THE GEOLOGY OF THE GLOUCESTER DISTRICT OF NEW SOUTH WALES.

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WITH ROCK ANALYSES BY W. G. STONE.

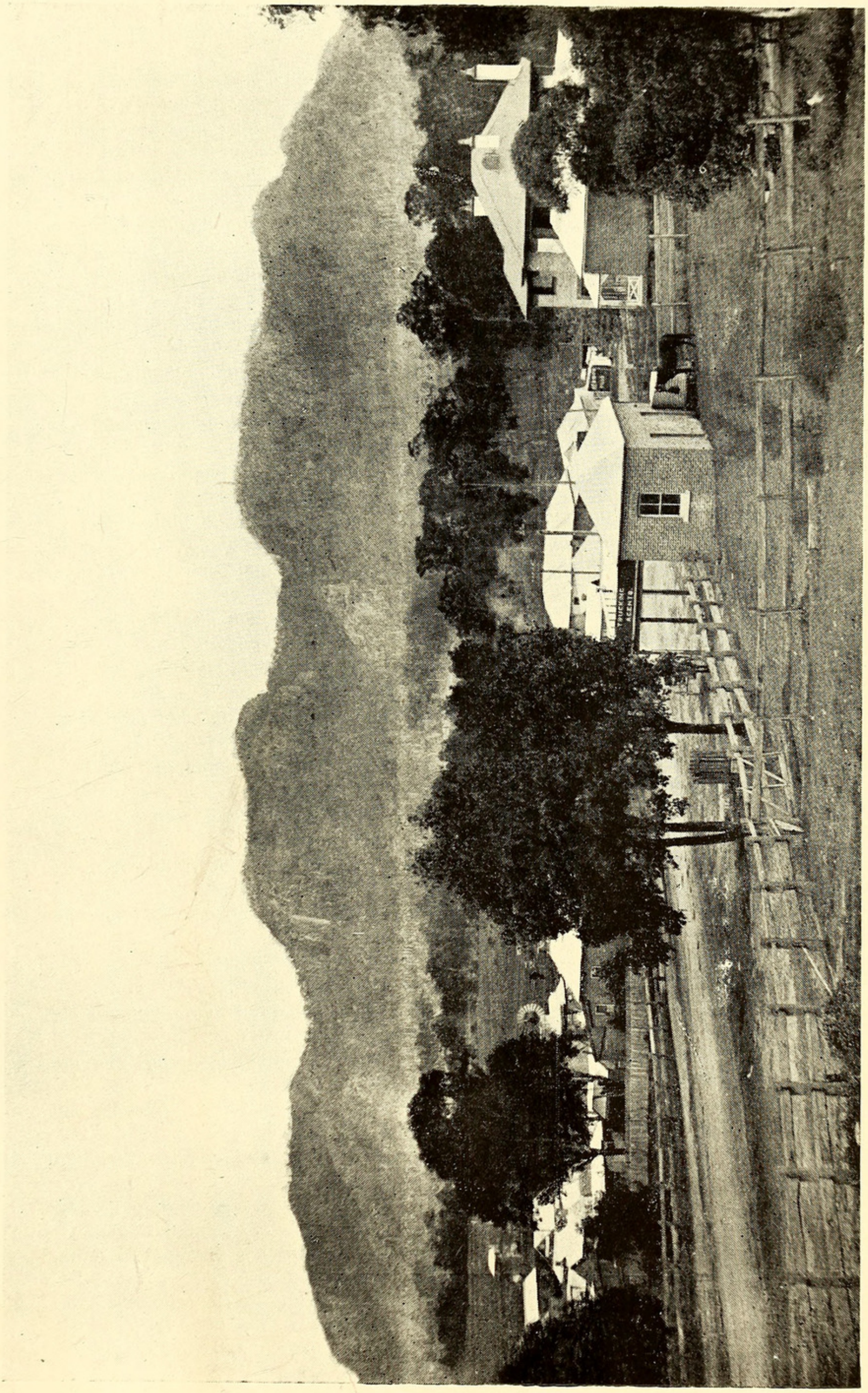
[With Plates XVI - XVIII.]

[Read before the Royal Society of N.S. Wales, December 7, 1921.]

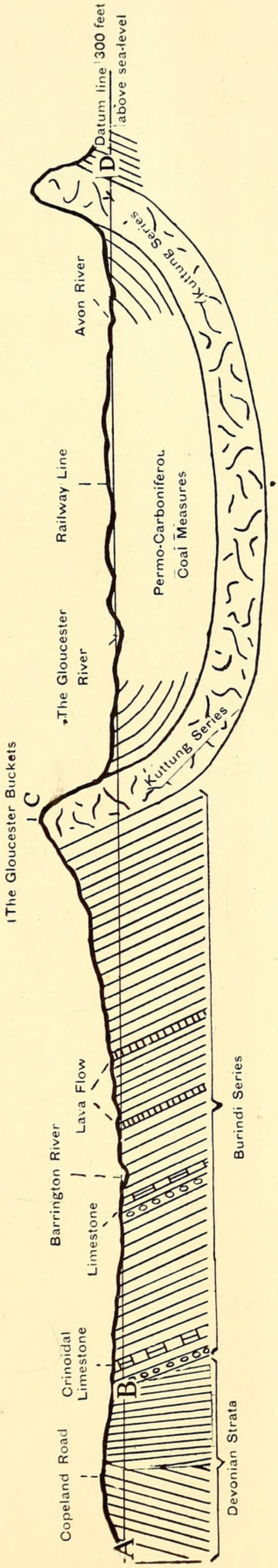
TABLE OF CONTENTS.

Introduction.

Very little has previously been published about the geology of this district. In 1915, the writer, in company with Professor W. N. Benson, D.Sc., examined the railway cuttings between the Bulliac railway station and the Manning River. A brief note of the observations then

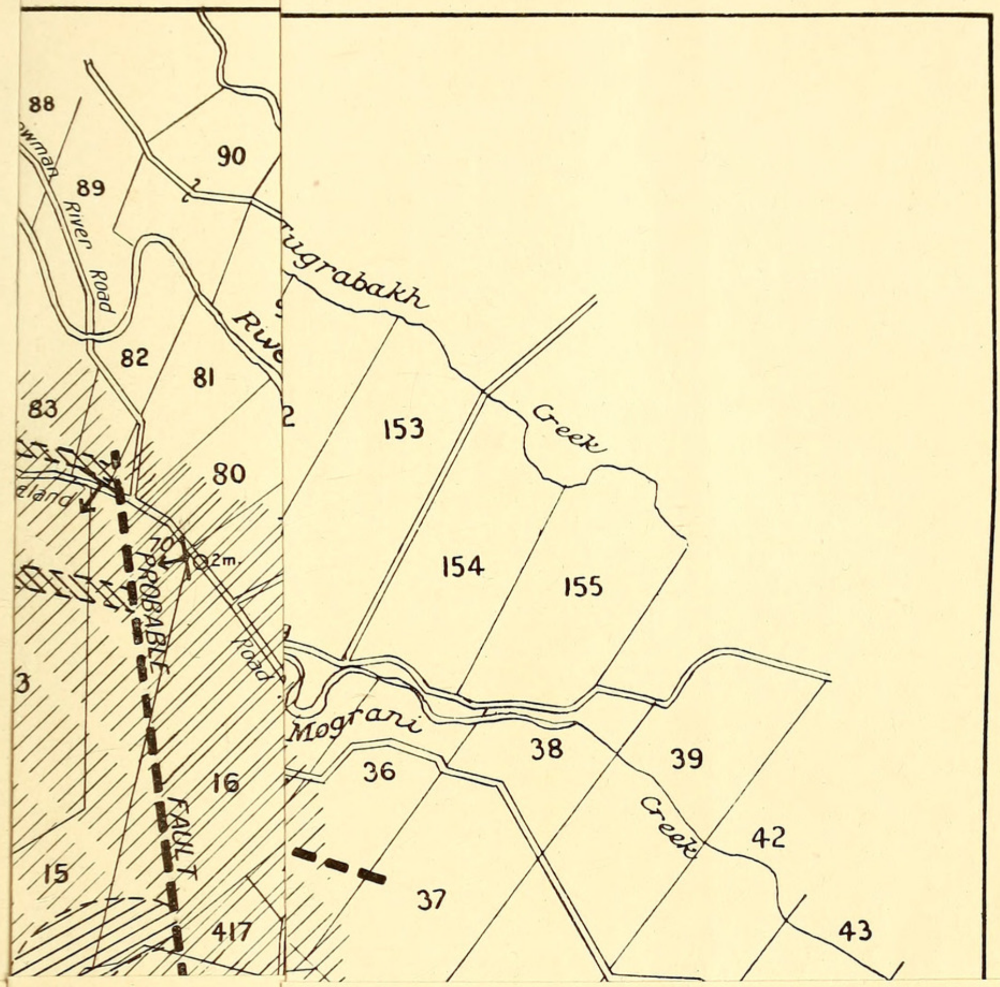


"The Gloucester Buckets"—Carboniferous Rhyolite Flows.

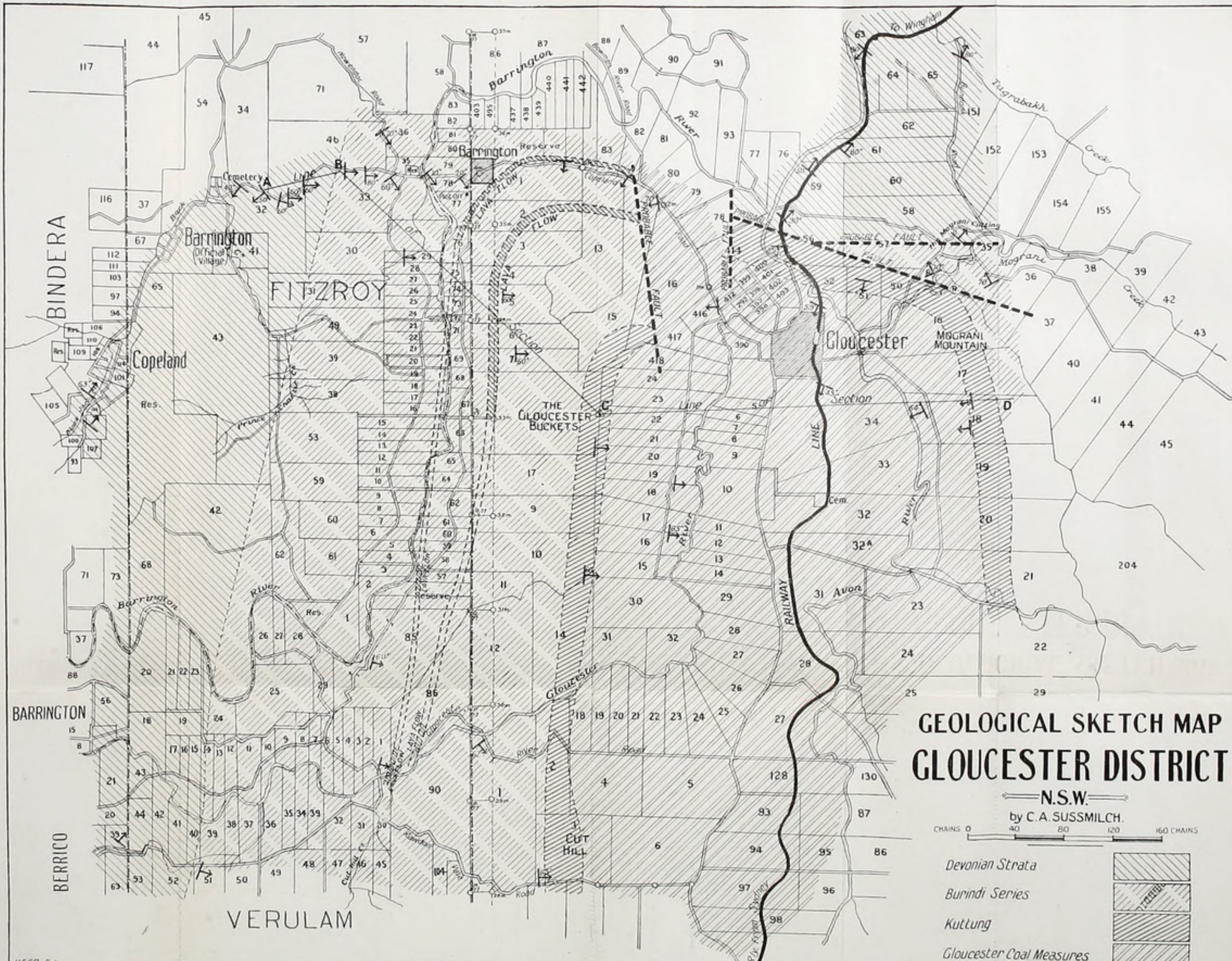


Geological Section along line A B C D on accompany Map, Plate XVIII.

Plate XVIII.



88
90
89
River Road
Tugrabakh
River
82
81
83
153
Creek
80
154
155
70
2m.
PROBABLE
FAULT
Road
Mograni
38
39
36
16
Creek
42
15
37
417
43


GEOLOGICAL SKETCH MAP
GLOUCESTER DISTRICT
N.S.W.
by C.A. SUSSMILCH.
CHAINS 0 40 80 120 160 CHAINS
Devonian Strata
Burindi Series
Kuttung
Gloucester Coal Measures
FITZROY
BINDERA
VERULAM
BERRICO
BARRINGTON
Barrington
Barrington (Official Village)
Copeland
Gloucester
MOGRANI MOUNTAIN
THE GLOUCESTER BUCKETS
CUT HILL
RAILWAY LINE
Barrington River
Gloucester River
Avon River
Mograni Creek
Tugrabakh Creek
To Wingham
LAVA FLOW
FAULT
Section Line
Cemetery
H.E.C.R. Delt.

made was contributed to the proceedings of the Geological Section of the Royal Society of New South Wales.[1] Since then, the author has made a number of short field trips to the Gloucester District, mainly for the purpose of working out the succession and thickness of the Carboniferous strata, and their stratigraphical relationship with the underlying Devonian strata. Time did not allow of the making of an accurate detailed geological map, and in the one which accompanies this paper, the boundaries of the various geological formations shown are only approximations. They are, however, sufficiently accurate to reveal the general geological structure of the district. I have to thank Messrs. V. B. Collins, A. F. Newman, and W. Clark for much help in carrying out the field work; and my thanks are due to Mr. W. G. Stone for having kindly made the analyses of the igneous rocks. I have also to thank Prof. Sir Edgeworth David for much kindly advice, when he accompanied me on one of my visits to the district.

Physiography.

The most striking physiographical feature of the district adjoining the town of Gloucester is a majestic group of rocky hills, with precipitous faces, lying to the west of the town, and known as the The Gloucester Buckets. These are made up of Carboniferous lava flows, now tilted on end. Almost equally conspicuous is another rocky range of hills lying to the east of the town, and known as the Mograni Mountain. This, in its geological structure, is similar to the Gloucester Buckets.

The North Coast Railway, from Craven to Gloucester, traverses a relatively low region 300 to 400 feet in altitude, a region about five miles wide and twelve miles long, in a north and south direction. This region has a gently

[1] This Journal, Vol. XLXIX, 1915, Abstract of the Proceedings of the Geological Section, p. xxvii.

undulating surface, but is bounded on both its eastern and western margins by precipitous, rugged ridges ranging up to 2,000 feet in altitude, and striking almost due north and south. These ridges consist of Carboniferous lava flows, whereas the low-lying region in between consists of Permo-Carboniferous Coal Measures. Similar features continue southward from Craven for at least another ten miles. North of Craven this region is drained by the Avon and Gloucester Rivers, as shown on the map in Plate XVIII.

At Gloucester, which lies at the northern end of this region, the lava flows of the eastern range, here known as the Mograni Mountain, swing round to an east and west direction, almost joining on to the western range—the Gloucester Buckets—and almost cutting off the valley of the Avon River at this point.

At first sight, this long, narrow, relatively depressed region might be taken for a rift valley, but a study of the geological structure dispels this view. The Carboniferous and Permo-Carboniferous strata have been folded into a huge synclinal fold, striking north and south. The weak coal-measures which lie in the trough of the fold have been deeply denuded, whereas the Carboniferous lava-flows which flank them on either hand have resisted denudation, and have survived as steep ridges.

In Tertiary times, a peneplain had been developed in this district, and at the end of the Tertiary Period (the Kosciusko Epoch) an elevation of about 2,000 feet took place, converting the peneplain into a tableland. Denudation since then has maturely dissected the tableland; mature valleys have been cut into the weaker geological structures, while the harder, resistant structures still survive as high ridges. The way in which the larger streams cut across the hard and weak structures alike, and the entrenched meanders, notably those of the Barrington River, as well as other features, all suggest that the mainstream channels ante-date the present topography, *i.e.*, they are revived streams.

Some twenty miles to the west of the region here being described lies the Barrington Tableland, 4,000 to 4,500 feet in altitude, its eastern margin being marked by a great fault escarpment. Its surface is part of the same peneplain as that which occurs in the Gloucester District, the two regions being elevated during the same uplift, but while the Gloucester region was uplifted only about 2,000 feet, the region to the west was uplifted 4,500 feet; and the stresses set up as a result of this unequal movement, developed the line (or lines) of faulting which mark the eastern face of the Barrington Tableland.

Geological Formations.

The geological formations represented in the Gloucester District are as follows:—

Post Tertiary	Alluvial Deposits	
Permo-Carboniferous	Gloucester Coal Measures	(? Upper Coal Measures)
Carboniferous	The Kuttung Series	Lava flows, conglomerates mud stones, and tuffs.
	The Burindi Series	Conglomerates, shales, limestones, tuffs, and lava flows.
Devonian	The Barraba Series	Banded shales, mudstones, limestones, and tuffs, with Radiolaria and *Lepidodendron australe*.
	The Tamworth Series	Banded radiolarian cherts intrusive tuffs, and spillite lavas.

A. The Devonian System.

Upon reference to the accompanying map it will be seen that Devonian strata outcrop extensively over the northern and western parts of the area shown. Excellent exposures may be seen in the cuttings along the railway line from Gloucester to the Manning River, starting at a point about one and a quarter miles from the Gloucester Railway Station. The strata in the hills around Copeland are also of Devonian age, and extend eastwards along the Copeland-Gloucester Road to a point about one mile west of the Barrington River Bridge. The whole series is very highly folded, the strata over very large areas being almost vertical; their general strike is about N. 40° West. No attempt has been made to study these Devonian strata in great detail; neither the base nor the top of the formation has been found yet in this district; so that it is impossible to give a complete section here. The main object in studying these beds has been to attempt to work out their stratigraphical relationship with the succeeding Carboniferous formations.

I. *The Tamworth Series.*—These are extensively developed, around the township of Copeland and in the railway cuttings between Gloucester and Bundook. They consist of spillite lavas, tuffs, radiolarian cherts, and mudstones, limestones, and more rarely, quartzites.

(*a*) *The Spillites.*—These do not occur in the immediate neighbourhood of Gloucester but are very extensively developed in the neighbourhood of Bundook. Here they outcrop along the railway line eastwards of Bundook railway station for about two miles. The western end of Kangat Mountain (2,000 feet high) is made up entirely of these lavas. They exhibit in places typical "pillow" structure, and are in places somewhat vesicular. Under the microscope they are seen to contain well-preserved pyroxene and albite felspar. These rocks have undergone a considerable amount of alteration in places, with abundant introduction of quartz and epidote. Similar spillites of Middle Devonian age have already been described in great detail by Prof. W. N. Benson,[1] from the Tamworth-Nundle District, consequently no detailed petrological description will be given here.

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[1] Geology and Petrology of the Great Serpentine Belt, Part III, by W. N. Benson, B.A., B.Sc., Proc. Linn. Soc. N.S.W., Vol, XXXVIII, p. 662, 1913.

The width of the outcrop, taken in conjunction with the dip of these spillites in the Bundook neighbourhood, would give a thickness of several thousands of feet for these rocks. Quite probably some strike faulting has taken place, giving duplication of outcrop. Even after allowing for this possibility, their actual thickness must be at least 2,000 to 3,000 feet. Such a great thickness of spillite ("pillow") lavas has not, so far as the writer is aware, been recorded from any other locality; and it at once raises the question as to whether the conditions of deposition usually postulated for such rocks are correct.

(*b*) *The Tuffs.*—These have a very large development, and are interstratified everywhere throughout this district with the other Devonian sedimentary rocks. They are typically fine-grained in texture, with a greyish-blue colour, and intermediate to subacidic in composition. Both coarser and darker coloured varieties also occur. These tuffs are in general regularly interstratified with the other sedimentary strata, but in many places they are seen to have intrusive relations with the radiolarian cherts and claystones, similar in every way to the intrusive tuffs of the Tamworth District described by Messrs. David and Pittman.[1] Particularly fine examples of these intrusive tuffs can be be obtained from the spoil heaps at the Mountain Maid Mine at Copeland, and excellent examples may also be seen in the railway cuttings between Gloucester and Bundook. The individual layers of tuff vary much in thickness, ranging from less than one inch to upwards of 100 feet in thickness. No really satisfactory explanation of these anomalous "intrusive tuffs" has yet been put forward.

(*c*) *The Radiolarian Cherts and Claystones.*—These constitute the most abundant of the strata of the Tamworth

[1] "On the Palæozoic Radiolarian Rocks of N.S. Wales, Q.J.G.S., 1899, pp. 16 - 37.

Series, and aggregate several thousands of feet in thickness. They are for the most part well laminated, consisting of alternating lighter and darker layers, the individual laminæ sometimes being very thin; radiolaria are very abundant in some of the layers. Beds of tuff are interstratified with these rocks, and in many places intrude them.

(*d*) *The Limestones.*—These are not common in this district. The largest bed known to the writer outcrops about four and a half miles N.E. of the town of Gloucester, on the road from that town to Bundook near where it crosses the Tugrabakh Creek. This limestone bed strikes N. 40° E. and stands in a nearly vertical position. It is about 100 feet in width, and is being quarried for use as a flux at the Cockle Creek Smelting Works. This limestone is of good quality, as may be seen from the following analysis:[1]

Calcium Carbonate	98·11%
Magnesium Carbonate	0·49
Ferric Oxide and Alumina	0·80
Gangue	1·09

No recognisable fossils have yet been obtained from this bed of limestone, but it is interstratified with what appear to be, from their petrological character, undoubted Devonian sediments.

(*e*) *The Quartzites.*—These have been observed only in the Copeland goldfield, where several beds occur, ranging individually up to 10 feet in thickness. One of these was noticed in the underground workings of the Mountain Maid Mine. They are fine-grained.

Fossils.—The only recognisable fossils so far found in the Tamworth Series are radiolaria and stems of the lycopod *Lepidodendron australe*.

[1] Mineral Resources of New South Wales, No. 25, Department of Mines. The Limestone Deposits of New South Wales, by J. E. Carne.

II. *The Barraba Series.*—The thick series of radiolarian mudstones and tuffs which outcrop on the Gloucester-Copeland road, between the six and seven mile posts, probably belong to this series. They, however, do not make good outcrops, and may possibly be part of the Tamworth Series. They contain abundant radiolaria, while specimens of drift Lepidodendron are not uncommon. Some of the mudstones outcropping on the railway line between Bulliae and Gloucester may also belong to this series.

III. *The Gold Reefs in the Devonian Strata.*—In that part of the district adjacent to the village of Copeland, the Devonian strata are intersected by a number of auriferous reefs. Those examined by the writer, viz., the Mountain Maid reef and Sawyer's reef, strike approximately east and west, and hade to the south.

The reefs are lenticular, varying from 6 to 10 inches in thickness, and the walls display well developed slickensides. The ore consists mainly of quartz, with a little pyrites, and with some angular fragments of country-rock embedded in it in places. The reefs are obviously, therefore, true fissure veins deposited along lines of faulting. The gold occurs in irregular shoots which are sometimes very rich, but which are usually short. These shoots pitch to the east. The gold is free, but the reefs also contain a little auriferous pyrites, and more rarely a little galena. Owing to their small size, and the smallness and irregularity of the shoots, these reefs have not proved very remunerative and not much work is at present being done on them.

B. The Carboniferous System.

The Carboniferous strata occur in the form of a large syncline striking practically due north and south. They are divisible into a lower series of marine origin—the Burindi Series—and an upper series of terrestrial origin—the Kuttung Series. The details of the Carboniferous strata as they occur along the lines B C on the accompanying geological map are as follows :—

The Kuttung Series	The Gloucester Rhyolites ...	1500 feet
	The Rhacopteris Beds	100 ,,
	The Conglomerates	150 ,,
The Burindi Series.	Tuffs and Mudstones (with marine fossils)	3250 ,,
	Productus Barringtonensis Bed...	20 ,,
	Tuffs...	140 ,,
	Quartz Keratophyre (No. 3 lava flow)	200 ,,
	Tuffs...	50 ,,
	Quartz Keratophyre (No. 2 lava flow)	400 ,,
	Tuffs...	250 ,,
	Marine Mudstones and Tuffs ...	800 ,,
	Oolitic Limestone...	20 ,,
	Mudstone	40 ,,
	Quartz Keratophyre (No. 1 lava flow)	200 – 400 ,,
	Mudstones	60 ,,
	Conglomerates	150 ,,
	Mudstones and Tuffs	1750 ,,
	Limestone (oolitic in part and tuffaceous)	60 ,,
	Mudstones	1900 ,,
	Tuffs...	120 ,,
	Conglomerates	30 ,,
	Mudstones	120 ,,
	Crinoidal Limestone (with Zaphrentis)	80 ,,
	Mudstones and Tuffs	50 ,,
	Conglomerates	20 ,,
	Mudstones	...(?)900 ,,
	Conglomerates	50 ,,
	Total ...	...12410 ,,

The possibility of there being some duplication of strata in the above section has been considered, but no evidence of such being the case has been found.

I. *The Burindi Series.*—The details of this series are shown above. They consist of conglomerates, limestones, mudstones, tuffs, and lava flows, and have a maximum thickness of 10,800 feet. This section has been taken from the valley of the Barrington River, on the western side of the Gloucester Buckets.

(*a*) *The Conglomerates.*—Several beds of conglomerate occur at and near the base of the Burindi Series, ranging individually from 20 to 40 feet in thickness. They contain well waterworn pebbles of quartzite, quartz-porphyry, aplitic-granite, and a dark coloured felspar porphyry; the pebbles ranging up to 12 inches in diameter. A few small pebbles of a cherty rock, not unlike the cherts which occur in the Devonian Series, have also been found. These conglomerates may be seen crossing the Copeland road, about one mile west of the Barrington Bridge, and also along the Nowendoc road, about half a mile north of its junction with the Copeland road. A bed of conglomerate also occurs at the junction of the Copeland and the Bowman River roads. This bed is over 100 feet thick, and contains many large pebbles. Its position is about 5,000 feet above the base of the Burindi Series.

(*b*) *The Mudstones.* —These form the bulk of the Burindi Series, aggregating many thousands of feet in thickness. They are blue-black to greyish-green in colour, very fine grained, and typically thin bedded. Tuffs are frequently interstratified with them. Certain bands contain marine fossils, but these fossiliferous bands appear to be few and far between. The fossils they contain are listed on page 245. At different horizons, fairly abundant fragments of fossil plants are found, including imperfectly preserved stems of Lepidodendron and Archæocalamites. This appears to be drift material.

(*c*) *The Limestones.*—Three distinct limestone horizons occur in this series. The lowest bed, about 80 feet thick, is a coarse, crinoidal limestone, the crinoid stems ranging up to three-quarters of an inch in diameter. It can be seen outcropping on the Nowendoc road, where it immediately underlies a bed of conglomerates. A similar crinoidal limestone outcrops on the stock reserve about two miles out from Gloucester, on the Taree road. Its position here is probably due to faulting. What is probably also the same limestone bed outcrops strongly in Tugrabakh Creek, near Brushy Mountain, about six miles from Gloucester. Here fossil corals *(Zaphrentis)* are associated with the crinoids. The second limestone bed outcrops strongly on the Copeland road, close to its junction with the Nowendoc road (Portions 33 and 35, Parish of Fitzroy). It is a dark, compact limestone, oolitic in places, and apparently devoid of fossils. It is upwards of 60 feet in thickness, and has been observed at intervals for several miles to the south (Port. 29 P. of Fitzroy and Port. 85 P. of Verulan). The third bed of limestone is also oolitic, and has so far yielded no fossils, it outcrops on the Copeland road, half a mile east of Barrington village.

These limestones are for the most part impure, as may be seen from the following analyses. In places they are tuffaceous, and regular bands of lapilli can be seen in them. These analyses have been taken from Mr. J. E. Carne's work on "The Limestones of New South Wales," (Mineral Resources of N. S. Wales, No. 25).

Crinoidal Limestone (No. 1 bed)	$CaCo_3$	$MgCo_3$	F 203 and Al 203	Gangue
Stock Reserve, two miles from Gloucester	79·68	0·97	2·28	15·79
Ditto, ditto	99·17	trace	0·36	0·56
Tugrabakh Creek, 6 miles from Gloucester...	89·30	1·56	1·35	7·75
No. 2 Limestone Bed (Por. 33 35, Parish of Fitzroy) ...	68·81	1·68	1·86	26·34

(*d*) *The Tuffs.*—These are for the most part fine grained, and are interstratified with the mudstones. They have their greatest development in the upper part of the Burindi Series, where they are associated closely with the lava flows, and here they are in some cases fairly coarse. They contain an abundance of quartz and felspar grains, more rarely a little biotite and with occasional fragments of rhyolite.

(*e*) *The Lava Flows.*—Three distinct lava flows have been noted in the Burindi Series, all outcropping in the valley of the Barrington River on the lower north-western and western slopes of the Gloucester Buckets. These lavas are quartz-keratophyres, and are described in detail on page 253. The lowest flow (No. 1) may be seen outcropping on the Copeland road immediately west of its junction with the Bowman River road, from here its outcrop runs just north of and parallel to the Copeland road for over a mile. As the village of Barrington is approached the outcrop swings to the north-west, crosses the road and disappears under the river flats of the Barrington River. Some lava flows outcropping on Portion 57 Parish of Verulam are probably a continuation of this flow. The Nos. 2 and 3 flows, which are higher in the series, outcrop to the south of the Copeland road, and their outcrops follow a similar and parallel course to the No. 1 flow. They have been traced as far south as McCraes farm (Port. 4, A. A. Cos. subdivision). Some similar lava flows which outcrop on the Gloucester River road (Port. 85 Parish of Verulam) are no doubt the southern continuation of these flows.

II. *The Burindi Fossils.*—The following is a list of the fossils so far found in the Burindi Series. Not much attention has been given to the collection of fossils, so that the list given is probably by no means exhaustive:—

Lycopodiales... *Lepidodendron* (decorticated stems), (? *L. veltheimiamum*).

Actinozoa ... *Zaphrentis* sp. ind.

Crinoidea ...	Crinoid stems.
Brachiopoda ...	*Dielasma sacculus.*
	Chonetes c.f. *Hardrensis.*
	Orthis australis.
	Athyris.
	Productus barringtonensis.
	,, *pustulosis.*
	Orthotetes crenistria.
	Spirifera crassa.
	,, sp. ind.
	Reticularia.
Trilobita ...	*Phillipsia* sp. ind.

As is usually the case with the Carboniferous marine fauna in New South Wales, brachiopods largely preponderate, while the individuals are usually quite small. There is, however, one fossil bed on McCrae's farm (Portion 4, A.A. Cos. subdivision), which is crowded with the large brachiopod, *Productus barringtonensis.* The rock is a coarse tuff, 10 to 20 feet thick, and this fossil is the only one found in it.

III. *The Kuttung Series.*—These follow the Burindi Series conformably, and have a total thickness of 1750 feet; they consist mainly of lava flows.

(a) *The Conglomerates.*—These have been taken as the basal beds of the series; they outcrop on the western side of the Gloucester Buckets where they are about 150 feet thick, while the pebbles are small. Further to the south where they cross the Rawdon Vale Road, they are somewhat thicker and the pebbles are coarse averaging from 4 to 6 inches in diameter. These conglomerates are probably the equivalent in this district of the Wallarobba conglomerates previously described for the Wallarobba-Clarencetown district[1] some 50 miles to the south.

[1] Sequence, Glaciation, and Correlation of the Carboniferous Rocks of the Hunter River District, N.S.W., by C. A. Sussmilch and T. W. E. David, this Journal, Vol. LIII, p. 246, 1919.

(b) *The Rhacopteris Beds.*—These are quite thin; they consist of tuffs with some shales, and immediately underlie the Gloucester Buckets rhyolite flows. They contain the following fossil plants :

Fibiales { *Rhacopteris intermedia*
(?) *Aneimites (Rhacopteris) ovata*
Cardiopteris polymorpha
Archæopteris sp. ind.

Equisetales—Calamitean stems.

(c) *The Gloucester Rhyolites.*—These being a very striking development in this district, forming the back-bone of the precipitous ranges which occur both to the east and west of the town. They are particularly well seen in the Gloucester Buckets (see fig.) where they are 1500 feet thick, as also in the Mograni Mountain; good sections may be seen in the railway cuttings immediately north of the railway bridge on the Avon River. A number of flows are included in the above thickness, but they are all very similar in character. This lava is a typical rhyolite, light in colour and frequently with well-marked flow structure. It is described in detail later on.

A comparison of the Kuttung Series of the Gloucester District with that of the Hunter River District some fifty miles to the south reveals the following important differences (*a*) the relatively small thickness of this series in the Gloucester District, as well as the almost entire absence of the conglomerates whose great thickness is such a characteristic feature of the Kuttung Series in the Hunter River area, and (*b*) the apparently entire absence of glacial beds in the Gloucester District. The broad details of the Kuttung Series of the two areas are as follows:

Hunter River District.	Ft. thick.	*Gloucester District.*	Feet.
Seaham Glacial Beds ...	1840	The Gloucester Rhyolites	1500
Paterson Rhyolite ...	300	The Rhacopteris Beds	100
Mount Johnson Beds ...	1950	The Conglomerates ...	150
Martin's Creek Beds ...	2200		
Wallarobba Beds .	2000		
Total ...	8290	Total ...	1750

Several possible explanations for these differences suggest themselves. The Kuttung Series were deposited under terrestrial conditions, and the high land which supplied the sediments may have occurred immediately to the south and south-west of the Hunter River area; if this were so one would expect the thickness of the sedimentation, and particularly of the conglomerates to become proportionally less northwards. On the other hand a considerable thickness of Kuttung strata may have been removed by denudation in the Gloucester District after their deposition and before the Gloucester Coal measures were laid down, as there is a considerable time and interval between the two formations. This might account for the absence of the Glacial Beds and perhaps of the Mount Johnson Beds, but would not account for the absence of the Wallarobba Beds which would normally underlie the rhyolites. These matters cannot, however, be definitely decided until detailed mapping is carried out in the intervening areas.

IV. *Relation of the Carboniferous formation to the Devonian.*—Unfortunately, no actual contacts between the Devonian and Carboniferous strata have been found in this district. In the northern part of the area shown in the map (Plate XVIII) outcrops of the two formations almost come into contact in the railway cuttings a short distance north of the Avon River railway bridge, but this junction is a faulted one, the Tamworth Beds here lying against the Kuttung Series; the whole of the Burindi Series is missing. In the western part of the map (Plate XVIII) a junction of the Devonian and Carboniferous strata is shown running parallel to the Barrington River on its western side, but the position shown is only an approximation. Both the Devonian strata and the lower Burindi Series are weak rocks and give either very poor outcrops or none at all; it is therefore, practically impossible to locate the base of the Carboniferous formation with any degree of certainty. On the Copeland road the base was taken at a bed of conglomerate which crosses the road about one mile west of the Barrington Bridge. Notwithstanding this absence of direct evidence there are some facts which suggest the evidence of an unconformity between the two formations. This evidence is as follows:

1. *The very general difference between the strike of the two formations.*—The strike of the Devonian strata in the area examined varies from due north to north 60° west, the great majority of the readings, however, are in the neighbourhood of north 40° west. The angle of dip is very high, in many places quite vertical. The Devonian strata therefore, have been strongly folded, the axis of folding being about north 40° west. The Carboniferous strata are also highly folded, also approaching the vertical in places, but are not so steep on the average as the Devonian strata. In the district under consideration they have been folded into a huge syncline whose axis strikes practically north and south; the axis of this syncline is opposed to the Devonian lines of folding.

2. *Nature of the strata of the two formations.*—The nature of the Devonian sediments indicates quiet deposition in moderately deep water in a locality far removed from a shore line; there is an entire absence of littoral deposits, and also an absence of a coastal marine fauna. It is true that a terrestrial plant *(Lepidodendron australe)* is fairly common, but this plant is represented by relatively large stems only, which might have drifted long distances from land, before sinking and becoming buried in the Devonian sediments. The Burindi strata on the other hand include such littoral sediments as conglomerates and oolitic limestones, while some of the mudstones and tuffs contain fossils of a coastal marine fauna. It is true that there is a notable absence of sandstone, although some sandy-shales occur,

but this could be due to the nature of the rocks on the land which was being denuded to provide the sediments. If this land consisted largely of Devonian strata the sediments found in the Burindi Series are just what one might expect to find.

3. *Comparison of the Devonian and Carboniferous marine fauna.*—No marine fossils of Devonian age, other than radiolaria have been found in this district, but the Devonian marine fauna from adjoining parts of north-eastern New South Wales is well known. Very few Devonian species have passed upwards into the Carboniferous Period, neither did many of the genera. No passage beds have yet been found. Taking all of the facts into consideration, it may be said that while no angular unconformity has been proved, there is certainly a strong disconformity between the strata of the two periods, and that important crustal movements occurred at the close of the Devonian Period.

C. The Gloucester Coal Measures.

These coal-measures, besides occurring over the area shown on the map, extend southwards past the village of Craven, down the valley of Ward's River to within a few miles of Stroud Road. This southern area has sometimes been referred to as the Ward's River Coal Measures. It will be seen that this coal basin is about 35 miles long, and from five to eight miles wide. No detailed surveys have yet been made of this little known coal basin, and the author himself has made only a cursory examination of the measures in the immediate neighbourhood of Gloucester. Here they consist of shales, sandstones, grits, conglomerates, and coal-seams totalling upwards of 1,000 feet in thickness. A fairly good section of these strata may be seen in the railway cuttings immediately to the north and south of the Gloucester railway station. In the cutting to the north of the railway station numerous coal seams are exposed, with an aggregate thickness of at least 50 feet of coal, and dipping South 30° W., at an angle of 57°.

A shaft has been sunk near Gloucester on one of these seams, near the bank of the Avon River, about one and a quarter miles west of the railway line. This shaft has penetrated a coal-seam 31 feet in thickness. This seam contains several well marked bands of shale, ranging individually up to 10 inches in thickness, and aggregating 4½ feet in thickness, there being 26½ feet of clean coal. An analysis of this coal, made in the Mines Department Laboratory, was as follows:—

Water	1·35	per cent.
Volatile Hydrocarbons	33·92	,,
Fixed Carbon	55·54	,,
Ash	9·19	,,
Total	100·00	

Sulphur ·754

Water converted into steam by 1 lb of coal at 212° F., 13·2

Specific gravity 1·307

Calories 7088

B.T.U. 12·964

The sample from which this analysis was made is said to have been taken across the full width of the seam, but excluding the bands. Good thicknesses of clean coal occur between the bands. The seam here strikes north and south and dips west at an angle of 64°. On the western side of the Gloucester River, however, the coal measures strike north and south, and dip east at about the same angle. From these dips, taken in conjunction with those in the railway cuttings at Gloucester railway station, it would appear that the coal seams, like the surrounding Carboniferous strata, occur in the form of a plunging syncline.

There is an interesting occurrence of these coal measures on Portion 81 close to the junction of the Copeland and Bowman River roads. Here, where they have been brought into direct contact with the middle part of the Burindi Series by faulting, they appear to dip under the Burindi Beds.

I. *Age of the Coal Measures.*—These coal measures contain an abundance of the fossil plant Glossopteris: they are obviously, therefore, of Permo-Carboniferous age. The composition of the coal given in the above analysis is very like that of the Borehole Seam in the Newcastle Coal Measures. The grits and conglomerates associated with the coal measures are very like those of Fassifern, in the Newcastle District. These facts, taken into conjunction with the thickness of the strata (1,000 feet or more), would indicate that these coal measures belong to the Upper or Newcastle Coal Measures, rather than with the Lower or Greta Coal Measures. This basin would appear to be a continuation of that shown by Prof. Sir Edgeworth David to extend northward from the Hunter River District towards Stroud. The two basins were, no doubt, at one time continuous, but have been isolated by folding and subsequent denudation.

II. *Stratigraphical relation to the Kuttung Series:*—If the above conclusion that the Gloucester Coal Measures are the equivalent of the Newcastle or Upper Coal Measures is correct, then the whole of the remaining subdivisions of of the Permo-Carboniferous formations totalling upwards of 10,000 feet are missing in the Gloucester District. If, however, it should be that they are the equivalent of the Greta or Lower Coal Measures, then only the Lower Marine Series would be missing, these latter in the Hunter River District are 4,600 feet in thickness. In either case, therefore, a thick series of strata is missing from between the

Kuttung Series and the Gloucester Coal Measures, and there is therefore a strong disconformity between the two series. The Gloucester Coal Measures, so far as the author's observations have gone, appear, except where they have been interfered with by faulting, to conform to the dip and strike of the Kuttung Series and to form part of the same great synclinal fold. It would appear to be the case, therefore, that the folding which produced this syncline took place after the Gloucester Coal Measures were laid down, *i.e.*, at the end of the Palæozoic Era.

Petrology and Rock Analyses.

A. The Volcanic Rocks.

Lava flows occur in the Carboniferous System in the Gloucester rocks, both in the Burindi Series and in the Kuttung Series.

(a) *The Burindi Lava Flows.*—Three lava flows occur in this series, they are all similar to one another in general characters, and are quartz keratophyres.

No. 1 *Flow.*—This rock in the hand specimen is light-coloured and aphanitic with moderately abundant phenocrysts of felspar; in places, however, the rock is quite glassy, and when so is almost black in colour. Under the microscope the groundmass varies from cryptocrystalline to glassy, and in the glassy examples there is an abundance of small rod-like microlites, frequently grouped into stellite aggregates. The phenocrysts consist almost entirely of felspars, a few of these are orthoclase, but the great majority are plagioclase, all are much corroded. The optical character of the plagioclase indicates a variety close to albite. An occasional small phenocryst of a pale green pyroxene is seen, which appears to be diopside, but is too much altered for accurate determination. Occasional small crystals of titaniferous magnetite also occur; inclusions of this mineral are abundant in the few pyroxene crystals.

Chemical Composition.

	Per cent.		Per cent.
SiO_2	69·82	SO_3	absent
Al_2O_3 ...	12·41	Cl	trace
Fe_2O_3 ...	1·10	S (FeSr) ...	absent
FeO	0·54	Cr_2O_3 ...	absent
MgO	0·29	NiO and CoO	absent
CaO	1·86	MnO	0·03
Na_2O ...	4·63	BaO	0·02
K_2O	1·67	SrO	trace
H_2O (100° C.)	1·05	LiO_2	absent
H_2O (100° C.)+	6·55	V_2O_5	absent
CO_2	0·03		
ZrO_2	0·25	Total ...	100·30
P_2O_5	0·05		

Specific gravity 2·266

Norm.

Quartz ...	32·46
Orthoclase ...	10·01
Albite ...	38·77
Anorthite ...	8·34
Diopside ...	0·65
Hypersthene...	0·40
Magnetite ...	0·93
Ilmenite ...	0·46
Hematite ...	0·48

Classification.

Class I. Persalane
Order 4 Britannare
Rang 2 Toxanase
Sub-rang 4 Lassenose
Magmatic name *Lassenose.*

The specimen taken for analysis was the glassy variety as this appeared to be the freshest. It will be seen that nearly 90% of this rock consists of quartz and felspar molecules, and that of the latter the albite molecules largely predominate. For a field name quartz keratophyre would appear to be that most suitable.

No. 2 *Flow.*—This rock in the hand specimen is typically pink in colour, is aphanitic, and usually markedly porphyritic, displaying an abundance of small red phenocrysts of felspar, with a variable number of small quartz phenocrysts. Under the microscope the groundmass varies from crypto-crystalline to glassy, spherulitic structure is commonly present. The quartz phenocrysts are strongly corroded as also are the felspars. Most of the felspar phenocrysts are albite, but some orthoclase phenocrysts also occur. The only ferro-magnesian mineral found is an occasional small phenocryst of a pale green hornblende.

Chemical Composition.

SiO_2	74·56	SO_3	absent
Al_2O_3 ...	12·87	Cl	trace*
Fe_2O_3 ...	1·80	S (FeSr) ..	absent
FeO	0·36	Cr_2O_3 ...	absent
MgO	0·29	NiO and CoO	absent
CaO	0·28	MnO	0·03
Na_2O ...	4·91	BaO	0·04
K_2O	3·43	SrO	trace*
H_2O (100° C.)	0·35	LiO_2	absent
H_2O (100° C.) +	0·91	V_2O_5	absent
CO_2	0·01		
TiO_2	0·40	Total ...	100·28
ZrO_2	absent		
P_2O_5	0·04	Specific gravity	2·622

Norm.		*Classification.*
Quartz ...	32·16	Class I. Persalane.
Orthoclase ...	20·02	Order 4 Britannare
Albite ...	41·39	Rang 1 Liparose
Anorthite ...	1·39	Sub-rang 4 Kallerudose
Corundum ...	0·61	Magmatic name *Kallerudose*
Hypersthene...	0·70	
Ilmenite ...	0·76	
Hematite ...	1·76	

It will be seen that this rock is not very different from the No. 1 Flow, differing mainly in containing a larger proportion of orthoclase, which however, is still subordinate to the albite. The same field name viz: quartz keratophyre is suggested.

No. 3 Flow.—This rock both in the hand specimen and under the microscope is so similar to the No. 2 Flow that a separate description is unnecessary. It also is a quartz keratophyre. No chemical analysis of this rock has been made.

(b) *The Kuttung Lava Flows.*—These form a thick series ranging up to a maximum thickness of 1,500 feet. This thickness undoubtedly represents many distinct lava flows, but as they are all very uniform in character one general description will serve for all.

In the hand specimen the rock is typically light-coloured, generally greyish-white to cream coloured, where the rock is more decomposed, as for example in the railway cuttings just north of the Avon River bridge, the colour may be greenish or reddish-brown. Flow structure is in many places strongly developed, and in places also a certain amount of contemporaneous brecciation has taken place, just as is the case in similar lava at Pokolbin. The presence of phenocrysts is rare, and when they are present they usually consist of felspar and are small and few in number.

Under the microscope the rock is glassy to cryptocrystalline, flow structure is commonly present, as also is spherulitic structure; the spherulites are small and rarely visible in the hand specimens. Occasional small crystals of plagioclase felspar are seen in most slides; these are usually too much altered to admit of accurate determination by their optical characters, but these characters, as far as they go indicate a felspar close to albite. More rarely small crystals of quartz and orthoclase are seen. All the phenocrysts are much corroded. No ferro-magnesian minerals have been detected, but occasional small patches of chloritic mineral may represent small one-time ferro-magnesian minerals; the total amount of such material is however very small. The chemical analysis given here was made from a specimen obtained in the Gap about a quarter of a mile south of the Gloucester Trig. Station, and from near the top of the Kuttung Series.

Chemical Composition.

SiO_2 ...	77·76	SO_3 ...	absent
Al_2O_3 ...	9·94	Cl ...	trace*
Fe_2O_3 ...	1·15	S (FeS_2) ...	absent
FeO ...	0·59	Ca_2O_3 ...	absent
MgO ...	0·18	NiO and CoO	absent
CaO ...	0·24	MnO ...	0·02
Na_2O ...	0·86	BaO ...	0·02
K_2O ...	7·75	SrO ...	trace*
H_2O (100° C.)	0·38	LiO_2 ...	absent
H_2O (100° C. +)	1·00	V_2O_5 ...	absent
CO_2 ...	0·30		
TiO_2 ...	0·15	Total ...	100·10
Zr_2O_3 ...	absent		
P_2O_5 ...	0·03	Specific gravity	2·582

Norm.		*Classification.*
Quartz ...	42·60	Class I. Persalane
Orthoclase ...	45·59	Order 3 Columbare
Albite ...	7·34	Rang 1 Alaskase
Anorthite	0·28	Sub-rang 2 Magdeburgose
Diopside ...	0·86	Magmatic name *Magdeburgose*
Magnetite ...	1·39	
Ilmenite ...	0·30	
Hematite ...	0·16	

This rock is obviously a typical potash rhyolite and contains nearly 96% of salic molecules. In the table of rock analyses on page 261 analyses of Kuttung lava flows from Mount Bright near Pokolbin and from Paddy's Hill near

Raymond Terrace are included for comparison. A comparison of the norms of these two rocks with that of the Gloucester Buckets is as follows:—

	Gloucester Buckets, *Gloucester.*		Mount Bright,[1] *Pokolbin.*		Paddy's Hill, *Raymond Terrace.*
Quartz ...	42·60	...	44·0	...	31·1
Orthoclase ...	45·59	...	42·8	...	3·3
Albite ...	7·34	...	7·3	...	53·2
Anorthite ...	0·28	...	1·1	...	1·7
Corundum ...	—	...	1·8	...	1·7
Diopside ...	0·86	...	0·9	...	—
Hypersthene	—	...	0·1	...	0·9
Magnetite ...	1·39	...	0·2	...	0·6
Ilmenite ...	0·30	...	—	...	—
Hematite ...	0·16	...	—	...	0·2
Magmatic name	Magdeburgose		Magdeburgose		Westphalose

Both these rocks occur on about the same horizon in the Kuttung Series as the Gloucester rhyolite. It will be seen that the rock for Mount Bright is practically identical with that for the Gloucester Buckets although these two localities are about 70 miles apart. The rock from Paddy's Hill on the other hand differs from the first two in being very rich in potash and correspondingly poor in soda.

B. The Intrusive Rocks.

Some dolerite dykes have been noticed intruding both the Devonian and Carboniferous strata, but these were too decomposed for petrological description. One very interesting (?) intrusive rock was found however, which merits description. This was found associated with the Gloucester rhyolites in the Gap, a valley cut through the Gloucester Buckets Range about a quarter of a mile south of the Gloucester Bucket Trig. Station. It cannot yet be definitely

[1] The Geology of the Eruptive Rocks of Pokolbin N.S.W., by W. R. Browne and A. B. Walkom. This Journal, Vol. xlv, 1911, p. 379 – 407.

stated whether this rock is really intrusive or whether it is a contemporaneous flow, as the field evidence was quite unsatisfactory so far as it was investigated, but it appeared to be an intrusive sill occurring about 500 feet below the top of the Gloucester Buckets rhyolite flows.

In the hand specimens this rock is a fairly dark-coloured compact aphanitic rock, showing under the pocket lens occasional small phenocrysts. Under the microscope the groundmass is seen to be crystalline to microcystalline, and to consist of a felted mass of very small laths of felspar; these felspar laths were too small for optical determination but appeared to be for the most part a plagioclase felspar. A few small phenocrysts of a plagioclase felspar are embedded in this groundmass, but were too much altered for specific determination. These felspar phenocrysts are strikingly marked by zonally arranged iron-oxide inclusions at or near the outer margin of the crystals. There also appears to be a considerable quantity of minute grains of iron oxide scattered through the groundmass.

Chemical Composition.

SiO_2 ...	55·64	SO_3 ...	trace
Al_2O_3 ...	17·70	Cl ...	absent
Fe_2O_3 ...	7·85	S (FeS_2) ...	absent
FeO ...	1·75	Cr_2O_3 ...	0·01
MgO ...	1·46	NiO and CoO	absent
CaO ...	1·31	MnO ...	0·25
Na_2O ...	8·51	BaO ...	0·01
K_2O ...	1·20	SrO ...	trace*
H_2O (100° C.)	0·72	LiO_2 ...	absent
H_2O (100° C. +)	2·24	V_2O_5 ...	trace
CO_2 ...	0·04		
TiO_2 ...	1·45	Total ...	100·25
ZrO_2 ...	—		
P_2O_5 ...	0·11	Specific gravity	2·721

Norm.		*Classification.*
Orthoclase ...	7·23	Class II Dosalane
Albite ...	67·59	Order 5 Germanare
Anorthite ...	5·56	Rang 2 Monzonose
Nephelite ...	2·27	Sub-rang 5 ×
Corundum ...	0·41	
Olivine ...	2·52	
Magnetite ...	2·32	
Ilmenite ...	2·74	
Hematite ...	6·24	
Apatite ...	0·34	

This rock differs strikingly from the Gloucester Buckets rhyolite, first in its very high soda content and corresponding low potash content, and second in the large proportion of iron oxides, particularly hematite. Some nephelite is shown in the "norm," but none of this mineral has been seen in the rock slides. The amount of hematite shown in the "norm" is somewhat unusual, and this probably represents altered magnetite, but owing to the very fine grained texture of the rock this point could not be readily investigated. This magma is evidently a somewhat uncommon one as no magnetic name for this type appears in the quantitative classification table. If no name has yet been applied to this type of magma the writer would suggest that of Gloucesterose.

I. No. 1 Flow, Burindi Series, Analyst W. G. Stone.

II. No. 2 Flow, Burindi Series, Analyst W. G. Stone.

III. Gloucester rhyolite, Kuttung Series, Analyst W. G. Stone.

IV. Rhyolite, Mount Bright, Pokolbin, Analyst J. C. H. Mingaye.

V. Rhyolite, Paddy's Hill, Raymond Terrace, Analyst W. J. Greig.

VI. Keratophyre, The Gap, Gloucester Buckets, Analyst W. G Stone.

Table of Analyses.

	I.	II.	III.	IV.	V.	VI.
SiO_2	69·82	74·56	77·76	77·82	75·06	55·64
Al_2O_3	12·41	12·87	9·94	11·46	14·21	17·70
Fe_2O_3	1·10	1·80	1·15	0·30	1·31	7·85
FeO	0·54	0·36	0·59	0·09	0·27	1·75
MgO	0·29	0·29	0·18	0·23	0·09	1·46
CaO	1·86	0·28	0·24	0·22	0·42	1·31
Na_2O	4·63	4·91	0·86	0·86	6·88	8·51
K_2O	1·67	3·43	7·75	7·19	0·58	1·20
H_2O (100°C.) ...	1·05	0·35	0·38	0·36	0·56	0·72
H_2O (100°C. +)...	6·55	0·91	1·00	1·40	0·62	2·24
CO_2	0·03	0·01	0·03	0·03	—	0·04
TiO_2	0·25	0·40	0·15	0·02	absent	1·45
ZrO	—	absent	absent	—	—	—
P_2O_5	0·05	0·04	0·03	0·04	0·03	0·11
SO_3	absent	absent	absent	0·07	0·11	trace
Cl	trace*	trace*	trace*	—	—	trace
S (FeS_2)... ...	absent	absent	absent	—	—	absent
Cr_2O_3	absent	absent	absent	—	—	0·01
NaO and CoO ..	trace*	absent	absent	—	—	absent
MnO	0·03	0·03	0·02	trace	0·04	0·25
BaO	0·02	0·04	0·02	0·02	—	0·01
SrO	trace†	trace†	trace†	—	—	trace†
LiO_2	absent	absent	absent	trace	absent	absent
V_2O_5	absent	absent	absent	—	absent	trace
Total... ...	100·30	100·28	100·10	100·11	100·18	100·25
Specific gravity ...	2·266	2·622	2·582	—	2·604	2·721

* Less than 0·01% † Spectroscopic reaction only.

Summary.

The Devonian strata which occur in the Gloucester District are similar to those already described from other parts of north-eastern New South Wales by Prof. W. N. Benson, they indicate the deposition of very fine sediments, together with enormous numbers of silicious radiolarian skeletons upon a sea bottom, which may have been fairly deep and was far removed from any shoreline; sub-marine volcanic activity was a pronounced feature during this period. Important crustal movement took place throughout the greater part of New South Wales at the close of the

Devonian Period (The Kanimbla Epoch) and coverted the greater part of this State into dry land; just how far these movements affected the Devonian sediments in the Gloucester District is not yet quite clear, but there is some reason for believing that they were folded and uplifted.

In Lower Carboniferous time (The Burindi Epoch) the Gloucester District was again under marine conditions, but the water was then undoubtedly shallow and not very far removed from a shore-line, as evidenced by the beds of coarse conglomerate which were deposited. A shallow water marine fauna, consisting mainly of brachiopods, trilobites, corals and crinoids, inhabited this sea. The sea floor was slowly subsiding, and upon it was deposited a a great thickness of mudstones, tuffs, limestones and conglomerates, while at times volcanic eruptions resulted in the pouring out of thick lava flows (keratophyres) over the sea bottom.

The long continued subsidence of the Burindi Epoch was finally interrupted by an upward movement, which did not fold the Burindi sediments, but elevated the region into dry land and ushered in the Kuttung Epoch. This new epoch was marked in this district mainly by intense volcanic activity and the pouring out of a thick series of lava flows (rhyolites). From here on there is a considerable gap in the geological record; just what happened is not yet clear, but apparently terrestrial conditions continued, and there may have been considerable removal of the Kuttung Series by sub-ærial denudation. Towards the close of the Permo-Carboniferous Period (the Upper Coal Measure Epoch) part of an extensive freshwater lake covered the Gloucester District, and on the slowly subsiding floor of this lake a thick series of shales, sandstones, conglomerates and coal seams was deposited.

The close of the Palæozoic Era was marked by orogenic earth movements on a grand scale, both the Carboniferous and Permo-Carboniferous strata were strongly folded and a series of high mountain ranges produced.