and these are overlain by Upper Kuttung glacial beds with tuffs and acid lava-flows. A palaeontological study of the marine beds would probably yield interesting results.

(c) Port Stephens.

Sussmilch and Clark(18) have described and mapped a number of isolated outcrops of Kuttung rocks, chiefly igneous, on the coast at Port Stephens. Stratigraphical details are somewhat meagre. It is known that both Kuttung and Burindi rocks are present in the area, and the Upper Kuttung is certainly represented, but other correlations are doubtful.

(d) Taree.

In association with well-bedded mudstones and tuffs there is a crinoidal oolitic limestone from which the corals Lithostrotion stanwellese Eth. fil., Aphrophyllum hallerense Smith, and (?) Carcinophyllum patellum Hill have been identified. They are evidently Upper Burindi. The details of the Carboniferous succession in this area are at present being investigated by Mr. Voisey.

(e) Kempsey.

Voisey(21) (22) has described from this area representatives of both Kuttung and Burindi Series. The former comprise in descending order:

1. Glacial beds, including tillite, varve-shales and fluvio-glacial conglomerate.

2. Cherty mudstones and tuffs containing Aneimites, etc.

3. Sandstones, tuffs and breccias of great thickness.

Unfortunately the junction between Kuttung and Burindi beds seems to be a faulted one, and the remainder of the Kuttung sequence is nowhere revealed.

It may be suggested, perhaps, that the sequence detailed above is equivalent to the Upper Kuttung Glacial and
Of the Upper Kuttung Series Queensland seems to possess equivalents only in the far north at Silver Valley, in the Herberton district, where there is a series of acid lavas, conglomerates, grits, sandstones, and shales containing Aneimites ovata. In marked contrast to the folded Drummond Range beds these rocks are sub-horizontal.

At Stanwell, 15 miles south-west of Bockhampton, the Lion Creek limestone is overlain by the Neerkol Series which carries, according to Whitehouse, that the Middle Carboniferous marine fauna, and this and a small occurrence at Mt. Barney, about 6 miles N.N.W. of Mt. Lindesay on the N.8.W. border, are to be linked with the Emu Creek Series of Drake as probable marine equivalents of the Upper Kuttung. The presence of whitish grits in the Neerkol Series overlying the typically bluish-black to green marine mudstones suggests a change to terrestrial conditions towards the end of the Neerkol epoch.

**Summary.**

From the foregoing facts the following appear to be reasonable deductions:

1. The Burindi series of New South Wales represent the whole of the Lower Carboniferous of Europe, the Lower Burindi being approximately equivalent to the Tournaisian and the Upper Burindi to the Visean.

2. Along a narrow belt of lowland, stretching from somewhere north of Babbinboon to the Lower Hunter Valley and the Williams Biver, deposition of the terrestrial Lower Kuttung Series proceeded synchronously with the Upper Burindi marine sedimentation.

3. Temporary transgressions of the sea over the coastal lowlands were responsible for occasional intercalations of marine among the terrestrial Lower Kuttung sediments.

4. In Middle Carboniferous (Upper Kuttung) time terrestrial deposition, largely glacial, took place from beyond Bocky Creek in the north to the Lower Hunter Valley, and probably all along the North Coast region from the Hunter Valley northwards to a point some miles beyond Kempsey.

5. A fairly close correlation is possible between the Carboniferous rocks in Queensland and those in New South Wales. In the former concurrent marine and terrestrial sedimentation went on during the whole of Lower Carboniferous time. The condition of affairs is expressed in the following table:

---

**Queensland Correlations.**

Australian geologists are under a deep debt of gratitude to J. H. Reid for his able and sustained efforts to unravel the stratigraphical tangle of the Upper Palæozoic of Queensland. Some years ago his views on the succession and correlation were set forth in a comprehensive and thoughtful paper, in which, among other things, he sought to link up the Carboniferous beds in Queensland and New South Wales. Reid's admirable pioneer work has made possible the more precise correlation here attempted.

On fossil evidence very similar to that adduced for Babbinboon Dr. F. W. Whitehouse has been able to demonstrate that the Rockhampton Series, including the Lion Creek limestone at the top, comprises both the Viséan and the Tournaissian. It is in fact the exact equivalent of the Upper and Lower Burindi Series of New South Wales. The resemblance extends to the considerable developments of oolitic limestone in both States, pointing to a great uniformity of conditions through a very big range of latitude.

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Much further to the west and occupying the Drummond Range is a considerable area of freshwater beds which apparently are Upper Devonian at the base with *Lepidodendron australe*, but grade up into beds with the Carboniferous plants *L. Veltheimianum* and *Aneimites australis*. Reid argues that the upper part of the Drummond Range Series is Lower Carboniferous and the terrestrial time-equivalent of the Rockhampton Series. On the evidence of the *Aneimites* it might be regarded as extending into Middle Carboniferous, but there appear to be tectonic reasons against this.

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3. Temporary transgressions of the sea over the coastal lowlands were responsible for occasional intercalations of marine among the terrestrial Lower Kuttung sediments.

4. In Middle Carboniferous (Upper Kuttung) time terrestrial deposition, largely glacial, took place from beyond Rocky Creek in the north to the Lower Hunter Valley, and probably all along the North Coast region from the Hunter Valley northwards to a point some miles beyond Kempsey.

5. A fairly close correlation is possible between the Carboniferous rocks in Queensland and those in New South Wales. In the former concurrent marine and terrestrial sedimentation went on during the whole of Lower Carboniferous time. The condition of affairs is expressed in the following table:
Earth-Movements Affecting the Carboniferous Buckets.

The Carboniferous beds in Queensland and New South Wales were to some extent governed in their deposition and were affected after consolidation by a series of important earth-movements. These have been dealt with briefly by Sir Edgeworth David.

1. Kanimbla Movement.

In the Great Serpentine Belt Benson has demonstrated that there is no evidence of a break between the Upper Devonian Barraba and the Lower Carboniferous Burindi Series; in fact, the two series are almost indistinguishable lithologically. Further west, on the western limb of the Werrie Syncline, one of us (S.W.C.) has found the base of the Burindi Series to be marked by a heavy conglomerate, though there is no observed angular unconformity. This basal conglomerate has been traced by Messrs. Lloyd and Mulholland for 30 miles beyond Babbinboon.

In the region west of the Blue Mts., and indeed over a very considerable area of the State, the Upper Devonian beds were folded along a general north-west direction at the close of Devonian time, during what Sussmilch has termed the Kanimbla epoch. It would appear that this folding did not extend to the Great Serpentine Belt, though there are evidences that it advanced as far east as Gosforth and Pokolbin, in the Lower Hunter Valley. The basal conglomerate at Babbinboon, which evidently wedges out eastwards, was probably derived from the erosion of the land lying to the west, which had been uplifted as the result of the orogeny.

The incidence of this epi-Devonian movement appears to have been confined to New South Wales.

2. Wallarobba Movement.

Next there is evidence of a movement of vertical uplift at the close of Lower Burindi time which raised some parts of the area of marine sedimentation just above sea-level. This is the movement called the Wallarobba Disturbance by Sussmilch and David. Its incidence is marked by the change from a marine to a terrestrial (Lower Kuttung) facies along a strip extending from north of Babbinboon to the Lower Hunter Valley. The base of the Lower Kuttung is marked in a number of places from Clarencetown to Babbinboon by heavy conglomerates. Sussmilch has

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<tr>
<th>New South Wales</th>
<th>Queensland</th>
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<tbody>
<tr>
<td>Terrestrial.</td>
<td>Marine.</td>
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<td>Emu Creek Series</td>
<td>Barnsbury Beds,</td>
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<td>Upper Kuttung Series</td>
<td>Upper Kuttung Series,</td>
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<tr>
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<td>Viséan,</td>
</tr>
<tr>
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### Table

<table>
<thead>
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<th>Period</th>
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<th>Principal Flora</th>
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</thead>
<tbody>
<tr>
<td>Lower Carboniferous</td>
<td>Lepidodendron sponge flora</td>
<td>L. ptychophylla flora</td>
</tr>
<tr>
<td>Upper Devonian</td>
<td></td>
<td>L. australis flora</td>
</tr>
<tr>
<td>Lower Dev.</td>
<td></td>
<td>Lower part of Drummond Range beds and L. australis beds.</td>
</tr>
</tbody>
</table>
CAREY AND BROWNE.

recorded evidence that in the former area the elevation was gradual and oscillatory. So far as we are aware this movement has not been recognized in northern New South Wales or in Queensland.

3. Drummond Movement.

For New South Wales Benson has shown that in western New England the Lower Devonian (?) Woolomin or Eastern Series has been folded and upthrust from the east against a long belt of Burindi beds, including Lithostrotion limestones. Sheets of ultrabasic rock are aligned along the thrust-planes. Other sheets of serpentine are known elsewhere in New England and the North Coast district, as at Solferino, Gordonbrook, Port Macquarie, Mt. George(2) and Tinonee on the Manning River, Ellenborough on the Hastings, and Nowendoc in the Upper Manning country. Some, at least, of these intrusions were probably contemporary with those of western New England.

The precise epoch of the folding, thrusting and intrusion in the Great Serpentine Belt has been a matter of some controversy. Benson(1) contended that they were late Carboniferous, but his arguments are not altogether convincing. Some years ago one of us (W.E.B.) suggested for the movement a late Burindi age,(4) and, though the premises were somewhat inadequate and, as it happens, partly erroneous, the conclusion may be substantially correct. The top of the Upper Burindi (or Lower Kuttung) Series is the only horizon where there is evidence of a tectonic break in the Carboniferous sequence. In most places where it has been identified the base of the Upper Kuttung Series is marked by a coarse, heavy conglomerate already referred to. In one locality, at Gosforth, this conglomerate rests on the Lower Kuttung Series with a distinct angular unconformity, and Osborne's map and sections of the Clarencetown-Paterson area suggest a similar relation there. Though no structural discordance has been reported elsewhere the violent lithological break is in itself an evidence of some marked crustal disturbance.

A possible interpretation of the facts is as follows: At the close of Burindi time as a result of pressure from the east there was an orogenic movement whose locus of greatest intensity was somewhere in New England to the east of the Great Serpentine Belt. To the west the pressure was relieved by thrusting, and beyond the fault (which may be called the Peel Thrust) the strata were only gently...
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folded. Into the most crumpled and faulted areas sheets of ultrabasic magma were injected. Erosion and injection by granite batholiths have since obliterated the Burindi and much of the Devonian terrain, and only the overthrust and serpentine-injected Upper Burindi beds and the Upper Kuttung conglomerates are left to tell the tectonic tale.

On the other hand one of us (S.W.C.) holds that the Peel overthrust and the injection of the serpentine may well have occurred during the Hunter-Bowen orogeny at the close of the Kamilaroi Period, as described below. Whether or not this is so, however, it is clear that an interval of tectonic disturbance marked the close of Lower Carboniferous time.

This was something more than a diastrophic epoch. It heralded the sharp decline in New South Wales of the hitherto dominant Lepidodendron flora and the marked rise of the Rhacopteris flora, which appears but sparingly in the Lower Kuttung beds. Furthermore it was after, and perhaps in consequence of, the elevation of the late Burindi mountains that the glaciation, which had started in Lower Kuttung time, reached its culmination.

Not improbably it was at this time that the Upper Devonian beds near Ashford in north-western New England, which underlie Kamilaroi coal-measures with a right-angled unconformity, were folded.*

In Queensland there appear to be evidences of a late Burindi orogeny.

(a) The Devonian Silverwood Series near Warwick,\(^{16a}\) not far across the border from New England, is overlain by Lower Kamilaroi beds with a sharp angular unconformity. No Carboniferous rocks have been identified in the area, but since it is in the northern continuation of the zone of intense late Burindi folding in New South Wales we think its deformation is most probably to be ascribed to that epoch.

(b) In the Drummond Range the Devonian and Carboniferous freshwater beds are folded along submeridional axes for 250 miles, and are unconformably overlain by the Kamilaroi Lower and Upper Bowen Series.\(^{15}\) North of the Drummond Range the area affected probably included Mt. Wyatt (where apparently Lower Carboniferous freshwater beds rest conformably on folded shallow marine Upper Devonian deposits) and the Star River (where the

* In this area there appear to be Burindi beds also, but their structural relations to the Devonian and Kamilaroi sediments are unknown.
Upper Devonian beds are folded, but the presence of Carboniferous beds is doubtful. It may also have extended to include the rocks of the Hodgkinson and Paseoe River areas.

Reid has argued that the orogeny started in late Lower Carboniferous time, and if so it would seem to have synchronized with the late Burindi movement in New England. It is highly probable that the folding and concomitant uplift provide the reason for the absence of younger beds in this area. The undeformed condition of the Silver Valley beds, much farther north, suggests that they postdate the folding.

(c) In the Stanwell area, south-west of Rockhampton, the Lion Creek limestone at the top of the Lower Carboniferous Rockhampton Series is overlain by the Middle Carboniferous Neerkol Series. Though no angular unconformity has been recorded the younger sequence commences with a heavy conglomerate which Reid regards as indicating a distinct tectonic break.

(d) At various places between Ipswich and Rockhampton there are sheets of serpentine in contact with Devonian rocks, the whole association so closely resembling that of New England that it is difficult to resist the conclusion that the ultrabasic rocks belong to the same petrographical province. Further, the Carboniferous Rockhampton Series is, according to Reid and Morton, conformable with the Devonian in the type-area, so that any diastrophism which affected the latter probably did not occur till after the Rockhampton epoch, when, as in New South Wales, folding under pressure from the east may have been accompanied by injections of ultrabasic magma, particularly along a line close to the western margin of the folded zone.

We are led to suggest that the late Viséan orogeny may have produced two zones of folding in Queensland, an easterly one, of considerable intensity with an axis running roughly from Rockhampton through Brisbane and extending into north-eastern New South Wales, and a westerly one, less intense, in the Drummond Range. In the intervening trough there was little or no folding, and this may account for the angular concordance of the Neerkol Series at Stanwell. It is of interest to note that Bryan in 1925 advanced a closely similar hypothesis of the folding which affected the Mesozoic rocks of south-eastern Queensland.
We are fully conscious that our tentative explanation is far from resolving the complexities of the Queensland problem; nevertheless it may, we think, be assumed provisionally that the orogeny under discussion affected three great belts in the Carboniferous geosynclines, in New England, the Drummond Range and the coastal belt of Queensland south of Rockhampton. Reid has suggested the name Drummond Movement in connexion with the folding of the Drummond beds, and we consider that the term may appropriately be extended to embrace all the diastrophism of late Viséan time in eastern Australia.

4. Lochinvar Movement.

There was apparently no orogeny at the close of Upper Kuttung time. In both Queensland and New South Wales wherever the lowest Kamilaroi beds are in contact with the highest Kuttung there is local angular conformity. There is, however, considerable regional overlap in the Lower Hunter Valley, and evidence of some vertical movement is seen in the heavy conglomerates at the base of the Lower Kamilaroi Dinner Creek Series at Stanwell (Q.), and in the abrupt change from terrestrial to marine sedimentation in New South Wales. This may be called the Lochinvar Movement. It comprised elevation followed by submergence and marine transgression. The complete change in flora from Kuttung to Kamilaroi is presumptive evidence of a considerable time-interval of which no sedimentary record is preserved.

5. Hunter-Bowen Movement.

The Burindi and Kuttung rocks of New South Wales were subjected to a further orogeny. In this the overlying Kamilaroi strata were also involved, and it is generally agreed that it occurred towards the end of Kamilaroi time, commencing about the close of the Upper Marine epoch. The area affected is limited more or less strictly on the west by a thrust-system striking parallel to the Peel thrust and at a distance of about 30 miles from it. This system under various names, has been traced with but little interruption from near Maitland in the Lower Hunter Valley in a general north-north-west direction to beyond the latitude of Gunnedah. Jensen(11) has observed in the Nandewar country a discordance between Kamilaroi and Carboniferous beds in Maule's Creek which may be due to the fault, and a little further north, near the head of Rocky Creek, it is

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almost certainly present. Thus the fault-system probably runs for upwards of 200 miles before disappearing under the Jurassic rocks of the Great Artesian Basin. As to the geological age of this thrust there is no direct evidence and no consensus of opinion. At its southern extremity it frays out into subsidiary faults, which sharply transgress the trend of the late Palæozoic folds, but for the greater part of its course it is in such striking parallelism with the axes of the folds that in our opinion it cannot but be closely related to them.

The position of the zone of greatest folding is not known, but not improbably it was in the New England area, where there are extensive intrusions of late Palæozoic granite. These extend across to the North Coast district, where also the strata are in places highly tilted. Southward the folding seems to have died out about the Hunter Valley.

It is quite conceivable that as a result of the late Palæozoic thrust from the east there was a renewal of movement along the Peel Thrust, and if so this may explain the schistosity which is so characteristic of the serpentine intrusions. Alternatively, the Peel thrust and the serpentine may belong to this epoch.

Reid has emphasised the fact that in Queensland there is a broad coastal belt which was involved in late Palæozoic folding. The folded zone is injected by granite and bounded westward by crumpling and overthrusting of the Kamilaroi Bowen Series along the eastern limb of the Great Syncline. It is significant that, as pointed out by Reid, this boundary is collinear with the bounding thrust-system in New South Wales. Though there is interruption through the transgression of the Mesozoic strata of the Great Artesian Basin there can be little doubt that continuity is maintained beneath them.

We have thus a wide belt of folded Upper Palæozoic strata, bounded westward by thrust-faults and extending perhaps from Townsville to Maitland—a distance of some 900 miles—in a great curve concave to the west, which in late Palæozoic time seems to have behaved as a tectonic unit under the influence of horizontally-acting forces directed from the Pacific Ocean. (See Fig. 1.)

We propose to call the late Palæozoic orogeny the *Hunter-Bowen Movement*. 
The position of the western boundary of this Tournaisian sea is somewhat speculative owing to a cover of later sediments. It must, however, have lain to the east of Pokolbin and Gosforth in the Lower Hunter Valley, where Upper Kuttung rocks rest directly on Devonian granite, and it cannot have been far to the west of the Werrie syncline.

Fig. 2 shows the strip, about 35 or 40 miles wide, which was reclaimed and converted into low-lying lacustrine areas in which the Lower Kuttung lavas and sediments...

Fig. 1.—Map showing the position of the Hunter-Bowen overthrust zone (the Queensland portion after J. H. Reid).

PALÆOGEOGRAPHY.

In Figs. 2 and 3 an attempt has been made to depict very roughly the marine and terrestrial areas of Burindi and Kuttung time in New South Wales and Queensland. The Upper Devonian sea, which had stretched far to the west in New South Wales, became very much restricted as a result of the Kanimbla orogeny, and Tournaisian deposition was confined to New England, where Carboniferous sediments were laid down upon the Devonian without unconformity.
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Fig. 2.—Map showing the approximate position of the strand-line in N.S.W. in Tournaisian and Viséan times.
were deposited, while the Upper Burundi (Viséan) sea continued to occupy the area to the east. The volcanic activity may have been related to the crustal movement.

The Drummond Movement at the close of Burundi time drove out the sea from most of the area it had occupied, leaving only a narrow strip in the north-east corner of the State still inundated. New England may have become a broad highland extending into southern Queensland and a scene of active erosion, while a wide, low-lying trough with large lakes occupied the space between this and the

![Map of Queensland and New South Wales showing distribution of land and sea](image)

**Fig. 3.**—Distribution of land and sea in Queensland and N.S.W. (a) in Burundi time, and (b) in Upper Kuttung time. Land areas blank; marine areas ruled; low-lying areas of terrestrial deposition stippled.
worn-down Kanimbla Mts. stretching north beyond Rocky Creek. This trough became filled chiefly with glacial and fluvio-glacial sediments and volcanic material. To the south in the Hunter Valley it bounded the New England highlands, but south of Newcastle the Kanimbla highlands extended out into what is now the Tasman Sea, and by their erosion supplied débris to the lowlands of the north.

The New England highlands were bounded on the east by another lowland trough which passed through Kempsey and Drake into Queensland. This was occupied in part by the sea and in part by freshwater lakes.

In eastern Australia Upper Kuttung glacial rocks are not known with certainty much farther north than Rocky Creek, N.S.W., and it would appear that the Middle Carboniferous glaciation, though of considerable geological interest, was areally insignificant in comparison with those that followed during the Kamilaroi Period.

In Queensland the boundary between land and sea throughout Lower Carboniferous time ran in some indefinable position between the Drummond Range and Stanwell, possibly somewhere within what is now the Great Syncline. Further north it curved forward to pass east of Silver Valley, where the Upper Kuttung Aneimites beds rest on a floor of pre-Carboniferous rocks. Whether the coastline shifted in sympathy with that in New South Wales we cannot say, as Carboniferous strata do not crop out in the area of the Great Syncline. The Drummond Range, with the country north of it perhaps as far as Cape York, formed a low-lying slowly-sinking area of freshwater deposition whose integrity remained unimpaired till the Drummond orogeny converted it into an elevated land-area, the southerly extent of which we do not know.

If folding and uplift of the Lower Carboniferous and Devonian beds between Rockhampton and Brisbane occurred at the time of the Drummond orogeny, the Middle Carboniferous geosyncline must have been restricted to a trough bounded east and west by highlands. The western portion of this—whether terrestrial or marine we know not—may have been continuous with the land trough in New South Wales passing west of New England, while in the east it was occupied by the sea, which stretched south from Stanwell to Mt. Barney and Drake. This long narrow corridor, which separated the mainland of Australia from the land Tasmantis lying to the east, was the sole
marine remnant of the Tasman geosyncline which had existed in eastern Australia from Lower Palæozoic time. Further south, where the floor of the trough was a little above sea-level, the lands were precariously united for a time until the rising tide of the Lochinvar inundation severed them once again.

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Trichosurus vulpecula, is a typical marsupial in that the female of the species possesses a pouch in which it rears its young. Whilst in this laboratory various marsupials were being examined with regard to their response to sex hormones, the female of the commonly occurring possum was injected with oestrone. At our disposal were four fully matured animals which had borne young. Further, we were able to study six fully grown females which had not yet reached sexual maturity, and a number of pouch embryos. All these possums were obtained in the neighbourhood of Sydney, New South Wales.

Observations at the Different Stages of Development.

In the hairless female pouch embryo the pouch is already evidenced by a linear furrow which leads into a small recess behind a semilunar fold opening cephalad (Plate XIV). As the animal grows, the pouch area becomes less evident, and on casual examination of the ventral surface of the almost fully grown or fully grown but sexually immature animal nothing very conspicuous is observed. The colour of the hair is white, becoming grey as the lateral surface and neck are approached. On manual examination, however, and brushing aside of the hair of the lower abdomen, a dry linear furrow is noticed; the length of this is about 3 cm. and on stretching it opens up to about 1.5 cm. in width. The bottom of this furrow is covered with a small...

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