ON THE SOURCE OF THE ERRATIC BOULDERS IN THE VALLEY OF RIVER CALDER, YORKSHIRE.

BY JAMES W. DAVIS, F.S.A., F.G.S., ETC.

FOUR years ago I had the pleasure of reading a paper before this Society on the Erratic Boulders in the Valley of the Calder. Since then, extended observations have led to a confirmation of the views I then laid before the Society. The result of those observations forms the subject of this communication.

It may assist a proper understanding of the subject if I recapitulate, as briefly as possible, the main facts of the case. The river has its source in two or three small streams which rise in the hills on the Lancashire side of the Pennine Anticlinal. These are joined into one stream, and pass along a narrow but deep valley cut at right angles to the range of elevated gritstone hills which form the boundary between Lancashire and Yorkshire. For five or six miles the valley is rarely more than about 200 yards in breadth, and on each side the slopes of the hills are extremely steep, composed of shales, surmounted by a precipitous gritstone escarpment. At Hebden Bridge the Calder is joined by the Hebden; in its course south-eastwards the valley gradually assumes larger dimensions, and south of Halifax spreads out into extensive level plains, along which the Calder has carved its channel with many devious turnings. On reaching the district from Mirfield to Wakefield these characteristics are still more apparent, its path being amongst the softer beds of the Coal-measures. Below Wakefield to the confluence of the Calder with the Aire at Castleford, the country generally is of a comparatively flat and uninteresting nature.

The lower reaches of the valley are filled with great quantities of gravels, sand, and boulders. At Wakefield

wells have been dug to a depth of twenty-eight and thirty feet, and at Thornhill and Dewsbury excavations have proved the deposits to be between forty and fifty feet in depth. Still further up the valley, from Elland to Sowerby Bridge, the gravels and boulders occur in some force, and are at least twelve to sixteen feet deep. The valley nearer its source than the latter locality is almost devoid of gravels; and where they do occur, as at Mytholmroyd, the travelled boulders are rare, or altogether absent. From Sowerby Bridge southwards the drift or gravel is composed of rounded pebbles and sand; these, near the surface, are almost entirely derived from the local sandstones and calliards; in the lower strata boulders of granite, trap, and syenite become gradually more frequent, until in the lowest parts they attain a great preponderance, and rocks of local origin are almost as rarely found as crystalline ones were in the upper part of the series. In the sections low down the valley, the boulders are frequently of considerable size, and at Dewsbury masses of granite and limestone were found near the base of the section exceeding a foot in diameter; they were in all cases well rounded and quite devoid of scratches. The following section of a well sunk at Dewsbury may be taken as an average example:—

1. Earth and sandy subsoil	7ft.	6in.
2. Boulders, consisting in the upper part of sandstone with a slight intermixture of granite, etc., gradually merging into	24ft.	0in.
3. Boulders, almost entirely of crystalline rocks not occurring in the district *in situ*	6ft.	0in.
4. Clay with sand and boulders	5ft.	0in.
Carboniferous sandstone		

A remarkable circumstance is the occurrence in the lower beds of rounded masses of flint, along with granite, syenite, and trap rocks, the latter having been identified with their parent rocks in Westmoreland and Cumberland,

and even in some few instances with rocks of Scotch derivation, whilst the flints are similar to those occurring in the Chalk in the eastern parts of the Yorkshire Wolds. There is an entire absence of shells of Mollusca, but near Thornhill the trunks of several trees have been found at a few feet below the surface of the gravel beds presenting an appearance indicating that they grew at no great distance from the position they occupied when found. A more detailed description may be found in the Proceedings of the Yorkshire Geological and Polytechnic Society for the year 1875, page 93.*

In addition to the boulders already enumerated, Shap Fell granite has been found in the district south-east of Wakefield. Though comparatively rare, they are found sufficiently often to form a characteristic boulder; the large masses of pink felspar being a very important constituent, which renders their identification unmistakable. The occurrence of this granite, as will be shown hereafter, throws a most important light on the origin of the gravels.

The question at issue is, "How were the erratic boulders transported into the Valley of the Calder?" There are two sources from which the boulders may have been derived, the one on the western side of the Pennine range of hills dividing Lancashire and Yorkshire, and the other occupying a part of the great plain of the Ouse in the central part of Yorkshire. In all probability the glacial clays, originally containing the boulders, may have had a common origin in the mountainous ranges of Westmoreland, or possibly amongst the mountains of the south of Scotland. Whether one or both these localities served as the source of the glacier, it appears to have passed along the valley of the Eden, grinding against the Crossfell escarpment until it reached

* See also a paper by J. Travis Clay, Esq., of Rastrick, Proc. Geol. and Polyt. Soc. of the West Riding of Yorkshire, vol. i. p. 201 (1841).

the somewhat lower ground of Stainmoor Forest. At this point a part of the glacier was deflected eastwards over hills rising to a height of 1,500 to 1,600 feet above the sea-level into the valleys of the Tees and its tributaries, and also into Arkendale and Swaledale, which are branches from the valley of the Ouse. The glaciers penetrated far down the valleys, and the immense quantities of boulders and till left on their recession testify to their great size and importance. The second portion of the Eden Valley glacier, which did not pass over Stainmoor, continued its course in a southerly direction, and one part of it, filling the valley between Mallerstang and Wild Boar Fell, passed along the district known as Lunds, and may have entered Wensleydale. Mr. J. G. Goodchild* has demonstrated that this glacier must have been 1,600 feet in thickness, and points to numerous evidences of its extent and action in this and the tributary dales of Snaizeholme Widdale and other streams. The remaining portion passed along the western escarpment of the Pennine Chain, and deposited great thicknesses of boulder clays in the valleys of Lancashire. Mr. Dakyns† is of opinion that the latter is the source whence the "erratics may very well have been washed down out of these glacial beds into the Calder valley by ordinary rain and river action," and I believe that this opinion is also shared to a great extent by other officers of the Geological Survey.‡ It has already been observed that the sources of the Calder are extended to the Lancashire side of the Pennine anticlinal, but an inspection of the country drained by it shows that it is surrounded by high hills, with the exception of the

* Quart. Journ. Geol. Soc., vol. xxxi., p. 73.

† Geol. Mag., New Ser., Dec. II., vol. vi., p. 46.

‡ See also "Notes on the Lancashire and Cheshire Drift," by E. W. Binney, read in 1842, and printed in the Transactions of the Manc. Geol. Soc., vol. viii., part i., page 30 (1869).

two valleys along which the railway lines run north-westwards to Burnley and southwards to Littleborough. The watershed between Burnley and Littleborough is formed by a series of hills rising about 1,400 feet above the sea-level, extending from Shievely Pike and Heald Moor southwards to Tooter Hill and along Trough Edge to the summit near Walsden. Throughout the whole of this district on the Yorkshire side of the watershed, with the exception of a small patch of gravel in Walsden, near the Waggon and Horses public-house, there is no trace of gravel or drift. The beds of the several streams in Dulesgate, Howroyd Clough or Ramsden Clough, though deeply cut, exhibit no sections in which drift can be found. On the western or Lancashire slopes of the hills boulder clays and drift occur, often reaching a thickness of 150 to 200 feet. In excavating Hollingworth Reservoir, which is four or five miles west of the summit, and 568 feet above sea-level, extensive beds of gravels were found, which contained marine shells of the genera *Fusus*, *Cardium*, *Purpura*, *Neritella*, etc. Marine shells in the drift are not uncommon in other parts of the district.

The Yorkshire and the Lancashire Calders rise near together at Calder Head. The latter is fed by many small tributaries which have their source on the slopes of the hills eastwards. These tributaries have formed deep valleys or cloughs, and exposed great thicknesses of gravel and boulder clay. Good examples may be seen in Cant Clough and Hurstwood Brook, near Worsthorn, and in the Catlow and Thursden Brooks. The boulders have been derived from the boulder clay, which still in many instances is found at the base of the drift. The latter is composed mainly of carboniferous limestones and sandstones, with an intermixture of Silurian grits, traps, quartzites, and granites. The carboniferous limestone occurs in such abundance that it

was formerly very extensively used for burning to obtain lime. The remains of lime-kilns may be seen studding the hill-sides throughout the locality. In the valley with Burnley for its centre, the remains of glacial origin occur frequently. The gravels in the valley of the Yorkshire Calder *may* have been derived originally from the boulder beds in these districts, but a glance at the physical features of the district renders this view of the case somewhat problematical. The distance from Todmorden to Burnley is $9\frac{1}{4}$ miles. The two Calders rise at Calder Head, four miles from Todmorden. The valley of the Yorkshire Calder, running south-eastwards, is narrow, rugged, and falls rapidly from a height of more than 700 feet above the sea-level at the summit, to about 380 feet at Todmorden. On either side the valley the ground rises rapidly, and is surmounted by precipitous escarpments of sandstone. The Pennine fault runs in a line with the valley, and has displaced the rocks, so that those on the Lancashire side are composed of the third grit, the opposite one being thick beds of the Kinderscout grit. Surmounting the latter, the picturesque groups of weathered rocks, the Bridestones and Hawkstones, ornament the sky-line. Near the source of the stream the Lower Coal Measures set in, and the sides of the valley being, in consequence, of a much looser and more friable nature, landslips have resulted, producing a great number of rounded hillocks. The Lancashire Calder rises and runs in a similar narrow valley, falling with equal or still greater rapidity in the opposite direction, the bed of the stream at Burnley being 350 feet below that of its source. Beds of gravel are occasionally exposed in the sides of the stream, as at Walk Mill, two miles from its source, and 200 feet less in elevation, where, beneath a bed of peat principally composed of the remains of hazel trees, there is a rough sandy gravel. The contained stones are for the most part semi-

angular, and have all been derived from the neighbouring hills. Granites, limestones, or other travelled boulders, do not appear to be present. Some distance lower down the valley, as Burnley is approached, however, the travelled boulders become common.

If the erratics in the bed of the Yorkshire Calder were derived from the boulder clays east and north-east of Burnley, it is quite evident that they could not have been transported by river action. The great rise to the summit of drainage disposes of that theory. The only agent equal to the task appears to be drifting icebergs. It is possible that large masses of ice may have been in existence in the Burnley valley, and these, becoming loose and floating away, would carry with them any stones or boulders with which they happened to be in contact. In order that these icebergs should be able to float over into the valley of the Yorkshire Calder, it would be necessary that the land should be lowered to the extent of between 750 and 800 feet, so that the sea might overflow the summit to a sufficient depth to afford a passage for the ice-floes and their contents. There are also other objections to this method of their entrance into the valley; amongst others, that the valley is entirely devoid of erratic blocks or boulders for many miles from its source, and it is only when the lower parts are reached that they occur, and the nearer the mouth of the valley the more numerous are the boulders. It might also be expected that some of the boulders would lie strewn on the sides of the hills bounding the valley; but hitherto both the hill-sides and their tops have proved entirely devoid of such evidence. For eight or ten miles the deep valley does not present any sections exposing erratic boulders. At some distance below Hebden Bridge, Dr. Alexander* quotes Mr. Gibson as having found a few

* Proc. Geol. and Polyt. Soc. of the W. Riding of Yorkshire, vol. i., p. 148.

fragments of granite or trap whilst the railway line was in process of construction, and a few well-rounded boulders are occasionally found at Mytholmroyd, two miles further down the valley, but they do not occur in any considerable quantity until North Dean is reached.

Turning next to the second source whence the boulders may have been derived, it is well known that the valley of the River Ouse contains immense quantities of boulder clay, brick-earths, sands, and gravels, derived from the glaciers which it has been shown descended Swaledale and Wensleydale. The boulder clay may be considered as the foundation on which the others are deposited, and where it has not been subjected to the action of water, still extends across the whole breadth of the valley from the elevated Permian limestone plateau on the west to the liassic and oolitic wolds on the east. Sections exposing the relative position of the series in the valley are not frequently exposed. The boulder clay occurs extensively east of Knaresborough, and southwards; and on the opposite side of the valley it is 60 or 80 feet thick near Easingwold. At York the boulder clay is 70 feet thick, and the new railway station works are all built on this material. South of the River Wharfe the clay has a thickness of 60 feet. It contains immense quantities of scratched stones; boulders of mountain limestone are numerous; pink granite, trap, syenite and others, derived from the mountainous districts, are common, and mixed with these there are also boulders of sandstone, chert, and chalk. The centre of the valley is covered with deposits of a more recent origin; sands and gravel occur plentifully, and appear to have been derived from the glacial clays beneath by the disintegrating action of water. The stones are generally more rounded, and the striæ, or ice-scratches, have been removed by attrition. In a few cases the boulders still retain scratches. "These

sands frequently exhibit very irregular stratification, and occasionally the beds are much contorted, as if from lateral pressure, such as might be produced by icebergs grounding in shallow water."*

There is little trace of glacial deposits on the Permian limestone, but on the western side, in the valley of the Aire, there is abundant evidence of glacial action. The hollow in which Bradford is situated is covered with a thick deposit of boulder clay, and at Guiseley and Apperley Bridge patches of similar drift occur. North of Leeds great masses of drift are found, consisting principally of stiff blue clay, containing rounded and angular stones of local origin, as sandstones and grit, and also many others of foreign origin, granite and trap being the most common. At Whinmoor, at a height of 380 feet above the sea-level, a boring went through 114 feet of boulder clay. These deposits are probably the remains of an old glacier which descended the valley of the Aire from the neighbourhood of Skipton. It is within the range of possibility that this glacier may have extended as far south as the neighbourhood of Barnsley, for Prof. A. H. Green has described a bed of glacial clay† filling a basin-shaped hollow about two miles north of that town. The exposure is three-quarters of a mile in length; the boulder clay is divided into upper and lower, and contains, besides stones of local origin, boulders of highly metamorphosed breccia, granite, and others, from the Lake District. There are other patches of glacial clay scattered over the district, and also quantities of drift. From a consideration of all the facts, Prof. Green arrives at the conclusion that the whole district was probably covered by a layer of till or boulder clay, resulting from the presence

* Memoir of the Geological Survey, Illustrating Sheet 93 N.W. p. 14.

† Proc. York. Geol. and Polyt. Soc., 1876, new series, pt. iii., p. 122.

of an ice-sheet which probably had its termination in this district, and, being thin, could not exert a very great influence in grinding up the rocks over which it passed. The greater part of the boulder clay so deposited has since been removed by denudation.

The glacier, whose existence is thus indicated, descended from the northwards, and consequently must have crossed the lower part of the valley of the Calder in the neighbourhood of the place where Wakefield now stands, and several miles west of its confluence with the Aire at Castleford. The facts already stated, though very briefly, go to prove that on the recession of the glaciers which once enveloped the country north of the hills separating the Calder from the Aire, immense quantities of stiff glacial clay, filled with sub-angular, scratched boulders of both local and distant origin, were left filling up the valleys. The land appears at this period to have been submerged to the extent of some four or five hundred feet, and the glacial clays subject to the denuding and abrading action of water. The boulders released from the clay, and rolled hither and thither by the waves, were gradually reduced to a more rounded form, and by the same process the scratches were obliterated. There can be little doubt that to this action is due much of the sand and gravel existing in the valley of the Ouse, and also in the Aire valley, in the neighbourhood of Leeds. The climate appears to have been still cold, and icebergs, broken off from the receding ice-sheet, or masses of ground-ice bearing the boulders frozen from the bottom into their mass, drifted in every direction, and, melting, dropped their burden of boulders in new localities.

Under such circumstances as these the valley of the Calder would be an estuary from the sea, of considerable width at its mouth, and gradually closing inland to a comparatively narrow channel. The united action of the

floating icebergs and the tides would be amply sufficient to account for the presence of the boulders which have already been described. They are most abundant in the lower and wider parts of the valley, and the boulders of distant origin preponderate in number, in every section, in the lowest beds, those higher in the series being for the most part, and near the surface entirely, composed of sand and boulders of local origin. The icebergs would in the first place supply the erratics in the lower beds, and as the ice-sheet still receded, and a warmer climate prevailed, the rolling action of the tides reduced the boulders higher in the series from the rocks of Carboniferous age which surrounded the valley, and were constantly being broken loose by the action of the water wearing away the shales supporting them.

The fact is, that in all the sections which have been noted in the lower part of the valley, the erratic boulders are always most numerous, and that they are much larger in size, frequently a foot or more in diameter, at the base of the section, diminishing in size and frequency higher up until they are lost completely, and layers with only stones of local derivation occur. In the higher parts of the valley, as at Elland and North Dean, where the beds are half the thickness of those at Wakefield or Dewsbury, no large boulders have been found, and they are rarely seen to exceed two or three inches in diameter. There is also a great decrease in the proportionate number of foreign and local stones even in the lowest beds. This arrangement of the heavier boulders at the base of the sections, and especially their localization in the lower parts of the valley, points most clearly to their eastward origin and the sorting action of the sea. Had they come westward by river action, the largest boulders would have been left in that part of the valley nearest its source, or, if carried to their present positions, would have been

disposed indiscriminately with smaller ones throughout the whole section.

That the latter theory is probably the correct one, receives additional support from the occurrence of erratic boulders in the valleys which branch from that of the Calder, as, for example, the Colne. It is quite impossible that these could have come from the west; the river rises on the high moorlands of Millstone Edge and Holme Moss, nearly 2,000 feet above the sea-level, and falls rapidly to its confluence with the Calder at about 200 feet above the sea-level.

Some other peculiar circumstances may possibly be accounted for if we suppose the land to have been submerged to about 400 feet lower than its present level, and at the same time these facts act reciprocally in affording evidence that such was really the case. There are numerous beds of gravel and well-rounded boulders, composed entirely of rocks of local origin, millstone grit, flagrocks, pieces of coal, and the harder shales, and, where the peculiar siliceous sandstone called Calliard occurs in the vicinity, it is found in the gravel or drift. These beds occur on the hill-sides bounding the valleys, and generally at a height of 350 feet, a little more or less, above the present level of the sea. Examples may be seen at Kirklees Park, near Mirfield, at Exley, in the Elland Cemetery, at Mytholm, in a branch valley west of Halifax, and in other places as far westwards as Hebden Bridge. These gravels are quite distinct from those in the bottom of the valley, and are usually found occupying a plateau formed by a gritstone, from which the softer superincumbent shales have been denuded. In each of the situations cited above they are at least a hundred feet higher than the present level of the valley. Where exposed in section, they are current-bedded, with thin layers of sand intermixed, and present every appearance of having been subjected to tidal action. The presence of these beds has

been accounted for in a variety of ways; but the one I now suggest—that they were the shores of the old sea—perhaps appears the most reasonable when considered in connection with the drift deposits filling up the base of the valley. If they are the remains of the shores of an old lake, as some authors have described them to be, there remains the difficulty of damming up the waters to so great a depth, which does not appear probable, and of which there is no evidence at present existing.

In conclusion, the evidence that the erratic boulders in the valley of the Yorkshire Calder were derived from the sources so plentifully supplied in the great valley occupying the whole of the centre of the county, rather than from the district westwards of the summit of drainage, appears conclusive. In the one case we have the source of the Calder bounded by a series of hills rising to a height of 1,500 feet or more, and the only openings being at Calder Head on the northern and at Hollingworth on the southern part of the Chain. In either of these the land rises rapidly from the Lancashire side to the height of 610 feet and 700 feet respectively, and in each case they form the summit of drainage. All evidence proves that the general form and direction of the valleys remains unchanged since pre-glacial times, and this being so, the ordinary action of rivers being the agent which has carried the boulders from the Lancashire districts over the summits of drainage may be dismissed as out of the question, and, along with it, the theory of some of the early geologists, of a great wave of translation which was supposed to have swept across the Atlantic to our shores, and was made answerable for every unaccountable phenomenon in surface geology presented to their notice. A more probable theory is that they were carried over by icebergs; but this necessitates that the land be submerged to the depth of 700 or 750 feet, and, if that be granted, there

can be no reason why the ice-floes should not have been occasionally stranded on some of the higher lands below the level of the water, and there have left evidence of their presence in heaps of travelled boulders, as well as in the lower parts of the valley. But such evidence is entirely wanting.

On the other hand, the glacial clays are extended across the mouth of the Calder, and the boulders derived from them may have been washed into the valley, during a slight submergence, by the action of the tides and waves, and also borne up the valley by ice-floes. The statement of Prof. Green that a glacier at one time extended as far south as Barnsley, and left its detritus spread over the country northwards, furnishes a source for the boulders actually within the valley of the Calder as far west as Wakefield, and during the denudation of this district by marine action the boulders would be naturally washed into the sheltered bay which the valley under those circumstances would form. It is not necessary that the land should be submerged more than 250 or 300 feet; but if it was lowered to the extent of about 350 feet, there is evidence of its former presence in the beds of sand and gravel which are found in many places on the hill-sides at a nearly uniform height above the sea-level.

THE TRIAS OF THE SOUTHERN PART OF THE VALE OF YORK.

BY H. FRANKLIN PARSONS, M.D., F.G.S.

In a paper which I had the honour to read before this Society in 1877, on the Alluvial Strata of the lower Ouse valley, I described briefly the Triassic rocks upon which the newer beds rest; but, as some further details concerning them have since come to my knowledge, I have thought it proper to bring them before the Society, so that if thought fit, they may be embodied in the Proceedings. This