PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY OF LONDON.

VOL. III. PART II. 1842. No. 85.

Jan. 19th.—"A Memoir on the Recession of the Falls of Niagara," by Charles Lyell, Esq., V.P.G.S., was read.

The general features of the physical geography of the district traversed by the Niagara between Lakes Erie and Ontario, Mr. Lyell says, have been described with a considerable approach to accuracy by several writers. Prof. Eaton, in a small work published in 1824*, gives a correct section of the formations between Lewistown and the Falls of Niagara, and also refutes the hypothesis of the Lewistown escarpment being due to a fault by an exposition of the true structure of the country. Mr. R. Bakewell in 1830†, published an account of the country adjacent to the Falls, and Mr. De la Beche in 1831‡, endeavoured to point out the gradual manner in which the receding Falls, if they should ever reach Lake Erie, would discharge the waters of the lake; Prof. D. Rogers also in 1835 § showed distinctly, that, as the Falls retrograde, they would cut through rocks entirely distinct from those over which the waters are now precipitated, and correctly represents the superior limestone at Buffalo as newer than the limestone of the Falls, though he omits the intervening saliferous formation. Mr. Conrad likewise, in his Report for 1837 ||, first assigned all the formations of the country to the Silurian system; but to Mr. James Hall (1838) ¶ is due the merit of having shown the true geological succession of rocks of the district.

The contents of the memoir may be divided into two parts: I. an account of the successive strata of the Niagara district; and II. a description of the phænomena exhibited by the Falls.

I. His sketch of the geology of the district, the author states, is derived either from the published surveys of Mr. Hall, or from the information he obtained while travelling with that gentleman in the State of New York during the autumn of 1841; and he acknowledges the great advantage he derived from the facilities thus afforded him. The strata between Lakes Erie and Ontario appear to belong to the middle and lower portions of the English Silurian system, and

* Mr. Lyell's attention was called to this work by Mr. Conrad.
† Loudon's Magazine of Natural History, 1830.
‡ Manual of Geology, three editions, 1831, p. 55; 1832, p. 55; 1833, p. 60.
§ Silliman's Journal, vol. xxvii. p. 326.
|| States' Report of the Geology of New York.
¶ Geological Report of the State of New York for 1838.

they are divisible into the following five principal formations: 1st. the Helderberg limestone; 2nd, the Onondago salt group; 3rd, the Niagara group; 4th, the Protean group; and 5th, the Ontario group,

1. *The Helderberg limestone*, which has derived its designation from the range of mountains of the same name, and is the newest formation of the country, is exposed where the Niagara flows out of Lake Erie, and on account of the organic remains with which it abounds, it is considered to be the equivalent of the Wenlock rocks of Mr. Murchison's Silurian system. The correctness of this stratigraphical position Mr. Lyell has verified by an examination of the succession of formations from the coal-field on the borders of Pennsylvania to the group in question, the intervening deposits consisting, first, of old red sandstone, having at its bottom a large development of shales and sandstones called the Chemung and Ithaca formations, but containing organic remains which resemble those of the Devonian system; and then 1000 feet of Ludlowville shales with fossils analogous to those of the Ludlow rocks of Mr. Murchison. The superposition of this vast horizontal series is beautifully exposed in the banks of the Genessee and other rivers; and near Le Roy as well as elsewhere, the Helderberg limestones crop out from beneath them. On account of the middle portion containing nodules and layers of chert, the whole deposit was first called the cornitiferous formation by Prof. Eaton. In this part of the State of New York, and still further to the west, in Upper Canada, the limestone is only 50 feet thick, whereas at Schoharie in the Helderberg mountains, 300 miles to the eastward, its thickness is 300 feet.

2. *The Onondago salt group.*—This series of beds, Mr. Lyell says, is extremely unlike any described member of the European Silurian group. With the exception of a stratum of limestone at the top containing Cytherina, it consists of red and green marls with beds of gypsum, the former being undistinguishable from the marls of the new red system of England; and they are also destitute of fossils. Salt springs are of frequent occurrence, but no rock salt has been discovered in the group. The breadth of the zone of country occupied by the deposit is not less than 16 miles, and Mr. Hall infers from it and the slight southerly dip of the strata, that the entire thickness in the neighbourhood of the Niagara is at least 800 feet, an estimate confirmed by the nearest sections eastward of the river. In some parts of the State of New York the thickness is not less than 1000 feet. Along the Niagara the formation has been greatly denuded, and is covered by superficial drift, except at a few places.

3. *The Niagara group.*—This series of beds commences near the rapids, above the great cataract. It comprises, 1st, the Niagara, or Lockport limestone, and 2ndly, the Niagara, or Rochester shale; and it contains in both divisions fossils identical with those of the Wenlock limestone of England, with others peculiar to North America. The limestone at the rapids and the Falls is 120 feet thick; the upper 40 feet, being thin-bedded, have given way to the frost and the action of the stream, but the lower 80 feet, being massive, forms at

the cataract a precipice, beneath which occurs the shale, also 80 feet thick.

4. *The Protean group.*—Under the water at the base of the Falls crop out the higher beds of this formation, the name of which has been derived from the variable nature of its component strata. In the district more particularly described in this paper the group is only 30 feet thick, but farther to the eastward it attains thrice those dimensions. On the Niagara it consists of 25 feet of hard limestone, resting on 4 feet of shale; while at Rochester, eighty miles to the eastward, it comprises, among other beds, a dark shale with graptolites, or fossiliferous iron ore, and beneath them a limestone full of *Pentamerus oblongus* and *P. lævis*, considered by Mr. Conrad to be one species. On account of the occurrence of this shell, the whole of these strata have been separated from the Niagara series.

5. *Ontario group.*—About half a mile below the Falls the uppermost beds of the Ontario group crop out. At the whirlpool they have a thickness of 70 feet, and at Queenstown of 200, but to the latter dimension must be added 150 feet of inferior beds, exposed between Queenstown and Lake Ontario. The entire group consists of

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| 1. Red marl with beds of hard sandstone in its upper division | 70 feet. |
| 2. White quartzose strata, so hard as to form at Queenstown a ledge projecting beyond the face of the escarpment | 25 — |
| 3. Red marl and sandstone | 250 — |

Other divisions of the group, concealed beneath the waters of the lake, may be studied in the cliffs of its eastern and north-eastern shores.

Mr. Lyell next proceeds to give a brief account of the geographical distribution of the formations or groups. The strike of the beds being east and west, and the dip very slight towards the south, the sections exposed along the Niagara afford a key to the structure of a large portion of the State of New York, the same deposits having been traced eastward through a region 40 miles in breadth by 150 in length, and westward to a much greater distance. The Helderberg and the Niagara limestones constitute platforms which terminate in parallel escarpments, from twenty to twenty-five miles apart, about sixteen miles of the intervening space being occupied by the saliferous group. The Helderberg escarpment, to the east of Buffalo, is 50 feet high; but in the neighbourhood of the Niagara it has been denuded and is half buried beneath drift; it is however resumed in Upper Canada, and eastward it may be followed to the river Hudson. The Niagara limestone escarpment presents at Lewistown and Queenstown a cliff 300 feet high, which may be traced eastward nearly 100 miles and westward for a much greater distance. The limestone series, however, constitutes only the uppermost third of the escarpment, the remainder being composed of the Protean and the Ontario groups; the whole section being as follows:—

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| 1. Niagara limestone, lower beds | 30 feet. |
| 2. Niagara, or Rochester shale | 80 — |
| 3. Protean beds | 30 — |
| 4. Ontario group: red marl, with hard beds in the upper part | 70 — |
| 5. ——————: quartzose grey sandstone, with Lingulæ, &c. | 25 — |
| 6. ——————: red marl | 100 — |
| | 335 feet. |

Though only the lower beds of the Niagara limestone occur in the escarpment at Lewistown, yet, in consequence of the gentle rise of the strata to the north, the summit of these lower beds is at a higher level than that of Lake Erie. The whole of the Niagara platform is covered irregularly with hillocks of drift, beneath which the limestone is polished and furrowed.

From the foot of the Queenstown escarpment to Lake Ontario, a distance of six or seven miles, is a low tract, consisting of sandstones belonging to the Ontario group, and dipping like the preceding beds slightly to the south.

A section which accompanied the memoir to illustrate the preceding details corresponds, the author says, in all essential particulars with one previously published by Mr. Hall; but the whole succession of beds has been verified by Mr. Lyell in more than one line of section, from north to south. He is induced to believe, from a comparison of English Caradoc and Llandeilo fossils with suites of organic remains examined in America, that a series of beds which underlie the Ontario group, and termed by American geologists the Mohawk group, may be older than the lower Silurian rocks, and wanting in England.

II. *On the Recession of the Falls.*—The following measurements, Mr. Lyell says, are of great importance in speculating on the past or future recession of the Falls. The distance from the point where the Niagara flows out of Lake Erie to the Falls is sixteen miles, thence to the limestone escarpment seven miles, and from this point to Lake Ontario about seven more. From Lake Erie to the commencement of the rapids, fifteen miles and a half, the river falls only 15 feet; but from the top of the rapids to the great cataract the descent is 45 feet; and the height of the Falls is 164 feet, perpendicular. From the base of the Falls to Queenstown, seven miles, the difference of level in the river is about 100 feet; but from that place to Lake Ontario, seven miles further, it is only 3 or 4 feet. If the Falls were ever at Queenstown, they must, the author observes, have been about twice their present height, having lost a small portion of the difference by the southern inclination of the strata, and rather more than 100 feet by the rise of the bed of the river.

With respect to the opinion of the Queenstown escarpment being due to a fault, Mr. Lyell states, that the strata on the banks of the Niagara, both above and below Queenstown, presenting the same relative position as at Lockport or Rochester, the escarpment must

be entirely due to denudation; and he has no hesitation in attributing this escarpment, as well as the Helderberg, to the action of the sea; these great inland cliffs having far too great a range to have resulted from a former extension and higher altitude of Lake Ontario.

The next question, whether the ravine through which the Niagara flows is to be regarded as a prolongation of the Queenstown escarpment and referable to the same period, or has been cut through by the river, is, the author states, of greater difficulty. From his own observations, he concludes that the ravine has been formed by the river; but he assumes, that a shallow valley pre-existed along the line of the present defile, resembling the present one between Lake Erie and the Falls. His reasons for conceiving that the river has been the excavating agent, are, 1st, the ravine being only from 400 to 600 yards wide at the top, and from 200 to 400 at the bottom, between Queenstown and the Whirlpool; 2ndly, the inclination of the bed of the river, 14½ feet per mile, being everywhere cut down to the regular strata; 3rdly, the fact that the Falls are now slowly receding; 4thly, that a freshwater formation, which the author ascribes to the body of water which flowed along the original shallow valley, exists on Goat Island and half a mile lower down the river, and could not have been deposited after the Falls had receded farther back than the Whirlpool. Mr. Lyell considers that the indentation of about two acres on the American side of the Niagara, and not referable to the action of that river, is no objection to the theory of the recession of the Falls, because he conceives that the stream flowing down it could have effected the denudation, aided by atmospheric agents; and because a similar objection might be founded on a ravine on the Canada side opposite the Whirlpool, where several parallel gullies have been deeply eaten into by streams. The characters of this ravine were carefully examined by Mr. Lyell and Mr. Hall, and appear to have escaped previous observers. What was anciently a ravine joins the defile of the Niagara at this point, but it is entirely filled with horizontal beds of drifted pebbles, sand and loam; the first, near the bottom of the deposit, having been cemented into a conglomerate by carbonate of lime. This is the only interruption of the regular strata along the course of the Niagara; and Mr. Lyell observes, it is desirable to ascertain if it be a prolongation of the ravine which intersects the great escarpment at St. David's, west of Lewistown.

The author states, that he is by no means desirous of attaching importance to the precise numerical calculations which have been made respecting the number of yards that the Falls have receded during the last half century, as there are no data on which accurate measurements could be made; and because fifty years ago the district was a wilderness. Mr. Ingrahaw of Boston has, however, called his attention to a work published by the French Missionary, Father Hennipen, in which a view is given of the Falls as they appeared in 1678. Goat Island is represented dividing the waters as at present; but besides the two existing cascades, a third is depicted on the Canada side, crossing the Horse-shoe Fall at right angles, and appears to

have been produced by a projection of the Table Rock. In the description Father Hennipen states, that this smaller cascade fell from west to east, and not like the other two, from south to north.

Seventy-three years afterwards, in 1751, a letter on the Falls, by Kalm, the Swedish botanist, was published in the 'Gentleman's Magazine.' It is illustrated by a plate, in which the third Fall is omitted; but the writer states in a note, that at that point the water was formerly forced out of its direct course by a projecting rock, and turned obliquely across the other Fall*.

Mr. Lyell then proceeds to show what are the geological evidences of the former prolongation of the river's bed, on a level with the top of the ravine through which the Niagara now flows. The existence on Goat Island of strata of marl, gravel and sand, containing fossil freshwater shells, was known before Mr. Bakewell's paper on the Falls was published, and they have been more recently described by Mr. Hall†; and Mr. Lyell states, that he was very desirous of ascertaining how far they extend on the banks of the river, or whether they could be detected below the present Falls. On the south-west side, in a cliff 12 feet in perpendicular height, a bed of gravel, 7 feet from the surface, contains eight species of fluviatile and one of terrestrial shells, determined for the author by Dr. Gould of Boston, the whole of the former now living in the waters of the Niagara, and some of them even in the rapids. At the south-west extremity of Goat Island this deposit must be 24 feet thick, and it rests on the Niagara limestone. On the right bank of the river, opposite the island, are two river-terraces, one 12 feet above the stream, and the other 12 feet higher; and both have been cut out of this freshwater formation. In making a mill-dam some years ago, the same species of shells as those on Goat Island were thrown out, and Mr. Lyell had still an opportunity of collecting them. He was also shown a tooth of the "*Mastodon Americanus*," which, with another tooth and a bone of the same animal, were discovered in the deposit 13 feet from the surface. From information given to the author by Mr. Hooker, the guide, the formation was found half a mile farther down the river, at the summit of the lofty precipice, 6 feet deep and composed chiefly of gravel. It contained in abundance *Cyclas rhomboidea, Valvata tricarinata* and *Planorbis parvus*. This patch of gravel demonstrates, therefore, the former position of the river at a level corresponding to that of the present summit of the cataract, and half a mile below the existing Falls. It proves however, Mr. Lyell says, much more; for in order that such a fluviatile deposit should have been accumulated in water tranquil enough to allow those shells to exist, there must have been a barrier farther down; and he is of opinion it may be safely placed as low as the Whirlpool, or three miles from the present Falls. If

* The author has observed distinct signs of recession in strata of the Silurian and Devonian epochs at the Falls of the Genessee in Rochester and at Portage, at the Fall of Allen's Creek below Le Roy, near the town of Batavia, and at the Falls of Jacock's river, three miles north of Genessee.

† Report for 1838.

this be admitted, then, the author says, "we may be prepared to concede that the still narrower ravine beyond the Whirlpool was excavated by the river cutting back its course."

A similar terrace, consisting of the Goat Island deposit, is distinctly seen also on the Canada side, and at about the same level between the Falls and the Whirlpool; but its extent, height and fossil contents have not been investigated.

If, Mr. Lyell observes, the river continue to intersect its way back, the sediment now depositing in its bed, above the Falls, will be laid dry in places, and cut into in the same manner as the Goat Island deposit.

Assuming that the cataract was once at the Queenstown escarpment, allowance must be made, in speculating on the probable time which has elapsed in cutting the ravine, for a very different rate of retrocession at different periods, dependent on the changes in the formation intersected, especially of those which successively constituted the base of the precipice. At Queenstown and Lewistown the fundamental rock, at the period when the Falls were there, was a soft red marl, and the river acted upon the same deposit for about three miles, where the rise in the channel, combined with the dip of the strata, caused the superincumbent hard quartzose beds, 23 feet thick, to form the base of the precipice. From this point the retrocession must have proceeded much more slowly for about a mile, or to the Whirlpool, where a small fall of 6 or 8 feet still marks the place of the highest beds of the sandstone. After, Mr. Lyell says, the cataract had remained nearly stationary for ages at this point, it next receded more rapidly for two miles, having soft red marl 70 feet thick to erode its way through; but beds of greater solidity, consisting of grey and mottled sandstone and Protean limestone, amounting in all to 30 or 40 feet, then offered a greater resistance, and continued to retard the backward movements of the Falls, the Protean limestone occurring at the base of the present precipice.

Lastly, the author offers some observations respecting the future retrocession of the Falls, quoting the opinions entertained by Mr. J. Hall (Report for 1838) on the effects which the strata above the existing cataract will have on the progress of the river, and pointing out results similar to those given by Mr. De la Beche in his 'Manual of Geology.' But all predictions, Mr. Lyell says, regarding the future history of the Falls may be falsified by the disturbing agency of man. Already a small portion of the waters of Lake Erie is carried off to supply the Welland canal, and another canal on the American side of Niagara; and numerous mill-races have been projected and others will be required along both sides of the river, as the population and wealth of the country increase. Many cities also, situated to the eastward of the great escarpment and at a lower level, may in aftertimes borrow water from Lake Erie, especially as the continued felling of the forests causes streams which were formerly constant to become dry in summer; and it must not be forgotten that Lake Michigan has lately been made by a cutting to feed the Illinois river, and that whatever quantity of

water is abstracted from the upper lakes is taken away from the Niagara.

Feb. 2nd.—"Sketch of the Geology of the South of Westmoreland." By Daniel Sharpe, Esq., F.G.S.

The object of this communication, the author says, is to describe the Silurian rocks and the old red sandstone of the south of Westmoreland, to define approximatively their geographical boundaries, and to compare their lithological structure and stratigraphical phænomena with the equivalent formations previously noticed in other parts of the kingdom.

The author, in alluding to the published labours of those who preceded him in the same district, mentions the memoir of Mr. J. Phillips on a group of slate rocks between the Lune and Wharf*, Prof. Sedgwick's on the Cumbrian mountains†, Mr. J. G. Marshall's on a section between the Shap granite and Casterton Fell‡, and Prof. Sedgwick's Geological Map of Westmoreland; also the abstract of his memoirs on the English stratified rocks inferior to the old red sandstone§.

The different formations are described under the heads of,—1. Coniston Limestone; 2. Blue Flagstone Rock; 3. Windermere Rocks; 4. Ludlow Rocks; and 5. Old Red Sandstone.

1. *Coniston Limestone.*—This calcareous band, which has been laid down in great detail by Prof. Sedgwick, was adopted by Mr. Sharpe as the base of his inquiries. It usually rests upon dark brown shale, and consists, in its lowest part, of a hard, dark blue, slaty limestone, from fifty to sixty feet thick at Low Wood; and in the upper, of thin beds of dark brown shale, alternating with others of blue limestone, which gradually diminish in thickness, and totally disappear towards the top of the formation. The bottom bed of limestone contains very few organic remains, but the shales and thinner calcareous bands abound with casts. A list of fossils given by the author includes fifteen Silurian species, seven of which belong to the lower Silurian rocks of Mr. Murchison; and the author places the Coniston limestone and associated shales on the parallel of that division of the Silurian system, but without attempting to define its exact relative position. Mr. Marshall, on the authority of Mr. J. Sowerby, places the Coniston limestone on the parallel of the Caradoc limestone. An exact account of the strike and dip of the rock, the author says, will be found in Prof. Sedgwick's memoir, but the general bearing of the strike of the beds throughout the western part of their course is stated to be north-east, though on approaching Shap more nearly east and west; and the ordinary dip is stated to be south-east, with an inclination rarely less than 30°, and frequently exceeding 60°.

* Geol. Trans., 2nd Series, vol. iii. part i. p. 1, 1829.

† Ibid, vol. iv. part i. p. 47, 1835.

‡ Proceedings of British Association for 1839.

§ Proceedings, vol. ii. p. 675; Athenæum, No. 736; Proceedings, vol. iii. p. 541.

2. *Blue Flagstone Rock.*—The shales of the last deposit pass upwards into a dark blue flagstone, the strike of which is parallel to that of the Coniston limestone, and the dip is conformable. It is stated to range from the west of Coniston by the village of Torver, the head of Coniston Lake, also south of the Ambleside road to Low Wray, and thence from the east side of Windermere, by Trout Beck and Kentmere, to the neighbourhood of the Shap granite. The faults which affected the Coniston limestone series extend into this deposit. No organic remains were found by the author, but he is of opinion that their absence may be owing to the rearrangement of the constituent particles of the rock when they assumed the slaty structure.

3. *Windermere Rocks.*—This vast series of beds, to which Mr. Marshall applied the name of Blawith slate, succeeds conformably to the blue flagstone, and is arranged by the author into three groups, which he calls the lowest, middle, and upper divisions. A line drawn from Coniston Water Head to Lindale, a distance of twelve miles, would cross the beds at right angles to the strike; and though the same strata are, according to the author, frequently repeated in a succession of parallel anticlinal ridges, yet he is of opinion that the total thickness of the formation exceeds 5000 feet.

3*a*. *Lowest Division.*—This portion of the Windermere rocks consists of gray schistose grits and argillaceous slates, containing thin beds of limestone on the banks of Coniston Lake. The strata are stated to be much affected by cleavage lines. The usual strike of the beds at the foot of Coniston is said to be north-east, but great variations are shown to occur in other portions of the district, in consequence of anticlinal ridges which range north and south. The boundary between this division and the middle one passes from the foot of Coniston Water to the ferry on Windermere, and thence by the foot of the valley of Kentmere, across Long Sleddale at Murthwaite Crag, south of Tebay Fell, Langdale Fell and Ravenstone Fell, to Rathay Bridge, but it is much affected by dislocations. The general range of the division, Mr. Sharpe states, may be traced by the grits and slates forming a series of bold hills which stand out in relief above the tame rounded masses of the argillaceous schists of the middle division.

The author alludes to a band of calcareous slates shown by Prof. Sedgwick to range from Blawith to the south-west, but he states that he failed to find its eastern continuation; he alludes likewise to Mr. Marshall's account of having found lower Silurian fossils in it; and he is induced, on this account, to conceive that the calcareous band may form the uppermost portion of the lower Silurian rocks. The lowest division of the Windermere series is stated to be well exposed on the shores of Coniston Lake.

3*b*. *Middle Division.*—This deposit consists of hard argillaceous rocks, usually striped or banded gray, blue, or white, and sometimes brown; it contains also beds of soft shale and hard grits similar to those of the lowest division. On the west side of Windermere the usual strike is north-east, but to the eastward of the lake the strata

are stated to be thrown into great confusion by faults ranging north and south. The boundary between this and the upper division is drawn by the author from Newby Bridge to Witherslack; but from Whitborrow to the Lune, the southern edge of the deposit is overlaid unconformably by various rocks of more modern date. East of the Lune the Windermere rocks are stated to be less concealed by other formations, the southern boundary ranging from a little east of Barbon to Barbon Fell House, where it is again overlaid by carboniferous limestone. The only traces of organic remains mentioned by the author are some crushed specimens, one of which he considers to be a Phragmoceras.

3*c*. *Upper Division.*—This division consists of hard, compact, purplish greywacke, little affected by cleavage, and can be distinguished from the Ludlow rocks only by the absence of fossils. The strata are greatly disturbed by north and south anticlinal faults. The division is exposed in only two limited districts; one south of Windermere, and the other east of the Lune, constituting Barbon Beacon and the western end of Casterton Fell, all the intermediate district being occupied by newer formations.

4. *Ludlow Rocks.*—This series rests, the author says, unconformably on the Windermere beds; but the want of conformity is stated to be inferred, not from the usual evidence of irregular deposition at the passage beds, but from the relative position of the two formations, the Ludlow rocks resting, in different places, on the middle and upper divisions of the Windermere series. The deposit is composed of hard, purplish gray, argillaceous strata, and though intersected by several cleavage plains, does not possess a slaty structure. The lines of stratification are usually well marked by thin rotten layers full of casts of shells, the intermediate portions being devoid of organic remains. The range of the Ludlow rocks, as limited by the author to beds which contain fossils, and commencing west of Kendal Fell, is stated to be a narrow strip at the base of Underbarrow Scar; and on the east of Kendal Fell, is a patch on the Tenter Fell, north-west of Kendal. In the valley of the Kent, the Ludlow rocks are concealed by newer deposits; but east of the valley they constitute the high anticlinal ridge of Benson Knot and Helme, the top of the latter, however, being old red sandstone; they occupy also all the country thence to the Lune, except the highest point of Lupton Fell, where the Windermere rocks are brought to the surface, being bounded on the west, south, and east by mountain limestone or old red sandstone. The usual strike of the beds is said by the author to be north and south, and the dip either east or west, the strike conforming to the direction of the principal faults. The chief anticlinal north and south ridges are stated to be Benson Knot, Helme, Old Hutton Common, and Lupton Fell: several east and west faults are likewise mentioned in the paper; as in Lambrigg Park and Fell, in Mansergh Common, west of Lunesdale, and at Old Town.

A gradual passage from the upper beds of the Ludlow rocks into the tilestone of the old red sandstone is exposed at the top of Helme at Old Town and the southern part of Mansergh Common; and

the author is induced to infer, from eleven of the twenty-five species found in the bottom beds of Herefordshire occurring also in the upper Ludlow rocks of that district, and from seven of the remaining fourteen species occurring low in the Ludlow rocks of Westmoreland, that the beds which have been considered to form the bottom of the old red sandstone ought to be included in the Silurian system. A further argument in support of this arrangement is drawn from the fact, that where the old red sandstone rests on the Windermere rocks these doubtful beds are wanting, the shells being found only where the Ludlow rock occurs.

A list of thirty-four species of fossils is given in the paper, consisting almost solely of Ludlow Testacea figured in Mr. Murchison's work, but the author does not state positively to what portion of the Ludlow series the Westmoreland beds ought to be assigned.

5. *Old Red Sandstone.*—The following distinct districts, composed of old red sandstone, occur within the area described by the author: (*a.*) that in the valley of the Lune and the neighbourhood of Kirkby Lonsdale; (*b.*) those near Kendal and in the valleys of the Kent, Sprint, and Mint; and (*c.*) that near Shap and Tebay.

5*a.* To the old red of the valley of the Lune, above Kirkby Lonsdale, the author assigns the bed of loose conglomerate and red clay, which he says dips under the scar limestone of Casterton, the limestone being inclined to the south-east at an angle of 30°, and the conglomerate to the east by north at an angle of 25°. The want of conformity is stated to be more manifest to the westward; for where the limestone bends round by Kirkby Lonsdale bridge it dips 25° or 30° to the south-south-east; at Catshole quarry the strata are arched with a north-west strike; at Hollin Hall quarry the dip is south-west 30°, and at Teamside 40° south-east; but the old red sandstone dips throughout, as far as the beds can be seen, to the east. At Casterton the loose conglomerate is 100 feet thick, and passes downwards into red marl, occasionally mottled blue, and estimated to be fifty feet thick. This marl rests on alternating beds of red marl and red sandstone, beneath which is a considerable deposit of dark red tilestone and light-coloured sandstone, forming the passage beds into the Ludlow rocks. The total thickness is estimated at 1000 feet. To the north of the Casterton fault, the lower beds of the old red sandstone are stated to be raised up and exposed, far to the eastward of their position below Casterton; and above this spot the right bank of the river is said to be composed of the lowest beds of the tilestones and the passage beds into the Ludlow rock, but the left bank to consist of tilestones and red sandstones. The dip is east, at an angle of 25°. Mr. Sharpe also assigns to the old red sandstone, but not definitively, the bed of brown gravel, or of brown clay full of pebbles, which covers the whole of the valley of the Lune to its junction with the Rathay, and up that valley nearly to Sedbergh. It forms a line of low hills on each side of the Lune, resting on the northern edge of the tilestones above Barbon Beck, and conceals the junction of the Ludlow rocks on the right of the Lune with the Windermere rocks on the left of that river.

*5b.* Several limited patches of old red sandstone occur in the neighbourhood of Kendal, the remnants, in the author's opinion, of a once continuous mass. They consist, near Kirkby Lonsdale, of red conglomerates, red marls, and red and light-coloured sandstones, with tilestones, which pass downwards into the Ludlow rocks. Some of these patches, as on the top of Helme and at Monument Hill, two miles north-east of Kendal, have been raised to a considerably higher level than the rest of the formation. Three miles above Kendal the old red sandstone is well exposed on the banks of the Sprint, consisting of

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| Loose conglomerate ..... | 60 to 80 feet. |
| Red marl ..... | 50 — |
| Thin-bedded red sandstone ..... | 30 — |

The strike of the beds is north by west, and the dip east by north 10°, and they are unconformable to the adjacent older rocks. Similar beds are slightly exposed in the banks of the Mint, near Lavrock Bridge, striking east, and dipping 5° north, a bearing different from that of all the neighbouring rocks. They are separated from a more extensive patch about Greyrigg by an anticlinal ridge of the middle division of the Windermere rocks, but they cover a considerable area capped by nearly horizontal beds of mountain limestone. Around Kendal is another doubtful deposit of brown gravel, and the castle stands upon it.

*5c. Shap and Tebay.*—The course of the Birkbeck, from its rise above Shap Wells to its junction with the Lune at Tebay, intersects a deposit of old red sandstone, and the same deposit extends for some distance eastward up the valley of the Lune. It consists of the usual triple division, but the passage beds into the Ludlow rocks are entirely wanting, and the lower beds thin out in ascending the valley from Tebay. It rests on the lowest portion of the Windermere series. The dip is only 5° or 10° to the north-east. On the opposite side of the ridge which separates the Lune from the Lowther, the old red again occurs in the valley of the latter river, the intervening ridge being occupied by masses of the doubtful brown gravel. Throughout this district the lowest beds of the mountain or scar limestone rest conformably on the old red sandstone.

*General Remarks; or comparison of the Westmoreland strata with the equivalents in other parts of the kingdom.*—The triple division of the Westmoreland old red sandstone, the author says, agrees remarkably with that of Herefordshire, as already stated by Mr. J. Phillips in his work on the Fossils of Devonshire; the only differences being the disaggregated state of the conglomerates, and the absence of the cornstones as well as of the Ichthyolites. The gradual passage from the bottom of the old red sandstone into the Ludlow rocks also coincides with the phænomena described in Herefordshire by Mr. Murchison. The Ludlow rocks of Westmoreland will also bear comparison with those of the border counties of England and Wales; but, owing to the absence of the Aymestry limestone, it is not possible, the author states, to fix the exact relative position of the former with respect to the latter, but he says that they exactly

agree with the upper division of the upper Silurian rocks of Denbighshire, as described by the late Mr. Bowman*. With respect to the Windermere series, the author likewise hesitates to place it on an exact parallel with any of the subdivisions of the Silurian as described in Mr. Murchison's work, but he states that it precisely agrees in part with lower divisions of the Denbighshire upper Silurian rocks, both in general characters and the details of the component strata. The Coniston limestone Mr. Sharpe, as already stated, prefers to consider as a lower Silurian deposit, than as the equivalent of any one of the members of that series of rocks.

The author then enters upon the inquiry of the principal epochs of disturbance and elevation of the Westmoreland rocks; and he shows, 1st, that the earliest period of disturbance was connected with the outburst of the Shap granite; inferring, from the conformity of the Windermere rocks with the Coniston limestone, that all these series were deposited before the outbreak of the granite; 2nd, that the old red sandstone resting horizontally on the elevated rocks of Shap Fell, proves that this formation was accumulated after the disturbance consequent upon the protrusion of the granite; 3rd, that all the faults which affect the old red sandstone, or any newer formation, are more modern than the outburst of the granite. Although difficulties attend the fixing of the age of the Ludlow rocks relative to the outburst of the granite, on account of the complicated irregularity of the position of the former, yet the author thinks, that from the want of conformity of the Ludlow rocks to the Windermere, and from the faults which traverse them extending into the old red sandstone, that they were deposited subsequently to the protrusion of the granite. Having thus defined the limit of that event, Mr. Sharpe proceeds to show its effects. In the south of Westmoreland, he says, it threw into a high angle the strata of Coniston limestone and Windermere schists, and produced the great east and west faults around Coniston and Windermere, as well as in Middleton and Casterton Fells; likewise the dislocations of the Coniston limestone, with their prolongations in the valleys of Coniston, Esthwaite, Windermere, Kentmere, Long Sleddale, &c., which are not continued into the Ludlow rocks. These valleys, or lines of cracks, Mr. Sharpe says, are quite distinct in character from the north and south synclinal valleys in those rocks; he is also of opinion that the valley of the Lune had a similar origin, but the older rocks being concealed by newer deposits, its resemblance to the other valleys is less complete.

Mr. Sharpe did not observe any proof of the Ludlow rocks having been disturbed anterior to the deposition of the old red sandstone, but, he says, there is abundant evidence of both those formations having been dislocated before the accumulation of the mountain limestone, as the limestone of Kendal Fell rests in a nearly horizontal position upon the upraised edges of an anticlinal ridge of Ludlow rocks, from which a covering of old red sandstone is considered to

* Athenæum, No. 719, Aug. 7, 1841.

have been partially denudated: the anomalous manner in which the limestone overlies the old red sandstone of Kirkby Lonsdale is, he says, another instance. The principal north and south faults of the Ludlow rocks, and a portion of the Windermere schist, between Windermere and the Lune, are, however, considered by the author to be of later origin than the mountain limestone, and he particularly refers to the disturbances at Natlands, Farleton Knot, Hutton Roof, Lupton Fell, Witherslack, Whitbarrow and Kendal Fell. Lastly, the author calls attention to the successive elevation of hills in one direction by forces acting at different periods as a phænomenon which has not received the thought it deserves; and he points out as an instance the Windermere schists forming the high chain of Middleton and Casterton Fells, which chains, he says, were elevated from the north at the period of the eruption of the Shap granite, nearly as they are at present, for they formed, he states, the boundary of the great hollow in which the Ludlow rocks were deposited; and the great faults which cross the Fells in an east and west direction were, he is of opinion, formed at the same period, the mountain limestone not having been broken through by the faults in which the Rathay, the Dee, and the Barbon traverse the chain: yet this chain of hills has been elevated, he adds, in the same north and south direction subsequently to the deposition of the mountain limestone, the whole band of limestone resting upon their eastern flanks having been thrown up to a high angle, and in some places much disturbed.

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In consequence of the unanimous consent to the proposition moved at the Meeting held on the 19th January by Mr. Greenough, and seconded by Mr. Horner, that the President should ascertain whether His Majesty the King of Prussia would condescend to allow his name to be enrolled in the list of royal personages, and that if the permission were obtained the President should make the necessary arrangements to carry the same into effect, Mr. Murchison stated at this Meeting, from the Chair, that having ascertained from His Excellency the Chevalier Bunsen, that His Majesty would accept this tribute on the part of the Society, he had, in the presence of one of the Vice-Presidents, the Secretaries, the Treasurer, and several of the Fellows, requested His Majesty to inscribe his name in the Obligation Book of the Society, assuring him at the same time, "that English geologists can never forget the debt of gratitude they owe to the country which has produced a Von Humboldt, a Von Buch, and an Ehrenberg, nor to the Monarch who is the Friend and Patron of those distinguished men."