DISCOVERY OF GLACIATED BOULDERS AT BASE OF PERMO-CARBONIFEROUS SYSTEM, LOCHINVAR, NEW SOUTH WALES.

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[With Plate IV.]

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The late Government Geologist of New South Wales, Mr. C. S. Wilkinson was the first, as far as I am aware, to recognise evidence of ice action in the above district. The evidence observed by him was of the nature of large erratics of quartzite, slate, granite, etc., imbedded in a mass of fine sandy shales containing a rich marine fauna of Permo-Carboniferous affinities.

The locality where Mr. Wilkinson observed these evidences was on the main Northern Road between Branxton and Black Creek, and about eight miles distant from the spot near Lochinvar where glaciated boulders have been recently discovered. Although, as far as I am aware, Mr. Wilkinson did not publish any reference to glacial action in New South Wales further than his paper on supposed glacial action in the Triassic Hawkesbury Series,[1] he is yet entitled to a considerable share in the discovery, as it was his observations and verbal information which led Mr. R. D. Oldham and myself to this district where striated pebbles were subsequently found.

In 1885 Mr. R. D. Oldham, Assoc. R.S.M., Senior Superintendent of the Geological Survey of India, visited the erratic horizon near Branxton, and was fortunate enough to discover a pebble faintly

1 Journ. Roy. Soc. N. S. Wales, Vol. xiii., 1879, pp. 105 - 107.—"Notes on the Occurrence of Remarkable Boulders in the Hawkesbury Rocks.

scratched and somewhat polished, which he considered to be of undoubted glacial origin.[1] There can be no question now in view of a later discovery this year that the markings on this pebble were really of glacial origin, though taken by themselves at the time they appeared to me, when the pebble was shown to me by Mr. Oldham, to be probable rather than positive evidence of contemporaneous ice action.

In 1887, in a paper read before the Geological Society of London,[2] I recorded the occurrence of numerous erractics in the Permo-Carboniferous Upper Marine Beds between Grasstree and Liddell, N. S. Wales. Many of these boulders were faintly scratched on the top, bottom and sides, but no grooves were visible. The markings on these boulders recalled the appearance of the surfaces of boulders in the redistributed boulder-clays of Glamorganshire in South Wales. I considered them to be of probable glacial origin, but the evidence was considered inconclusive by several members of the Geological Society of London who examined the boulders, and it must be admitted that the striæ were very faint.

In 1895[3] I exhibited at the Australasian Association Meeting in Brisbane a photograph taken by me of a block of granite measuring two feet three inches high by one foot three inches by at least three feet three inches long, bedded in the Upper Marine Permo-Carboniferous Rocks near the end of the Railway Cutting nearest Black Creek, west of Branxton Railway Station. The block is bedded on its edge, and the stratum on which it rests is indented, while the stratum above does not partake at all of the indentation, showing that the disturbance of the bed on which the boulder rests was due to the impact of the boulder as it fell

1 Records Geol. Survey of India, Vol. XIX., p.t i., p. 44.

2 Q.J.G.S., Vol. XLIII., pp. 190 - 196.—"Evidence of glacial action in the Carboniferous and Hawkesbury Series, N. S. Wales."

3 Proc. Austr. Ass. Adv. Sci., Vol. VI., Brisbane—President's Address, Section C., p. 70.

probably from an ice raft, and not to any folding subsequent to the imbedding of the boulder. The peculiar position in which the boulder has come to rest with one of its narrow edges downwards is also in favour of its having been dropped from some height on to what at the time was a muddy sea-floor. Mr. R. D. Oldham has already pointed out (*op. cit.*) that the close association of large unbroken fronds of such delicate fossils as the *Fenestellidæ* with the boulders at Branxton precludes the possibility of the boulders having been carried to their present resting place by ocean currents; for some of these boulders weigh many tons, and an ocean current strong enough to move such huge blocks would obviously twist and tear the fronds of the *Fenestellidæ*. The latter, however, show every evidence of having been deposited in tranquil water, as they are in an exquisite state of preservation and so numerous as to constitute what might be termed a polyzoal shale horizon.

Last January Mr. W. G. Woolnough, B.Sc., Demonstrator in Geology at the University of Sydney, made the important discovery of a beautifully facetted and glacially striated pebble in a railway cutting west of Branxton Railway Station, at thirty-four miles seventy-two chains from Newcastle. This pebble is figured on *Plate* 4, fig. 1.

The opinions therefore of Mr. C. S. Wilkinson and Mr. R. D. Oldham as to there being undoubted evidence of glacial action in these beds has now therefore received important confirmation.

Recent discovery at Lochinvar.—A few days after the discovery by Mr. Woolnough, I was engaged in making a geological section near Lochinvar, in company with Mr. Oliver Trickett and Mr. E. C. Andrews, B.A. of the Geological Survey, and Mr. W. G. Woolnough, and we discovered at one and the same time what appears to be the base of the Permo-Carboniferous system, and an important glacial horizon. The best outcrop of these beds is about seventy chains north-east of the bridge at the township of Lochinvar. The strata containing the glacial boulders are about three hundred feet thick. The matrix in which the boulders are imbedded consists of fine shale, gritty in places, of a reddish-purple to purplish-brown colour, and bearing a remarkable general resemblance to some of the glacial shales in the Bacchus Marsh District of Victoria. The last mentioned, as is well known, contain such plant fossils as *Gangamopteris spathulata*, McCoy, which admits of their being provisionally correlated with the Permo-Carboniferous Glacial beds of N. S. Wales. The association, however, of the Triassic plant *Schizoneura* with the uppermost of the Glacial beds at Bacchus Marsh suggests that the latest of those beds may be referred perhaps to Triassic time. It was chiefly the close resemblance of the Lochinvar beds to those of Bacchus Marsh that led me to search the former for glacial pebbles. Upwards, the glacial beds at Lochinvar pass into ripple-marked, soft, flaggy sandstones, containing marine fossils of Lower Marine Age. Traced downwards the glacial beds are found to rest on hard tuffs which at a still lower level are seen to be interstratified with tuffaceous felsitic shales containing *Rhacopteris*. I propose, provisionally, to draw the line for the base of the Permo-Carboniferous System at the base of these glacial beds and at the top of the hard tuffs. The latter I propose for the present to consider as the top beds of the Carboniferous System. The change in the lithological character of the rocks on either side of this line is certainly very strongly marked: and there also appears to be a marked change of dip which lessens from 18° in the Carboniferous tuffs to 10° in the Glacial beds.

As regards the included boulders in the Glacial beds they vary in size from a few inches up to about two feet. The boulders consist of quartzite, sandstone, argillite, granite, diorite, greenish felsitic (?) rocks, serpentine etc. Perhaps from five to ten per cent., more or less, were originally glaciated, but owing to redistribution and attrition in probably shallow sea water it is exceptional to find boulders which have retained well defined grooves or striæ. The boulders vary from angular to rounded, and unlike those at Branxton and Grasstree, these exhibit distinct grooves as well as striæ, in this respect resembling those of Bacchus Marsh. The superficial markings, however, have I think a somewhat older appearance than those of the Bacchus Marsh boulders. The boulder reproduced in fig. 2, *Plate* 4, may be considered fairly typical of those in the Lochinvar Glacial beds. The ripple-marks in the flaggy sandstones near the top of the glacial beds show that shallow water conditions obtained at all events towards the deposition of the last of this group of beds.

No fossils, macroscopic or microscopic, have as yet been found in these three hundred feet of glacial beds. It is only at the very top of the beds that marine fossils, *Spirifer* and *Eurydesma*, have been found.

The height of the outcrop of these glacial beds above the sea is about two hundred feet. Their geological horizon is no less than approximately between 5,000 and 6,000 feet below that of the Branxton erratic horizon.

Mr. E. C. Andrews, B.A., is of opinion that some of the four hundred and forty feet of "Shales with erratics," as described on the section below, might also be considered as glacial beds. He states that he found striated pebbles in the paddocks where these upper beds had been denuded. These striated pebbles were not, however, *in situ* as were most of those found by us on the horizon of the beds three hundred feet thick. No favourable section was available for ascertaining whether or not a striated rock pavement lay at the base of the glacial beds.

Appended is a section showing the position of the glacial horizons respectively at Branxton and Lochinvar with reference to the Sydney Coal-field where it underlies the building of the Royal Society. It must not be assumed, however, that these beds all exist under Sydney, though there is a strong probability that at all events the Upper Glacial horizon, (that of Branxton), and even that of the Greta Coal Measures, would be met with under Sydney :—

Section under Sydney.

Continuation of Section in descending order, between Lake Macquarie and Lochinvar, New South Wales.

			Feet.	Total Depth.
I. TRIASSIC—Hawkesbury Series. Total thickness, 2,900 feet.		Hawkesbury Sandstone ...	1,000	1,000
		Narrabeen Beds	1,900	2,900
II. PERMO-CARBONIFEROUS SYSTEM. Total thickness about 13,800 feet.	Newcastle Coal-measures		1,200	4,100
	Dempsey Beds		2,000	6,100
	Tomago Coal-measures		700	6,800
	Upper Marine Series. Total thickness 5000 feet.	Upper Marine Beds above Branxton Glacial Horizon	3,500	10,300
		*Branxton Glacial Horizon		
		Upper Marine Beds below Branxton Glacial Horizon	1,500	11,800
	Greta Coal-measures Total thickness 130 feet.	Greta Coal-measures ...	130	11,930
	Lower Marine Series. Total thickness about 4,800 feet.	Marine Sandstones of Ravensfield Series ...	1,000	12,930
		Shales with occasionally Foraminifera	800	13,730
		Harpur's Hill Conglomerates and tuffs—Sandstones	270	14,000
		Marine Shales	1,000	15,000
		Marine (?) Shales with erratics and thin flows of Andesite and basic lava	900	15,900
		Shales with occasional erratics, perhaps striated	440	16,340
		Sandstones with bands of conglomerates passing down into marine ripple-marked flaggy beds	60	16.400
		*Lochinvar Glacial Beds ...	300	16,700
III. CARBONIFEROUS		Tuffs, Sandstones and Shales with *Rhacopteris* and *Calamites*...	1,700	