count. Its bottom is a very gradually sloping one, tolerably deep at the western end or opening of the bay, and shallow at the eastern extremity. Now the eastern portion is the only one which we need consider, as it is within it that the site of *Is* is said, according to every version, to be. In this space then, the deepest sounding that I have been able to find is between seven and eight fathoms, so that an elevation to that extent would convert the whole of the eastern end of the bay into dry land. Now all the facts which we have detailed above, tend to show that the depression of the land is still at work, and assuming that it has continued ever since (how long before we need not inquire) the traditional date of the submergence of *Is*, we get an average rate of depression of three feet per century—by no means an extravagant allowance. The effect of the elevation of the land some forty-five feet would, it will be seen by referring to the accompanying sketch-map, not disturb the geographical descriptions of the district given by *Cæsar* and others. I wish it to be understood that I am in no wise arguing that the depression in question was anything more than a local one; as I am aware that it is held that the Northern, Southern, and South-western coasts of France are within the European area of elevation. That such a local sinking of the land exists in *Basse Bretagne*, I think I have shown sufficiently; and my object will be served if I have also shown that, at the time that *Is* is said to have been the pride of *King Gradlon's* kingdom, there is every probability that land did exist at the very spot with which that semi-mythical city has always been associated. That such a probability greatly enhances the value of the tradition, and of the otherwise slender evidence which supports it, is obvious. I have thus done my best as a geologist to bring back an old legend within the realms of truth, and I must now leave it to the antiquary to find out more concerning lost and forgotten *Is*.

IV.—ON THE DRIFTS OF THE WEST AND SOUTH BORDERS OF THE LAKE DISTRICT, AND ON THE THREE GREAT GRANITIC DISPERSIONS.

By D. MACKINTOSH, F.G.S.

(Continued from our last number, p. 256.)

Boulder-scars.—From *Maryport* to *Parkgate*, the E. coast of the Irish Sea at intervals exhibits accumulations or concentrations of large boulders, which are locally called *scars*. They may be seen in all stages of formation, from the denudational area, where they are in course of being left by the washing away of the clayey matrix, to the depositional area, where they have become half-covered with recent sand and shingle. In many places (as between *Seascale* and near *Silecroft*) there are so many boulders within a small area as to show that a considerable thickness of the clay must have been removed. With the exception of having tumbled down as the cliffs were undermined and worn back by the sea, many of the boulders may still rest nearly in the positions they occupied in the clay, but

(as is evidenced on the coast at Parkgate) others, up to a great diameter, may have been shifted horizontally. Some of the scars exist where the Boulder-clay would appear to have risen up into ridges or mounds, as no clay is now found opposite to them at the base of the sea-cliff. Others are clay and boulder plateaux, visibly connected with the cliff-line. Most of the scars, I believe, are remnants of the great Lower Brown Boulder-clay. The most conspicuous boulder in the scars S.W. of Bootle, is Eskdale-fell granite, accompanied by a little Criffell granite, and a great number of the usual felspathic erratics.

Drifts near Silecroft and Holborn Hill.—The Eskdale granitic drift near Silecroft suddenly bends round and runs up Whicham valley for some distance E. of the Parsonage. The S.W. end of Millom Hill (which chiefly consists of cleaved felspathic ashes, granular felstone and porphyry), presents the appearance of a beach strewn with many pebbles of granite and other rocks. Here I saw a *roche moutonnée* with its glaciated side towards the hill, but not in the line of any valley. On the adjacent plain there is much granitic drift. Its inland boundary bends eastwards to the N. of Holborn Hill, crosses the Duddon estuary, and re-appears on Dunnerholme Island, and near Soutergate. The boundary then runs S.S.E. by Great Urswick, a little N. of which I found a granitic boulder.¹ Pebbles of it (probably washed northwards along the sea-coast from its original boundary S. of Baycliff) may be seen near Bardsea. Between Millom Station and Millom Hill, the Upper Boulder-clay knolls apparently alternate horizontally with sand and gravel knolls, but the few sections visible justify the supposition that the two drifts thin out below or above one another in a manner indicating distinct periods of deposition. Between Millom Station and Silecroft, a similar dovetailing of drift-knolls may be recognized, and in one part of the railway-cutting the sand is interstratified with subordinate beds of clay, but not Boulder-clay.

Striated Limestone crossed by Drift-carriage.—About half-a-mile S. of Millom Station, a gently-swelling eminence, 75 feet above the sea, has lately been quarried, and the result has been the exposure of the most thoroughly, continuously, and extensively glaciated rock-surface I have yet anywhere seen (Nov., 1870). The grey limestone has been uniformly planed down, polished, and traversed by white grooves and striæ. The finer lines have been cleanly cut, but in many places the coarser striæ and grooves (the latter about $\frac{1}{8}$ th of an inch in breadth) consist of a close succession of rough dints, as if small, sharp, angular quartz fragments had been made to roll over, or as if the floating ice which held the fragments had vibrated after suddenly grounding (?). One might suppose that the polishing of the rock and the microscopic lines were produced by land-ice, were it not that the latter cross each other at nearly all angles.

¹ The boundary in Furness, and in many places further North and South, must have been more or less deeply submerged, and one cannot long trace drift-boundaries without having to abandon the notion that they must always have been marked by dry land, or that dry land necessarily existed where there are driftless areas.

Most of the lines visible to the naked eye point N.E. or obliquely across the valley of the Duddon. Most of the few strongly-marked grooves run between N. and N. 35° E., or approximately in the main direction of the Duddon valley. The ramifying rough crevices in the limestone would appear to have existed before the glaciation occurred. They are partly filled with sand and fine gravel, which may belong to the Middle Drift period, and which may have once covered the whole rock-surface, and furnished the ice with grinding material. If so, its removal by the ice must have been followed by the accumulation of the Upper (?) Red Boulder-clay which covered the glaciated rock-surface, and still covers it where quarrying operations have not extended. But this clay did not result from the grinding up of the limestone, for (according to an analysis made by Mr. Heywood, of Millom) it contains silica 62·97, and alumina, 17·50 per cent. Nearly all, if not all the stones and boulders in this clay, have come from directions which cross the grooves and striæ (a few of the microscopic lines excepted), and the main direction of the ice-marks (N.E.) is nearly at right angles to the main direction of the drift-carriage (N.N.W.). The glaciating agent, therefore, could not have been the carrying agent, though it may have been of the same nature. The boulders are chiefly Eskdale granite and Eskdale or Wastdale granilite, granular felstone apparently from Wastdale, etc. The existence of the striæ under a covering of Boulder-clay furnishes an illustration of one of the fundamental principles of geology, namely, that the sea preserves the most delicate marks on rocks in *areas of deposition*, a principle which Mr. de Rance overlooked when he asserted that the *roche moutonnée* at Grange Bridge could never have been touched by the sea (GEOL. MAG., March, 1871).

FIG. 7.—Glaciated Block of Limestone from the Rock-surface of a Quarry near Millom. Scale, one-fifth of original.

Limestone Sculptured by the Sea.—Not far from the above quarry, at Hodbarrow Point, the pebbles and boulders of the red clay are used by sea-waves to hollow out the originally rough and uneven surface of limestone strata, and the effect produced is a perfect fac-

simile of many of the smoothly sculptured rocks one may see in all limestone districts, where the irregularly pitting and roughening action of rain-water and frost has not obliterated the evidently ground-out basins and channels. On the hill-slopes between Silverdale Station and Yealand, and in many other places around Morecambe Bay, the Silurian grit pebbles may still be found in the hollows they once ground out. Under drift the sculptured limestone surfaces often become decomposed, while in the open air, in situations where rain-water innocuously runs off, they have remained nearly intact.

Valley of the Duddon.—Beyond the northern boundary of the granitic drift stream above described, and on the way to Thwaites, there are immense boulders of felspathic breccia, ashes, and porphyry. W. of Green the striæ run E. 30° N. I have elsewhere noticed the great pinel knoll near Green. About Thwaites there are many knolls and slope-coverings of pinel, with boulders up to eight feet in average diameter. Here, and all along the W. side of the Duddon estuary, there is much green, grey, and blue porphyry, *in situ*, along with ribboned or banded felspathic slag, felspathic breccia and felspathic ashes; and a tributary ice-laden current may have carried boulders of these rocks into the great drift-current already mentioned. Between Thwaites and Duddon Bridge there are numerous *roches moutonnées* on the slope rising from the W. side of the flat bottom of the Duddon valley, and among them we have the old story repeated, namely, the obliquely-upward glaciation of rocks *from* and *not along* the valley. The transverse configuration of the ground shows that (in many instances at least) the glaciation did not result from lateral grinding exerted by a valley-glacier, and it is worthy of remark that the direction of this glaciation approximately corresponds with the striæ W. of Green and at Millom quarry. The eastern slope of the upper valley of the Duddon is covered with a succession of gently-swelling knolls (with rocky nuclei) of pinel, and overlying loam, both containing large boulders. In many places there are *roches moutonnées*, with parallel undulations or wide -shaped grooves (as well as minute striæ), pointing N.N.E. or nearly in the direction of the valley. But the great wonder of the Duddon valley is the

Lateral Moraine near Seathwaite.—On walking along the road near Seathwaite Church, in company with the Rev. F. A. Malleeson, of Broughton-in-Furness, and Mr. Postlethwaite, a neighbouring squire, I was almost astounded at the appearance presented by what at first looked like a black causeway of large blocks thrown down in haste by a pre-historic race of giants, and I could not believe that the spectacle was natural, until Mr. Postlethwaite assured me that it was so. It runs along the grass-covered (and apparently drift-covered) slope which rises gently from the east side of the valley to the ridge called Walna Scar. There are no rocky scarps above from which the blocks could have tumbled down. They are nearly all quite angular, and are rudely congregated, often piled on one another, within a well-defined zone, a few scores of yards in breadth, and

about two miles in length. At the northern end this post-marine lateral moraine (for such evidently it is) rises up to about 300 feet above the bottom of the valley. At the lower end it descends nearly to the bottom of the valley. N. of it, and at a higher level, there are numerous rocky scarps from which a shallow glacier may have collected the blocks. But they may have been partly derived from the tributary glacier which once evidently came down through Seathwaite tarn cwm, which left many perched blocks on the platform in front of the cwm, and finally deposited the small irregular moraine which, with solid rock at intervals, dams back the water of the tarn.

Notes on the Drifts of Furness.—I have described these drifts in the Quart. Journ. Geol. Soc. vol. xxv., and would here very briefly state the results of a second series of observations. The greatest masses of yellowish-brown pinel I have yet encountered are near Lindal, at a height of about 300 feet above the sea. They reach a thickness of about 120 feet, and, at a lower level, a still greater thickness is said to have been proved. It resembles the pinel which runs under the sea on the E. coast of Furness, and is evidently on the same horizon with the Lower stony Boulder-clay of Blackpool. In Furness we find what may be called the central and maximum development of this formation, and it graduates northwards into the pinel of the Coniston Old Man (which, on the Walna Scar road, rises to a height of at least 1200 feet above the sea), and southwards into the more sedimentary Lower Boulder-clay of Lancashire. In no part of the N.W. of England, so far as I have seen, is there any appearance of a line of demarcation between the pinel of the hillslopes and the adjacent recesses and valleys, and the Lower Boulder-clay of the plains. The erratic boulders in the pinel at Lindal, Ulverstone Railway Station, the sea-coast near Bardsea, etc., would appear to have come in straight or curved lines from Millom Hill, and the slopes thence stretching Northwards to Duddon Bridge.

Dispersion around Hill-bases and up Valleys.—Beaches of pinel curve round the small hills and run up the small valleys N. and N.N.E. of Ulverstone. Most of the imbedded boulders are local, but a few, consisting of porphyry, would appear to have come from the W. side of the Duddon valley. It is difficult to conceive of their having come in a straight line over the elevated intervening hilly district, and no similar erratics, so far as I am aware, are to be found on the higher plateaux or passes of this district. We may, therefore, infer that these boulders were floated round by way of Ireleth, stranded on the jutting sea shores near Ulverstone, and carried up the small valleys by ice-laden flow-tides or wind-currents. But the lateral or *up-valley* dispersion of portions of drift diverted from the borders of great ice-laden currents has been a common and not merely an exceptional occurrence in the N.W. of England.¹

¹ In E. Lancashire, along the boundary of the great North-western drift, boulders have found their way into valleys lying at nearly right angles to the general course of the drift. Far up in the narrow valley called Swineshaw, near Staley Bridge, there are many stones of Eskdale granite and Wastdale granilite which reach a height of 900 feet above the sea. They are associated with stones which must have come from various points of the compass.

From Greenod to Newby Bridge.—At Greenod, on the west side of a tidal channel, we may see a miniature illustration of the fact, that when angular fragments get imbedded in loam or clay, they soon lose all chance of ever becoming rounded,—a fact of much importance in speculating on the origin of hill-side drifts. In Haverthwaite Schoolyard a boss of rock has been glaciated from E. 30° N. Near Newby Bridge Cottages, the slate rock in the railway cutting is polished and striated between N. 40° E. and N. 60° E. Farther north, at the foot of Windermere Lake,¹ the striæ run N. 20° E. The glaciated surface is covered with well-rounded gravel and sand, and a little pinel fills up the underlying rough cavities. The drift here swells out into great knolls, which rise at least 100 feet above the level of the river.

Around Silverdale, Burton, and Milnthorpe.—Near Silverdale Station the limestone has been striated from the N. Between here and Yealand, more or less rounded limestone boulders may be found in positions where they might easily be launched, as many of their fellows probably were, by coast-ice. But the most wonderful array of limestone boulders, some of them 15 feet in average diameter, may be seen on the south side of Farlton Knott, near Burton. On walking from Burton to Heversham, I unexpectedly met with a great number of boulders of Shapfell granite, one of them $4 \times 3\frac{1}{2} \times 2\frac{1}{2}$ feet. They are abundant at and near Whasset, and all round Milnthorpe, but I saw only one pebble of this granite farther E. than the neighbourhood of Whasset.² The granite has come from about E. 15° N. or from Wasdale Crag, and I think it must be something more than a coincidence that this is nearly the general direction of the truly remarkable

Parallel Drift-ridges S.E. of Kendal.—The N.N.E. direction of these ridges (which are well represented on the shaded Ordnance Map) not only points to Wasdale Crag and the neighbourhood, but across a series of notches on the intervening crest of Whinfall Beacon and Greyrigg Forest (1544 and 1619 feet above the sea). On the watershed between Kendal and Low Gill, many of the ridges point in various directions, and this is the case with most of the ridges in the neighbourhood of the River Lune. At the mouths of Long Sleddale and Bannisdale (where Shapfell boulders have been found) most, though not all of the ridges point approximately N. and S. Over a considerable area S.E. of Kendal, and further S.

¹ I may here remark, in answer to Mr. de Rance, that while in Bowness and the neighbourhood, I ascertained from various persons, who were thoroughly acquainted with all the ins and outs of the lake, that none of the detritus or sediment brought in by the Brathay river can find its way through the lake to the lower end, and thence to the sea; and one reason assigned was that the currents generated by wind, etc. (which often reach a great depth, as proved by net sinking), more frequently flow from the S. or up the lake, than from the N. Lacustrine deposits, which have all resulted from the action of fresh-water, afford the only true measure of subaerial degradation since the Glacial period.

² I never saw any Shapfell granite farther S. than the road between Yealand and Silverdale. Professor Phillips mentions its occurrence in a canal S. of Lancaster. Within the area of the great North-western drift, farther south, a certain kind of Dalbeattie (Criffell) granite might be easily mistaken for Shapfell.

than Milnthorpe, the ridges are wonderfully parallel, and point, as already stated, N.N.E. It is certain that many of these ridges have rocky nuclei, and that many at least of these nuclei ran in the above direction before the Drift period is probable from its near coincidence with the larger axes of Benson Knott (1035 feet), New Hutton ridge (1097 feet), etc. The parallel drift-ridges vary in height from 20 to 30 feet near Burton Railway Station to more than 100 feet near Milnthorpe, and in the area where their parallelism is best defined between Farlton Knott and Oxenholme. As a general rule, the more northerly ridges consist chiefly of Boulder-clay, which (as between Oxenholme and Low Gill) rests on alternately jagged and glaciated rock-surfaces, but their shape has been completed, and their final direction given by an addition of gravel and sand. About Oxenholme Station, a great part, if not the whole, of some of the ridges is made up of stratified gravel and sand, and this remark applies more or less to the ridges further E. and S. The gravel in many instances is well rounded, in others subangular. Between Milnthorpe, Burton, and Carnforth, where I have more particularly examined them, the ridges, so far as can be seen, are all sand and gravel, with subordinate beds of red loam or loamy clay. I have been assured that, near Milnthorpe, the ridges, at some depth beneath the surface, contain a great thickness of sand. The low oblong knolls rising out of the peaty and marshy flat stretching W. and S. from Burton Station are of the same character as those which rise to a greater height in the neighbourhood. The hollows around these knolls were probably once occupied by a lake which gradually became filled up until conditions favourable to the growth of peat originated. But the knolls are distinct in shape, composition, position, and magnitude, from any deposits to which a small (or even a large) lake could ever have given rise, and are evidently a low-lying con-

FIG. 6.—Parallel Drift-ridges, looking N.N.E. from the Railway Bridge, northwest of Holme.

tinuation of the sand and gravel ridges further north, and the Carnforth sand and gravel knolls further south.

The ridges under consideration are, generally speaking, not linearly parallel. In the same line an oblong hollow is succeeded by an oblong eminence, as if the eminence had been partly formed by the abstraction of matter from the hollow, but this may not necessarily have been the case. Most of the stones and boulders as far S. as Yealand have come from about N.N.E., and consist chiefly of upper Silurian grit or mudstone, and some porphyry, breccia, and dark felstone (from near Wasdale Crag, ?). At Carnforth, further S., the stones and boulders are nearly all limestone, which likewise probably came approximately from the N.

From these facts it may be inferred that the ridges may possibly represent three periods—the period when the rocky nuclei were formed by denudation—the period when the Boulder-clay was arrested by these nuclei—and the period when the sand and gravel which partly or entirely compose the ridges were deposited. However this may be, it may, I think, safely be asserted that *the present aspect and parallelism of the ridges* is due to the agency which deposited the sand and gravel, or to marine currents with or without floating ice; and this view of their formation may be applied to the curved parallel ridges which ramify like a fan from the neighbourhood of Wasdale Crag, and which have probably been finally shaped by the current that distributed the granitic boulders.

Southerly Extension of the Great N. Western Drift.—The Wasdale Crag and Carnforth¹ drift-stream would appear to have nearly, if not altogether, terminated a little S. of Lancaster. Some distance further S. the ground was monopolized by the great drift stream from the N.W., already described. This stream may have received some slight contributions from the N.N.E. stream. Among the boulders exhibited in Peel Park, Salford (nearly all of which were found in the neighbourhood), I detected many old Cumberland acquaintances. The following is a rough estimate of the relative per-centage of the larger boulders, which I made with the assistance of Mr. Plant, F.G.S.:—Felspathic trap running into porphyry and breccia, 50; Silurian grit (apparently from Furness) and local sandstone, 30; Eskdale fell granite, 19; Criffell granite, 1;=100. To the east of Manchester I have seen no Criffell granite. At Snape Green brickyard, near Southport, the Criffell seemed to preponderate over Eskdale granite. (For further remarks on the southerly extension of the north-western drift see explanation accompanying the Map, p. 312.)

General Results.—From the facts stated in the eight articles I have written on the Drifts of the N.W. of England,² I think it may be

¹ The finest sections of sand and gravel I have yet seen are at the Carnforth Railway Station, and on the Canal side. At the latter place there is gravel above and below, and sand in the middle. At the village, a great deposit of sand contains enormous limestone boulders, one of them $9\frac{1}{2} \times 9\frac{1}{2} \times 5$ feet. In addition to limestone, in the Carnforth drifts, there are Silurian grits and volcanic rocks from about N.N.E., and Carboniferous grits, etc., from the N.E.

² *Geol. Mag.*, August, October, December, 1870, and February, June, and July, 1871; *Proceed. W. Riding Geol. Soc.*, 1870; *Quart. Journ. Geol. Soc.* vol. xxv.

inferred that land-ice may have planed, smoothed, polished, and striated rock-surfaces, and pushed loose *débris* forward to the nearest protected situations, but that rounded, smoothed, and polished boulders must have been chiefly shaped by floating-ice and sea-waves,¹—that floating or ground ice glaciated a great part of the Lake-district; that the four drifts were deposited by the sea and floating-ice, though more or less of the clay and loam composing them may have originated as subglacial mud; that the blue clay was accumulated

FIG. 9.—Map of the Three Great Granitic Dispersions in South Britain.
(Explanation on page 312.)

under a comparatively shallow sea, and denuded (if not upheaved and again depressed), before it was overlaid by the pinel or Lower Brown Boulder-clay; that the middle sand and gravel were accumulated during the gradual *rise*, and not during the fall of the land, as Mr. de Rance believes; that the Upper Boulder-clay of the

¹ According to Forbes no *actual* glacier is capable of smoothing or polishing boulders, though by means of a gritty base it may smooth and polish rock-surfaces.

plains, which I believe to be equivalent to the foxy-coloured loam of the mountains, was deposited (in many places on the extensively denuded surface of the middle drift) during a succeeding submergence, the vertical extent of which was at the very least 1300 feet; that after the land again rose, glaciers lingered in the inner and upper valleys and cwms of the Lake-district, but that they did not reach a great length, or leave many extensive moraines; that during a great part (though not the whole) of the Glacial period in the Lake-district and W. Yorkshire, the conditions were similar to those now prevailing in nearly the same latitude, in the Baltic Sea, and in the Atlantic off the coast of Labrador.

Map of the Three Great Granitic Dispersions in South Britain.—C, E, S, the sources of the Criffell, Eskdale, and Shappell (Wasdale Crag) Dispersions. The left hand finely dotted line represents the possible western boundary of the Criffell and Eskdale drift. According to Curry, the Criffell drift extends further eastwards than I have mapped it. According to Buckland, the Shappell drift ramifies (as represented) to the neighbourhood of Durham. Green is my authority for the Shap boulder at Royston. I found granite near Longridge (a few miles N.E. of Preston), at Rochdale, the upper reservoir, Swineshaw valley, and at Stockport. Many boulders of granite have been found by Mr. Sainter at Macclesfield. Granite has found its way to an altitude of more than 1100 feet on Holcombe Hill, north of Manchester (Mr. Eccles). It has been discovered by Dr. Alexander at Mitholmroyd, east of Todmorden, and by Mr. Green in the Wye Valley, Derbyshire. These straggling dispersions are not included in the map. Trimmer has found stones of granite decreasing in size and numbers from Chester to Conway. Ramsay thinks that the foreign drift of Anglesey came from the N.N.E., so that the western boundary of the granitic drift in the map may not represent the extreme limit of the dispersion. I have traced the western boundary from near Pentre Halkin, Flintshire, to Padeswood Station, near Mold, and a short distance to the west of Wrexham. There are many large boulders of granite at Farndon, eight miles south of Chester. They are chiefly Eskdale granite, though Criffell is not altogether absent. Five out of six of them are intensely glaciated, whereas in Eskdale not one out of six can be said to be well glaciated. Between Wolverhampton and Bridgenorth there are numerous boulders and angular blocks of granite, some of which are four feet in average diameter.

V.—DESCRIPTION OF THE RECENTLY DISCOVERED CAVERNS AT STAINTON.

By ALAN GRANT CAMERON, Esq.,
of H. M. Geological Survey of England and Wales.

HAVING formed one of a party of sixteen, who have lately further explored the recently discovered caverns at Stainton, notices of which have appeared in the *Times* and other journals, I wish to furnish a few details of the exploration, which may possibly prove interesting. The caverns are in the Carboniferous Limestone formation, and situated at a point one mile and a quarter south-east of the Dalton station of the Furness Railway, Lancashire.

The rock is being very extensively quarried there, and the entrance to the caverns is in the east side of the quarry, about the 250 contour line, and some 50 feet from the bottom of the quarry. It is said to have been long known as a "fox-hole." This aperture leads into a gallery 235 yards in length, running a little north of east, and at an easy slope. Several short, blind galleries branch off from either side; one rather longer gallery, however, re-opening into the main