On the Waianamatta Shales.

By the Rev. J. E. Tenison-Woods, F.G.S.,F.L.S., V.-Pres. Linn. Soc. N.S.W., Hon. Mem. Roy. Soc. N.S.W., Tasmania, S. Australia, &c., &c.

[*Read before the Royal Society of N.S.W., 4 July, 1883.*]

The name of the Waianamatta beds has been given to a supposed group or series of strata which are said to lie above the Hawkesbury sandstone. The name is derived from Waianamatta Creek, the native or aboriginal designation of South Creek, which, arising from the Cut Hills, joins the Hawkesbury River near Windsor. The area of the Waianamatta basin, as it is termed in the late Rev. W. B. Clarke's "Sedimentary Formations of New South Wales," 4th and last edition, is laid down in the geological map prefixed to that work. It is there represented as being of an irregular oblong, about 50 miles long, from north to south, and with an average width of 15 miles. The basin thus represented runs nearly parallel with the coast and the Blue Mountains, at about equal distances from both.

Mr. Clarke's definition.—The following is the definition of Mr. Clarke, taken from the same edition of his "Sedimentary Formations," p. 72: "Waianamatta Beds.—The Hawkesbury rocks are succeeded by another group or series of strata named by me from the Waianamatta or South Creek, which runs longitudinally through the basin which fills in the area between a surrounding enclosure of the former series, which must have been broken up in part, and denuded either completely before or during the deposit of the sandstone overlying the coal measures. The deep ravines which mark the Hawkesbury rocks give rise to rounded, smooth, undulating, softer, argillaceous strata, in the bottom of the creeks of which, and in the beds of the river Nepean or Hawkesbury, and of George's River, are marks of old erosion in the harder rocks below the argillaceous shales. Pot-holes are very common in the Hawkesbury beds, under the Wianamatta strata, where exposed at the points of junction, at some distance from the present creeks and drainage channels. Such may be traced at Myrtle Creek, near Picton, and on the Windsor Road, near Parramatta. These certainly prove a partial or general erosion before the whole series of the Waianamatta strata were laid down. The nearest beds of the latter to the underlying Hawkesbury rocks are shales, which have occasionally filled in

hollows previously existing, or contributed patches forming considerable masses as well as thin layers to the uppermost Hawkesbury rocks. In this way fishes have been found at various levels in shale patches, as on the Blue Mountains, at Parramatta, at Biloela (or Cockatoo) Island, and other places near Sydney. The Waianamatta beds are, however, not all shale, for there are fine sandstones more compact and heavier than the Hawkesbury, calcareous sandstones and ferruginous nodules, bearing fishes and small fresh-water molluscs, which remind one of the somewhat similar nodules of Permian beds of Germany."

It is difficult to gather the meaning of the author in this passage. He speaks of a "basin which fills in the area between a surrounding enclosure of the *former series*." One would imagine that the "former series" here referred to is the Hawkesbury formation, but he goes on to refer to the series as being "broken up and denuded either completely before or during the deposit of the sandstone." Clearly here the rocks referred to are palæozoic formations anterior to the coal, which must in this hypothesis have entirely disappeared, since nothing is seen of them now. Then, if the enclosure has been broken up and denuded away, it is impossible to arrange for the basin. Lastly, according to this statement, both the Hawkesbury and Waianamatta must fill up the basin. The difficulties of all these positions will be dealt with in the following paper.

Mr. Clarke then goes on to speak of the fossil fish found in these shales, also of varities of iron ore, fossil wood, plant impressions, and calcareous sandstones, "which latter," he says, "form the highest levels and summits of insulated hills that attain but moderate elevation (1,100–1,300 feet) in the centre or on the outskirts of the basin, which latter is chiefly confined to the heart of the county of Cumberland and part of Camden, of which Bulbunmatta or Razorback Range and Menangle Sugarloaf are outlying relics of a once wider extended plateau."

Mr. Beete Jukes also refers to Mr. Clarke's conclusions, and coincides with them. In a paper read before the Geological Society of London in 1847 (see vol. iii-iv, p. 224), he describes these shales as 300 feet thick, lying on the top of the Hawkesbury sandstone.

From these opinions, which have been followed without question by nearly every subsequent writer, we gather (1) that there is a distinct formation of shale lying on the top of the Hawkesbury sandstone; (2) that it lies in a basin on the eroded surface of the older formations between the Blue Mountains and the sea; (3) that the shale on the tops of such hills as Mount Sugarloaf, Razorback, and other hills in the neighbourhood of Campbelltown, are the outliers and fragments of what was once a plateau of Wianamatta rock.

Incorrectness of these views.—Having carefully visited the localities in which the Waianamatta formation is said to exist, I have come to quite different conclusions from the late Messrs. Clarke and Jukes, and it is with the greatest respect for both these eminent and veteran geologists that I record my opinions in opposition to theirs. But it is only lately that facilities have been accessible to geologists to enable them to examine the true nature of these shales. The cuttings and tunnels in connection with the new waterworks have afforded great advantages for the inspection of the strata. I do not think that either of the two gentlemen referred to would have written as they did concerning the Wianamatta had they examined the ground with the aid of the recent excavations. The conclusions I have come to are—(1) that the shales in question do not lie on the top of the Hawkesbury sandstone, but are intercalated with it; (2) that these shales, which lie on the summits of such hills as Sugarloaf, Razorback, Kenny's Hill, cannot be outliers of one elevated plateau, because they are mere seams of shale from the Hawkesbury sandstone, which occupy quite different levels in that formation; (3) that these shales do not occupy any basin in the formerly eroded rocks; (4) that both in the contained fossils and the stratification the shales are one with the Hawkesbury sandstone; (5) consequently there is no such formation as the Waianamatta. I shall discuss the evidence for these conclusions separately.

1. Shales not lying on the top of Hawkesbury sandstone.—The highest portions of the Hawkesbury rocks are quite destitute of any shales. At Clarence siding, on the railway, 3,658 feet above the sea, there is not a trace of shale, nor indeed along any of the large sections of the rocks. A few plant remains at Mount Victoria cannot be the remains of a formation such as the Waianamatta. Again, at all the sections of the sea-coast above Bulli and Wollongong the sandstone is the uppermost formation.

But it may be contended that the shales were deposited in a basin and did not reach the higher summits. Mr. Clarke supposed that there was first a valley of erosion cut out in the palæozoic rocks, and the Waianamatta was deposited in this valley or trough. But throughout the sandstone we find beds of shale from 3 feet in thickness to irregularly banded grits and shales of much greater dimensions. These differ in no way from the so-called Waianamatta at Campbelltown and the neighbouring valley. Even in this valley much of the highest portions of the sandstone have no shale upon them. In every gully or watercourse the sandstone crops out, and finally sandstone without any shale upon it can be seen along the valley of the Nepean at every level from 200 up to 1,000 feet.

So-called Waianamatta shale intercalated with the Hawkesbury sandstone.—The evidence of this is very visible from the various

levels at which the shale is found, and secondly from its moderate thickness. Along the course of the canal the cuttings reveal many irregular beds of shale. They undulate, not from upheaval but from the irregularity of the strata. Where the erosion of the natural surface has brought them within reach of decomposition, they form a mass of black soil exactly like what is termed Waianamatta. In the many sections exposed I have not been able to find a single instance of Waianamatta shale which was not clearly intercalated between the sandstone strata.

The tunnels have all manifested the same fact. If the Waianamatta were one formation filling up a basin of the eroded Hawkesbury sandstone, the tunnels and shafts should reveal in some portion of the valley strata of shale of some considerable thic ness. I examined the materials of all the shafts. Sandstone predominated, with beds of shale of varying thickness like all the Hawkesbury rocks. What is called Waianamatta shale is a regularly stratified rock, horizontally disposed, with fine calcareous lines of stratification or an alternation of blue grey and blackish lines. On the planes of bedding there are plant remains and a good deal of silvery mica. They are jointed, and the joints have a fine calcareous facing. Now this is exactly the character of nearly all the shales which run through the Hawkesbury rocks. The latter may be always known by its white appearance where fresh quarried, yellow and red where weathered, and by the false bedding. This is a universal character and a most distinct one. The rock of the Hawkesbury series is always false bedded, the shales never. In the Sugarloaf Hill referred to by Mr. Clarke, shafts have been sunk and a tunnel cut right through it. There are many beds of shale of varying thickness but sandstone (very carbonaceous) with some false bedding predominates. The usual character of these hills is best seen from the following records of the strata passed through in five shafts along the Nepean tunnel.

Shaft No. 1, 631 *feet above sea-level.*

Sandstone, white and false-bedded with round grains	73	feet.
Shale, with plant impressions	13	,,
Sandstone as before	124½	,,
Tota thickness of strata ...	210½	feet.

Shaft No. 2, 637 *feet above sea-level.*

Clay and loose boulders	10	feet.
Very impure shale, or jointed sandstone ...	15	,,
Sandstone false-bedded	189½	,,
Total thickness of strata ...	214½	feet.

Shaft No. 3, 675 *feet above sea-level.*

Clay	9	feet.
Jointed sandstone and layers of shale ...	11	,,
Sandstone	222	,,
Shale	½	,,
Sandstone and shale	9	,,
Total thickness of strata ...	251½	feet.

Shaft No. 4, *about* 721 *feet above sea-level.*

Clay	10	feet.
Jointed sandstone and layers of shale ...	17½	,,
Shale	1½	,,
Sandstone	25	,,
Shale	4½	,,
Sandstone	117½	,,
Shale	4	,,
Sandstone	15	,,
Shale	½	,,
Sandstone	101	,,
Total thickness of strata ...	296½	feet.

Shaft No. 5, 752 *feet above sea-level.*

Clay	8	feet.
Shale	13	,,
Sandstone	3	,,
Shaly sandstone	7	,,
Sandstone	293	,,
Total thickness of strata ...	324	feet.

It will be observed that these shafts were sunk outside the Waianamatta basin, as laid down in Clarke's map, but the limits of that map are merely sketched in, and in any case the shafts sunk in the portions marked as Waianamatta are just of the same character as those specified above. I found in all beds of shale of varying thickness alternating with Hawkesbury sandstone.

2. *The shales of Sugarloaf, Kenny's Hill, Razor-back, &c., not portions of a former plateau.*—This is evident from the fact that they occupy such different levels, and there are no faults or dislocations to account for it. It is remarkable that, though there are numerous volcanic dykes breaking through the sandstone and shale, there is little disturbance. The beds broken through are tilted a little at the sides of the dykes, but this extends only a very

short distance. As a rule the Hawkesbury rocks are remarkably uniform and undisturbed; they may be traced over miles of country without the least evidence of tilting or upheaval. At the sides of creeks and gulleys one observes frequently a regular inclination of the sandstone towards the centre from each side, not due to any elevation or tilting, but showing that the levels or contours of the surface on which the sands were deposited were similar to what they are now.

By observing the levels of the various masses of shales in different hills we shall see how they could not have belonged to one plateau. The shale on Mount Sugarloaf is about 700 feet above the sea; that on Razor-back Range is in places 500 feet higher. There is no dip from one to the other, and there are apparently no faults or subsidence. Moreover, a shaft has been sunk close to the summit of Mount Sugarloaf, and a tunnel cut very nearly through its centre. All the spoil-heaps of both these show that Sugarloaf is just like the rest of the Hawkesbury sandstone, with beds of shale running through it. It has neither more nor less shale than any other part of the formation. Finally, the character of the shale is not that of a large deposit which has filled up the valley; quite as much is covered by sandstone as exposed on the surface; in fact, wherever it can be fairly followed, it is found to be a mere seam rarely more than a few feet in thickness. To claim for it a thickness of 300 feet is utterly incorrect.

If we stand on any of the elevations in the Nepean valley, we shall see that the hills of shale occupy very different levels. If they all belonged to one formation its thickness should be nearer to 600 than 300 feet, but when each of these hills is examined in detail the shale is discovered to be a seam amid the Hawkesbury rocks. Thus, at the end of Woodhouse's paddock (Mount Gilead), and between it and the canal, there is a high bank of shale, which is (say) 430 feet above the sea-level. As this is followed towards Sugarloaf, sandstone takes its place. At Brook's Point another thick seam of shale is seen to be covered by the sandstone. Many other examples could be given.

No basin formed in eroded rocks.—There is nothing in the physical features of the country marked as Waianamatta shale to show that is a large basin or ever has been. There is a gradual rise from the sea to the Blue Mountains, and no traces of any former eastern barrier, which must have been at least 600 feet high to meet the requirements of a basin such as the so-called Waianamatta, and the height at which its deposits are found. The almost westerly direction of the railway from Sydney to Parramatta meets with no barrier higher than 36 feet, and this itself is composed of shale. From this point the line keeps along a S.S.W. direction, crossing diagonally all the drainage valleys. Except in these there is a steady rise, very slight and gradual it is true, but

still a slope, and not a basin. Campbelltown is 209 feet above the sea at the railway station. There is a rise of sandstone and shale between it and the valley of the Nepean, which is only 80 feet below this rise, and it is 150 feet above Campbelltown. From this there is a much more rapid rise towards the main range. The lowest part of the so-called basin is the valley of the Nepean, and this, we have seen, is 150 feet higher than the entrance of the valley, to which it descends in a series of terraces, instead of being itself a basin.

We find the same thing in crossing the so-called basin, where it is marked in the map of Mr. Clarke. From Parramatta to Blacktown there is a rise of about 100 feet. From this to the valley of the Nepean the country is a series of low ridges, divided by valleys of erosion, through which the drainage of the country flows. These valleys are Eastern Creek, Roper's Creek, and South or Waianamatta Creek. The greatest depth to which these valleys have been eroded is 77 feet below the summit of the Blacktown plateau. None of them are wide. The ridges between them rise to within 20 feet of the highest portion of the plateau, but as they are followed south they rise even above it. Some of the valleys cut through shale and some through sandstone. So that clearly there is no basin here. The true description of its physical character is that there is a low plateau, not so high as that above Campbelltown by less than 40 feet. This plateau slopes towards the north-east, down which the streams drain by the Nepean and Hawkesbury into the sea. The Campbelltown area is merely a higher portion of this large plain. The valley of the Nepean is the widest of these eroded channels. It is rather over a mile in width at Penrith, and 97 feet below the highest part of the plain at Blacktown.

When we examine the rocks of this plateau they do not offer any evidence of having been deposited in a basin of wide extent. The strata do not show any regular depression towards any centre. The shales may have in some cases been deposited in shallow lagoons of some extent, but still no more than mere shallow areas in the sandstone, and disconnected with each other. This portion of the subject will be referred to again.

Palæontologically the shales one with the Hawkesbury rocks.—If the Waianamatta is to be considered as a separate formation, it must be on account of its clearly lying above the Hawkesbury, and having a distinct fauna of its own. Neither of these positions can be sustained. From what has been already said, it is certain that we constantly meet with sandstone, in no way distinguishable from the Hawkesbury rocks, lying above shales in no way distinguishable from what has elsewhere been called Waianamatta shales I need not repeat the facts bearing out these conclusions.

The palæontological evidence is very complete. The shales are much richer in fossils than the sandstone, but they are not usually

so well preserved. However, a careful search, aided by some experience in Australian fossil plants, has enabled me to identify the following fossils in the localities given :—

Fossil Flora of the Shale.

Alethopteris (Pecopteris) australis, Morr. ...	Sugarloaf Hill
Thinnfeldia odontopteroides, Morr.	Kenny's Hill
Phyllotheca concinna, Tenison-Woods	Mount Gilead
Podozamites distans, Presl.	South Creek
Podozamites sp.	Sugarloaf Hill
Gleichenia?	Sugarloaf Hill
Macrotæniopteris waianamattæ, Feistm.... ...	Kenny's Hill

Hawkesbury Sandstone.

Alethopteris australis, Morr.	Mount Victoria
Thinnfeldia odontopteroides, Morr. ...	Mount Victoria & Dubbo
Thinnfeldia media, Tenison-Woods	Dubbo
Phyllotheca sp?	Mount Victoria, Woolloomooloo
Podozamites distans?	Woolloomooloo Bay
Gleichenia dubia, Feistm.	Mount Victoria
Macrotæniopteris waianamattæ, Feist.	Mount Victoria

The above are the species which have been identified with certainty, but there can be no doubt that the general character of the fossils is the same, and only the mode of preservation is different. Dr. Feistmantel has pointed out that the formations are closely connected. In the lists above given I have adhered nearly to those forms which I have identified myself, because in former enumerations I am inclined to think that not sufficient attention was paid to whether the fossils were taken from the sandstone or shale. Moreover, I think that the limits of what were called the Waianamatta shales and the Hawkesbury sandstones were not defined, so that it was not certain whether what one observer regarded as belonging to one formation was not accepted in an opposite sense by others.

But there is one other place where the palæontological identity of the shales and sandstones meet, and that is in the mesozoic coal basin around Moreton Bay. All the fossils of the shales and sandstones about our Blue Mountains are intermingled there. All the evidence on this point should form a separate essay, to which I hope to address myself shortly. But I may mention an important fact for which hereafter I shall offer proofs in detail. The Ipswich or Moreton Bay coal beds are identical in their fossil contents with the shales and sandstones of all the so-called carbonaceous shales of Victoria, at Geelong, Cape Otway, Western Victoria, &c.; they also have the closest relations with the Jurassic plant beds of India, of Siberia, and Yorkshire in England; from which we may conclude that in Australia the Lower Jura is largely represented, and that our Hawkesbury rocks and shales belong to that period.

Origin of the Shales.—It does not seem very easy to account for the shales in the Hawkesbury sandstone. They are impure carbonaceous sandstones, with a good deal of silvery mica and such other minerals as would result from the decomposition of felspathic or granitic rocks with vegetable matter. It has been commonly agreed to call them lacustrine shales, but not a single item of evidence has ever been adduced that they occupied the sites of fresh or saltwater lakes. Fossil fish have been found but rarely, and those specimens I have seen were not in shale but a horizontally stratified sandstone. We have, however, a horizontal finely laminated stratification in many localities which looks like the action of water, and is not unlike some of the lacustrine strata of the central provinces of France. But every other clue disappears. No freshwater shells or remains have been found. The present lacustrine fauna of the world has few very immediate connections with any older than the Lower Cretaceous, but there are well recognized freshwater fauna of the age of these beds. The freshwater bands of the Purbeck beds contains species of genera which still exist, such as *Paludina, Limnea, Planorbis, Physa, Valvata, Unio, and Cyclas.* I do not think that we are justified in regarding our shales as of lacustrine origin until some evidence of this kind is forthcoming. Besides, it will be remarked by the most casual observer that the bands of shale do not occupy depressions or basins in every case; they are of undulating outline, and often pass up inclines and over elevations which have existed on the former surface. I am inclined to think that these bands mark periods during which a thick vegetable growth flourished upon the surface. The plants we find are all land plants, and the abundant remains of roots show pretty clearly that they grew in the place where they are now found. It seems to have been a heathy stunted vegetation, such as grows even now on poor sandy soil. The common fossil, *Alethopteris australis*, is not to be distinguished from an Oolitic fossil Fern which is found all over the world in rocks of the same age, and, as far as appearances go, it is very like the common *Pteris aquilina*, which at the present day also occurs in moist, sandy, and desert places all over the world. Probably *Alethopteris* was an *Asplenium*, but nevertheless its habits were those of the living *Pteris*. Now there are places on the east coast of Australia where a level poor soil gives rise in the course of time to a black carbonaceous deposit, such as we see here. It arises from the decomposition of the plants which grow on the surface. Sometimes shallow marshes will occur amidst them. Loose sand drifted across these moorlands would entomb them, and cause them, I have little doubt, to present such appearances in section as the Hawkesbury shales. I imagine that they represent long periods of time, and that their highly fissile character is partly the effect of pressure.

It is to be remarked further that plant impressions of a black carbonaceous appearance are found through the sandstone, showing an occasional growth of plants on the sandy surface. At any rate, in the presence of such plant remains, often with roots, we have no other evidence but that of a terrestrial vegetation, and are not justified in having recourse to any other hypothesis. The plant remains are not aquatic ; and there are strong reasons for supposing that *Thinnfeldia* was a Conifer allied to *Phyllocladus* (our Celery-topped Pine), and not a fern.

Joints.—It will be remarked that the shales are conspicuously jointed with a uniform direction. I have found that the jointing is always at right angles to the strike of the dykes of diorite, basaltic rock and trap, and which so numerously intersect the formation. We may regard these dykes as so many wedges of rock inserted in the mass, and of course increasing the lateral pressure. This would be quite sufficient to account for the joints, which are obviously connected in direction with the volcanic intrusions.

Dykes.—All around the Nepean Valley dykes are common. It is remarkable that they have disturbed the surface but little, and the Hawkesbury sandstone is only tilted a few inches at each side, the elevation extending a few yards in a horizontal direction. In the immediate vicinity of the dykes the sandstone is metamorphosed into a hard siliceous rock, sometimes not distinguishable from the injected material. This is easily understood if we remember that the sands are felspathic, and probably altered back again by heat into the form of the granitoid rock from which they were originally derived. The surface portions of both dykes and matrix are much altered by water, and these are the only portions I have been able to examine.

Shales on Sydney sandstones.—In a few places around Sydney shales are found in somewhat thicker beds than the shales near Campbelltown, but they are different in character, and far less carbonaceous. They are at least 100 feet lower than any of those round the valley of the Nepean.

That they are of the same character as the shales in other portions of the formation can be seen from the following section obtained in a boring at the Oaks Brickfield, near Neutral Bay :—

Height above the sea, about 150 *feet.*

Shale	16 feet.
Sandstone...	104 ,,
Shale	23 ,,
Sandstone...	208 ,,
	351 feet.

The shale here is somewhat of the same composition as elsewhere, but less micaceous, and with considerably less carbonaceous

matter. It is a very pure fire-clay, with so little iron in it as to render it very valuable for fire-resisting purposes.

In the boring for coal at Moore Park by the Diamond Drill Co., at 20 feet above the sea, the section gave 143 feet loose sand, 900 feet false-bedded sandstone with occasional shaly seams, but no record of the amount of shale was preserved, as the cores themselves were kept for exhibition at the Garden Palace, and where they were destroyed by fire. A band of ironstone 263 feet thick was found at the base of the Hawkesbury rocks, and then the coal measures were reached and bored for 550 feet without meeting coal.

Economical value of the Shales.—Up to this no great use has been made of the shales, but there can be no doubt that they are of considerable commercial value. For the manufacture of pottery, certain patches of shale would be found to answer as well as any in the world. It consists of a true silicate of alumina, finely levigated and mixed together, with very little iron or other minerals. The alumina predominates, and this is to the advantage of the ware. Generally speaking, the more the alumina the harder the ware, and the more silica the softer the ware ; the latter is less dense and bears less heat than the former. Bricks have been made from the shale from a very early date in the Colony. They are largely made from the shale at Lithgow ; at Waterloo, by Messrs. Goodlet & Smith ; and at the Oaks' brick-works, at Neutral Bay, and other places. In the latter locality the shale is particularly free from iron and grit and contains more alumina, so that a very white brick comes from the kiln. It is very tough, and shows a colour and structure which manifests how easily fine pottery could be made of the same substance ; in fact it seems a pity to use such material for bricks. I am told that a high price is paid for fire-bricks to use with these, the builders evidently not being aware that no finer fire-brick could be found than that manufactured from this clay. No doubt it will be largely used and its value appreciated before long : the only matter of regret is that near Sydney the supply of shale is somewhat limited.

For all the reasons previously given, I think that the term "Waianamatta formation" should be abandoned by geologists, as not being represented by any distinct group of rocks.

I have to express my thanks to Mr. Keele and Mr. McKinney, and other assistant engineers, for their kindness and attention to me during these investigations, especially in determining all the levels and making the measurements of strata. All these gentlemen, as assistant engineers in the Waterworks Department, were thoroughly acquainted with the locality, and showed me, during many days' research, every point of interest and importance.