THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. IV.

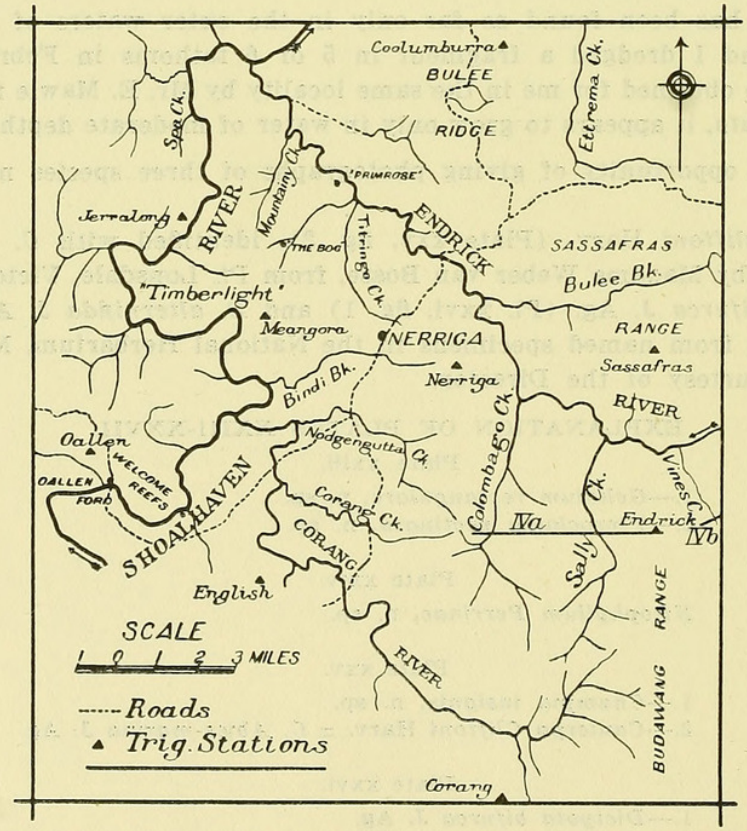
NERRIGA.

By FRANK A. CRAFT, B.Sc., Linnean Macleay Fellow of the Society in Geography.

(Plates xxviii–xxix; four Text-figures.)

[Read 28th October, 1931.]

Foreword.—This paper is designed to give a detailed physiographic survey of an area where horizontal and folded rocks exist side by side under varying conditions, and to determine their relationship to the land forms developed. The physiographic history of part of the tableland is further dealt with, and it has been possible to date the various features with reference to late Tertiary basalt. This should be of assistance in areas of a similar type where such a key is not found. The magnetic meridian (trigonometrical survey declination 9° 30′) is used in the text and maps, which are based on the parish and county maps kindly supplied by the Lands Department.



Text-fig. 1.—Map of the Area, showing the principal names used. See also Plate xxviii.

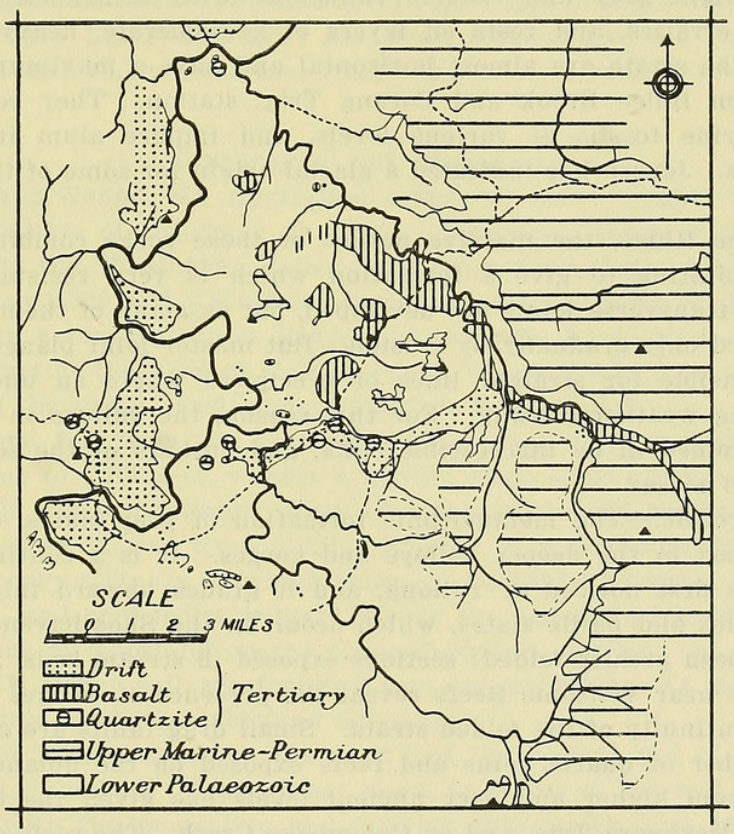
The Area Dealt With. Text-figs. 1 and 3.

When standing on one of the clear hills near the head of Corang River, an observer may see the area described in this paper to be part of a wide upland plain

stretching far to the west until it is broken by long meridional ridges, which are vague and shadowy in the distance. The Shoalhaven River flows over this tableland to plunge into the gorges of its lower course. Eastward, the plain rises into irregular ridges and buttes which, in their turn, give place to the even heights of Bulee Ridge and its southern extension—Sassafras Range. The higher areas form the crest of a tilted plain which rises from the coast; the eastward slope is a wilderness of narrow ravines carved by tributaries of the Clyde and lower Shoalhaven Rivers, but these lie beyond the scope of the present enquiry, which is concerned with the westward fall from the coastal highlands and with part of the great upland plain.

Geology and Resistance to Erosion. Text-fig. 2.

The geological features which have been noted in the earlier papers of the series continue into this area, although their relative extent and importance are found to change as one goes southward. For example, the horizontal Permian



Text-fig. 2.—Geological Sketch of the Area. Devonian beds probably occur in the south-east of the portion marked "lower Palaeozoic".

sandstones have determined many of the physical features of the Nerriga district, but they end against the northern flank of Currockbilly Range, which is formed of older quartzites. A general physiographic classification may be made on the basis of age, as follows:

Tertiary.—There is a considerable extent of stream gravels and drift between 1,650 and 2,050 feet. As in the Nerrimunga Creek area, these deposits fill valleys which had been eroded in the upland (Shoalhaven) plain, and they extend over part of that surface in the vicinity of the main stream. The more northerly occur-

rences are similar to those which have already been described, but southward one finds the fine clays replaced by grit, and grits by pebble beds. Included in the series are clays containing plant remains, presumably of late Tertiary age, but it has not yet been possible to have a determination made.

Basalt flows have been associated with the drifts, and considerable portions of them remain in the valley of Endrick River, whence they extend over low parts of the sub-divide on to the Corang drainage area. There the past extent is indicated by the presence of grey contact quartzites, which are found scattered over the sandy uplands between 1,900 and 2,060 feet. The disappearance of so much basalt can be attributed to pre-erosional weathering and the removal of soluble products after erosion of the more recent valleys and gorges had commenced. The hard and chemically inactive quartzites survive the basalt, and in places protect the friable drift which underlies them. Much of the late Tertiary landscape is still in a good state of preservation.

Permian.—The Upper Marine Series is present in the eastern part of the area; it consists of light grey and reddish sandstone with occasional bands of conglomerate and erratics, and rests on layers of agglomerate, heavy conglomerate and breccia. The strata are almost horizontal and have a maximum thickness of 700 feet between Bulee Brook and Corang Trig. station. They contain a great number of marine fossils at various levels, and impure alum in certain conglomerate bands. Jensen has indicated a glacial origin for some of the pebbles and erratics.

As on Bulee Ridge, the massive nature of these rocks combines with their widely-spaced jointing to give a formation which is very resistant to erosion. Meridional and transverse joints are developed, but as many of them are irregular, they are widened only gradually by erosion. But master joint planes do exist, and they are responsible for straight lines of precipices where an underlying weak stratum is being weathered away. For this reason, the valleys in the sandstone country are hemmed in by inaccessible cliffs, and outliers of the series generally take the form of mesas.

Older Palaeozoic.—The metamorphic formation of grey slates, quartzites and schists is exposed in the deeper valleys and gorges. It is a continuation of the Ordovician beds first noticed at Tallong, and it grades upward into little-altered sandstones, shales and fissile slates, which occur on the Shoalhaven Plain. These rocks have all been greatly folded; sections exposed in stream beds, in road and in mining cuttings near Welcome Reefs reveal the presence of wedges of softer rock breaking the continuity of the folded strata. Small drag faults are common; there is a great number of quartz veins and reefs exposed on the upland surface, and their erosion from higher and very ancient levels has given the quartz-breccias which occur at Meangora Trig. and on Colombago Creek. The reefs contain a little gold—a fact which has led to a great deal of profitless mining, as the veins and reefs generally cut out within 300 feet of the present surface. Despite the great folding and displacement of these strata, no regional faults or shatter zones have yet been disclosed.

Passing eastward from the Shoalhaven, a series of white and reddish quartzites and sandstones is met with in the vicinity of Nerriga, with the meridional strike common to all of the older rocks in this locality. These are marked as Devonian on the State geological map, but I do not know of any definite evidence to confirm the supposition. Red slates are seen at the junction of Endrick River and Colombago Creek, and these are associated with massive white quartzites which dip eastward at high angles, and can be traced southward to the heights of

Currockbilly and Budawang Trigs. Jensen refers to great anticlines in this latter mass, which he takes to be of upper Devonian age, and which is probably a northward continuation of beds of that age on Clyde Mountain.

The white quartzites appear to be the equivalent of similar beds found to the west of Bungonia and Marulan, and between Lithgow and Goulburn. In this area they determine certain surface features in the upper Endrick and Corang valleys, and they rise southward to form the dominating features of that landscape. Where Permian strata rest on the main ridge of the harder rocks, the passage beds are agglomerates containing huge masses of quartzite. These give place to conglomerates of decreasing coarseness, and to still higher grits and sandstones.

As we have found elsewhere, topography has been determined largely by resistance to weathering and erosion. The higher surface features are of quartzite or horizontal sandstone, whilst the Shoalhaven Plain is developed in less resistant strata. These have weathered to a depth of 200 to 300 feet, and give rounded forms when subjected to erosion. The hard rocks exposed in the gorges hinder downcutting, but they rise to the tableland level (2,000 feet or more) in very few places. Both the Tertiary basalt and drift are weak formations; the basalt has largely succumbed to chemical weathering, whilst the drift is readily eroded by running water.

Topography and Physiography.

1. *Sassafras Range.*—In Australian maps the term "range" denotes a water parting irrespective of its shape or origin. Sassafras Range is an area of tableland separating the Shoalhaven Valley from the coastal slopes, and having an even surface between 2,500 and 2,650 feet above sea-level. It bears a close resemblance to its northern extension, Bulee Ridge, but towards the south a different type of landscape is met at the head of Corang River, where the highest points rise above 2,800 feet and the name "Budawang Range" is first applied.

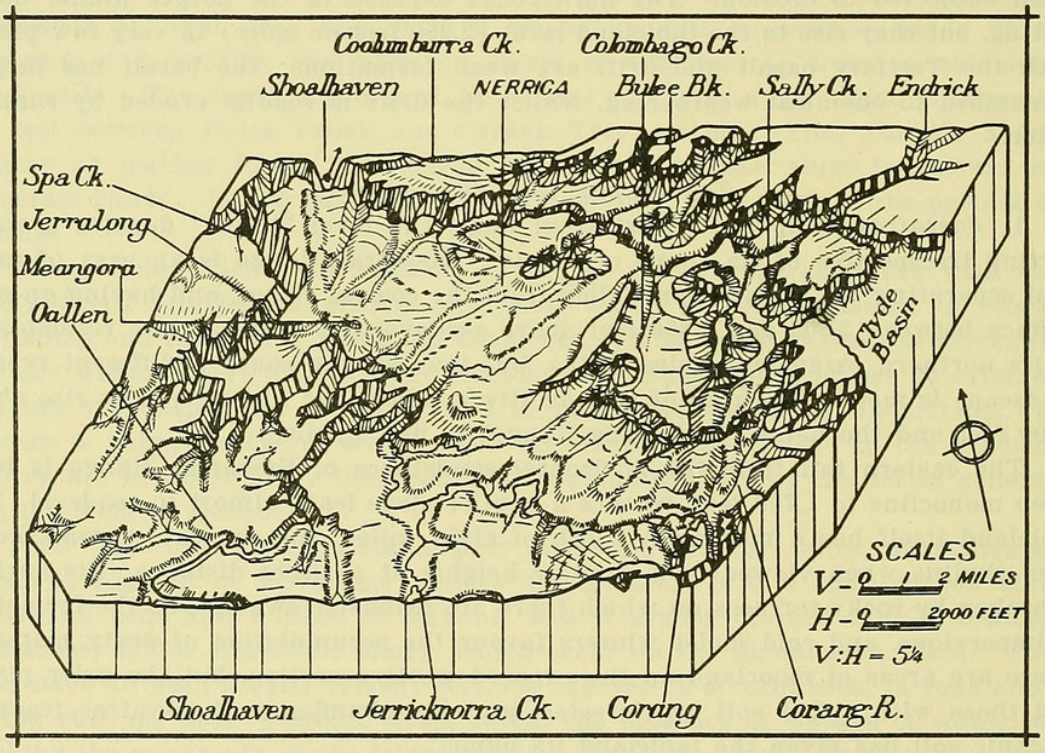
The eastern fall from the horizontal sandstones of Sassafras Range is by a steep monocline to 1,700 feet, whence a gentler slope leads almost to sea-level. The tableland itself has a maximum width of eight miles, and presents a remarkably even skyline when viewed from similar heights at a slight distance. Its surface is broken by rocky terraces on which there are extensive swamps, as the formation is impervious, and cold moist winters favour the accumulation of peaty material. There are areas of moorland on the exposed western section, but the drier places and those with richer soil are forested, and the abundance of sassafras trees on volcanic soil has given the tableland its name.

An area of basalt occurs on the crest and the eastern fall of the plateau; its extent is limited, and its thickness not much in excess of 100 feet. Jensen (1908) associated it with the monocline and faulting into which that feature may have developed, and ascribed a late Tertiary age to it. The great dissection of the slopes combines with irregular bedding in the sandstones to make observation a difficult matter, but the basalt is a local occurrence, and has had no surface connection with the flows of the Endrick Valley, although it antedates the existing eastward fall.

The western side of this higher tableland is an erosion scarp 600 feet high, but broken remnants of a former extension are found on the western side of Endrick River. The scarp is surmounted by precipices up to 200 feet high, formed as the result of long-continued sapping of the massive upper sandstones. Long sections of the cliffs are quite unbroken, but in places where the joints are closer, weathering has produced some fine monuments. Major joints have been widened

in places to give narrow gulches and these, with occasional broken corners, form the only means of access to the tableland. The most notable break is that point used by the Nowra road, where the sandstones are thin and considerably weathered.

Following this scarp from Vines Creek northward, its height and difficulty are found to decrease with the thinning of the horizontal rocks. At Bulee Brook these are found as low as 1,900 feet, but on the Nowra road the base has risen to 2,150 feet, and the higher part of the older surface on which they were deposited continues northward past Coolumburra Creek until a cross-ridge is reached which runs westward to the junction of the Shoalhaven and Endrick Rivers. Here the sandstones are again found as low as 1,900 feet, but still further north the base rises to Touga Trig. station. The breaking down of this scarp gives a false impression of lowness to the tableland when it is viewed from the hills about Nerriga, and there are few points from which the fine massiveness of the southern portion can be appreciated.



Text-fig. 3.—Block Diagram of the Area. Note the change in land forms as one goes westward from the horizontal sandstones, and the entrenchment of the Shoalhaven and Endrick Rivers.

The streams run parallel to the major joints, of which the meridional have had the most marked effect in determining stream courses. Deep and narrow ravines are found on the eastern slopes, but the Shoalhaven Plain has acted as a base-level of erosion for the western side, thus limiting the depth of those valleys. However, the heads of these in the higher tableland are narrow and difficult of access, and the streams which pass through them from the upland swamps fall to the broad valley of the Endrick by a series of cascades over low precipices.

The western fall was described as a fault-scarp by Jensen—a view which I took to be correct after making a hurried visit in 1927. It is, however, a normal erosion scarp of considerable age, and its relatively unbroken nature is due to the extreme slowness of erosion in the massive tableland block.

Valley of Endrick River. Plates xxviii, xxix; Text-figs. 3 and 4.

The main stream rises at Sassafras and breaks through the western scarp to flow in a wide valley partly filled with basalt. The head of this valley is directly east of Endrick Trig., and its upper slopes are of basalt which has come from a low part of the divide between 2,300 and 2,400 feet, and has poured down a widening valley between perpendicular cliffs, lying 400 to 800 yards apart. There is a further expansion when the main stream is reached, and the Endrick flows for a short distance in a level channel, with basalt on the right and swampy terraces of horizontal sandstone to the left. Small waterfalls carry it below this local plain level, and thereafter its course is in a shallow trench eroded in basalt and in the older rocks. Alteration of the horizontal sandstones at the 2,000-foot level shows that the basalt once extended to the present left bank of the river, and even now a small patch is found on this side immediately above the junction of Sally Creek.

There are great bays in the cliffs to the right where valleys of a triangular plan indent the tableland, but erosion on the left has been far more destructive, and now only isolated relics of the original surface remain. From this side two large affluents are received—Sally and Colombago Creeks—both of which drain extensive swamps.

The valley of Sally Creek is a mile wide, and branches penetrate the higher country. Isolated tablelands or large mesas are found to the east, but there has been greater reduction to the west, where sections of the divide have been considerably lowered. A notable gap is found in the Clyde watershed immediately south of Endrick Trig., where swamps rise from either side into a level col at 2,300 feet. In this locality Sally Creek falls rapidly across quartzite bars, which mark the end of its upper swamps at 2,200 feet. On the downstream side there is more horizontal sandstone, and the gentle, swampy course is resumed until the stream turns slightly eastward to pass into a shallow quartzite gully, which is followed to the Endrick.

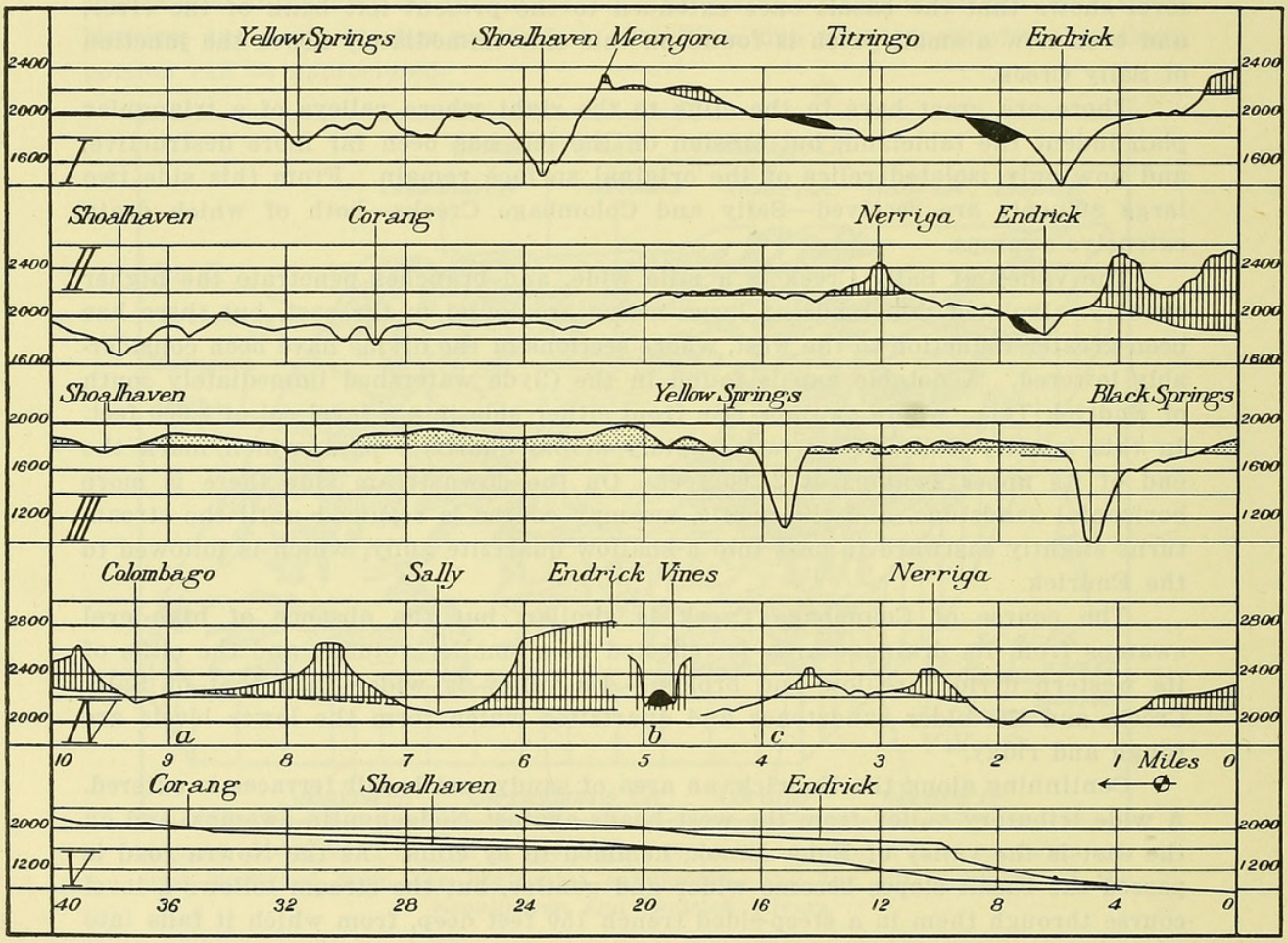
The course of Colombago Creek is similar, but the absence of high-level swamps from its drainage area is reflected in a smaller volume, and the cliffs of its western divide are low and broken. Its valley is wider than that of Sally Creek, and the older sandstones and quartzites which form the lower levels are rough and ridgy.

Continuing along the Endrick, an area of sandy and basalt terraces is entered. A wide tributary valley from the west heads against Nodgengutta swamps, and on the east is the valley of Bulee Brook, hemmed in by cliffs. As the Nowra road is passed the basalt slopes become wider and gentler, but the stream follows a level course through them in a steep-sided trench 150 feet deep, from which it falls into a gorge by a series of cataracts.

The lower part of the valley is marked by the recession of the scarp to the east and by the approach of a level ridge from the west, which divides the Endrick from the Shoalhaven. A dissected and undulating terrace is found between 1,700 and 1,900 feet: drift occurs on the Shoalhaven side between 1,650 and 1,900 feet, and some of its extends to the edge of the Endrick gorge. On the ridge leading to the junction of the streams, sand and grit have been altered to grey quartzite at 1,840 feet, and give an outcrop 40 yards wide. Similar material is found at 1,680 feet, but it may have gravitated from above.

The presence of basalt flows makes this valley particularly interesting, as it preserves the conditions existing before the beginning of the "canyon cycle", and

indicates the amount of erosion which the uplands have since undergone. Part of the basalt comes from "the Vines", where it rises to 2,400 feet on the Clyde watershed. Vines Creek has a lateral branch on either side of the flow (Text-fig. 4), cutting against the original precipices of the sandstone valley. Passing the Endrick at 1,980 feet, the basalt is found as a strip on the northern bank known as the "red ground", and continues beyond Sally and Colombago Creeks, the more northerly extension being chiefly on the left bank. The river swings from side to side of the flow, and has cut through the deepest part of the basalt-filled channel near Bulee Brook. Passing thence to the junction of Titringo Creek, basalt is found again in the river bed immediately below the road crossing, but this may have been a centre of extrusion. Otherwise it forms a series of terraces which



Text-fig. 4. i.—Profile showing the development of the Shoalhaven Plain below the base of the horizontal sandstones (hatched), and its extension into the Endrick valley. The basalts (black) occupy pre-canyon valleys, and the two principal streams have cut gorges in the ancient landscape. Part of the profile west of Meangora Trig. is projected to the line from the north. ii.—Profile south of the gorges. Note the protective influence of the sandstones and the land forms developed. Re-dissection in the Endrick valley has given a trench similar to that which was filled with basalt, and the valleys to the left also post-date the basalt and drift. iii.—Profile of the drifts (stippled) of the Shoalhaven Plain. The section line gives the modern grade of the river compared to its original profile. iv.—*a* and *c*, land forms in the horizontal sandstones; *b*, basalt in the valley of Vines Creek. v.—Profiles of the three principal streams. Vertical exaggeration: i-iv = 5·3; v = 8·8.

have been sharply cut across by the deeper valleys and gorges. Beyond Titringo Creek, from whose valley the basalts have been largely eroded, the course of the flows becomes uncertain as the surface is covered with sand, which has been cemented in parts to a gritty sandstone. Although they continue immediately to the north-west, the basaltic exposures are at a higher level, and it is probable that the main continuation has been eroded by the modern Endrick, and that contributions have been made from the vicinity of "the Bog", where basalt rises to 2,020 feet.

An occurrence of particular interest is found overlooking the gorge at Primrose. Here the base of the flows is at 1,680 feet, and they rest on a thickness of 20 to 30 feet of roughly-stratified coarse drift. The relationship of the drift and the basalt has been revealed by the shafts and tunnels of alluvial miners, who have obtained a little fine gold from the gravels.

There have been a number of flows, giving a maximum thickness of more than 350 feet near Titringo Creek. Layers of solid and vesicular basalt alternate; a little stream drift is found between them, and although it is generally not more than a few inches in thickness, in places to the west of the Nowra road local channels have been filled, to be covered again by the next flow. Most of the gravels have been metamorphosed as a result, although the thicker patches are not greatly changed, and sand is found beneath the flows some distance above the crossing. Weathering and erosion have resulted in the formation of terraces, which are best observed between the road and Titringo Creek. They are bounded by stony banks, and typical levels are found at 1,840, 1,900 and 1,950 feet.

Where Titringo Creek crosses the edge of the basalt at 1,680 feet before plunging into the gorge, it is found to overlie a deposit of horizontal shale and soft white sandstone, from 5 to 10 feet thick. This material rests on folded strata, and has been slightly depressed where the basalt has poured over its thicker portion. Fine white clays are found further up the same creek at 1,900 feet, where they also underlie the basalt, and contain fossil leaves. To sum up:

The valley of Endrick River is found to be eroded in a tableland of the order of 2,500 to 2,600 feet above sea-level. A series of valleys was developed at 2,000 feet; a channel was cut to a depth of 300 to 400 feet in this surface, and was filled with basalt and some drift, which probably extended to the Shoalhaven. Drift is found in places above the basalt, and partly cemented sands occur on the hillsides facing eastward between Colombago Creek and Primrose. Subsequent erosion has given a channel similar to that filled with basalt, but the lower valley has been more deeply dissected by the attack of revived streams.

Upper Valley of the Corang. Plate xxix; Text-figs. 3 and 4.

The head streams of Corang River rise in a desolate tableland, and their upper courses through swamps and gullies traverse unoccupied country. Passing southward and westward from Sassafras Range the sandstone tableland rises above 2,800 feet, although its continuation to the east of Sally Creek is marked by cols of some depth. Coming to the westward turn of the watershed around the head of Corang River, the upper layers of sandstone have been eroded, and a local plain is found at 2,500 feet with a surface broken by a maze of ravines dominated by Corang Trig. station. This peak is a circular cone—a remnant of the higher sandstones—from which the whole expanse of country between the coast and the western divide of the Shoalhaven can be seen. Great precipices here

mark the eastward and southward fall to the Clyde gorges, whilst lower cliffs towards the north fall abruptly to level swamps which feed the Corang.

The heads of this stream flow from the horizontal strata to older rocks in a gentle channel about 2,120 feet until they reach a great bar of light-coloured quartzite, which runs northward under the trig. station and rises to high, square hills across the stream. Here the valley sides close in, and the Corang falls through a precipitous gully in a series of low cataracts, emerging to flow in a shallower trench and a much wider valley, which is also rough and broken. On the right bank, the high ridges either retreat from the stream to give rocky terraces some hundreds of yards in width, or they fall uniformly towards it, with a sharp drop to the river over the last hundred or two hundred feet. On the left, the ridge from Corang Trig. falls steadily, and merges into the general level of the Shoalhaven Plain at 2,100 feet before the Braidwood road is reached.

Approaching this road, the Corang passes to extensive flats somewhat above 1,900 feet as harder sandstones and quartzites are replaced by shales and more friable sandstones. Its further course is over plains or beside low hills until the junction of Corang Creek is neared, where precipitous sandstone bluffs are found on either side. The valley again becomes gentler and shallower as the Nerriga-Oallen road is reached, but the stream soon falls into a steep trench leading to the Shoalhaven.

There are two important tributaries—Corang and Jerricknorra Creeks. The first rises in a level, swampy valley whose sides are crowned with horizontal sandstone; it flows past the Braidwood road and follows a tortuous course across local plains and between gently rounded hills into a shallow gully, which joins that of the main stream. Jerricknorra Creek comes from the tableland near Corang Trig., and passes through broad undulations to the Corang. Its lower valley is level and includes wide flats; the clear and grassy landscape contrasts with the sterility of the higher tablelands.

The Corang and its tributaries are typical streams of the Shoalhaven Plain; their heads are actively eroding in hard rocks, but the lower courses are mature, and lie only a hundred to two hundred feet below a general plain level until the fall into the gorges begins.

Nerriga. Plates xxviii, xxix; Text-figs. 3 and 4.

Nerriga is situated on a depression in the Corang-Endrick sub-divide, which continues as a low ridge to overlook the junction of the Endrick and Shoalhaven Rivers. Towards the south-east are three isolated hills rising 400 feet above the hamlet; they are crowned by cliffs, but the newer sandstones also extend over some of the neighbouring lower and gentler ridges. South of these hills is a great sandy valley, partly occupied by the Nodgengutta swamps and partly by a small creek falling to the Endrick. Their divide is a barely perceptible rise in the level plain, but as one continues southward higher sandstone ridges are reached which separate the valley from those of Colombago and Corang Creeks.

There is a sharp fall from the mesas towards Nerriga and the Endrick River, but the head of Bindi Brook is found in a level valley between them. About Nerriga itself there are two lines of basalt—one in the valley of Titringo Creek, and the other passing Bindi Brook to Nodgengutta Creek. Small eminences near the hamlet are formed of glassy contact quartzite about 2,100 feet, whilst similar material is found on the eastern edge of the basalt at Titringo Creek, and on the sandy plain south of the Nodgengutta-lower Corang stream line. Directly west of

Nerriga a hollow in the sub-divide is partly filled with basalt, and it seems that flows came from this locality to pour over the lower country on either side.

Most of the basalt has been eroded from the valley of Titringo Creek, which is asymmetric, with a steep rise on the eastern side to a ridge composed of soft ancient rocks. Towards the south, Bindi Brook has cut through the basalt line, and continues some distance along a level valley before it falls to the Shoalhaven through a ravine. The valley of Nodgengutta Creek and the lower Corang is simply a shallow trench with a plain at 1,900 feet on the south, and a somewhat higher bank on the north. Small areas of drift and Tertiary contact quartzite rise to 2,040 feet on the sandy southern side, whilst sand and pebble drift also occur between 1,920 and 2,020 feet to the north.

When the dividing ridge turns northward past Meangora Trig., its upper surface is an outlier of the horizontal sandstone, which weathers into low cliffs at the heads of gullies. The westward fall to the Shoalhaven is broken, but gullies from the cliffs on the eastern side widen into valleys as they pass across the sandy and basalt slopes to the gently undulating plain by Titringo Creek.

Still continuing northward, the desolate peninsula of Timberlight is passed on the left, whilst the basalts of the Bog (1,950–2,020 feet) and of Mountainy (1,900–2,110 feet) are found—the first falling eastward, and the second occupying ancient depressions and the heads of old valleys on the divide itself. These appear to be local flows, and a series of level ridges continues north of them at a uniform height of 2,100 feet. At first there is a steep fall directly to the Shoalhaven whilst a terrace at 1,800 feet is found on the Endrick side, but further north these conditions become reversed, and the end of the high ridge falls almost sheer to the Endrick, and overlooks a wide peninsula or terrace between the two streams. This lies between 1,800 and 2,000 feet, and has drift and Tertiary quartzites at the lower level. A screening of pebbles is also found on the high ridge and may represent the weathered remains of Permian conglomerate, as relics of sandstone and grit of that series occur at 2,000 feet at the north-western head of Mountainy Creek.

It will be seen that this ridge rises a little above the level of the Shoalhaven Plain, and distinctly above the basalt-filled and drifted Tertiary valleys. But south of Nerriga Trig. the horizontal sandstones have not only been cut through, but a level valley has been formed and partly filled with sand (in places consolidated by iron oxide), along which water may have flowed in either direction through its whole length about the period of basalt flows, for the basalts at either end of the valley rise above the present indefinite divide which crosses its floor. But even here no appreciable change in stream direction is indicated, although this place and the break at Nerriga show how such a divide can be lowered in places by attack from either side.

The Shoalhaven Plain. Plates xxviii, xxix; Text-figs. 3 and 4.

Passing westward to the vicinity of the Shoalhaven River, a different type of country is entered. A quartzite hill rises to 2,250 feet between the Braidwood road and Corang Creek, but it falls away to an extensive plain whose highest point is rather short of 2,100 feet. In the vicinity of Welcome Reefs and of Oallen Ford this plain surface presents a very even skyline and, although it has been considerably dissected, it remains the most striking feature near the Shoalhaven.

If we take the western section of the contour map, the even ridges are prominent. An examination of the field shows another thing—hard rocks are

absent from a large part of the uplands, although they occur in the gorges and even in some of the shallower valleys. The upland slopes are of argillites and soft sandstones; the dominant colour of the countryside is yellow—the ridges, the slopes and the gullies alike share this feature, which is due to hydrated iron oxide in the weathering strata. The downward limit of weathering is found between 1,700 and 1,800 feet, so the surface of the original plain in the vicinity of valleys is thoroughly rotted to a depth of 200 or 300 feet, and is very susceptible to erosion. Near Welcome Reefs, mining operations on the surface at 1,900 feet show the original stratification to be well preserved, but the decomposing clay rocks have a soapy feeling, and break up readily on exposure to air.

Where sandstones occur the groundwater has been able to circulate more readily, and it has carried iron in solution to the surface. This has been redeposited in joints and cracks, adding greatly to the hardness and resistance of the rock. In other places, surface deposition has given masses of limonite, which form knobs on the hillsides. The high points generally owe their existence to these surface features, and once the hard crust is removed, the unprotected weathering rock is rapidly eroded to give cols in the ridges. Such conditions exist on either side of the river with the exception of those places covered by drift sand and pebbles. The landscape is characterized by rounded forms; the valleys are wide and trough-shaped, and are asymmetric where harder rocks occur closer to the stream on one side, either in the valley or on the tableland surface. The hilltops are rounded, and the lowering of ridges at the heads of gullies gives a confused appearance to the dissected parts. All of these features are well brought out by the contours.

This part of the tableland is of particular interest, for it is here that the river becomes entrenched in the uplands. Near Oallen Ford, the stream is 200 feet below the Shoalhaven Plain; steep bluffs are found in places along its course, and a gentle fall to the east of Oallen contrasts with the sharper and more gullied slope across the river. Immediately below the ford the banks close in, and the river occupies a rocky channel to Welcome Reefs, where Ningee Nimble Creek is received. This stream drains a series of wide, gentle valleys, but its lower course is in a stony bed swinging between precipitous bluffs. Below its junction wide gullies are found on either side of the river, which follows a gently-falling course of considerable roughness, with rising cliffs in places. This section may be viewed from the hills above the Corang junction (Plate xxix); at the confluence of that stream both it and the Shoalhaven are hemmed in by cliffs, which form a gorge 300 feet deep. From here the grade of the river becomes steeper, and although in places the slopes on one side or the other are gentler for short distances, the channel becomes steadily rougher as the river cuts across bars of hard rock. On the outer bends huge bluffs rise sheer from the river to a height of 400 feet, but they do not extend for any great distance. Passing Meangora Trig. the river sweeps around Timberlight, falling tumultuously through narrow crevices in the rock bars. With increasing depth the gorge takes the form of a steep "V" in section, and the widening below Jerralong Creek gives a most impressive character to the scene. There are no considerable streams from the right in this section, and those on the left fall sharply to the river, the waterfalls on Jerralong Creek being very fine. In places the northern side of Timberlight slopes to the river at an angle of 60 degrees.

Much of the river's work has been done in weak rocks, and the presence of highly resistant strata at the lower levels has retarded downcutting, and has

helped give a smooth profile. The Endrick, on the contrary, has cut down through a more uniformly resistant part of the formation—not so hard as the rocks of the Shoalhaven channel, nor so readily eroded as those of the uplands—and the result has been the formation of a uniform "V"-shaped trench (Plate xxix). The upper limit of the most effective attack is found in a series of falls across a huge bar of grey quartzite, whereas the Shoalhaven has a gentler fall over a longer distance, and is lowering the sloping section at a more uniform rate. But even where its grade is gentle the Shoalhaven is a turbulent stream, as its course is broken by bends, rocks and bars. In time of flood the rush of water in its gorge shakes the hills, and most of the rocks borne by the river are reduced to sand and mud long before the eastward bend is reached at Tallong.

Let us now retrace our steps through the uplands, this time passing over the high-level drift.

This begins near Mountainy Creek about 2,000 feet, where it appears to be overlain by basalt, but the first notable deposits are found on Timberlight peninsula, where the aggregate thickness of 270 feet rests on 6 feet of heavy ferruginous conglomerate, which is overlain by laminated clays, pebble and sand beds. These are similar to those recorded immediately to the north at Black Springs and Spa Creeks; the lowest points on their base are at 1,720 feet, and the basal conglomerate occupies channels across parts of the peninsula. The clay beds differ from those observed elsewhere in containing very little plant material, but otherwise there is no great difference between them and their northern extension on the opposite side of the gorge.

Passing to Yellow Springs Creek, part of the clay is replaced by quartz gravel, but the general nature of the deposits does not change. The base lies at 1,740 feet, and like similar strata at Timberlight, Black Springs and Spa Creek, it has been worked for the gold contained. Extensive tunnels driven into the basal conglomerate reveal its horizontal character, and show its upper surface to be even. A feature of this material is the amount of granite which enters into it. In the natural sorting much of the heavier granite has been left in this upstream section, whilst more of the lighter quartzite has been carried beyond to form the northern parts of the drift at Black Springs. The general diameter of the pebbles is from 3 inches to 12 inches, but exceptionally large masses, including Tertiary contact quartzite, are up to 24 inches on the major axis. Practically all are well-rounded, as the Shoalhaven above Oallen has, and has had, an appreciable grade, and the Corang and Mongarlowe are swift in their upper courses. The virtually horizontal section of the drifted channel between Spa Creek and Oallen may owe its negative grade to a slight local subsidence of the order of (say) 100 feet after the excavation of the channel, and before the commencement of deposition. Relative uplift to the north would give a similar result.

The drift continues southward from Yellow Springs, and only thin deposits are found on the higher ground by the lower end of Corang River. The main bed is cut across by the Shoalhaven at Oallen Ford, and a branch passes into the valley of Ningee Nimble Creek at Welcome Reefs. Above Oallen it is found on either side of the modern stream with a base of 1,790 feet—only 50 feet above the present-day water level—and a broad valley has been partly filled with it. The most southerly extension of the coarse basal conglomerate is immediately below the ford at 1,725 feet, where the pebbles are cemented by quartz crystals and pyrites, and are overlain by clay beds containing abundant plant fossils. This material may fill a local deep of the old channel, for it does not continue upstream for any

distance. Passing to the southern edge of the contour map, the base of the drift has risen above 1,800 feet, and extensive sluicing has disclosed considerable beds of pebbles and sand, crudely stratified in places, and more or less consolidated. Here the fine clays are replaced by gritty brown sands, and there are great numbers of round pebbles with diameters up to 9 inches. These features are in conformity with the rising base of the deposit and with the conditions under which the greater part of it was laid down.

It may be contended that a powerful current was necessary for the transportation of the large pebbles in the basal conglomerate, and that the present grade of the old channel between Oallen and Spa Creek would not allow of this. It must be recognized that there are possible small errors in the various heights which I have given, and that earth movements which elevated the plateau may have produced slight differences from place to place, but my figures showing a variation from the horizontal through a range of 20 feet between the points named cannot be far from the truth, and in any case the validity of the subsequent argument is not affected. The channel was approximately horizontal when deposition began, and erosion was proceeding upstream in the Shoalhaven Plain, with a base level corresponding to the modern height of 1,600 feet. The main stream and its tributaries, on coming from their swifter upper courses to the level channel at Oallen, tended to drop their entire loads in still water which had been ponded up by a blockage in the channel considerably downstream. In time of flood this material was carried northward and distributed in the level channel, for the accumulation upstream and the consequent local fall given to the river in that vicinity would give the current sufficient power to sweep the material along for some distance, in the same way that a breaking dam in a level valley would be carried down by the impounded water. Such a combination of circumstances would be sufficient to give a layer of coarse material in the level channel with a reasonably uniform thickness, such as the conglomerate stratum which we have recorded.

The rising local base level due to further obstruction of the stream to the north would check erosion in the channels being cut in the Shoalhaven Plain and would, in effect, restore those conditions of general maturity which had existed before the commencement of this dissection. The supply of large pebbles and masses of rock would gradually cease, and the largest pebbles would be those brought from the vicinity of the divides, from a landscape which had already been subjected to erosion over the period of time involved in the formation of the 2,000-foot level (i.e., the Shoalhaven Plain). These would be dropped when the current first became less swift, whilst the greater part of the finer material would be swept further on, and then deposited. This would account for the gravel and clay beds, and intermediate pebble horizons, such as that at 1,900 feet in the Nerrimunga Creek area, could be ascribed to widespread scattering of the pebbles under conditions of very shallow water after the existing lakes had almost been filled with drift.

The origin of the material involved may be briefly noted, although more ample information will be given in a subsequent paper. The granite pebbles of the lower conglomerate were derived from the river channel above Oallen, and the quartz gravel from mature granite slopes in the uplands about Braidwood. The clay came from a similar source, and from the argillites of the Shoalhaven Plain, whilst the quartzite pebbles were derived from Upper Marine conglomerates and

from quartzite beds towards the divides. A wide area may have contributed the sand which forms the upper part of the drift.

Andrews (1910) has noted similar beds in the valley of the Lachlan about Parkes and Forbes. Their nature and history bear a close resemblance to those of the Shoalhaven sediments, and suggest that similar conditions prevailed in the two places. In the case of the Lachlan valley, Andrews ascribed sedimentation to subsidence, but a similar view would not account for all the peculiarities of the Shoalhaven, as we shall see presently. A layer of pebbles corresponding to those at our 1,900-foot level was explained as being due to increased erosion following a revival of streams, which was brought about by uplift towards the source of the river. These pebbles were, in their turn, overlain by clays, and such a drastic change in the nature of the drift cannot be reconciled to the idea of notable uplift in the drainage area involved, even if we allow for a considerable lapse of time between the two. The clays correspond to the finer drift and sand overlying the 1,900-foot pebble beds.

A more likely explanation would involve a change in the incidence of rainfall. At the present time, for example, much of the rain is given by comparatively few storms, and the depth of the Shoalhaven at Oallen varies from zero to fifty feet. Under such conditions, streams which are level and normally of slight volume are capable of transporting large rocks and pebbles in times of flood, thus giving their courses an anomalous appearance. The advent of this type of rainfall regime would increase both the amount of erosion and the size of the material transported, whilst a return to less stormy conditions would have the opposite effect, and would also allow weathering to disintegrate rocks much more thoroughly before erosion takes place. The upper pebble horizons can be ascribed to periods of greater storminess, but not necessarily to periods of heavier annual rainfall.

In conclusion, we may define the Shoalhaven Plain in this area as being a deeply weathered surface about 2,000 feet which had been trenched to a depth of 300 feet about the time of basalt flows. The main channel was subsequently filled with drift, which was also spread over parts of the neighbouring plain, and has since been cut across and considerably eroded. As with Nerrimunga Creek, the Shoalhaven falls gradually past 1,700 feet, but the fall below 1,600 feet is steep, although it has been partly regulated by the hard rocks encountered. Further consideration will be given to the alluvial deposits under the heading—"Tertiary Valleys".

Land Forms.

Many of the essential features of the area are similar to those of the more northerly parts of the Shoalhaven Valley, but local variations and unique developments call for description, which might deal specifically with the higher levels and with the Tertiary valleys.

The Higher Levels.—The first suggestion of a peneplain level is found between 2,400 and 2,500 feet, comprising parts of the country at the head of Corang River and the level, swampy valleys of the high tablelands. There are higher levels about 2,800 feet, but they are of too fragmentary a nature to yield inferences of any great value. In some places, such as the vicinity of Endrick Trig., relics of broad valleys exist 300 feet below the highest points of the landscape, and are the results of normal erosion and not of exaggerated terrace weathering of the type noted on Bulee Ridge. There is a possible correlation between this level and similar features in the Tallong and Nerrimunga Creek areas, and in the valley of

Mulwaree Creek to the west. The description of these isolated features as relics of an ancient peneplain is at least justified in the fact that the present Shoalhaven valley has been formed by the removal of rocks which rose to the height of Sassafras Range and Bulee Ridge. Valleys now occurring about this level were formed when the base-level of erosion was considerably higher than the position which it occupied, relatively speaking, during the erosion which formed the Shoalhaven Plain.

Of the nature of this second level there is no doubt. It extends far into the block of horizontal sandstones, and while it exists on them in places, elsewhere it is cut to 300 feet below their base (Text-fig. 4). The great extent of the 2,000-foot level to the west of the horizontal rocks further emphasizes its independence of them, and while local terraces and precipices are explained in terms of sapping and the so-called benching action, the regional features are essentially independent of such factors, and occur impartially in horizontal and highly folded strata.

This level is pre-basaltic in age, and its relative narrowness in the Endrick valley is due to the resistant nature of the rocks in which much of the cutting has been done. On the slopes east of Meangora and Nerriga Trig. stations, mechanical erosion has not been very active since the volcanic period, for the slopes and parts of the basalt flows are still covered with sand which has been partly consolidated into a gritty white or red sandstone. The width of the Endrick valley in these places has changed very little in the time involved.

The process of destruction in the massive sandstones is of interest. Attack is along joints, and may be considerable even away from permanent streams. Take the ridges between valleys as examples; tributary gullies extend into these ridges along the most notable lines of weakness, and fissures are formed along the same lines which, in time, cut right through the ridges. These are well developed in the tableland at the head of Corang River (Plate xxix) and in the cliffs near Bulee Brook. In the former case the fissures are from a few inches to several feet in width, and their further development has given narrow ravines which cut right through the Corang-Clyde divide. In the course of time, after a fissure has extended downward to a weaker stratum, widening commences and the sides of the fissure, being attacked from beneath, recede to leave a gap in the ridge, possibly at quite a low level. This process is accelerated because angles in the cliffs are involved, and these constitute natural weaknesses.

A typical example occurs south of Bulee Brook, where the original end of the ridge is a mesa separated from the tableland by a level col, which slopes away gently on either side to a wide valley (Plate xxix and Text-fig. 4). The hills and passes west of the Endrick between Nerriga and the head of Corang River have a similar origin, and in places the action has been carried below the base of the horizontal rocks to approach 2,000 feet.

This gives an insight into the country around Tallong, where there has been considerable erosion under similar conditions, but through a smaller vertical range. There, wide valleys also head in breached divides, and the level forming the Shoalhaven Plain extends to the heads of the streams. Again the horizontal sandstones in their harder portions rise above the more easily eroded members of the older rocks.

Tertiary Valleys.—We have noted the pre-basaltic valleys eroded to a depth of 300 feet in the Shoalhaven Plain. Those on the Shoalhaven side were filled with drift, but that of the Endrick with basalt. Further erosion has been accomplished in stages; the first resulted in the formation of trenches or channels very similar

to those which had been filled, and the second involved the cutting of deep gorges. The first were carved under conditions similar to those existing before the basalt flows and sedimentation, or such a coincidence as that noted would hardly be possible. We may ask—how much erosion has been accomplished in the Endrick valley since the outpouring of the basalts? The answer has already been given for that section by Nerriga and Meangora Trig. stations, and there is no reason for supposing a much greater degree of widening further upstream. The valleys and gorges below the level of the basalt are of recent origin, as are the gullies in the floors of the valleys of Colombago and Sally Creeks, since these occur below the basalt and drift. But the valley of Vines Creek, which breached the Clyde divide, is entirely pre-basaltic (Text-fig. 4), and there seems to be no reason for coming to a different conclusion when considering the other mature and swampy valleys of the Endrick heads. In the main valley the cliff scarps approach the basalt in many places; the precipices tend to rounded forms and monuments on their crests and in their broken parts, giving an appearance of considerable age, and indicating that a condition of stability had been reached before the trenching of the 2,000-foot level. Similar conditions are shown in Plate xxix.

But although there has been no essential alteration in the dimensions of this valley, or rather, in that part unaffected by the "canyon cycle", it must not be thought that the process of erosion in the uplands has come to a standstill. The streams coming from the cliff bases carry pebbles with them, and after rain new sandbanks and strips of shingle may be observed along their courses, although erosion is reduced to a minimum by the presence of trees, heath and swamp plants which have not been interfered with by man. In addition, drift overlies the basalt in parts, especially near the mouth of Colombago Creek and thence towards Sally Creek, where large pebbles are observed which were probably derived from the Upper Marine beds.

Similar conditions appear to have existed during the period of basalt flows; there are pebbles between the various lava sheets, an old stream channel has been recognized near the Nowra road, and the basalt at Primrose is underlain by 20 to 30 feet of coarse drift. But the absence of any thickness of drift between the basalt sheets is more remarkable than these occurrences when we consider the deep drift in the neighbouring Shoalhaven valley, and the erosive competence of the upland streams of the Endrick. For if similar conditions had prevailed in the two co-existent valleys while the Shoalhaven deposits were accumulating, the basalt sheets of the Endrick valley would alternate with thick layers of drift.

There are two possible explanations of this: either the filling of the Endrick valley with basalt prevented the accumulation of sediments in it, or those flows and their equivalents further to the north filled the trench in which the Shoalhaven was flowing, and caused the accumulation upstream.

Let us assume the necessary conditions for the first case and disallow the second for the time being. We can now explain deposition by a relative uplift northward, or by a general subsidence of the land surface to give a negative base-level of erosion. (This latter condition would be satisfied if the channels were carried below sea-level as it then existed.) It has already been shown that differential uplift northward was not considerable; the meridional profiles of the Shoalhaven Plain between Oallen and Tallong, the profile of Bulee Ridge and the existing grade of the drifted channel combine to attest this, and even if we allow a relative uplift of the order of 100 feet towards the north, it explains the flattening of the old channel but not the sedimentation. Differential uplift imme-

diately to the north of the lower Shoalhaven during or since the outpouring of the late Tertiary basalts is discounted by the topography of that area, and by the uniformity of the base of the basalts between Warrima (near Tallong) and Robertson. The study of Tallong disclosed no differential movements in its vicinity, and certainly no late- or post-Tertiary uplift to the east (see also Craft, 1928).

The idea of general subsidence is complicated, as it involves uplift to allow the trenching of the Shoalhaven Plain, thus lowering the effective base-level by 400 feet at the mouth of the Endrick; then subsidence of the same order which was almost immediately followed by the filling of the Endrick trench with basalt; then by uplift, again of the same order, following the deposition of the drifts and allowing a new channelling of the Shoalhaven Plain and of the Endrick valley, and finally by the uplift which made the erosion of deep gorges possible. The coincidences of such an explanation do not recommend it, and movements of large areas are postulated in order to explain localized features. In addition, the nature of the coastal slope must be considered, for it shows the effect of much erosion accomplished before the cutting of the deep gorges, as we have seen at Tallong and on the slope falling from Sassafras Range to Nowra.

Considering the second of our alternatives—that of basalt filling the stream courses and causing sedimentation upstream—an explanation that would only satisfy conditions south of the Endrick junction is insufficient, for the alluvial deposits also occur towards Tallong. It is possible that basalt issued from the Endrick valley, as contact quartzite is found at 1,840 feet overlooking the junction of the Endrick and Shoalhaven Rivers, but this feature does not appear in the drift across the gorge immediately to the north.

About Tallong, however, there are basalt flows and centres of extrusion on either side of the river. Parts of them are sharply cut off by modern precipices, and there are extensive remains of contact quartzites about the 2,000-foot level in that district to mark their former greater extent in the vicinity of the modern canyons (Papers i and iii of the series). The Caoura flow rises to 2,080 feet and begins on the Shoalhaven cliffs near Badgery's Lookout, and there is every probability of its having extended into the valley of the main stream and having risen to that same level.

Tertiary quartzites in the drift show it to post-date the commencement of volcanic activity, and in such places as the vicinity of Bungonia Lookdown, Inverary, and above the junction of the Corang and Shoalhaven we find basalt or its contact quartzite lying on the higher levels of the drift. Intermediate stages have been noted in both the Nerrimunga Creek and Nerriga areas in association with the drift, further demonstrating the intimate connection of the two phenomena. Lava flows commenced before the beginning of deposition, and lasted until after the 2,000-foot level had been attained. Their extent and thickness have been shown, but we may again quote the Caoura and Endrick flows; the former lies between 1,850 and 2,080 feet, whilst the latter has an extreme range between 1,680 feet at Primrose and 2,160 feet by Titringo Creek at Nerriga. Even taking the upper level of the flows as the 2,060 feet recorded close to the Nowra road above Endrick River, it is clear that sufficient basalt has existed in the Shoalhaven Valley to block the streams entrenching in the 2,000-foot level, to cause the accumulation of drift and its ultimate spreading out on that plain surface. Moreover, the idea of a gradual or intermittent rising of the barrier to account for the diversity of the various layers of drift is one which finds adequate recognition in

this explanation, and the relative absence of drift between the basalt sheets of the Endrick valley is not difficult to understand, even if the flows occurred at the same time as those near Tallong which were the primary cause of deposition. It is possible that the two synchronized, and in any case the notable Endrick flows had only to sustain a level in the comparatively narrow valleys they were filling in excess of the effective level of deposition. We thus find a satisfactory explanation of all the facts involved without having recourse to the postulation of widespread and arbitrary earth movements.

To summarize this briefly: Uplift resulted in the erosion of valleys from 300 to 400 feet deep in the levels of the Shoalhaven Plain. Basalt flows filled the trench of the Endrick, and similar flows near Tallong interrupted the cycle of erosion and caused the filling of the Shoalhaven trench with sediments, which spread over the neighbouring plain. After the cessation of volcanic activity the barrier was cut through and the drifted plain was channelled to give forms similar to those of pre-basaltic times. The Endrick, confined in a restricted valley, did not depart far from its original course; but the Shoalhaven, wandering over the plain, assumed and maintained a highly irregular pattern which was probably determined, in part, by the incidence of its tributaries, and which differs considerably from the original linear outline.

Physiographic History.

Relics of the Kanimbla folding which affected all the rocks up to the upper Devonian occur in the form of quartzite ridges in the south-east of the area. The Upper Marine Series, of Permian age, were deposited in the east on a subsiding peneplain of some irregularity, and the modern Shoalhaven occurs immediately to the west of their periphery. It is unlikely that the Upper Coal Measures had any great thickness in this area, and probably the Triassic rocks did not extend into it at all. In fact, a stream following the Shoalhaven line along the crest of the greatest of the ancient folds may have contributed to their formation. Evidences of an old peneplain of indeterminate age are found at a modern height of 2,500 feet, whilst older levels are found still higher. In the late Tertiary period the Shoalhaven Plain, already a very ancient feature, had been carved out of the folded and intrusive strata (the latter occurring further south), and the dissection of the horizontal rocks had been carried to maturity. This plain was probably not more than a couple of hundred feet above the existing sea-level, whilst the sandstone tableland rose 800 feet higher. Effective uplift of the order of 400 feet led to the partial dissection of this surface, but the channels were blocked by basalt flows and filled with basalt and sediment. A period of quiescence then allowed the re-formation of these features, and normal uplifting was resumed to raise the land to its present height, and allow the formation of the modern canyons. It has previously been concluded that the most recent uplifts were rapid and involved a rise of the order of 1,000 feet, but this may be rather understated. In any case, the maximum limit is of the order of 1,400 feet.

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EXPLANATION OF PLATES XXVIII AND XXIX.

Plate xxviii.

Topographic Map of Nerriga District, based on parish maps of the Lands Department. Detail is by corrected compass traverses, and heights by aneroid with reference to Trig. stations.

Plate xxix.

1.—View southward from Endrick Trig. The valley of Sally Creek is in the middle distance, with Budawang Range on the left. Currockbilly Trig. is the high point in the far distance, and the square hill to the right of it is also of quartzite, which continues northward across the left of the light patch in the valley. Colombago Creek is between the ridges in the right background.

2.—View eastward from Corang Trig., showing the levels about 2,800 feet, and the terrace at 2,500 feet cut across by ravines. Pigeon House (2,358 ft.) lies to the right beyond the Clyde gorge.

3.—Pre-canyon valley of the Shoalhaven, looking upstream from near the junction of Corang River. The level of the Shoalhaven Plain is shown, and the drift-filled valley lies behind the hill to the right.

4.—The valley of Endrick River. The sandstone tableland (2,400-2,500 ft.) is in the background; lower levels in the middle distance are an extension of the Shoalhaven Plain, with cleared basalt slopes as a line to the right of the canyon. The ridge at 2,100 feet and the junction terraces are on the right, whilst the Shoalhaven flows across the foreground.