IV. Remarks on the geology of the banks of the Tweed, from Carham, in Northumberland, to the sea coast at Berwick

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included between the two surfaces. Similar reasoning may be applied to the fluid contiguous to this new containing surface, and so on throughout the whole of the mass. From this we infer that the motion is at every point directed to the vertex of the given cone. Also, let V = the velocity of the vertical descent of the horizontal surface, and h its distance from the vertex of the cone, and let us consider a point on this surface, at which the direction of the velocity makes an angle θ with the axis. The velocity at this point = $V \sec \theta$ and $V \sec \theta$

$$= -\frac{c}{y^2} \cdot \frac{dy}{ds} = -\frac{c \sin \theta}{h^2 \tan^2 \theta}. \text{ Hence } -c = \frac{h^2 V \sin \theta}{\cos^3 \theta}. \text{ There-}$$

fore in general $\omega = \frac{V \sin^2 \theta}{\cos^2 \theta} \cdot \frac{h^2}{y^2}$. If g = the distance of any point from the vertex $g \sin \theta = y$, and

$$\omega = \frac{V h^2}{\cos \theta} \cdot \frac{1}{g^2 \cos^2 \theta}.$$

As the vertical velocity $\omega \cos \theta$ varies as $\frac{1}{(g \cos \theta)^2}$, it is the same at all points of a plane perpendicular to the axis. Hence the fluid descends in parallel slices; that is, a portion which at any instant is included between horizontal planes will always be included between horizontal planes.

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IV. *Remarks on the Geology of the Banks of the Tweed, from Carham, in Northumberland, to the Sea Coast at Berwick.*
By N. J. WINCH, Esq. Secretary of the Natural History Society of Newcastle-upon-Tyne*.

THE rocky strata which border the Tweed from Carham Bourn, where the river begins to form the boundary between Northumberland and Scotland, to the sea shore at Berwick, appearing to be associated in a manner so different from the order generally considered by geologists as the natural arrangement, will oblige me to abstain from theory altogether in the following remarks. It is, therefore, my intention to lay before the Society merely a series of notes lately made during an examination of the north-eastern termination of our district, accompanied by specimens which will serve to assist in verifying the correctness of the observations. A superficial view of the banks of this beautiful river presents a succession of eminences, I can scarcely call them hills, chiefly composed of diluvium, con-

* Read before the Natural History Society of Newcastle-upon-Tyne, on the 20th of July last; and now reprinted from the Transactions of that Society.

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taining numerous basaltic boulders, water-worn, as usual. This soil is red; but colour does not always indicate the nature of the rocks below, for a red soil also covers the porphyries and sienites of the north of England and the south of Scotland. By a cut on the side of the road immediately beyond Coldstream Bridge, the incumbent mass of loose earth is shown to be not less than fifty feet thick, at that spot, from the top of the bank to the road, and for fifty feet more, to the brink of the stream, no rock is seen to crop out from under the debris; and subsequent remarks led me to think that this part of the country was generally clothed by a diluvial soil of considerable thickness. To avoid repetition, it may not be amiss to enumerate the rocks which are the subject of these notes. Excluding basalt, they are all stratified, and, with few exceptions, dip towards the southward of east, but at very different angles, some beds rather exceeding than falling short of 45° . The suite comprises dolomite, indurated marl, and limestone containing gypsum, red and variegated sandstone, with nodules of red ochre, bituminous shales and sandstones, with vegetable remains, encrinal limestone, also with vegetable exuviae, shale, with bivalve shells, and numerous beds of coal; the whole series appearing to rest upon transition rocks, which, to the north-west and south-west form the Lammer Muir and Cheviot range of mountains.

At the distance of sixteen miles, in a direct line from the sea, and in the vicinity of Carham, a small burn enters the Tweed on its south side, dividing Northumberland from Roxburghshire. Here a bed of close-grained iron-gray basalt occupies the bed of the river for a considerable distance, and near Carham Church rocks of pale-brown dolomite may be seen on its banks. This limestone seems to be superior to the basalt, and is heaped together in irregular masses, but that these are a part of a regular stratum is evident, for at Had-don Rigs, a mile south from this place, the stone is quarried to the depth of ten feet for agricultural purposes, though, from the veins of reddish-brown chert which pervade it, the produce of pure lime is much diminished. Besides chert, calcareous spar occurs in the rock, which, at the quarry just noticed, is about ten feet thick, with a covering of ten feet of soil. The next point where rocks are exposed to view is on the north side of the river; at the foot of Spring Hill, about a mile west of Birgham. Here numerous thin strata of soft arenaceous limestone, of an ash colour, interstratified with greenish-gray indurated slaty marl, mixed with sand and mica, form cliffs of nearly sixty feet high, and the river flows over strata of the same description. In this limestone, veins of flesh-coloured compact

compact gypsum* and nodules with crystals of brownish-red selenite are tolerably abundant. The rocks lie very regular, and dip, at a trifling angle, to the south-east. The relation they bear to the red and variegated sandstones will be noticed when the strata situated lower down the Tweed come under consideration.

In the bed of the rivulet called Firebourn, a slip or dyke is worthy of notice; in the language of miners, it casts up to the east, and the thin strata of limestone and indurated marl, before mentioned, may be seen in the water-course, dipping at an angle of 40° in that direction. On the banks of the river, at a trifling distance lower down, another slip divides the rocks, and brings two beds of micaceous sandstone into contact with the calcareous series; the upper of these sandstone beds is slightly tinged red, owing to its mica being oxidated, but the lower is of a pale yellowish-brown colour, and ambiguous character, rather resembling a coal sandstone; their aggregate thickness, with a thin micaceous parting, is fourteen feet. Half a mile below Firebourn there is a ford across the Tweed, noted in Border History; its direction is south-east, and may have been occasioned by the dyke. On the south side of the river the ruins of Wark Castle stand on an eminence sixty feet high, composed of calcareous strata, similar in every respect to those at Spring Hill, but their dip is in an opposite direction. These impure limestones seldom exceed a foot in thickness, and gypsum is interspersed through them. At about a hundred yards west of the Castle, rocks of dolomite again crop out on the banks of the river, but to the eastward this peculiar mineral was no more to be seen; nor could I thoroughly satisfy myself as to its geological position, though I have every reason to believe that it rests upon the basalt, and suspect this rock belongs to the same bed as occupies the north shore of the Tweed at Carham, and is here again brought to the surface by the Firebourn Dyke.

Again, passing to the north side of the Tweed, near the Temple at the Lees, eight alternations of the same calcareous beds as form the cliffs at Spring Hill and Wark, (except that the lower stratum of limestone contains very minute bivalve shells filled with calcareous spar,) occupy the bank and the bottom of the river; their thickness above ground is about ten feet, and their dip towards the north-west. No strata of this description were again noticed for nearly six miles, and

* Gypsum is also found at Fluers, some miles higher up the Tweed, on its north bank, and has been found by the Rev. A. Baird, on the banks of the Whiteadder, near Hutton Hall.—*Geological Essay on Berwickshire*, in the Preface of Johnston's *Flora of Berwick*, p. xxi.

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when again seen, were found associated with red sandstone, in the vicinity of Norham.

The town of Coldstream stands on what are usually called coal-measures, comprising sandstones and bituminous shales, exactly the same as those of the Newcastle coal-field, and wherever diluvium does not form the shores of the river, these may be traced for the distance of two miles and a half. The little river Leat, which here empties itself into the Tweed, passes through Mill Haugh, where the late Lord Home bored for coal, but to what depth I could not ascertain. An extensive free-stone quarry is worked in this field to the depth of thirty feet; the upper and middle beds are white micaceous sandstone, fine-grained, and full of coal pipes, the lower is free from these vegetable exuviae*. A strong chalybeate spring rises to the day, and runs into the Leat at a short distance from the quarry. Both above and below Coldstream Bridge the Tweed flows over these coal measures, which dip, at a trifling angle, to the south-east, and the rocks on the south side having been cut through, micaceous sandstone, alternating with bituminous shale, and covered with a bank of red earth, are laid open to view, and beds of the same nature may be noticed half a mile lower down the stream. But the cliff at Lennel Braes, on the north side, two miles to the eastward, exhibits the most perfect section of this suite of strata to be met with in the vicinity. At the Braes the perpendicular cliff extends for more than a hundred yards, and was estimated by me at forty feet in height, exclusive of its diluvial covering, but the correct section, published in Mr. Witham's pamphlet *On the Vegetable Fossils found there*, makes its elevation forty-four feet†. The uppermost bed is sandstone, which is succeeded by four others, alternating with slaty sandstones, or coal metals and shales inclosing balls of clay iron-stone. Their dip is north-east, and the rocks on the south side of the river appear to resemble them. The petrified trunks of trees are irregularly dispersed through the lower bed of shale, and are both of the monocotyledonous and dicotyledonous classes of vegetables; but for an accurate description of these interesting fossils the pamphlet before mentioned must be referred to. At no great distance east of this escarpment a quarry has been opened on the side of the bank to the depth of twenty

* Sandstones, bearing strong indications of being associated with beds of coal, are quarried at Sprouston, in Roxburghshire; for an account of which see Mr. Buddle's pamphlet "*On the search for Coal in a Part of the Counties of Roxburgh and Berwick*," in 1806," pp. 10, 11. These sandstones are very hard, and filled with coal pipes.

† Mr. Witham's paper will be found in the *Phil. Mag. and Annals*, N.S. vol. viii. p. 16.—*EDIT.*

feet,

feet, and is situated more than twenty feet above the river. The stone here has a slight tinge of red, similar to the stratum in the upper part of the cliff at Firebourn, which abuts against the calcareous beds. It dips to the southward, and is divided by thin slaty micaceous partings, and capped by about ten feet of loose sand, the abode of flights of sand-martins. On the north side of the Tweed, at the distance of a mile above Twizell Ferry, rocks of well-defined red sandstone make their appearance. It is fine-grained in texture, of a dark reddish-brown colour, and abounds with spangles of silvery mica. The cliff is of considerable elevation, and from hence to the sea coast, thick beds of red and variegated sandstone, at some places covered by the thin calcareous strata previously mentioned, and at others interstratified with them, become prevalent, though coal measures may be noticed in their vicinity. On descending the river until opposite Twizell Boat-House, fine-grained micaceous red sandstone rocks, and those of the coal formation, or at least such as have heretofore been considered exclusively as such, are in close contact. On the north shore, low rocks of the latter description appear *in situ*, and it may be worth remarking, that, on ascending the river Till, for the distance of a mile westward, Twizell Castle may be seen, built on an extremely hard gray micaceous sandstone, filled with coal scars*, and so promising did this neighbourhood appear, as to induce the proprietor to make a trial for coal. Three-quarters of a mile further up the Till, the red rocks are again met with, and worked at Mill Quarry, but at Dunston Haugh, two miles and a half from the Castle, the stratum quarried is yellowish-white, and seemed to be a coal sandstone. But to return to Tweed side. On the south bank, above the Ferry House there is a perpendicular cliff, forty feet high, of white sandstones, though tinged red on their surfaces by the oxidation of their mica; the beds are separated by thin micaceous partings, and in every respect resemble the rock quarried below Lennel. On the north side, just below the ferry, the cliff is not less than 50 feet above the stream, and composed of fine-grained red sandstone, with small scales of silvery mica. On descending the river, the rocks on the south shore continue red, micaceous partings divide the thick strata, through which nodules of red ochre are dispersed in abundance, and those on the north side agree with them in every character.

* Minute fragments of red garnets are embedded in this sandstone; a circumstance I have never noticed in the sandstones of the Newcastle coal-field; but in the millstone grit at Shaftoe Crag, near Wallington, the same mineral was detected by W. C. Trevelyan, Esq., and it abounds in the grauwaacke of Bournemouth, north of Berwick. The Twizell sandstone I suspect to be an old member of the carboniferous limestone formation.

Opposite Newbiggin, the elevated cliffs are rendered singular by an escarpment of bright red marl, which, from a distance, is a striking object. The dip is towards the south-east. Near Norham Boat-House, the Tweed sweeps round the foot of a promontory of not less than seventy to eighty feet in height; its rocks are red, and differ in no respect from those a little higher up on the north bank of the river. To the eastward, Norham Castle stands upon an eminence overlooking the Tweed, and, as the stones of which it is constructed are red and white, the vicinity of quarries of both these kind of rock is evident; but the geology of its immediate neighbourhood may be studied to most advantage by carefully inspecting the abrupt cliffs below the Castle mount. A beautiful and interesting section is there developed. The lowest bed, which is scarcely above the level of the stream, consists of a whitish sandstone and limestone forming a breccia; on this rests a stratum of reddish sandstone, forty feet thick, which is, in turn, capped by fourteen thin seams of soft ash-coloured limestone, interstratified with an equal number of others of greenish-gray slaty marl, mixed with sand and silvery mica; their aggregate thickness is twenty-five feet, which, with five feet of diluvium, will give seventy feet as the elevation of the escarpment. When viewed from below, the upper part of this singular cliff appears to be striped with the regularity of a ribbon. In the thick bed of sandstone, pear-shaped nodules of extremely hard white micaceous sandstone abound, and greatly impede the work of the quarry-men; some of these nodules are not many inches in diameter, but I measured one of two feet and a half; they are not ranged in lines, but their sharper extremities point towards the north-west, which is the full rise of the stratum containing them. Proceeding eastward to the vicinity of Horncliffe House, the rocks are still red sandstone, with similar calcareous seams as those near Norham resting upon them, and a cut, made to widen the road to the Chain Bridge, lays open thirty feet of rock, comprising six different strata; the lowest is red sandstone, the others limestone and slaty indurated marl. A slip of six feet cuts through these beds. Above West Ord, a cliff of sixty feet again exhibits the nature of the rocks; here the variegated sandstone rests upon the red, which is filled with nodules of red ochre, and is covered by the calcareous series so frequently mentioned; and at the plantations, a little lower down the river, six alternations of these thin beds are covered by thick strata of red and variegated sandstone. At Ord Mill, the red rock alone is visible; the dip of the whole series is southward of east. Diluvium now covers the rocks on the south
of

shore of the Tweed the whole way to the harbour, but on the north bank, Berwick Castle stands upon an elevation about ninety feet high. Under the soil the rocks are variegated and red sandstones, of extremely fine-grained texture; the beds are thick, in which they may be compared to the *posts* in this part of our district, while the thin calcareous strata occupy the place of our *metals* and bituminous shales; but so considerable a proportion of carbonate of lime do all the sandstones hereabout contain, that they effervesce on the application of diluted mineral acids. The dip southward of east. From the rocks on which Berwick Castle is constructed to the entrance of the harbour the space is covered by soil; but both towards the north and south high and rugged cliffs bound the ocean. Those to the north shall first be brought under consideration. On passing through the Sally-port, and before reaching the Pier, the following succession of rocks rise to the day:—1st. A thick stratum of fine-grained brick-red micaceous sandstone. 2d. Hair-brown limestone, with small encrinites. 3rd. Slaty micaceous sandstone, of an ash-gray colour. 4th. Red sandstone. 5th. Encrinal limestone. 6th. White sandstone, blotched by red ochre and containing coal pipes. 7th. Encrinal limestone. 8th. Slaty micaceous sandstone. 9th. Encrinal limestone. 10th. Variegated sandstone. These strata occupy the space from the Sally-port to the Pier. The limestones are of inconsiderable thickness, and envelope bivalve shells as well as encrinites. The red and variegated sandstones are very fine grained, with but little mica; and the coal sandstones white, when not tinged by yellow ochre. At this point, which may be about a hundred yards north of the Pier, a slip dyke, of considerable magnitude, intersects the cliff, and may be traced eastward into the sea; its breadth is three yards, the south side of the chasm being filled for two yards by shale, and the north side by a rib of brownish-purple limestone, so hard as to give fire with steel; it is of a fine texture, with a splintery fracture, and impressions of the lanceolate leaves of some species of *Variolaria* of Ad. Brongniart, *Stigmaria* of Sternberg, are dispersed through it. The hade of the dyke is inconsiderable, but to the south of it the strata dip to the south-east at an angle of 45°. A little to the north, the rocks become less inclined, and dip to the east at a trifling angle; the upper is a stratum of ash-coloured shale, twelve feet thick, filled with *Producti* (*Productus scoticus*, Sowerby, Mineral Conch. t. 59, f. 3; and *Productus antiquatus*, t. 317, f. 1, 5, 6.), the shells of which retain their pearly lustre; the lower stratum is encrinal limestone, inclosing specimens of very large *Producti* (*Productus gigant-*
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teus, Sowerby's Mineral Conch. t. 320.)—being the same fossil which gives the name of cockle-shell limestone to one of the beds in the neighbourhood of Alston. On the beach the limestone is laid bare by the action of the waves, and exhibits the extraordinary undulations long since noticed in the stratification at Holy Island. Probably the stratum may be the same; but it is not safe to hazard conjectures on the identity of mineral beds on a coast where their dips are so various, and positions unconformable.

On the south side of the harbour, at the distance of half a mile from the bridge, the strata incline to the south-east at an angle of 45° , and are arranged in the following order:—1st, fine-grained pale red sandstone; 2nd, a thin stratum of slaty micaceous sandstone; 3rd, twenty-five feet of dark red micaceous sandstone; 4th, shale, with thin strata of encrinal limestone; 5th, red sandstone, divided by the same limestone:—the total thickness of these beds is one hundred and twenty feet. Below Spital Mill, half a mile further south, a thick stratum of sandstone, of peculiar appearance, crops out; it is yellow, blotched with red, and is very friable, its grains scarcely adhering; and on the beach, about twenty yards north of this spot, the limestone is separated by a parting of ash-coloured shale, containing bivalve shells (*Corbula limosa*, Fleming's British Animals, 426.) in abundance. Near Spital Farm, a dark gray compact limestone, containing vegetable exuviae, similar to those noticed in the limestone in the dyke on the north side of the harbour, rises to the day about high-water mark, and may be considered another of the anomalous rocks of this coast. At the foot of the rail-road, situated a little further south, coal sandstone, inclosing casts of large vegetables, (*Stigmara ficoides*, Sternberg, t. 12. f. 1, 2, 3; and *Lepidodendron obovatum*, t. 6. f. 1.) and bituminous shale alternate, beyond which a quarry has been worked in the red rock to the depth of forty feet. The stone it affords is hard and fine-grained, and has been used in constructing the new pier. Proceeding southward to Huds-head, the red rock, of which the cliff here consists, abuts against the coal sandstone, which is close behind it, and within two hundred yards one of the Scremerstone shafts is sunk. At North Scremerstone, two miles from Berwick Bridge, the rocks are red sandstone, shale, and encrinal limestone, the latter of which has formerly been quarried, and a little to the south, an extensive quarry is now open at a place called the Red Houses. The stratum is 18 feet thick, and affords a blueish-gray stone, close in its texture, and containing encrinites. It dips at an angle of 45° , and undulates in the same way as the limestone upon the beach

beach on the north side the harbour. Proceeding inland to Sunnyside Hill, where workmen are now employed in widening the great south road to Berwick, two excavations are made in the solid strata. At the northern cut, which is now twenty-two feet deep, the lowest rock is dark-gray encrinal limestone, covered by beds of coal measures of inconsiderable thickness, but interstratified with four thin seams of coal. The southern cut, which is nearer the summit of the hill, is at present fourteen feet deep, the lowest rock is a thin limestone bed; 2nd, a thin seam of coal with a band of shale; 3rd, limestone; 4th, coal and shale; 5th, red sandstone; 6th, coal and shale. The dip is, as usual in this vicinity, to the east. Sunnyside Hill is a mile south of Berwick. Near the coast, I observed no basalt *in situ*, and the only well-defined dyke of that description met with, was at Ousenton Bourn, a mile and a half east of Cornhill; the rib of basalt is 18 feet wide, and crosses the bourn from west to east. The blocks lie in a horizontal position, and the stone is dark-gray, approaching to black, with large greenish crystals of glassy felspar.

[To be continued.]

V. *An Examination of those Phænomena of Geology, which seem to bear most directly on theoretical Speculations**. By the Rev. W. D. CONYBEARE, M.A. F.R.S. F.G.S. &c.

[In Continuation from vol. viii. p. 406.]

Observations on Article V. "The decreasing violence of the Convulsions affecting the Strata at successive Geological Periods."

WE have already noticed the effects of the dislocating forces which must have acted during the deposition of the strata referred to the Transition and Carboniferous formations, and we have found that the agency of these forces must have been universal and extreme during the first, and very general and very violent during the second period: in proceeding, we shall find that they are comparatively rare and partial in the formations of later origin, although they have never entirely ceased; and we are led by a strict analogy to ascribe the actual volcanic phænomena to the same causes, though at present acting with an energy greatly diminished.

Next to the carboniferous strata occur those of the magne-
sian lime, new red sandstone and lias: these as well as the succeeding oolitic formations remain very generally undisturbed, and in a position so little inclined that they have been thence denominated by many geologists on the continent as

* Communicated by the Author.